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

Annual Reports Year 3 (2012)

NSERC Research Network Grant: NETGP 375118 – 08

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Ocean Tracking Network (OTN) Canada Network Overview

1. Network Objectives

Overall objectives of the network

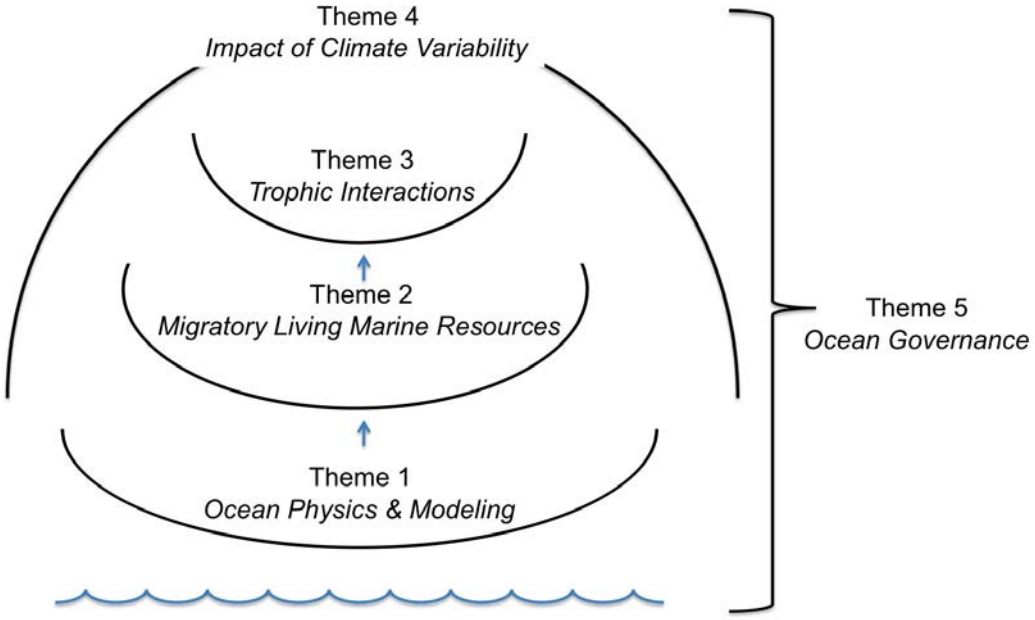
The paramount objective of the OTN Canada Network is to better understand changing ocean dynamics and their impact on ocean ecosystems, animal ecology, and ocean resources, with the aim to address critical issues in resource management and implications for ocean governance.

Within this context, OTN Canada has three overarching questions:

1) What are the physical, chemical, and biological oceanographic linkages that determine the population structure, dynamics, movement and critical habitat of marine organisms? 2) How will climate variability, change and anthropogenic activities affect the distribution and abundance of marine organisms? and 3) What are the ocean governance implications, including social, economic and legal dimensions, of OTN findings?

Under the umbrella of these larger issues, OTN Canada research will directly address one key, integrative question across the entire Canadian continent and its three ocean Arenas (the Atlantic, Arctic and Pacific): What are the movements of continental shelf marine animals, how do these movements affect species interactions, and what are the consequences of environmental variability/change and human activities on these species' distributions and abundance?

OTN Canada is organized around five key research themes within and across Canada's three Ocean Arenas (the Atlantic, Arctic and Pacific).



We are focusing our investigations on key species of interest and on sharing and integrating research strategies, expertise and emerging technologies to understand changing marine ecosystems across Canada. To assure comparison across the Arenas, included for each Arena are measurements of oceanographic characteristics and variability at various spatial and temporal scales, movements of key species at several trophic levels, and analysis of key acoustic "bioprobes" (animals that carry tags which record locations visited, ocean conditions and interactions with other tagged animals) and "roboprobes" (remotely controlled gliders that measure physical, biological and chemical conditions) to complement measurements from fixed OTN curtains. Ultimately, information obtained will be exploited to address socioeconomic and resource management issues.

2. Progress and Integration of the Network

In just over two and a half years, OTN Canada has made great progress. Researchers have accumulated an outstanding track record of first-rate science and developing an integrated Canada-wide research network with increasing international reach. A key focus of the NSERC network is the training of students and postdoctoral fellows (PDFs), as well as technicians and research assistants. During this report year, OTN Canada was supporting, in whole or in part, the programs of almost 100 of these trainees. Details of all the projects and subprojects are described in each of the individual reports that follow the Network Overview.

Integration of the Network within and across Themes and Arenas 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 Meetings/Symposium/Special sessions

Great Lakes Acoustic Telemetry Observing System (GLATOS) Annual Meeting, February 2012, Rogers City, Michigan

Scientific Director S. Iverson, and several OTN Canada researchers, as well as VEMCO scientist and collaborator D. Webber, attended the annual meeting of the GLATOS in Rogers City, Michigan on the 14th and 15th of February 2012. At the meeting were ~70 researchers, and overviews of new and ongoing studies of Great Lakes fishes were presented, as well as workshops on technical issues related to acoustic telemetry. Presently, GLATOS is establishing GLATOSCweb, an online data query and management system constructed with input from OTN and POST. One of the aims of OTN's participation was to explore the present and future links between OTN and GLATOS in order to better establish connectivity between the Lakes, the St. Lawrence River, and the Atlantic. This evolving relationship will allow study of important migratory and invasive species, and provide collaborative links to researchers in other regions using acoustic telemetry

Special session at the 2012 Ocean Sciences Meeting, February 2012, Salt Lake City, Utah

OTN Canada and Global, NOAA, and Kintama Research Services organized a special session ('Integrating Oceanography and Animal Tracking - the Ocean Tracking Network') at the 2012 Ocean Sciences Meeting in Salt Lake City, Utah on February 20C24, 2012. Eight oral presentations and 12 poster presentations were given by members of OTN Canada as well as international researchers and

collaborators. This venue proved an excellent opportunity to raise the profile of OTN and its research among the broader ocean sciences research community.

Midterm Report, Phase II Proposal and Arena PI Meetings, spring 2012

OTN Canada was informed in early January 2012 that the reporting period for the Network Midterm Report, and submission of revised proposal for years 5-7 (2014-2016, "Phase II") is listed in the NSERC offices as 1 January 2010 to 30 June 2012, with an initial due date of July 2012. This differs by a year from the milestones OTN Canada had outlined in the accepted proposal, which listed June 2013 as the timing for the midterm and proposal review. Given this sudden and unexpected timeline of a year earlier, revising dates and planning for Phase II has been a major undertaking for the whole Network for 2012. NSERC and S. Iverson agreed that the target submission of the two documents would be the end of 2012.

Principal Investigators from all arenas have been holding meetings both separately and together to strategize on proposal preparations. To move forward together, OTN Canada Arena Leaders held a nation-wide conference call meeting in February 2012. All PIs from the Atlantic Arena met in person at Dalhousie University in Halifax, NS on April 10, 2012. Presentations on the status of projects in the morning were followed by a discussion of progress so far and strategies for Phase II in the afternoon. Co-leaders from the Arctic and Pacific Arenas joined the afternoon discussion by teleconference. This discussion broke a lot of ground for the Phase II proposal writing session the June symposium. The Arctic and Pacific Arenas likewise held several arena-wide meetings during the report year, focusing on integration of the research and discussions for Phase II of the OTN Canada Network. A second Arena Leader teleconference was held in May. Further planning meetings were held at the June Symposium (below).

Second Annual OTN Canada Symposium, June 2012, Halifax, NS

The OTN secretariat organized and hosted the Second Annual OTN Canada Symposium on June 4-6, 2012 at Dalhousie University in Halifax, NS. The purpose of this symposium was to bring together all students, PDFs, and eligible PIs to present projects and results, discuss research strategies, and focus on integration of the OTN Canada Network and sharing of research tools and programs within and across Arenas. An additional aim for this year's symposium was to host several planning sessions for the Phase II proposal.

The first day of the Symposium started with welcome and introductory remarks by S. Iverson. This was followed by a plenary session by S. Hinch and colleagues on their experiences with integrating their scientific research with management actions. The remainder of the morning consisted of two concurrent sessions: one featuring research presentations by six HQP and the other being a social sciences workshop. The latter was led by the collaborators (R. Apostle and D. VanderZwaag) for Theme 5: Oceans Governance, and focused on presentations and discussions towards the production of articles for a special edition of Journal of International Wildlife and Policy. Other PIs presented on their work to update the social sciences team.

An after lunch plenary session on integrating oceanographic measurements and modelling with animal tracking led by Svein Vagle was followed by a continuation of the morning's concurrent sessions. In the Theme 5 workshop PIs continued to update the social scientists on their work. These presentations were followed by a lengthy discussion. Meanwhile, eight more HQPs presented on their work, followed by three minute 'speed talks' by those HQP presenting posters later in the day. The posters were viewed by

all in the early evening during a social session. Industry partners (VEMCO, Satlantic, etc.) were also present, allowing them to meet the researchers using their equipment and discuss matters of common interest.

The second day of the symposium began with a plenary session focused on OTN infrastructure and evolving needs, led by F. Whoriskey. The remainder of the morning was a continuation of HQP presentations (ten in total). After lunch a plenary session began with a lecture on OTN from a data and analysis perspective by J. Mills-Flemming followed by a data visualization and modeling workshop for all PIs and HQP, which also highlighted the need to better understand performance characteristics of OTN acoustic technology. Finally, two concurrent sessions wrapped up the afternoon. In the first, S. Iverson led a plenary presentation and discussion for all PIs and collaborators on plans for Phase II (years 5-7) of OTN Canada in anticipation of the proposal writing workshop the next day. At the same time senior HQP D. Lidgard and S. Heaslip facilitated a workshop and discussion for all HQP on their wants and needs from OTN. After a break, all reconvened at the University Club for networking, drinks, and dinner.

Two concurrent sessions comprised day three. S. Iverson led an all day proposal writing workshop for the Phase II Proposal writing team. The team discussed the re-examined elements of the original proposal, reviewed progress so far, and considered ways of refocusing future work in order to best meet the goals of the Network. Considerable discussion centred around the organization of projects. While the original approach organized projects by Arenas, and this served the network well in in the initial years of the projects, it was felt better integration of projects could be achieved by organization around three overarching Framework Questions (FQs) and four major Cross-Cutting Activities (CCAs, activities which cut across one or more FQs). As a result, the team constructed a new conceptual framework focusing on these questions and CCAs (see table 1 below). The writing team agreed to write their individual Phase II project proposals in the context of the new framework. Further agreements were made on how to proceed with the proposal to have it ready by the end of the year. Also on day three, I. Jonsen led a half-day workshop for HQP on the use of the data analysis platform, Platform for Ocean Knowledge Management software (POKM).

Modellers and Observers Meeting, November 2012, Halifax, NS

F. Whoriskey chaired a half-day workshop at Dalhousie University to better integrate the activities and data of oceanographic modelers and observers involved with OTN based at Dalhousie University. PIs and HQP from each group presented on their research and the whole group discussed matters on common interest, including data collection, availability, uptake, and integrative use. Future meetings of this nature will likely include taggers and discussion of their needs and better integration of all activities.

ICES Annual Science Conference, 23-27 September 2013, Reykjavik, Iceland – special session accepted

S. Iverson was asked to be a co-convener of a special session, now accepted for the 2013 ICES meeting in Iceland in Sept 2013, entitled: “'Hi-tech Tagging': Advances in Studying Spatial Distribution”, at which she is also the invited keynote speaker. This session focuses on advances in acoustic telemetry and other tracking methods and suggests using OTN Canada as a prototype for similar projects in other areas. Industry presence will be encouraged to attend and to participate in an open forum on recent and future developments and needs.

2.2 Joint research, publications/presentations and data exchange

Selected examples of the activities within and among Themes and Arenas are highlighted bellow as illustration of the integration and networking that has been initiated. More extensive lists are contained in the individual reports.

The research group led by Christopher Taggart (Dalhousie) is pushing forward technology development and transfer to industry of accelerometry tags. The group is also collaborating with other OTN Canada researchers at Mount Alison and Acadia on field deployments with these new tags. Over the past year the technology progressed to the point where the size of the tags was reduced by 40% and the power consumption by 50% compared to the prototype. The tag design and specifications have been passed to industry partner VEMCO (through a report and during a half-day workshop) for their use in market studies and for potential commercialization. Free swimming trials with the novel tags have been carried out with Atlantic sturgeon in Minas Basin (Bay of Fundy, NS) in September 2012 in collaboration with Mike Stokesbury and his student Jeff Beardsall. The purpose of these trials is to investigate post-release behavior and identify behavioral responses to ambient noise from power generating tidal turbines. Free swimming deployments were also made on shortnose sturgeon in the Kennebecasis River (NB) in collaboration with Matthew Litvak and his student Andrew Taylor. The objectives of this work are to constrain relationships between size and acceleration on a size-range of shortnose sturgeon and to investigate their behavioral patterns in the wild.

PIs Keith Thompson and Jinyu Sheng (Dalhousie), and Julian Dodson and Martin Castonguay (Laval) and their HQP collaborate on a combined observation-modeling project in order to better understand how American Eels migrate from the St. Lawrence estuary to their spawning grounds in the Sargasso Sea. By combining model-simulated ocean currents with environmental preferences of the animals (e.g., specific light level, water temperature) plausible migration routes and animal distributions are being obtained for different assumed behavioral preferences, which, in turn, are validated against observed migration routes. With a modeling framework in place much of the research over the last year has focused on ways of inferring environmental preferences. A two-day workshop was held at Dalhousie in July, 2012 attended by researchers Thompson, Shan, Sheng, Ohashi, Dodson, Castonguay and Beguer. A joint presentation was delivered at the Ocean Sciences Meeting in Salt Lake City in February by Mélanie Béguer and two joint manuscripts are being prepared at present.

PIs Katja Fennel, Sara Iverson, Don Bowen and John Cullen (Dalhousie) and their HQP are collaborating on a project aimed at inferring phytoplankton biomass from light measurements made by grey seal bioprobes. Phytoplankton is a major contributor to vertical light attenuation, thus it should be possible to infer changes in phytoplankton biomass from changes in the light attenuation coefficients determined from the seal tags. So far graduate student Karl Lagman has analyzed light data from 33 tags that were deployed between September 2009 and December 2010 on grey seals on the Scotian Shelf (NS) and the resulting attenuation coefficients in the mixed layer show promise as a plankton biomass proxy. In order to validate and intercalibrate sensors and to establish a proxy relationship between attenuation coefficients and phytoplankton biomass the tags were also deployed on a sampling device with a full suite of bio-optical measurements and coincident with bottle sampling in Bedford Basin (with support

from John Cullen's group). Results were presented in conference presentations by S. Iverson at the Ocean Sciences meeting in Salt Lake City in February 2012 and by K. Lagman at the CMOS conference in Montreal in May 2012. Future steps will bring the data obtained from the seals on areas of productivity back to interpreting prey distributions and seal foraging hotspots on the eastern Scotian Shelf and Gulf of St. Lawrence.

PDF Steve Kessel (Arctic), along with PDF Nigel Hussey and PI Fisk (Windsor), is leading a paper that is reviewing acoustic telemetry studies that use range tests. Steve Cooke (Carleton) is a collaborator and co-author, along with international collaborators.

Arctic (Windsor, U. Vic) and Atlantic (MUN) researchers are beginning to collaborate on questions directed at species at transition zones in the Atlantic/Arctic and the effects of changing climates on their movements and distributions.

The techniques and study designs developed by the Pacific salmon group (UBC, Carleton) are now being used by the Atlantic salmon group, initiated in the studies of the Bras D'Or salmon.

Experience in telemetry studies spanning two decades on migrations of adult Pacific salmon, coupled with recent collaborations with social scientists and fisheries extension specialists, has led Pacific Arena investigators (UBC, Carleton) to a better understanding of how harvest management actions are influenced by telemetry science. This experience is serving as a template to inform other Arenas and subprojects of OTN Canada on how to better link their science with policy outcomes.

2.3. HQP exchange

A few examples of HQP exchange are highlighted bellow with more extensive lists contained in the individual reports:

- M. Beguer (HQP, I.2.2 American eel project) from the Université Laval spent time at Dalhousie (with K. Thompson's and Jinyu Sheng's groups, projects I.1.2 and I.1.3) in fall 2011 to become more familiar with model products and gain basic modeling skills directly applicable to her project. In July 2012 a two-day workshop was held at Dalhousie attended by researchers Thompson, Shan, Sheng, Ohashi, Dodson, Castonguay and Beguer to further collaboration on eel modeling.
- F. Bröll (HQP, I.1.1 Oceanographic observations) from Dalhousie spent time with Matthew Litvak's group from Mount Alison University and with Mike Stokesbury's group from Acadia University and participated in joint fieldwork.
- Knowledge and HQP transfer has occurred between the OTN Canada sturgeon project and OTN Global international partners (i.e., McLean's term in Australia with Heuple and Simpendorfer at James Cooke University and Beardsall's term in Australia with Sean Tracey at the University of Tasmania); also between OTN Atlantic sturgeon and oceanography projects (Litvak, Taylor, Taggart and Broel, Beardsall, Stokesbury, Logan-Chesney).
- OTN HQPs are afforded the unique opportunity of being part of a national collaborative research network. The Symposium provided a venue for discussing how to best capitalize on OTN resources to promote learning, training, and collaboration among HQPs. In light of strong interest in a more integrated communications platform for HQPs, the OTN Canada website is undergoing some restructuring. A private discussion forum is in production that serves to bring attention to

potential research collaborations, professional development and travel opportunities, social events, and available grants among HQPs.

2.4. Other major accomplishments

Some of the major accomplishments of 2012 are presented below.

Atlantic

- The accelerometry component has significantly enhanced accelerometer and inertial navigator tag design and worked with VEMCO in technology development and transfer. Free-swimming trials on various sizes of pollock and cod have defined acceleration metrics that scale with size. Collaborations are underway to study Atlantic and shortnose sturgeon in the wild.
- Migrating animals are being simulated as moving particles within oceanographic models in order to answer questions about the environmental cues that underlie migration behavior and also to infer plausible migration routes between the point detections at OTN listening devices. These methods are presently applied to American Eel. Assimilation methods are being implemented that combine the models with observations in statistically optimal ways in order to reduce model errors. Physical as well as biological variables are being assimilated. Approaches are being developed to infer environmental information from animals that were equipped with electronic sensors (referred to as bioprobes), which can be used to further improve model predictions.
- Pairing technology with statistical modeling, data on predator populations and mathematical models describing salmon population dynamics, Network researchers were able to identify estuaries as period of high mortality, identify predation as a likely vector and show that this mortality is substantial enough to affect long-term population viability.
- Using a combination of acoustic pingers and moored hydrophones, we have demonstrated considerable variation in migratory behavior of the European eel within the St. Lawrence River. The moored array of hydrophones at Cabot Strait recorded outmigrating eels in December, but also indicated a very low survival of eels migrating from the Gulf of St. Lawrence. One possible cause of this is predation; data from satellite tags revealed an unexpectedly high predation rate from porbeagle sharks.
- Grey seal bioprobe researchers at Dalhousie successfully engaged VEMCO and the Sea Mammal Research Unit (SMRU), St. Andrews, Scotland, to work together to combine expertise for the development of a Bluetooth enabled VMT and GPS satellite tag, which will allow the transfer of data from the VMT to ARGOS satellites for data download and thus remove the necessity of capturing animals to retrieve data. The first prototype of these tags is being tested in fall 2012. This beta-testing will provide input and encouragement to industry suppliers (VEMCO and SMRU) to develop fully integrated VMT tags, which will allow this "bioprobe" technology to be used in other marine species (both within OTN Canada and beyond) that are large enough to carry these instruments (e.g., sturgeon, sharks, other seal and marine mammal species).

Arctic

- The most comprehensive range testing of acoustic tags ever undertaken and the first in the Arctic occurred during the report year. Range tests were: deployed for 1 year; at 3 depths (~ 80, 400 and 1000 m); used multiple 69 and 180 kHz tags (V7, V9, V13, V16) and two locations (Resolute

Bay and Cumberland Sound). Initial results indicate that range of acoustic tags may be greater in arctic marine environments, but higher power tags may not be detectable at close range in this quiet environment. Results will be compared to range tests carried out in sub-tropical and temperate locations.

- Extensive spatial and temporal (full year deployment of instruments) collection of oceanographic data has taken place in two key ecosystems of the arctic; Cumberland Sound (low arctic) and Resolute Bay (high arctic). These are the first data collected in Cumberland Sound since the 1950's and indicate some changes in temperature and profile and that the potential surface water in the Sound may have a Pacific origin. These data will contribute to regional and large scale modeling of climate and oceanographic processes by Atlantic region collaborators.
- A massive VEMCO positioning system (VPS) was deployed in the high arctic to quantify the movement and behavior of the keystone fish species arctic cod. Part of this system was moved in mid-September prior to ice formation, a large volume of data was downloaded at this time and indicates that tagged cod, sculpin and Greenland shark spent a significant amount of time in the region. These VPS systems will be left for a full year, providing the first attempt to understanding a full year's cycle of the arctic cod and sculpin. In addition, whale and seal observations, including satellite tags on 3 ringed seals, in the VPS region will provide novel insights on the interactions of these key arctic species.
- For the first time, acoustic receivers were successfully deployed and retrieved at depths > 500 m. A total of 15 VR2 acoustic receivers were deployed at depths between 1,000 and 1,200 m for a full year in Cumberland Sound. All receivers were retrieved, none were damaged and > 100,000 detections were recorded from >90 individual fish. These are the first data ever collected for deep-water fish species and provide new insights on the seasonal movement patterns of the commercially important Greenland halibut and by-catch species arctic skate and Greenland sharks. These data are already being used by DFO and the Government of Nunavut for the development of an artesian Inuit fishery in Cumberland Sound and proposal to protect this fishing stock.
- Research in Cumberland Sound is one of the most comprehensive ecosystem assessments of fish and marine mammal movements and interactions, based on acoustic fish and oceanographic data outlined above, chemical tracer and contaminant data collected, and also satellite tag deployments, boat survey and listening devices used to study marine mammals.

3. Training of Highly Qualified Personel (HQP)

The following table summarizes the HQP who have been supported by the Network during 2012.

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. The Networking Session of the OTN Canada June 2012 Annual Symposium also provided an impetus for future activities. Appendix A provides a complete summary of student names within projects and examples of work within the Network. Complete descriptions of HQP involvement are contained in the individual project reports.

Table 1. Summary of the number of Highly Qualified Personnel (HQP) trained within the scientific program of OTN Canada by Arena.

HQP	Atlantic Arena		Arctic Arena		Pacific Arena	
	Total	Completely Supported by Grant	Total	Completely Supported by Grant	Total	Completely Supported by Grant
Undergrduates	14	5	3	1	3	-
MsC	12	6	2	1	10	1
PhD	10	6	3	1	7	-
Post Doctoral Fellows	6	4	4	2	3	1
Research Associates	11	2	-	-	2	-
Technicians	1	-	-	-	4	1
Co-Op	4	1	-	-	-	-
Total	**58**	**24**	**12**	**5**	**29**	**3**

4. Participation of key partners

Government

The involvement of Canadian Department of Fisheries and Oceans (DFO) occurs in 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 Scientific Advisory Committee and ten of the twenty-seven 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.

On 13 July 2012, OTN executive (Executive Director Fred Whoriskey, Scientific Director Sara Iverson) met with Dave Gillis, Director General of Ecosystem Science for DFO, at which they discussed the continuing collaboration between OTN and DFO. During these meetings the relationship between the Network and DFO, and the mutual benefits that are derived, was confirmed. To continue to strengthen connections, Dave Gillis agreed to sit on the Steering Committee for the developing new Strategic Plan for OTN and to provide input into the scientific planning for all of OTN.

Canadian 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.

On 13 July 2012, OTN representatives (Executive Director F. Whoriskey, Scientific Director S. Iverson and Dalhousie Vice President Research Martha Crago) met with the Vice Presidents and Program Directors of both CFI and NSERC in Ottawa to discuss some of the new strategic directions and future challenges of a unified organization with financially distinct research projects and expectations. All present agreed that a tight integration of the NSERC and CFI activities was highly desirable; however, each funding agency also has specific requirements independent of the other that must be met. The proposed changes to OTN's governance structure were discussed, as were progress on the strategic planning exercise and the scale of OTN national and international science activities and goals. Both NSERC and CFI indicated that they were pleased with OTN's progress and future plans, especially given the early stage of the rollout of the OTN infrastructure.

Industry

OTN Canada continues to have a number of industry collaborators. These industry collaborators, such as VEMCO, Satlantic, Kintama, Lotek, and others, have been integral in helping it solve problems, develop new technology, construct needed equipment, and brainstorm about better ways to use it. Examples are many and are included in individual project reports, but include working with OTN PIs to miniaturize tags and subsequently test their success, to allow deployments in the smallest fish to date and collaborating with bioprobe PIs to develop the next phase of VMT tags with SMRU, St Andrews, Scotland, as described above. This would make it possible to use VMT technology in the Arctic and Pacific Arenas, where it is not possible to recover tags on large bioprobes, such sharks, sturgeon or other seal species being studied. Members from the Atlantic Arena also worked with VEMCO on new tag design and specifications for accelerometers and for their use in market studies and for potential commercialization. VEMCO's chief scientist, D. Webber, traveled to Cape Breton in spring/summer of 2012 to work with Atlantic salmon investigators on configuration and deployment of optimal acoustic receiver arrays to meet projects aims in the Bras d'Or system. The Arctic Arena continues to work closely with VEMCO on optimal design of receiver arrays. OTN Canada's industry partners VEMCO, ROMOR and Satlantic, also contributed to the June symposium and meetings. In particular, VEMCO very generously contributed to two evenings' events, and ROMOR provided additional support. Support from these industry partners has a great impact on the synergy of the network, and their willingness to help generate the opportunity for the OTN Canada members and collaborators to get together is demonstrates the importance of industry collaborations.

Universities and other research institutions

The many universities and research institutions with whom the OTN Canada PIs and collaborators are associated provide the 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.

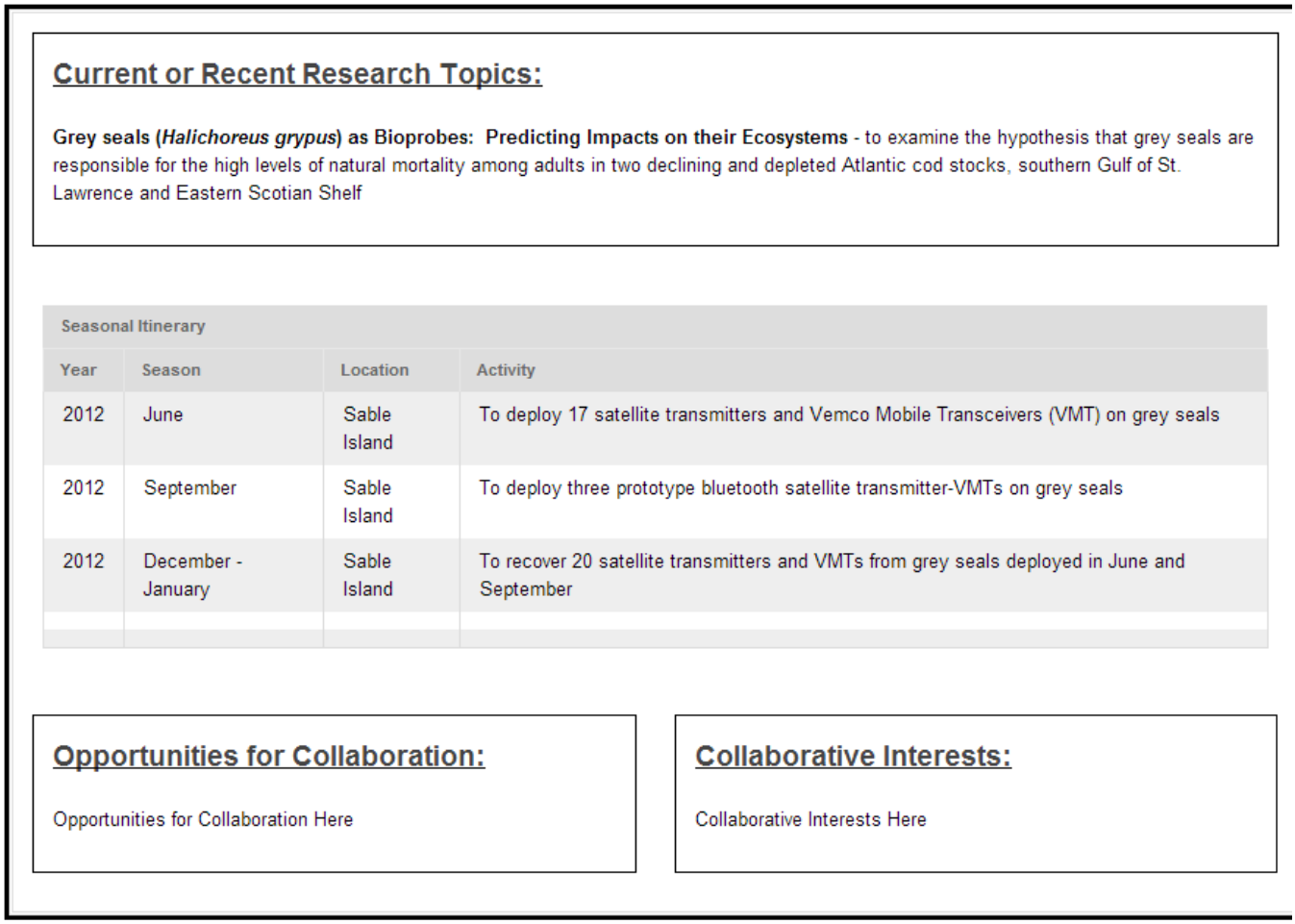
5. Dissemination and other contributions

Publications and presentations.

See individual reports for details.

Newsletter and Website.

The bi-annual OTN newsletter shares news and events from Canadian and Global perspectives, including updates on deployments, tracking initiatives, research outcomes, and data warehousing activities. 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 third edition was distributed at the 2012 OTN Canada Symposium, mailed electronically, as well as hosted on both the OTN Canada and Global websites. The newsletters have become regular items included in information packages to new members and potential collaborators due to their value in reflecting significant Network achievements and progress.



Current or Recent Research Topics:

Grey seals (*Halichoreus grypus*) as Bioprobes: Predicting Impacts on their Ecosystems - to examine the hypothesis that grey seals are responsible for the high levels of natural mortality among adults in two declining and depleted Atlantic cod stocks, southern Gulf of St. Lawrence and Eastern Scotian Shelf

Seasonal Itinerary

Year	Season	Location	Activity
2012	June	Sable Island	To deploy 17 satellite transmitters and Vemco Mobile Transceivers (VMT) on grey seals
2012	September	Sable Island	To deploy three prototype bluetooth satellite transmitter-VMTs on grey seals
2012	December - January	Sable Island	To recover 20 satellite transmitters and VMTs from grey seals deployed in June and September

Opportunities for Collaboration:

Opportunities for Collaboration Here

Collaborative Interests:

Collaborative Interests Here

In May 2012, OTN Canada began distributing a quarterly news bulletin featuring items relevant to the OTN Canada member community— specifically, HQP and PIs, as well as NSERC. The two- to three-page bulletins are a step towards greater intranetwork communication and collaboration through member profiles, calls to action, and status reports. The August bulletin featured news on media coverage from the Wave Glider test mission, German Chancellor Angela Merkel's visit to Dalhousie, equipment software updates, important dates, and a feature on HQP research supported by OTN. The newsletters and news bulletins have been well received across the Network.

Both the Canada and Global websites continue to be updated and expanded with information for OTN Canada researchers and the Global community. Noteworthy expansions include a research section attached to HQP profiles on the OTN Canada site. The sections, which are private among HQP, identify collaborative interests and opportunities, seasonal itinerary, and information on current research topics (see below). The creation of this research section is a response to desires expressed during the 2012 OTN Canada symposium for HQP to better recognize and take full advantage of a network environment in their training and education programs. In tandem with the profile additions is a discussion forum hosted on the OTN Canada site in which HQP may exchange information valuable to the OTN HQP community.

Data management/sharing.

In November 2012, the OTN Data Centre published OTN Global discovery metadata, which includes data access via CSV/KML files for stations and mystery tags. The OTN Canada metadata can be found online at http://members.oceantrack.org/data/discovery/OTNCanada.htm. This metadata allows data to be discoverable via the internet and provides users with a contact point to learn more about the data. The metadata is now used with the GoogleEarth application providing a visualization tool for users. The OTN data policy was amended to comply with international data standards of practice. A simplified data policy was added to the amended policy to reflect the most basic principles of OTN data owner/usership. Further information on OTN Data Policy is available online (http://www.marinebiodiversity.ca/OTN/policies/otn-data-policy-ver-11-oct-30).

In September 2012, OTN acquired data from the Pacific Ocean Shelf Tracking (POST) project adding approximately 7 million records to the data warehouse, which is now just over 30 million records in total. In addition to housing this data, OTN will maintain three of the former POST arrays, which are central to work being conducted by the Pacific Arena and collaborators in both Canada and the US.

OTN has begun contributing data to the Ocean Biogeographic Information System (OBIS: http://www.iobis.org/), via OBIS Canada (http://obiscanada.marinebiodiversity.ca/). The two (of six submitted to date) datasets currently available on OBIS may be found here: http://iobis.org/mapper/?resource_id=2429,2308

Priorities for next year include initiating replacement of manual processes with automated methods, emergence of regional nodes including North East Pacific, Southern Africa and Australia, growth of OTN Canada deployment and tracker activity, new institutional and commercial partners and rapid introduction of benthic pods and near real time transceivers, buoys and gliders.

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 spinCoffs. These are far too numerous to describe here and are detailed in the individual reports that follow.

OTN Scientific Director S. Iverson took part in the tour by German Chancellor Dr. Angela Merkel to Dalhousie on 16 August 2012. Chancellor Merkel, whom Forbes magazine has named the Most Powerful Woman in the World five times, visited Dalhousie University to witness the signing of an MOU between the Halifax Marine Research Institute and the Helmholz Association in Berlin on joint oceans research. During the visit, eight scientists from Dalhousie presented the major oceans research projects to the Chancellor, who earned a doctorate in quantum chemistry in 1978. S. Iverson represented OTN and presented the key questions being addressed by OTN Canada and worldwide, and demonstrated current and developing technology behind OTN. Notable political figures attended the event as well, including the Premier of Nova Scotia and the Minister of State (Science and Technology). Dalhousie HQP Edmund Halfyard and Franziska Broell also met with Chancellor Merkel in their role as students working within the OTN. Iverson and Broell participated in a panel discussion hosted by the Chancellor on oceans science, challenges, and future Canadian-German research opportunities and collaborations. http://metronews.ca/news/halifax/338325/german-chancellor-in-town-thursday/

http://www.lapresse.ca/sciences/201208/16/01-4565802-le-canada-et-lallemagne-renforcent-leur-collaboration-scientifique.php

http://rabble.ca/blogs/bloggers/christophermajka/2012/08/berlin-wallet-merkel-invests-harper-divests

http://www.dal.ca/news/2012/08/17/german-chancellor-makes-the-most-of-her-dalhousie-visit.html

6. Changes, Reprofiling, and Delays

Deviation from the original overall research objectives.

There have been no significant deviations to the overall 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).

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, Arena Leaders or the Theme Leaders Committee (TLC) raising concerns about the progress of specific projects and suggesting possible solutions or new directions.

Two requests were received during the 2012 report year. One by the eel group (J. Dodson) was simply to carry forward funds and extend the termination date of this project from December 31, 2012 until December 31, 2013. The rationale for requesting the change is to support a PDF and MSc students, who both began late, support ARGOS fees and cover travel of HQP. The committee unanimously agreed that

the request was reasonable and well justified, and was not requesting new funds, and this was approved. The second request by the Pacific group (S. Hinch) was to move funds from PDF salary to technician salary. The rationale for requesting the change was that the PDF hired to do an extensive amount of field and lab work and data analysis and paper writing had accepted a PDF position in Australia. The plan to hire an experienced technician to replace this PDF was deemed to be very sound, as there was insufficient time to find a qualified PDF and the fieldwork that needs to be done is critical to the Pacific OTN projects. As well, since the original PDF will work on the data and papers, there was no net loss in HQP or productivity from this group, and this request was unanimously approved.

Additional reprofiling was conducted for the Cape Breton Bras d'Or salmon work (B. Hatcher et al.) and the social sciences fieldwork (led by D. Vanderzwaag and R. Apostle), as outlined and discussed at the Nov 2011 SAC, and subsequently both were unanimously approved by the full SAC.

Technical issues

There were no central technical issues during the report year, other than the ongoing work in developing technology and tag capabilities, described in individual reports.

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

I. Atlantic Arena

1. **Project Number:** I.1.1

2. **Project Title:** Integrated Interdisciplinary Observing and Modeling Platform – Observing Component

3. **Project Leaders:** J. Cullen, C. Taggart (Dalhousie), P. Smith (DFO)
   Collaborators: B. Greenan, D. Hebert (DFO)

4. Public Summary of Report

The OTN Observing Component collects a wide array of physical, biological and chemical observations along the Halifax Line (HL), which serves as the test bed for OTN research in the Atlantic Arena. To date, physical data from several sources on and near the HL dating back to April 2008 have been assembled and analyzed to provide time series of Nova Scotian Current transport, tidal currents, seasonal drift rates vs. depth, and fine-scale hydrographic properties on the HL. Meanwhile, Dalhousie's Marine Observations Support Team (MOST) has established an effective program of ocean glider operations, sampling the ocean interior of the Scotian Shelf 230 days during the reporting period while developing web-based data presentations and a framework for regular interaction between network members who supply and use the data. The Observing Component is now providing data to the OTN program while making significant progress in the development of new systems for describing distributions of phytoplankton and in relation to hydrographic conditions in the OTN study area. A new multi-parameter approach has been developed to retrieve estimates of chlorophyll concentration from optical sensors on the gliders. It shows promise for use on a range of autonomous ocean sensor systems that are deployed in open waters where no direct validation of estimates can be made. The accelerometry component has significantly enhanced accelerometer and inertial navigator tag design and worked with VEMCO in technology development and transfer. Free-swimming trials on various sizes of pollock and cod have defined acceleration metrics that scale with size. Collaborations are underway to study Atlantic and shortnose sturgeon in the wild. A paper on the use of high-frequency accelerometer tags and their utility is nearing publication and a paper on the new tag technology is close to submission stage. Efforts are now underway to address the assimilation of accelerometer data plus constraints on swimming velocity using tail beat frequency and size. The ocean model will provide the x, y, z temperature and flow fields that can be used to determine the 'most likely' trajectories through minimizing a cost function.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Mathieu Dever (OO)	PhD	100	100	1 Oct 2011-30 Sep 2012
Thesis topic: Characterization of Nova Scotian Current and its variability along the Halifax Line				
Matthew Beck (OG)	MSc Student	100	100	1 Oct 2011 – 30 Sept 2012
Thesis topic: A multiparameter approach for estimating chlorophyll a from ocean gliders.				
Adam Comeau (OG)	Research Assistant	100	100	1 Oct 2011 – 30 Sept 2012
Richard Davis (OG)	Research Assistant	75	0	1 Oct 2011 – 30 Sept 2012
Chantal Giroux (OG)	Co-op Student	40	0	4 Sept 2012 – 30 Sept 2012
Chris Jones (OG)	Research Assistant	20	0	1 Oct 2011 – 30 Sept 2012
Jon Pye (OG)	Research Assistant	75	0	1 Oct 2011 – 30 Sept 2012
Shannah Rastin (OG)	Co-op Student	100	0	4 Sept 2012 – 30 Sept 2012
Kendra Chisholm (AC)	Co-op Student	100	100	1 May – 30 August 2012
Elizabeth Campbell (AC)	Co-op Student	20	0	1 January – 30 April 2012
Franziska Broell (AC)	PhD	100	100	1 Oct 2011 – 30 Sept 2012
Thesis topic: Accelerometry; the key to monitoring temperature-dependent fish growth and activity in the wild.				
Andre Bezanson (AC)	Part-time Elect. Eng. (PhD, Biomed. Eng.)	10%	10%	1 Oct 2011 – 30 Sept 2012
Thesis topic: Design and fabrication of high frequency phased array for imaging the inner ear.				

OG: The Ocean Glider Group, now named Dalhousie's Marine Observations Support Team (MOST), spent this year running glider missions, collecting oceanographic data for validation of the optical measurements, developing data management and presentation systems, and working with Network researchers to serve their needs for data. Troubleshooting was also an important component of the work, as we continued to encounter reliability problems with the gliders. Team members have developed into experts with this new system of ocean observation, and they are now excellent representatives of OTN technology. Richard Davis is the lead technician for the glider component. His primary roles are project and logistics management, particularly ensuring all safety procedures are followed in lab and aboard vessels, and participation in field operations. Other activities include supervising Adam Comeau, Jon Pye, Chris Jones and co-op students, making snap judgements during operational emergencies, overseeing data analysis, requisitioning and purchasing equipment, coordinating activities with other research groups, managing the budget, and training graduate students. In addition, he effectively represented OTN for media presentations on the Wave Glider deployments (see section 10(a)). Adam Comeau is the primary field technician. He maintains and operates the gliders, OTN small vessels, and field equipment, and also performs specialized data analysis. Jon Pye is an Information Technology specialist. He creates and maintains databases, programs missions for the gliders, maintains computer hardware, and is developing the OTN glider web presence. Graduate student Matt Beck is working on his MSc thesis on developing new estimates of chlorophyll from glider measurements. This involves extensive skill in programming and in the application of hydrological optics. Chris Jones works part time and writes code to process discrete data collected during glider deployments and recoveries. His MSc degree in statistics is immensely valuable as he supports data quality control efforts. Finally, the two co-op students, Chantal Giroux and Shannah Rastin, participate in field sampling, process discrete water samples and aid in data entry. Overall, the group is developing a capability that is central to modern oceanography and all involved are gaining the skills and knowledge to helping others to use this research approach.

AC: Andre Bezanson, with help from Franziska Broell, takes a leading role in the design, construction and programming of the high frequency accelerometer tags and the high frequency inertial tags. His expertise has led to a 40% reduction in the size of the tag and a 50% decrease in power consumption since we began developing the tags a little over a year ago. The tag design and specifications have been passed to VEMCO for their use in market studies, further enhancement, and potential commercialization. The intellectual property (IP) associated with the tag and software development is jointly owned by Broell, Bezanson and Taggart though we have made much of the technology development freely available to VEMCO for further development and for the betterment of the Canadian economy.

The work has also resulted in a draft manuscript by Bezanson et al. (see below) entitled "Design and fabrication of a low-cost acceleration data logger for lab and field application in physiological studies"; perhaps targeted at *Sea Technology* or *Ocean Technology*. Working as a team they have become somewhat of experts in accelerometer technology and as representatives of new OTN technology they have received a considerable amount of media coverage (see below) as well as inquiries from other researchers around the world. Broell also enhanced her advisory acumen through training Kendra Chisholm and Elizabeth Campbell in requisitioning and purchasing equipment, animal husbandry and CCAC Certification, fish measurements and tagging, conducting swim trials with accelerometry data logging, record keeping, data extraction and data pre-processing. Together, this team developed considerable strength in advance fish-tag technology and accelerometry studies.

6. Progress towards Objectives/Milestones (1 Oct 2011 – 30 Sep 2012)

The main objective of this component is to develop and calibrate new ocean observation technologies, including interdisciplinary sensor systems on ocean gliders and accelerometers on fish, as a powerful and cost effective capability for surveying essential physical, chemical, biological and ecological processes and interactions in coastal waters and shelf seas. It will also provide validation data sets for the integrated modeling component and time series for data assimilation. Specific objectives for this initial phase are:

(1) Develop a system for integrating bottom pod, ADCP and glider data to provide a physical description of the system;

(2) Develop procedures for deploying gliders and obtaining optical data products;

(3) Develop new optical data products to provide biological and physiological information;

(4) Develop new approaches to modeling biological-optical-physical interactions (with I.1.2);

(5) Validate that acceleration metrics in a fish are a function of size-at-time;

(6) Determine key parameters from the acceleration frequency spectrum and/or other relevant statistics that scale with size at age;

(7) Demonstration that similar acceleration metrics will provide estimates of activity of marine animals (fish, sea turtles, seals etc.).

(8) Demonstration that acceleration metrics will provide in situ estimates of feeding activity and energy budget estimation.

OO: As part of the OTNC training agenda for HQP, PhD candidate Mathieu Dever passed his qualifying exam in July, 2012, based on a review of "The arrested topographic wave", by G.T. Csanady [1978, J. Phys. Oceanogr., 4(1), 83-90].

Mathieu has assembled and examined physical data from the Halifax Line and the "deflected" OTN version thereof (Figure 1a). The data include:

- ADCP and bottom-mounted MicroCat from three mooring sites (T1-T3) spanning the Nova Scotian Current, deployed semi-annually since April 2008,
- OTN detections from 254 hydrophones on the deflected Halifax Line, recently completed in April, 2012 (Figure 1a),
- Some benthic pod observations of bottom temperature, salinity, pressure and dissolved oxygen at the eight stations along the deflected Line,
- Atmospheric measurements from two Environment Canada meteorological buoys in the area, and
- Hydrographic data from glider transects along the Halifax Line (Figures 1b and 2).

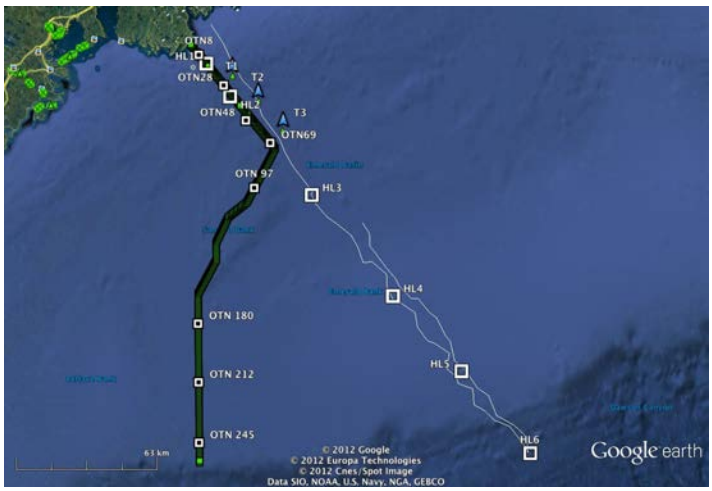


Figure 1a. Stations comprising the Halifax Line (HL1-6), the deflected Halifax Line of hydrophones (OTN1-254), including benthic pod locations (OTN8,28,48,69,97,180, 212,245), and a sample glider trajectory between the coast and HL6.

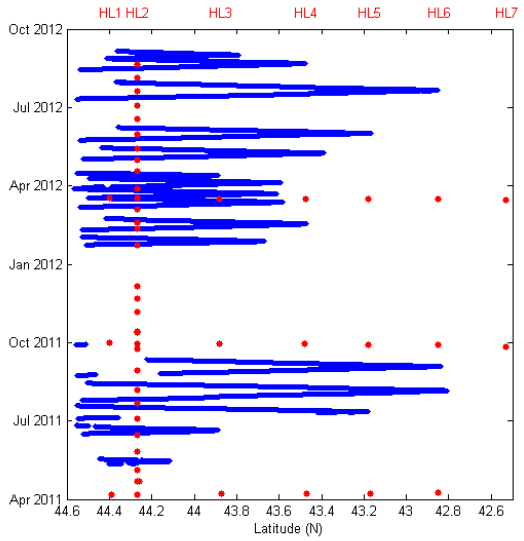


Figure 1b. Glider transects conducted since April, 2011. Red dots indicate sampling at stations on the Halifax Line.

Products of Mathieu's analysis include:

- Nova Scotian Current transport time series derived from ADCP and glider data from 2008-present
- Tidal analysis of ADCP data
- Estimates of seasonal drift rates vs. depth from the ADCP records
- Fine-scale hydrographic properties on the Halifax Line from glider data

OG: *Glider operations* – During the reporting period, protocols for maintaining, deploying and recovering the Slocum gliders were finalized. Maintenance of the two gliders is not a trivial matter and hard-gained experience is driving our protocol development. Checklists have been developed that reflect both the manufacturer's recommendations and experience of the glider group, making operations on board the ship less prone to operator error. Documentation is being produced that standardizes all the protocols.

One of the mandates of the Marine Observation Support Team is to have a glider transiting the Halifax Line nearly continuously. The Gantt chart in Figure 2a and the heat map in Figure 2b show their success so far. Since the gliders were returned from repair in early 2012 (see section 7b) we have had a glider in the water at all times, with only short refurbishment periods in between. For this reporting period the gliders were in the water 230 days and travelled 3823 km, collecting more than 4 million data points.

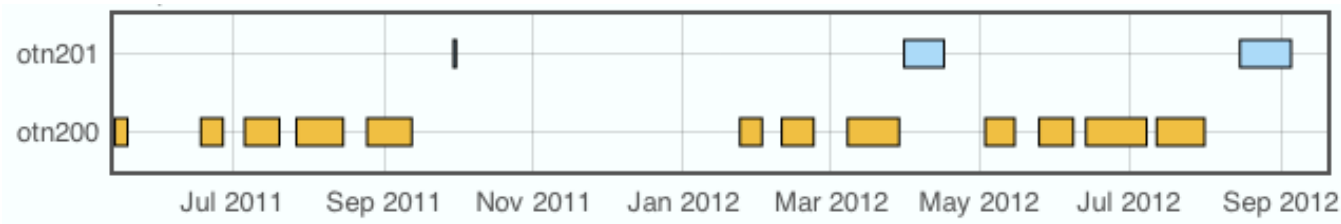


Figure 2a. Gantt chart showing the time periods when the two Slocum gliders were sampling the Halifax Line.

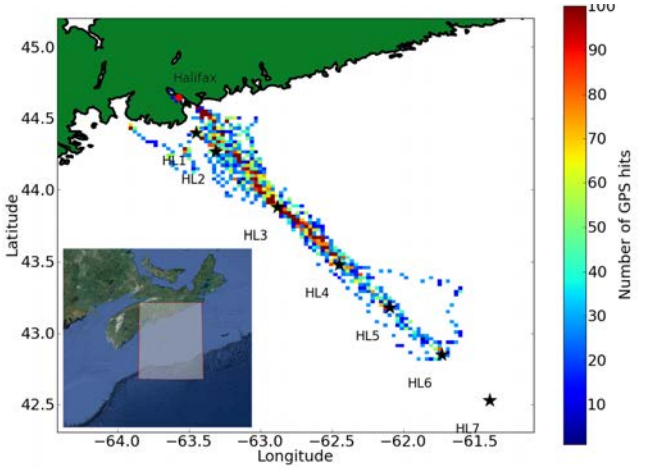
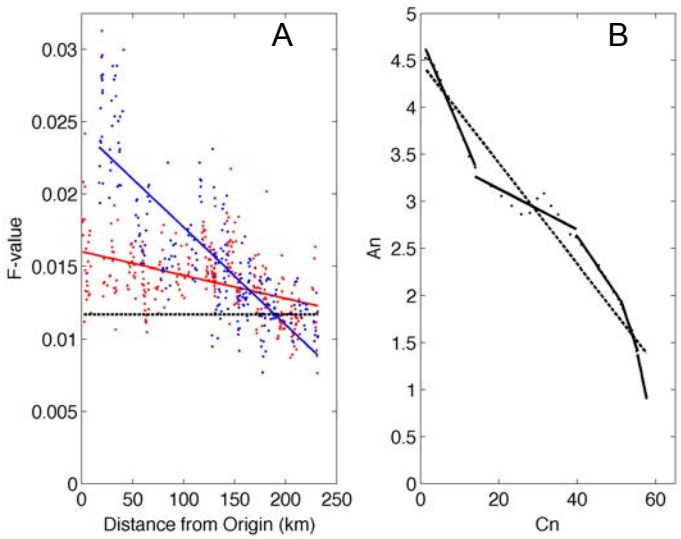


Figure 2b. Heat map showing the density and location of GPS hits for the gliders as they surface every 6 hours to communicate to shore via Iridium satellite communications. Stars mark stations on the AZMP Halifax Line.

New optical data products: chlorophyll concentration – Optical data products are under development by graduate student Matthew Beck under John Cullen's supervision. The challenge is to calibrate the chlorophyll fluorometer onboard the glider when it is impossible to obtain direct samples for groundtruthing at many locations and times. A multi-parameter optical approach for estimating



chlorophyll concentration from glider measurements has been constructed. By merging two previously published methods (Sackmann *et al.* 2008, Xing *et al.* 2011) into one protocol, we will be able to get better estimates of chlorophyll concentration from *in situ* instrumentation. The new methodology constructs a calibration factor for the fluorometer that can vary in time and space, unlike conventional calibrations that are fixed for an entire mission (Figure 3). Beck and colleagues describe this work in a 16-page extended abstract that has been posted prior to the Ocean Optics XXI meeting in Glasgow, Scotland, this October, during which he will present a poster.

Figure 3. A multiparameter optical method is designed to increase the accuracy of chlorophyll *a* estimates from *in situ* fluorometers deployed on the OTN Slocum gliders. **A.** An F-value ([mg chlorophyll *a* m^{-3}] $count^{-1}$, also called the calibration factor) is applied to the readings from fluorometers to estimate the concentration of chlorophyll. The default calibration supplied by the fluorometer's manufacturer, 0.0117 [mg chlorophyll *a* m^{-3}] $count^{-1}$, is shown with the black dashed line. F-values from the new method are plotted as a function of distance from the Nova Scotia coast for outgoing (red, n = 319) and incoming (blue, n = 234) legs during a glider mission in summer 2011; they vary from 0.0076 to 0.0313 [mg chlorophyll *a* m^{-3}] $count^{-1}$; regression lines show trends, both of which are significant at $p < 0.001$. Results suggest that systematic errors may be associated with the use of a static calibration factor to estimate chlorophyll *a* concentration. Potential sources of these errors are being examined. **B.** The Xing *et al.* (2011) method depends on the relationship between i) measurements of chlorophyll fluorescence and the statistical relationship between chlorophyll and light penetration, compiled into a parameter *Cn*, and ii) a parameter representing light penetration, *An*. The linear slope of the *An* vs. *Cn* relationship (black dashed line) allows for the calculation of a profile-specific F-value for converting fluorescence to chlorophyll *a*, where each profile provides a single data point in (A). The method is currently being modified to accommodate multiple F-factors per profile by dividing the water column into optical depths, with an F-factor being calculated from the slope of each optical depth segment (solid black lines). In principle, this will increase the accuracy of chlorophyll *a* estimates even further, and allow OTN gliders to autonomously correct for changes in phytoplankton taxonomy and physiology in both the horizontal and vertical dimensions. These analyses will by validated through a combination of indirect comparisons with bio-optical relationships and direct sea-truth samples collected when gliders are deployed and recovered.

Oxygen concentration – Both Slocum gliders are equipped with Aanderaa optodes for measuring oxygen concentrations. Considerable time has been spent during the last reporting period to obtain accurate oxygen measurements, as the values directly reported by the instruments are incorrect by as much as 10%. The optodes themselves had to be reprogrammed to transmit raw data into the logged data stream. The raw data are then corrected for the effects of temperature and salinity as measured by the on-board Sea-Bird CTD, thereby removing major inconsistencies in the uncorrected data (Figure 4).

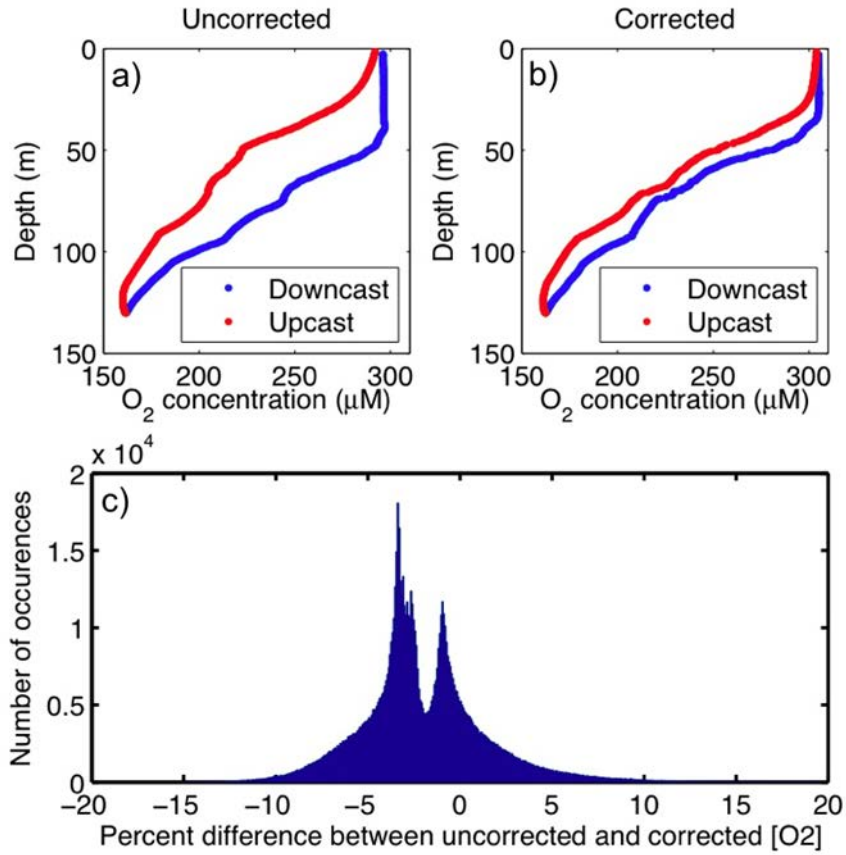


Figure 4. Effects of temperature and salinity corrections on oxygen concentration as measured by Aanderaa oxygen optodes deployed on a Slocum glider. **a) and b)** show the effects of the corrections on measured oxygen profiles, with the corrected profile showing less hysteresis. **c)** Histogram of the difference between uncorrected and corrected oxygen measurements. The bimodality observed in the histogram is most likely due to the upcasts and downcasts requiring differential amounts of correction.

New approaches to modeling biological-optical-physical interactions – In consultation with Katja Fennel and Hugh MacIntyre, John Cullen continued to develop a bio-physical modeling framework that replaces chlorophyll *a* with measures related to the absorption of light by phytoplankton, thereby streamlining the modeling effort, generating predictions that can be compared directly with optical observations, and eliminating sources of error. The modeling framework was described during invited lectures in Tianjin and Qingdao, China and the ASLO Aquatic Sciences meeting in Otsu, Japan.

AC: Our main objectives over this past year were to: **1)** enhance the accelerometer tag design, **2)** further develop the inertial navigator tag (3-axis accelerometer, 3-axis magnetometer [pitch, roll, yaw], and 3-axis compass), **3)** continue to work with VEMCO in moving toward technology development and transfer, **4)** conduct multiple free-swimming trials (Aquatron pool tank) on various sizes of pollock and cod to define acceleration metrics that scale with size, **5)** conduct free swimming trials in the wild with Atlantic sturgeon in collaboration with the Mike Stokesbury and his team working on hydro-acoustic tagging to measure tail-beat frequency and define sturgeon activity patterns that may be related to ambient noise), **6)** conduct free swimming trials in the wild with various sizes of shortnose sturgeon in collaboration with Matthew Litvak and his team working with conventional V9 acoustic tags to define acceleration metrics that scale with size as well as identify sturgeon activity (e.g. feeding) patterns, **7)** begin outlining how to use ocean modeling and assimilation of tag data to determine 'most likely' fish trajectories, **8)** publish peer-reviewed paper on the use of high-frequency accelerometer tags and their utility in indentifying fish activities, **9)** publish a paper on the new tag technology and application.

(1) **Enhance the accelerometer tag design**: Our earlier prototype has been reduced to 60% of its initial size (Fig. 5). The new version also uses less power for sampling and has increased efficiency in writing

data to an increased memory block. This tag was used in a variety of our swim trials detailed below. Efforts are underway for further size and power-use reduction.

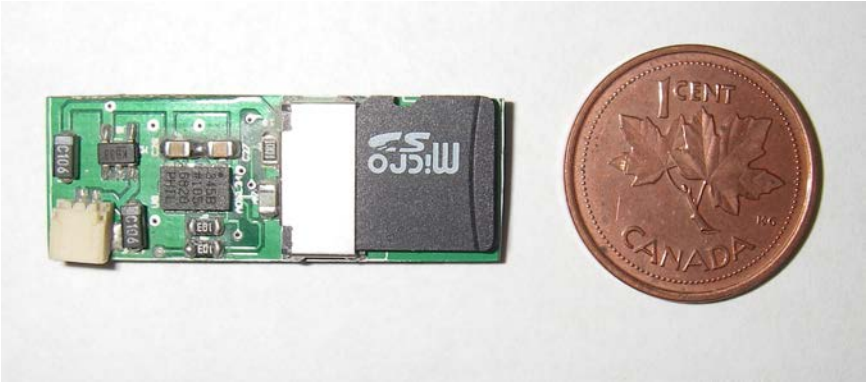


Figure 5. Enhanced high-frequency accelerometer

(2) **Develop the inertial navigator tag**: An inertial tag (Fig. 6) was developed using 3-axes accelerometer (nominally 50 Hz), magnetometer and compass. The inertial sensor is currently being deployed on Atlantic sturgeon in the Minas Basin in collaboration with Mike Stokesbury and his MSc student Jeff Beardsall (detailed below). The aim of this research is to investigate post-release behavior, TBF and behavioural response to ambient noise in the Minas Basin.

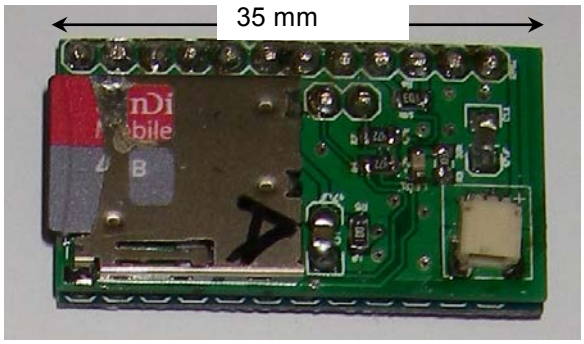


Figure 6. The inertial sensor with high-frequency accelerometer, magnetometer and compass.

(3) **Work with VEMCO toward technology development and transfer**: We are continuing to work with Bruce Oakley, Richard Vallee and Dale Webber at VEMCO to further enhance the tag technology beyond what we have been able to achieve and this work recently culminated in a half-day information exchange workshop with VEMCO where in we summarized our research to date and addressed the future design and use of enhance accelerometers. At this meeting VEMCO was presented with a technical report entitled 'High Frequency Data-logger Design Review' compiled by Andre Bezanson. The issues addressed included the facts that: a) we have maximized our potential in optimizing the accelerometer development though there is room for improvement, b) to successfully use accelerometer tags in the field, a priori parameterisation between acceleration and behaviour or physiological characteristics of interest is essential, c) determining the appropriate sampling frequency to resolve these parameters is essential, d) suboptimal sampling rates will result in underestimation of activity or a insufficient battery life and a lower signal to noise ratio, e) successful application of accelerometer tags consists of three stages (Fig 7); the lab phase where behaviour or physiological characteristics of interest are measured, statistical parameters and sampling frequency are determined and algorithms that use these

parameters to identify behaviour/activity or physiological characteristics are developed; the engineering phase where algorithms are incorporated into the micro-processor of an accelerometer tag, and necessary sampling frequency (or sub-sampling) is set to maximize battery duration; and the field phase where the 'smart' accelerometer tag is deployed in a field study.

Subsequent to this meeting, VEMCO completed an assessment of what is possible in terms of the electronics and packaging and were fairly confident they could develop a field logger that would be somewhere in the range of 10-12 mm diameter with a memory capacity up to 64 megabytes. Sampling rate in the field unit would likely be programmable and could potentially reach 500 hertz if required. They would also assess the development of a lab model with special packaging that would allow one to change the battery. Prior to proceeding with these developments they would conduct a market study to try and fully understand all the applications that might exist (e.g., aquatic, terrestrial, medical, etc.). Though busy pursuing other developments, VEMCO concluded there is merit in such a product and hope that they can begin development after the market assessment, perhaps as soon as fall 2012 or shortly thereafter.

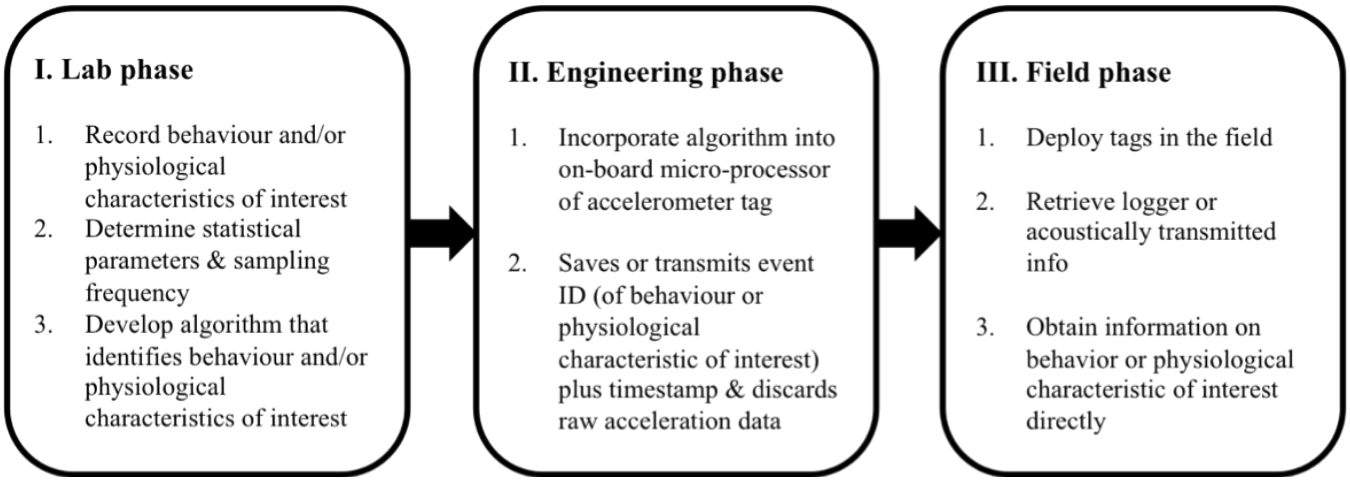


Figure 7. Three-stage approach for successful application of accelerometer tags for fish in the field.

(4) **Conduct multiple free-swimming trials (Aquatron pool tank):** Two fish species, pollock (*P. virens*) and Atlantic cod (*G. morhua*)) were used to test relationships between size and acceleration (Tail Beat Frequency; TBF). A total of 18 pollock spanning a size range from 25 to 56 cm were used in free swimming trials in the pool tank of the Aquatron. Fish were fitted with 50 Hz recording accelerometer sensors fitted into small pressure cases that we developed in early 2012 in collaboration with Andre Bezanson. We collected 800 hours of swim-trial data among these fish, each deployment lasting between 12 and 24 h. A total of 23 cod spanning a size range from 47 to 72 cm were also used in similar free swimming trials (Fig. 8) wherein we collected 1187 hours of data among the 23 fish with each deployment ranging between 12 and 24 hours. The above data will undergo thorough analyses starting late 2012 and continuing into early 2013. The initial focus will be to obtain relationships between acceleration (TBF) and size, and possibly other acceleration metrics. The animals are being maintained in the Aquatron while they continue to grow and our intent is to repeat the swim trials in January and/or February 2013 to test relations developed from the above analyses and confirm that intra-individual variation in acceleration is also a function of size.

Figure 8. Photograph of 20 cod free-swimming in the Aquatron pool-tank, each carrying high frequency accelerometer tags deployed for periods of 12 to 24 hours.

(5) **Free swimming trials in the wild with Atlantic sturgeon**: We have worked in collaboration with the Mike Stokesbury and Jeffrey Beardsall (MSc student) at Acadia to investigate post-tagging release effects on Atlantic sturgeon, the effect of noise levels in the Minas Passage on the sturgeon as well as to measure tail-beat frequency and define sturgeon activity patterns that may be related to ambient noise. For this purpose sturgeon are being equipped with our high-frequency recording inertial sensors (above) and a logging hydrophone. Initial deployments were successfully conducted in September 2012, including one incorporating the deployment of an inertial sensor on an Atlantic sturgeon for a 6-h period. Additional deployments are to follow.

(6) **Free swimming trials in the wild with shortnose sturgeon**: In collaboration with Matthew Litvak and Andrew Taylor (MSc student) at Mount Allison we are working to measure relationships between size and acceleration (e.g. TBF) on a size-range of shortnose sturgeon in the Kennebecasis River, New Brunswick and to investigate their activity (e.g. feeding) patterns in the wild. For this purpose sturgeon are being equipped with Pop-up satellite tags from Desert Star Systems that are capable of recording temperature, depth, light levels and orientation of the animal (accelerometer, magnetometer). The tags will also carry our high-frequency accelerometers (above) and a VEMCO V9 tag to track movements of the animals during deployment. Deployment design and recovery were tested in June 2012 and multiple deployments on multiple sturgeons in the river will be conducted over a 14-d period starting 30 September 2012.

(7) **Use ocean modeling and assimilation of tag data to determine 'most likely' fish trajectories**: To date we have only completed a series of semi-formal discussion and planning exercises to collaborate with ocean modellers Keith Thompson and Anna Katavouta (PhD student) at Dalhousie. Our goal is to address the assimilation of accelerometer where the tag data time, temperature, depth and acceleration (size-at-time, i.e. growth) plus constraints on swimming velocity using tail beat frequency and size. The ocean model will provide the x, y, z temperature and flow fields that can be used to determine the 'most likely' trajectories (and growth rates from temperature-time) through minimizing a cost function over all possible paths based on time and size-varying constraints. These are measure that can be used to determine temperature-dependent growth over time as well as activity and energy budgets. The results can directly impact fishery regulations and management policies that hinge on credible science relevant to sustainable management where there are challenges in obtaining reliable data on stock metrics (number, size, biomass, age, growth, maturity, fecundity, spawning, distribution etc.). Growth is a key as it influences maturity and fecundity and with numbers it determines biomass. We intend to further develop this in the coming year.

(8) **Publish peer-reviewed paper on high-frequency accelerometer tags and identifying fish activities**: We are now in the post-review revisions of a paper submitted to J. Exp. Biol. (see Broell et al. below) entitled 'Accelerometer tags: detecting and identifying activities in fish and the effect of sampling frequency.' Based on review and the Editor's comments we fully anticipate this paper to be accepted by November 2012. The paper focuses on a novel use of accelerometer tag technology to remotely detect and identify fish activity that occurs over short time scales (ms) as well as the effect of

accelerometer sampling frequency on detection and identification We developed statistical algorithms that are capable of detecting fast-start activities (feeding and escape) with 90% confidence and identifying them with 80% confidence (Fig. 9).

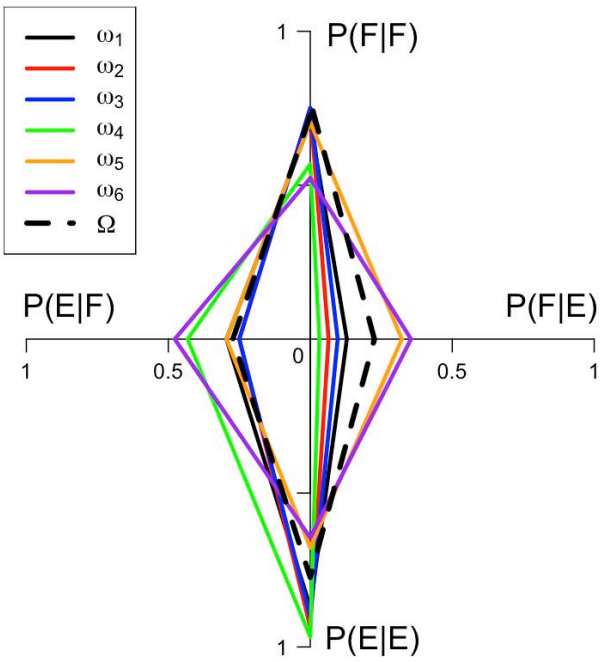


Figure 9. Quadrangle representation of ω parameter efficiency space for all ω parameters showing probabilities of activity identification. Correct identifications are represented by the vertical between P(E|E) and P(F|F). Misidentifications are represented by the horizontal between P(E|F) and P(F|E). Axes values indicate probabilities of identification. Black dashed line represents the parameter set Ω.

Typical accelerometer studies use sampling frequencies ≤32 Hz and we show that identification probabilities decrease significantly at sampling frequencies <50 Hz. To our knowledge, this is the first time that feeding and escape has been statistically parameterized using high-frequency acceleration data. Apart from some generally descriptive and cautionary work published in 2004, this also appears to be the first study to quantitatively demonstrate the significance of sampling frequency on the detection and identification and how this may compromise, through aliasing, the estimation of important physiological variables such as activity and energy-budgets.

(9) **Publish a paper on the new tag technology and application:** We have completed a draft manuscript, Bezanson A.B., Broell, F., Taggart, C.T. Design and fabrication of a low-cost acceleration data logger for lab and field application in physiological studies"; likely to be targeted at *Sea Technology* or *Ocean Technology*. The paper details the design and fabrication of a low cost acceleration data-logger for investigation of the activity of aquatic wildlife. As acceleration is directly linked to factors such as animal activity, metabolic rate, feeding patterns and response to predatory stimuli, the data-logger provides valuable data. It is shown that in the process of activity identification high sampling rates are essential if correct identification of the activity is to occur (Broell et al. in post-review revision). Commercially available (costly) acceleration sensors typically offer low frequency (1-30 Hz) sampling rates [VEMCO, Cefas, Little Leondardo Ltd.] and are mostly bulky devices [e.g. Cefas Tag: 40mm x 28mm x 15mm at 7.3g or Little Leonardo: 12x45mm 10g), which means our data-logger represents a

significant advancement in the development of low cost marine acceleration sensors. In the design of a low cost acceleration data logger several key factors are taken into consideration, such as size, weight, buoyancy, sampling rate and sampling duration. It is the aim of this paper to provide a discussion on the design decisions and tag application as an aid in the development of future aquatic data-loggers.

Significant Deviations from the Original Objectives or Plans

OG: There have been no significant deviations.

AC: There have been no significant deviations.

Coordination and Integration

OO: Collaborator D. Hebert and HQP M. Dever met frequently with members of the glider observing group to discuss missions for the glider and how the data were to be analyzed. Calibrations of the benthic pod instruments were also discussed extensively.

OG: The Glider Program hosts weekly meetings during which any aspect of glider operations, data collection or data usage are discussed. Besides the glider team (including John Cullen and MSc student Matthew Beck), regular participants include Dr. Dave Hebert of BIO, who provides significant guidance and expert advice on the deployment of autonomous vehicles and the processing of oceanographic data, Lenore Bajona of the OTN data group, and graduate student Mathieu Dever. Others, such as Drs. Fred Whoriskey and Katja Fennel, attend for coordination and planning meetings. Now that the gliders are in regular operation and modeling efforts are well underway, the glider group meetings are expanding to include direct interaction with modelers — both graduate students and post-docs — to facilitate the direct use of data and joint development of QA/QC procedures that are best suited to meet the needs of users. The weekly meetings are also used for logistical planning of external activities, such as deployment of wave gliders to track tagged salmon or glider personnel helping to download moored receiver data.

AC: Franziska Broell, in concert with Taggart, has taken the lead in virtually all of our collaborations within the OTN Atlantic Area, including Thomson et al. (Dalhousie), Litvak et al. (Mount Allison), Stokesbury et al. (Acadia), VEMCO in Halifax 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. She has also taken the lead in working with our international colleagues including Takuji (Kyoto University), Serena Wright (CEFAS and Swansea University, UK), Paolo Domenici (Istituto per l'Ambiente Marino Costiero, Italy), and John Fleng Steffensen (University of Copenhagen), and Dominique G. Roche and Sandra A. Binning (Australian National University).

Scientific and/or Engineering Significance of Results

OO: The characterization of the Nova Scotian Current seems to be proceeding nicely, with results conforming to the initial hypotheses. Next steps include discussing the significance of these properties in affecting the character of migration paths and timing on the Scotian Shelf for particular species, such as Atlantic salmon or seals.

OG: The glider group HQP are now experts at operating ocean gliders routinely, troubleshooting their operation despite numerous challenges, and retrieving, managing, and displaying oceanographic data. This capability is highly significant for the OTN observations component and has also been applied to the operation of Liquid Robotics Wave Gliders, which will likely figure prominently in the future of

OTN. The team is also providing the foundation for observations support of the new MEOPAR Network of Centres of Excellence, which begins operations soon.

The development of new procedures for retrieving glider-based estimates of chlorophyll *a* from multi-parameter optical observations is approaching the first stage of completion. Already, results show sources of variability that cannot be resolved by the methods as originally published. Revised procedures will certainly be important for the retrieval of chlorophyll estimates from autonomous platforms, the use of which is expanding very rapidly. Simply, the measurements from thousands of ocean robots will never be fully validated with direct measurements; indirect calibration using other optical measurements will be required, and the research conducted as part of this project is both timely and directly relevant.

Even as we focus on retrieval of chlorophyll *a* concentration as a measure of phytoplankton biomass, we pursue a new modeling framework in which chlorophyll is abandoned as the linchpin variable in descriptions of phytoplankton dynamics. This suggestion, though well-grounded in scientific arguments, is controversial but by no means unprecedented. We expect that the day will come when it is implemented, and this OTN research will be part of its foundations.

AC: 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 shows that a >30Hz sampling frequency is essential to detect and identify fish activity in the wild and that those activity estimates, along with swimming costs (e.g. tail beat frequency) can be used for metabolic and energy expenditure estimation. From an engineering perspective, our novel accelerometer tags have been greatly enhanced in terms of size and energy consumption and are now being seriously considered for further enhancement (beyond our in-house capabilities) by VEMCO; something that speaks for itself in terms of advanced engineering and technology development.

7. Difficulties encountered

Equipment and technology issues

OG: As with the last reporting period, significant issues were encountered with the two Teledyne Webb Slocum gliders operated by OTN. The most debilitating of these was that both gliders leaked while on mission, requiring unplanned and difficult recoveries. Gaps longer than a few days in the glider deployment record (Figure 2a) are due to equipment failures. Technical details are provided here for the record:

Glider 200 aborted mission on 12 September 2011, while glider 201 aborted on 30 September 2011. Both gliders were sent back to Webb for troubleshooting. The initial source of leaks was assumed to be the WET Labs ECO sensors as they have leaked in the past in other gliders. While the sensors did leak, the major sources of incoming water were incorrectly installed CTD sensors. A lock washer had been left out during assembly, allowing the mounting screws to back out. Glider 200 did not go back in the water until 23 January 2012, and then without the WET Labs ECO sensors, as repairs to them were taking too long. Both gliders with fully functioning ECO sensors were available 30 March 2012. Glider 200 aborted mission on 1 August 2012 with a minimal amount of water in the hull. The glider is currently at Webb. The WET Labs ECO sensors are again the primary suspects. This is based on an observed anomaly, where the 880 nm backscattering channel of one of the WET Labs ECO sensors becomes saturated during missions where the glider is known to leak (see section 10m). We are anxiously awaiting news from Webb as to whether this supposition is true or not.

Other issues have also cropped up. The air bladder in glider 201 took too long to inflate, which would waste battery power and decrease the life of the bladder itself. The air pressure switch had to be shipped to Webb for recalibration and the bladder now inflates properly. The bellofram in glider 201 has recently been found to be damaged. The source of the damage is unknown. The forward compartment of glider 201 will be shipped to Webb for repair in late September 2012 and the glider should be back on mission by early October 2012.

AC: The one major difficulty we have encountered has been the long-term maintenance of pollock and cod in the Aquatron facility. Though we have worked closely with Aquatron staff and the University Vet, it is apparent that keeping pollock healthy over extended periods (>3 month) is very difficult and apparently not related to our tagging protocols. This is not necessarily the case with cod, though we did loose a number through an unknown infection and/or temperature increase associated with recent heavy rainfall events. Fortunately the University Vet has been able to stem the unknown infection and losses have been recently curtailed.

We have also encountered difficulties in securing sufficient funds to acquire pop-up tags for deploying our accelerometers in the field. Fortunately we will receive some support from Frederick Whoriskey and Matthew Litvak.

8. Networking and outreach

Intra-Network Collaboration and Partner Meetings

OG: Several individuals within OTN have either used glider data products or expressed high interest. Data have been provided to Dr. Dave Hebert for comparison to AZMP values. Dr. Blair Greenan and his graduate student Mathieu Dever regularly use glider-based current estimates to compare to moored ADCP data. Dr. Katja Fennel and her graduate student Karl Lagman have attached seal tags to the validation instrumentation package deployed by the Marine Observation Support Team (MOST) in order to study inter-tag variability in irradiance sensors embedded in the tags. Dr. Fennel has also had meetings with the MOST in regards to using glider data to set boundary conditions for oceanographic models run by her group. Dr. Don Bowen and Dr. Damian Lidgard have expressed interest in attaching a VMT to a glider in an effort to detect tagged seals in the Sable Island region. Several meetings took place with Dr. Jinyu Sheng and his group, particularly Dr. Kyoko Ohashi, and Dr. Keith Thompson and his group concerning modeling and glider data. Also, Dr. Ohashi was instrumental in determining the return course of the Liquid Robotics Wave Glider as it transited from the Gulf of St. Lawrence to Halifax. OTN technicians Duncan Bates and Susan Dufault use the glider and discrete data to examine the relationship between the effort required to upload bottom pod data and environmental parameters. Finally, MOST has provided support to Dr. Chris Taggart by testing various pieces of equipment during weekly sampling trips.

Collaboration is facilitated by regular meetings of the Glider Group as described in 6d. These are being transformed to include direct collaboration of those making observations and modelers.

AC: 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 et al. (Mount Allison), Stokesbury et al. (Acadia) and Thompson et al. (Dalhousie) as detailed above under our Objectives. To date these have proven rewarding for all collaborators due to the various synergies and will continue into the future.

As also detailed above, it is clear that our regular meetings with our VEMCO partners are proving extremely beneficial and will continue into the future.

Interaction/Outreach to Broader Community

OG: The technical team supporting OTN ocean glider operations, now referred to as Dalhousie's Marine Observations Support Team (MOST), has been firmly established as a cornerstone of developing ocean observations initiatives centred at Dalhousie, including the $25M MEOPAR (Marine Environmental Observation, Prediction and Response) NCE, and Dr. Doug Wallace's Canadian Excellence Research Chair (CERC) programme. The MEOPAR network is designed to develop potent capabilities to observe, predict and — based on that information — to respond to marine environmental risks. Marine observations are thus centrally important. A planned interdisciplinary sensing system, funded by MEOPAR/CERC with MOST providing technical support, is to be installed on the Atlantic Condor to conduct regular surveys of the Scotian Shelf as the vessel transits weekly between Halifax Harbour and Sable Island. Collaborating with MEOPAR researchers from Memorial University of Newfoundland, MOST will also operate and help to develop a relocatable profiling buoy to be deployed originally in Bedford Basin. Both MEOPAR activities will complement the OTN shelf observations program and enhance ongoing collaboration with colleagues at BIO and their plankton monitoring program. Simply, this highly qualified team, which exists today because of OTN support, will facilitate a broad range of leveraged ocean observation activities on the Scotian Shelf and beyond for years to come. Each activity will benefit from, and contribute to the value of, OTN SNG research.

Individual members of Dr. Doug Wallace's group have been given considerable logistical support, notably graduate student Liz Kerrigan (working on oxygen isotopes in sea water, supervised by Wallace and Markus Kienast) and undergraduate student Emily Chua (undergraduate summer intern working on oxygen isotopes and coloured dissolved organic matter, supervised by Wallace and Cullen). Data from the Slocum gliders and logistical support from MOST have been requested by scientists at Defense Research and Development Canada to aid them with their glider activities.

9. Dissemination of information and results

Refereed Journal Articles (1 total)- Accepted/published

OG:

Cullen, J.J., R.F. Davis and Y. Huot. 2012. Spectral model of depth-integrated water column photosynthesis and its inhibition by ultraviolet radiation. Global Biogeochemical Cycles 26, GB1011. doi: 10.1029/2010gb003914.

Refereed Journal Articles (1 total)- Submitted

AC:

Broell, F., Noda, T., Wright, S., Domenici, P., Steffensen, J.F., Auclair, J-P., Taggart, C.T. submitted. Accelerometer tags: detecting and identifying activities in fish and the effect of sampling frequency. J. Exp. Biol. (accepted: in post-review revision)

Conference Presentations (1 total) – Invited

OG:

Cullen, J. J., A.B. Barnett, A.J. Comeau, Y. Huot and H.L. MacIntyre. A framework for describing the dynamics of phytoplankton based on optical measurements, including fluorescence. ASLO Aquatic Sciences Meeting, Otsu, Lake Biwa, Japan, July 2012 (Oral presentation invited as tutorial).

Conference Presentations (10 total) – Contributed

OO:

Dever, M., B. Greenan, P. Smith, D. Hebert, and J. Sheng. Characterization of the Nova Scotia current and water properties along the Halifax Line: an observational integrated approach. OTN Annual Meeting, Halifax, 2012 (poster)

Dever, M., B. Greenan, P. Smith, D. Hebert, and J. Sheng. Characterization of the Nova Scotia current and water properties along the Halifax Line: an observational integrated approach.CMOS Annual Meeting, Montreal, May 2012 (poster)

OG:

Beck, Matthew R., A.J. Comeau, R.F. Davis, J.D. Pye and J.J. Cullen. Optical approaches to estimating chlorophyll from ocean glider surveys. OTN Annual Meeting, Halifax, 2012 (poster)

Davis, R.F., A.F. Comeau, J.D. Pye and J.J. Cullen. Deployment of Interdisciplinary Ocean Gliders on the Halifax Line. OTN Annual Meeting, Halifax, 2012 (poster)

Lagman, K.B., K. Fennel, L. Bianucci, D. Bowen, J.J. Cullen and R.F. Davis. Can light attenuation estimates from electronic seal tags be used as phytoplankton proxies on the Scotian Shelf? CMOS Annual Meeting, Montreal, May 2012 (poster).

Beck, M.R., A.J. Comeau, R.F. Davis, J.D. Pye, and J.J. Cullen. Defining a multi-parameter optics-based approach for estimating chlorophyll a concentration using ocean gliders. Ocean Optics XXI, Glasgow, October 2012 (Extended abstract posted online: 16pp.)

AC:

Broell, F., Noda T., Wright S. 2012. Fine-scale behaviour in fish: acceleration signatures of feeding and escape and the effect of sampling frequency. CCFFR, Jan 2012. Oral presentation.

Broell, F., Noda T., Wright S. 2012. Tracking fish behaviour with accelerometer tags: the effect of sampling frequency. Ocean Sciences Meeting, Feb 2012. Poster presentation.

Broell, F. 2012. Tracking fish behaviour with accelerometer tags: the effect of sampling frequency. Conference for Dalhousie Oceanography Graduate Students, March 2012. Oral presentation.

Broell, F., Noda T., Wright S., and Taggart C.T. 2012. Tracking fish behaviour with accelerometer tags: the effect of sampling frequency. Second OTN Canada Symposium, Dalhousie University, June 2012. Oral presentation

10. Other contributions and deliverables

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

OG:

In July, John Cullen was interviewed by Jennifer Henderson for spots on CBC radio and TV, and also by Tom Murphy for the CBC Nova Scotia Newsmaker of the Day segment. The interviews were about rising ocean temperatures and the need for sustained observations of the ocean.

Cullen is featured in a video on "Climate Science: Oceans" that received regular play on the Weather Network (http://www.theweathernetwork.com/climate_change/gallery/846/4830971/63/collection). He was also interviewed by Rob North for CBC Radio and Connie Thiessen for News 95.7 concerning ocean science and election to the Royal Society of Canada.

Mr. Davis was interviewed several times by different media sources in connection with the efforts of OTN to use a Liquid Robotics wave glider to track tagged animals, in particular juvenile salmon, in the Gulf of St. Lawrence. Below is a list of interviewers and links to the interviews:

- Kelly Slivka for the New York Times Green blog: http://green.blogs.nytimes.com/2012/07/10/a-new-way-to-track-fish/).
- Rob North for CBC News: http://www.cbc.ca/news/canada/nova-scotia/story/2012/08/22/ns-wave-glider-fish-robot.html
- Brett Ruskin for Global News: http://www.globalmaritimes.com/video/salmon+glider/video.html?v=2271643247&p=1&s=dd#video
- Selena Ross for the Halifax Chronicle Herald: http://thechronicleherald.ca/novascotia/129191-high-tech-tracker-hits-the-waves

AC:

CBC radio interview with Franziska Broell and website article 'Tiny chip tracks fish movements', 9July 2012. Focus on the development and use of our accelerometer sensors.

(http://www.cbc.ca/news/technology/story/2012/07/09/ns-fish-science.html)

Franziska Broell meeting with German Chancellor Dr. Angela Merkel in the scientific panel discussion on ocean sciences, see DalNews 17 August 2012.

(http://www.dal.ca/news/2012/08/17/dal-profs-and-students-talk-oceans-research-with-chancellor-merk.html).

DalNews article, 'Student fish-tracking collaboration makes a splash'. 12 Sept. 2012. Describes the collaboration between Franziska Broell and Andre Bezanson in the development of accelerometer sensors and their application and use.

(http://www.dal.ca/news/2012/09/10/student-collaboration-on-fish-chips-makes-a-splash.html)

Picked-up by Sciencedaily.com "University Students Design Unique Marine-Tracking Device", 18 Sept. 2012, (http://www.sciencedaily.com/releases/2012/09/120918154110.htm)

OTN news Bulletin contribution (HQP spotlight – Franziska Broell), August 2012

Canadian Geography interview with Franziska Broell, 21 September 2012, To be published in the Discovery section of the Jan/Feb 2013 issue.

Invited or contributed open-to-public presentation/contribution.

OG:

Cullen, J.J. "Optical observation of the ocean: 150 years of progress." Dalhousie University Faculty of Science Public Lecture Series, also replayed regularly on Eastlink Podium TV.

*Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, Glider runs, and/or data deposition to an agency/database (e.g., MEDS, GenBank, OBIS, etc.), as well as a contribution to a larger piece of work in any of the former***.**

OG:

Raw data from the Slocum gliders is made available to the OTN data group. Talks with personnel at BIO, particularly Dr. Dave Hebert and Tobias Spears, Head of the Ocean Data and Integration Section, have begun to formally integrate physical data from the gliders into the AZMP database. This integration will not happen until the final QC protocols are in place.

AC:

Bezanson, A. High Frequency Data-logger Design Review. April 22, 2012. Provided to VEMCO for their use in advancing the accelerometer design beyond our capabilities.

Invited or contributed consultation with an agency; public or private

AC:

One half-day formal consultation on advanced accelerometer design with VEMCO.

Internet publishing, portal, blog, electronic publications

OG:

The full-featured web presence for the Slocum gliders awaits some decisions on quality control of initial data offerings (to be developed in consultation with OTN SNG modelers) and preparation of supporting text, but a development site is now available for viewing at http://glider.ceotr.ca/. During glider missions, data are decimated for ease of transfer and transmitted from the glider each time it surfaces, to be presented on the site in near real-time. The data are replaced with full-resolution corrected data when the glider is recovered. Mission metadata products such as current estimates and glider tracks are available on the website. The glider website also features mission notes contributed by the glider pilots in real-time, details on course corrections, mission parameter updates, and aborts/errors. A system for automatically publishing depth profile plots for interesting scientific parameters is being developed.

A temporary web presence was also developed for the Liquid Robotics Wave Glider mission in June of 2012, featuring a real-time public data stream built collaboratively with Liquid Robotics (http://glider.ceotr.ca/waveGlider.html). AJAX/JS, Flot, and the Google Maps API were leveraged to create an interactive map of animal detections with accompanying environmental data over the course of a two-month wave glider deployment that covered 2000 km from the Gulf of St. Lawrence to Halifax Harbour. Code developed for this project will power a more permanent set of data products upon receipt of the new platforms, allowing for swift integration with the current glider website.

Anything else that isn't a primary publication that has you communicating (specify) with others (specify).

OG:

J.J. Cullen: Visiting Professor and Invited Lecture Series, China, October 2011:

"Optical observation of the ocean: 150 years of progress." National Marine Forecasting Center, Beijing; East Sea Subadministration, State Oceanic Administration, Shanghai; Ocean University of China, Qingdao.

"Describing the dynamics of phytoplankton in ecosystem models." College of Marine Science, Tianjin University of Science and Technology; First Institute of Oceanography, Qingdao.

"Observations and Models for Marine Environmental Prediction." First Institute of Oceanography, Qingdao.

John Cullen meeting with German Chancellor Dr. Angela Merkel in the scientific panel discussion on ocean sciences, see DalNews 17 August 2012.

(http://www.dal.ca/news/2012/08/17/dal-profs-and-students-talk-oceans-research-with-chancellor-merk.html).

AC:

Broell, F., Noda, T., Wright, S. 2011. Analysis of fast-start movements using accelerometry and video tracking in the Great Sculpin (*Myoxocephalus polyacanthoceaphalus*). University of Washington Library.

As a result of media coverage we communicated with Dina Dechmann, Universität Konstanz, Germany, who expressed interest in our high-frequency accelerometers and the application to bats and pigeons to investigate flock behaviour. We were also contacted by Salvador Jorgensen affiliated with Monterey Bay Aquarium, California who expressed interest in our high-frequency accelerometer tags and we provided instructions on how to build them.

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

OG:

The glider group has provided considerable logistical and operational support to two separate Wave Glider trials, the first in fall of 2011 and the second in summer 2012. These trials were designed to test the efficacy of the Wave Glider in performing two different tasks: 1) upload data from bottom-moored receivers and then transmit that data back to shore so that expensive ship-based activities are reduced; and 2) act as a mobile detector of tagged animals so that a detector could be put in an area of interest without the added cost of mooring receivers.

MOST figures prominently in two major initiatives that will be significantly leveraged by OTN and which will contribute directly to the effectiveness of OTN observations in years to come. Richard Davis and Jon Pye from MOST will form the core of the Halifax-based component of the Observations Core of the $25M MEOPAR network. Their activities will dovetail with a major program of underway sampling planned for the Atlantic Condor, a major initiative associated with Dr. Doug Wallace's Canada Excellence Research Chair program and a planned component of MEOPAR. Expert personnel will be thus be central to a broad range of complementary and coordinated ocean observations based at Dalhousie.

AC:

Last year we leveraged our funds with colleagues from The Australian National University by submitting a Peter Teakle Sustainable Fishing Research Grant to address accelerometry in association with black marlin. Although we were unsuccessful we were advised by the foundation that we "came close" and were encouraged to submit a 2013 grant application. That application is now reaching finalization and will be submitted to investigate the use of accelerometry to estimate growth, activity and post-release

effects in commercially and recreationally targeted species of coral reef fishes on the Great Barrier Reef. If the application is successful this work will involve the deployment of our accelerometer and inertial sensors on commercially targeted species in the Great Barrier Reef in 2013.

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

OG:

Although it was known that the light sensors on seal tags measured light attenuation that could be related to the abundance of phytoplankton, we had not appreciated how well the approach might work. Karl Lagman and Katja Fennel pursued the technique and found promising results. The glider group were able to provide parallel optical sampling support and technical expertise to the analyses. This has led to plans for a much more thorough and more discriminating research plan.

AC:

See k) above.

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.

OG:

Multiparameter estimates of chlorophyll concentration – As mentioned in section 6b, graduate student Matt Beck is developing a new method to estimate chlorophyll *a* concentrations from *in situ* measurements of fluorescence and irradiance. Proof of concept has been demonstrated (6n). but the method has not been fully validated. Discrete measurements of relevant environmental variables are collected when gliders are deployed and recovered; this will support validation.

Diagnostic for leaking gliders – Ideally, it should not be necessary to worry about leaking gliders. It has been a problem for us, however, and timely detection of leaks is critically important because the gliders must be recovered quickly once the problem develops. Through careful inspection of data streams, the glider team observed a pattern that developed before a leak caused damage or failure. This diagnostic will be used in mission control, and may save a great deal of time and effort, if not a glider.

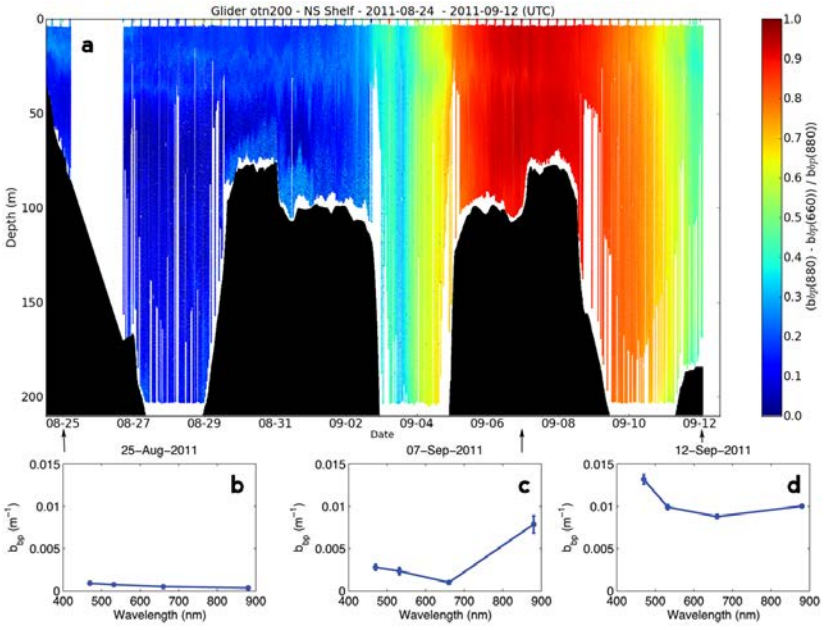


Figure 10. Detection of leaks in the glider instrument bay. a) Measurements of backscattering by particles (b_{bp}, m^{-1}) at 660 nm and 880 nm during a transect by glider 200 are plotted as ($b_{bp}(880)$ - $b_{bp}(660)$)/$b_{bp}(880)$, showing: **a)** low values when backscatter is low and inversely proportional to wavelength as expected for many particle assemblages; **b)** high values when readings at 880 nm increase due to influence of the leak; and **c)** lower again when the leak causes elevated readings at the other wavelengths. These patterns can be detected with a diagnostic algorithm to warn operators

about impending problems with a glider.

AC:

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. 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 etc.)

A proof of concept in relation to any of the above

OG:

A Liquid Robotics Wave Glider was tested to see if it could perform two separate and distinct tasks. Using the station-keeping ability of the Wave Glider, one was parked over an OTN bottom pod and used for an acoustical upload of data from the pod. The upload was slow, but successful enough to encourage a pilot project in which a Wave Glider would be used to upload data from bottom-mounted receivers and send that data to shore via satellite. A separate Wave Glider was deployed with acoustic receivers on-board to determine if it could detect both tagged animals and sentinel tags in the Gulf of St. Lawrence and Scotian Shelf. In both respects it was a successful mission, meaning that Wave Glider deployed to upload data could perform double duty by detecting tagged animals.

AC:

All of our accelerometer and inertial tags have been successfully deployed. VEMCO's interests in further development and potential commercialization attest to the success of the concept.

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.

OG:

The two Slocum gliders can be tracked in real time via the main website for glider operations, which can be found at http://glider.ceotr.ca/. Also, linkable .kml files are generated in real time that can be viewed in Google Earth. These files allow any individual to see the course of the glider and to view important diagnostics such as battery use.

AC:

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

Other

AG:

Franziska Broell received the 2012 C-DOGS CMOS prize for the best overall talk ($250 CAD)

Franziska Broell received a Clemens-Rigler Travel Award for attending and presenting at the 2012 Canadian Conference for Fisheries Research ($175 CAD)

11. Collaborations with Industrial and Government Partners

OO:

DFO scientists Dr. Blair Greenan, Dr. David Hebert and Dr. Peter Smith (now retired) are actively involved in this project making available observations form the Halifax Line and other DFO monitoring programs (e.g. AZMP) and a PhD student (Mathieu Dever) is jointly supervised. In turn our research products will be available to scientist and managers at DFO with interactions facilitated by our DFO collaborators.

OG:

Interactions with DFO and the Liquid Robotics Wave Glider program are described in several sections above.

AC:

We are actively engaged in our technology advancements and collaboration with VEMCO and potential commercialization as detailed above. As stated in 5b above, the IP associated with the tag and software development is jointly owned by Broell, Bezanson and Taggart though we have made much of the technology development freely available to VEMCO for further development and for the betterment of the Canadian economy.

Cash and in-kind contributions from partners for year 3.

Name of supporting organization: **CFI**	**Year 3** 2012
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 (glider accessories)	$2,440
3) Donation of material (glider batteries)	$31,122
4) Field work logistics (Argos and Irridium time, boat tims, trick rental)	$34,912
5) Provision of services (sensor calibrations, consultancy)	$61,892
6) Other (specify): _shipping costs for calibration	$3,000
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$133,366
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff (Blair Greenan and Dave Hebert)	$22,100
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities (storage facility and loading dock space)	$16,200
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$38,300
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **Dalhousie University**	**Year 3** 2012
Cash contributions to direct costs of research	$21,119
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	$2,000
3) Donation of material	
4) Field work logistics	$4,000
5) Provision of services	$2,000
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	$4,000
2) Salaries of managerial and administrative staff	$1,000
3) Other (specify): _____	
Total of all in-kind contributions	$34,119

Name of supporting organization: **VEMCO**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$4,000
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$4,000

12. Expenditures and Support

Year 3 (2012)

Budget Item	Year 3 (2012)				
	Proposed	**Actual Expenditures** 1 Jan - 30 Sep 2012	**Total Balance** 30 Sep 2012	**Projected Balance** 31 Dec 2012	**Deviation**
1) Salaries and Benefits					
a) Students	$105 000	$96 748	$8 252	$0	0%
b) Postdoctoral Fellows	$135 000	$89 566	$45 434	$651	0%
c) Technical/Professional	$40 800	$36 792	$4 008	$0	0%
d) Other	$0	$0	$0	$0	
2) Equipment or Facility					
a) Purchase or Rental	$14 000	$7 995	$6 005	$2 008	14%
b) Operations/Maintenance	$11 000	$6 824	$4 176	$764	7%
c) User Fees	$80 00	$4 772	$3 228	$842	11%
3) Material and Supplies					
a) Materials and Supplies	$12 000	$11 826	$174	$0	0%
4) Travel					
a) Conferences	$6 000	$19 443	-$13 443	-$7 402	-123%
b) Field Work	$0	$0	$0	$0	0%
c) Collaboration/Consultation	$0	$0	$0	$0	0%
5) Dissemination					
a) Publications	$4 500	$0	$4 500	$500	11%
b) Other	$0	$0	$0	$0	
6) Other (specify)					
a) Other	$0	$0	$0	$0	
b) Other	$0	$0	$0	$0	
Totals					
Totals	**$336300**	**$273966**	**$62 334**	**-$2 638**	

Note: This financial report covers all three Oceanography (I.1) projects.

Actual expenses up the end of August were entered (ledgers for September are not yet available).

Projections were made as follows:

1) Salaries and benefits were projected forward to the end of the year. The projected remaining balance was entered or, if all funds were projected to be used up, a zero was entered instead (under the assumption that salary support would come from a different source to make up the shortfall).

2) Equipment and Facility expenses were projected to the end of the year assuming that the average spending between Jan 1 and Aug 31 continues at the same rate.

3) Actual expenses for Materials and Supplies include ledger expenses up to the end of August and invoices incurred during the month of September. We project that the remaining balance of $174 will be spent by the end of the year.

4) Travel expenses are significantly over budget for the period Jan 1 to Sept 30, 2012. However, three trips that were charged to OTN will be moved to other grants and the OTN account reimbursed (this was taken into account in the projection, resulting in a projected year 3 balance of negative $7,402). Also, unused travel funds from year 1 in the amount of $6,000 had been carried forward. When applying these year 1 travel funds the projected balance reduces to negative $1,402 (a deviation of 23%).

5) Dissemenation costs are listed under 5b (other activities) in error and should instead be listed under 5a (publication costs) as per budget justification. We project that $4000 in publication charges will be paid by the end of the year for the papers recently published and in press.

a) Significant deviations from the proposed expenditures

Our travel spending was anomalously high this year because of participation of several HQP in the Ocean Sciences Meeting in Salt Lake City (which had a special session on OTN). We expect travel spending to be lower next year and expect the budget shortfall to be made up by the end of year 4.

b) How the remaining Projected Balance of your Year 3 on 31 Dec 2012 will be spent

See explanations above under b.

c) Whether Year 2 (2011) actual expenses for October-December were on target with what was forecast in last year's report

Year 2 spending in category 1 Salaries and Benefits did exceed the budgeted amount significantly, however, there was also a significant carry forward from year 1 due to delays in hiring postdoctoral fellows and in recruiting graduate students. The total spending in this category at the end of year 2 (i.e. spending that occurred during years 1 and 2) deviated only insignificantly (i.e. much less than 20%) from the budgeted amounts of years 1 and 2 combined.

Year 2 spending in category 2 Equipment and Facilities was very close to that budgeted and projected.

Year 2 spending in category 3 Materials and Supplies was identical to that projected and very close to the budgeted amount.

Year 2 spending in category 4 Travel was also identical to that projected and insignificantly over the budgeted amount.

Year 2 spending in category 5 Dissemination Costs was identical to that projected. As already described in last year’s report there is a significant deviation of $2000 in category 5b, which was budgeted for a glider workshop that did not take place.

d) Conference travel budget justifications

Two of our HQP, Franziska Broell and Laura Bianucci, attended the Ocean Sciences Meeting in Salt Lake City in February 2012 and presented their OTN results. Seven of our HQP, Mathieu Dever, Jorge Urrego-Blanco, Kyoko Ohashi, Laura Bianucci, Karl Bryan Lagman, Anna Katavouta and Vasili Korabel, attended the CMOS meeting in Montreal in May. All of them presented either a talk or a poster about their OTN results (see details in section 9d of the project reports).

We feel it is important in several respects for HQP to attend these meetings and present their results, including exposure to national and international science outside of the network, networking opportunities

and skill development. Conversely, it is important for OTN to present research findings to a broader national and international audience.

We would also like to note that several conference participations where OTN results were presented were covered by other funds and that none of the PIs charged travel funds to the project.

Year 4 (2013)

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$63 000	$61 494		2%
b) Postdoctoral Fellows	$0	$0		
c) Technical/Professional	$33 800	$33 800		0%
d) Other	$0	$0		
2) Equipment or Facility				
a) Purchase or Rental	$14 000	$14 000		0%
b) Operations/Maintenance	$8 000	$8 000		0%
c) User Fees	$5 000	$5 000		0%
3) Material and Supplies				
a) Materials and Supplies	$0	$0		
4) Travel				
a) Conferences	$0	$0		
b) Field Work	$0	$0		
c) Collaboration/Consultation	$0	$0		
5) Dissemination				
a) Publications	$0	$0		
b) Other	$0	$0		
6) Other (specify)				
a) Other	$2 000	$0		100%
b) Other	$0	$0		
Totals				
Totals	$125 800	$122 294		

1) Salaries and benefits

a) Three PhD students will be supported in year 4 @ $20,498/yr.

i) one PhD student will work primarily on the analysis of physical data collected along the Halifax Line (from benthic pods, ADCPs and gliders) and will collaborate in model-data comparisons and assimilation of these data;

ii) one PhD student will work on glider deployment, operation and calibration as well as on analysis and interpretation of interdisciplinary glider data and the development of data products for assimilation into the models;

iii) one PhD student will work on research development, calibration and interpretation of accelerometry for fish growth/activity data

b) One part-time technician (MSc level) at 50% FTE (@ $33,800/yr) who will assist in glider deployment, operation, recovery, and the analysis of glider data and development of data products

2) Equipment or Facility

a) This budget line covers the boat rental fee for the *in situ* sampling that is necessary for validating glider observations. We have budgeted for 14 ship days per year (one ship day of 8 hour duration at $1000).

b) This budget line covers instrument calibrations ($8000/yr) specifically the calibration of the profiler, the AC9, the fluorometer, the CTD and the oxygen sensors. These sensors are all part of the optical/chemical/physical profiling package owned by the Department of Oceanography and will be used for in situ sampling (ground truthing of glider observations).

c) Sample analysis costs are budgeted at $1000 per trip for 5 trips per year and cover the analysis of CDOM, particulate absorption, chlorophyll, nutrients, POC, PON, and oxygen for 2 stations at 4 depths. These analyses will be conducted by the Department of Oceanography's marine analytical services group on a cost recovery basis.

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

I. Atlantic Arena

1. Project Number: I.1.2

2. Project Title: Integrated physical and biological modeling component

3. Project Leaders: J. Sheng, K. Fennel (Dalhousie)
Collaborators: K. Thompson, J. Cullen (Dalhousie); P. Smith, B. Greenan (DFO)

4. Public Summary of Report

The main objective of this project is to characterize the time-varying, 3-dimensional structure of the ocean in order to enable interpretation of migration behavior and mortality patterns of OTN species in the context of their environment. The ocean structure we aim to characterize includes physical variables (current velocities, temperature, salinity) and chemical-biological variables (including dissolved oxygen and plankton biomass). The spatially explicit evolution of these variables is being simulated with the help of a suite of state-of-the-art numerical models, which operate in combination with ocean measurements made by OTN and other available observations. The model suite includes nested domains of varying spatial resolution focused on the Gulf of St. Lawrence, the Scotian Shelf and the Gulf of Maine in the northwestern North Atlantic. Preliminary model simulations are available to all OTN investigators. In addition several collaborative studies are being carried out with other OTN researchers. For example, migrating animals are being simulated as moving particles within the models in order to answer questions about the environmental cues that underlie migration behavior and also to infer plausible migration routes between the point detections at OTN listening devices. These methods are presently applied to American Eel. Assimilation methods are being implemented that combine the models with observations in statistically optimal ways in order to reduce model errors. Physical as well as biological variables are being assimilated. Approaches are being developed to infer environmental information from animals that were equipped with electronic sensors (referred to as bioprobes), which can be used to further improve model predictions. Specifically, temperature and light measured by grey seal bioprobes are analyzed in order to infer phytoplankton biomass.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Shiliang Shan	PhD Candidate	100	100	Oct 1, 2011 – present
Thesis topic: Numerical study of circulation and hydrography on the Scotian Shelf and shelf break				
Jorge Urrego-Blanco	PhD Candidate	40	40	Oct 1, 2011 – present
Thesis topic: Subtidal circulation over the northwest Atlantic Ocean using OPA				
Dr. Kyoko Ohashi	PDF	100	100	Oct 1, 2011 – present
Research topic: Reconstructing 3D circulation on the Gulf of St. Lawrenece and Scotian Shelf and effect of physical environment on the migration of American eels in the region				

Personnel	Title	% Time in project	% Support from SNG	Dates
Dr. Yaoming Song	PDF	20	20	Oct 1, 2011 – present
Research topic: Circulation on the Bay and Fundy and the Gulf of Maine				
Dr. Laura Bianucci	PDF	100	100	Oct 1, 2011 – July 31, 2011
Research topic: Coupled physical-biological and biogeochemical modeling of the northwestern North Atlantic				
Karl Lagman	MSc candidate	100	100	Oct 1, 2011 - present
Thesis topic: Bias correction of biological variables through spectral nudging and derivation of plankton biomass estimates from bioprobes				
Dr. Paul Mattern	PDF	100	100	Sept 1, 2012 - present
Research topic: Data assimilation for a coupled physical-biological model of the northwestern North Atlantic				

No technical staff is supported by this project.

6. Progress towards Objectives/Milestones (1 Oct 2011 – 30 Sep 2012)

Point measurements of the passage of tagged animals across fixed lines of underwater acoustic receivers must be interpreted in the context of physical, biological and chemical ocean characteristics. This requires a synthesis of physical, biological and chemical measurements by OTN, along with other available data streams, in order to generate a dynamically consistent, time-varying, three-dimensional view of the ocean. In this project advanced physical, biological and chemical models are developed for predicting this time varying, three-dimensional structure of physical (e.g., currents, temperature and salinity), biological and chemical variables (e.g. oxygen, nutrients, phytoplankton abundance and other measures of the state of lower trophic levels). This modelling work is part of a larger, general purpose Observation and Modeling Platform that also supplements existing observational capabilities (within OTN and other sustained monitoring programs) with new observation tools (project I.1.1 *Advanced Observing Component*), and develops effective methods for combining the models developed here with observations, i.e. data assimilation, (project I.1.3 *Data Assimilation Component*). This project directly supports projects I.2.1 *Atlantic Salmon*, I.2.2 *American Eel*, I.2.4 *Grey Seals* and I.2.5 *Sea Turtles* by providing validated model hindcasts. In addition, this project uses bioprobe data collected by project I.2.4 *Grey Seals.*

The specific project deliverables are listed followed by a description of progress toward each of these deliverables:

1. Nested-grid ocean circulation models for the Atlantic arena, some coupled with biological models and O_2 dynamics, that can be used in hindcast, nowcast and forecast mode. The system will be generic to facilitate application to the other OTN arenas.

Jorge Urrego-Blanco (PhD student) and Dr. Jinyu Sheng developed a nested-grid coupled ocean-ice model based on NEMO (Madec, 2008) for the eastern Canadian shelf. The nested-grid model has two sub-models: a coarse-resolution (1/4 degree) outer sub-model (domain MD1 in Fig. 5 of the OTN proposal) for the northwest Atlantic Ocean (Urrego Blanco and Sheng, 2011), and a fine-resolution ((1/12 degree) inner sub-model for the Gulf of St. Lawrence, Scotian Shelf and Gulf of Maine. A two-way nesting technique is used to exchange information between the outer and inner sub-models. The nested-grid ocean-ice model was integrated for 18 years from the beginning of 1987 to 2004 to generate the time-dependent, three-dimensional (3D) circulation and hydrography over the northwest Atlantic (Fig. 1). In the present model setup, the model forcing does not incude the tidal forcing, indicating that the nested-grid model generates non-tidal currents.

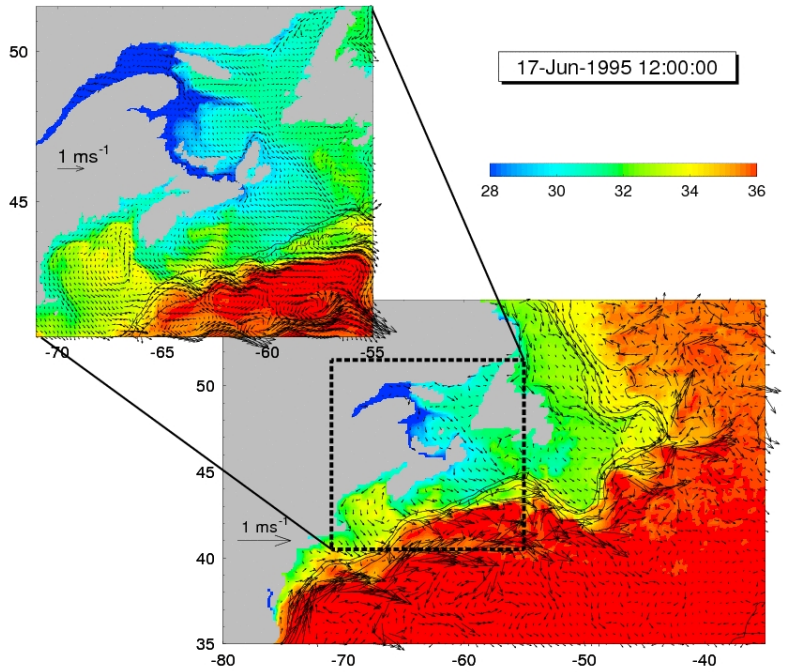


Figure 1: Near-surface salinity and non-tidal currents at 12:00 on June 17, 1995 produced by (lower right) the coarse-resolution (1/4 degree) outer model (lower right) and the fine resolution (1/12 degree) inner model (upper left) of the nested-grid model based on NEMO.

Dr. Kyoko Ohashi (PDF) and Dr. Jinyu Sheng continued to upgrade and validate the shelf circulation forecast model known as DalCoast. Major modifications to DalCoast include (a) extension of the previous model domain to include the whole Bay of Fundy and Gulf of Maine (domain MD1 in Fig. 5 of the OTN proposal); (b) specification of freshwater runoff from major rivers in the model region; (c) specification of the net sea surface heat and freshwater fluxes using atmospheric fields taken from the North American Regional Reanalysis; and (d) specification of large-scale circulation at the open boundary using the model results produced by MD1. The new version of DalCoast is forced by tidal forcing and atmospheric forcing calculated from the North American Regional Reanalysis data and integrated for 5 years (1999-2003). Model results were used to examine the circulation variability and also the effect of freshwater discharge from the St. Lawrence River on the circulation and hydrography in the Gulf of St. Lawrence and Scotian Shelf (Fig. 2). We also started to examine the effect of circulation on the migration of American eels on the Gulf of St. Lawrence by tracking particles that are carried by the 3D ocean currents in the region. Figures 3 and 4 show respectively positions of particles at the midnight of December 15 and at the noon of December 16, 2011. 25000 particles were released in the St. Lawrence Estuary (SLE) near Riviere-du-Loup, Quebec on October 15, 2011. Within the SLE, the particles undergo "selective tidal transport" (if the zonal component of currents is positive, they swim northwestward. Otherwise, they rest near the bottom). Outside of the SLE the particles are passive laterally but undergo diurnal vertical migration.

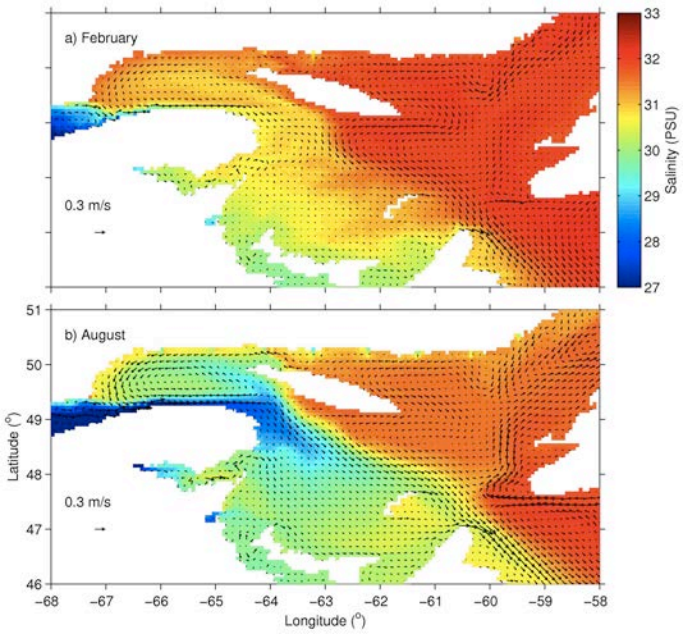


Figure 2. Monthly-mean near-surface (2 m) salinity and currents in February and August in the Gulf of St. Lawrenece calculated from model results produced by the new version of DalCoast. The domain of DalCoast covers the Gulf of St. Lawrence, Scoian Shelf, Bay of Fundy and Gulf of Maine.

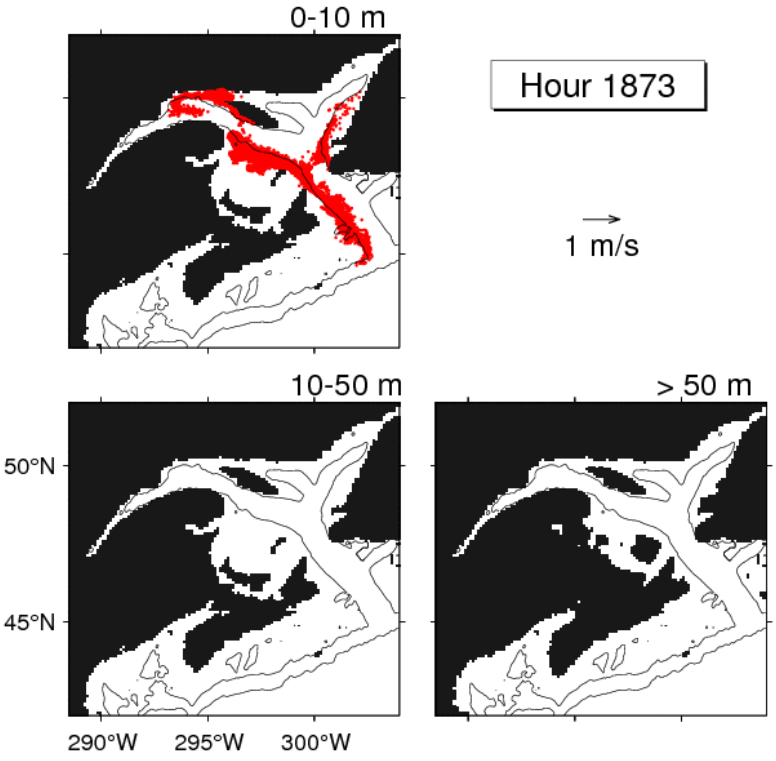


Figure 3. Positions of particles at the midnight of December 15, 2011, when the particles are in the top 10 m due to diurnal vertical migration. The velocity vectors shown in the top left and bottom right panels are instantaneous model currents at 2 m and 50 m, respectively.

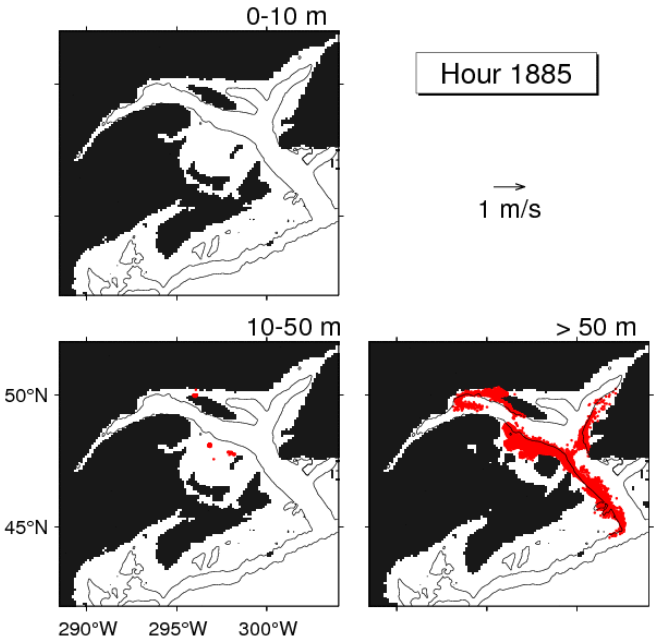


Figure 4. Positions of particles at the noon of December 16, 2011, when most of the particles are at depths of greater than 50 m due to diurnal vertical migration. The velocity vectors shown in the top left and bottom right panels are instantaneous model currents at 2 m and 50 m, respectively.

Shiliang Shan (PhD student) and Dr. Jinyu Sheng used a nested-grid modelling system developed early by Shan et al. (2011) to examine main physical processes operating over the shelf break of the Scotian Shelf (Fig. 5). The modelling system has five submodels based on DalCoast and CANDIE. The inner-model submodel has a horizontal resolution of 500 m, will be relocated to the inner scotian Shelf of the Halifax Line. Shiliang Shan also worked with Dr. Keith Thompson on (1a) the impact of environmental preferences on the movements and distribution of marine animals and (b) impact of physical coditions on the migration of American eels from the eastern Canadian Shelf to the Sargasso Sea.

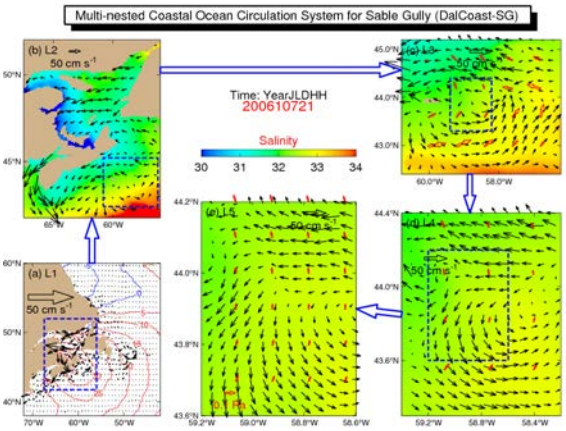


Figure 5. Instantaneous near-surface currents and salinity produced by the 5-level nested-grid modelling system on day 107, 2006. Red arrows represent wind stress vectors and black arrows represent the depth-mean currents in (a) and near-surface currents in (b-d).

Dr. Laura Bianucci (PDF) and Dr. Katja Fennel continued development of the biological ROMS model for the northwestern North Atlantic shelf and adjacent deep ocean (referred to as MD4 in Fig. 5 of the OTN proposal, shown in Fig. 6). Work in year 2 (the previous reporting period) had focused on model set-up, assembly of available data sets for model forcing and validation and generation of first model-data comparisons for model evaluation. During this reporting period (year 3) focus has shifted toward the addition of dissolved oxygen to the biological model and the implementation of methods for reducing model-data misfits in order to produce simulations that are as realistic as possible.

With respect to the addition of dissolved oxygen Dr. Bianucci performed a comparative assessment of oxygen sources and sinks between the Vancouver Island shelf in the Pacific Arena and the northwestern

North Atlantic shelf in the Atlantic Arena. She found that special attention should be paid to the processing of organic matter in the sediments (i.e. sediment remineralization) not only because this process represents an important oxygen sink but also because a fraction of bioavailable nitrogen is removed through sediment denitrification. This removal of nitrogen could help mitigate oxygen losses. The main result of her assessment is that in the Atlantic Arena, which is characterized by wide shelves where a large fraction of primary production is supported by locally remineralized nutrients, this mitigating effect is pronounced while in the Pacific Arena, where shelves are narrow and the majority of primary production is supported by upwelled nutrients from the deep ocean the effect is neglible. The results of this study have been published in the journal Biogeosciences.

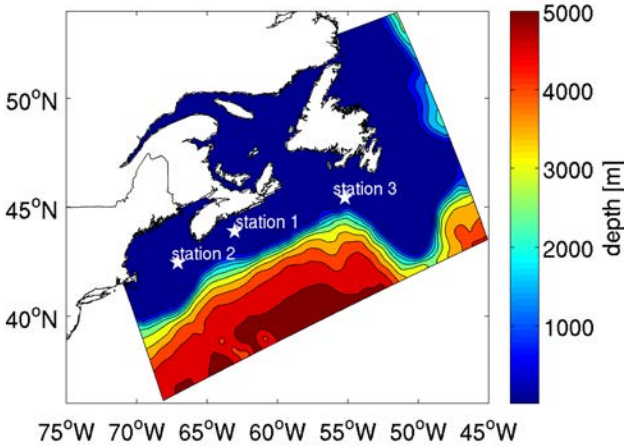


Figure 6: Bathymetry of the biological model MD4. The stations indicated were used in the spectral nudging experiemnts described in the text.

With respect to the implementation of methods for reducing model-data misfits Dr. Bianucci has focused on an emulator tenchinque that allows one to optimize selected parameters in the 3-dimensional model, while Karl Lagman (MSc candidate) has explored the use of spectral nudging for the biological model within a simplified 1-dimensional framework. Dr. Mattern has begun implementing an ensemble-based data assimilation technique (the Ensemble Kalman Filter) for improved state estimates of the 3-dimensional model. The emulator experiments carried out by Dr. Bianucci focused on improving chlorophyll estimates in winter when low light levels and deep mixing lead to low chlorophyll concentrations in the model (lower than observed by satellites, see Fig.s 7 and 8). By joint optimization of growth parameters and death rates Dr. Bianucci reproduced the chlorophyll observations (Fig. 8b) and assessed wether a decoupling of predators and prey (as hypothesized by Behrenfeld in 2010) is responsible for the relatively high winter chlorophyll concentrations in the model. She found simulated mortality rates to be relatively constant during winter indicating that increases in light after winter solstice are sufficient to result in positive net phytoplankton growth in the model. These results are submitted for publication.

In collaboration with Dr. Thompson, Karl Lagman and Dr. Fennel tested the spectral nudging method (which has been applied to physical models only so far) on a simplified biological model. Spectral nudging and the more widely used conventional nudging reduce model bias and drift by constantly pushing models toward a prescribed climatology. In this case output from the 3D MD4 model (shown in Fig. 9) was assumed to be the truth and its first two harmonics were used as climatology. Spectral nudging has the advantage of leaving short-term variability intact, while conventional nudging tends to dampen such variability. Somewhat surprisingly spectral nudging did not perform significantly better than the conventional nudging in these experiments (Fig. 10). The results are being prepared for publication.

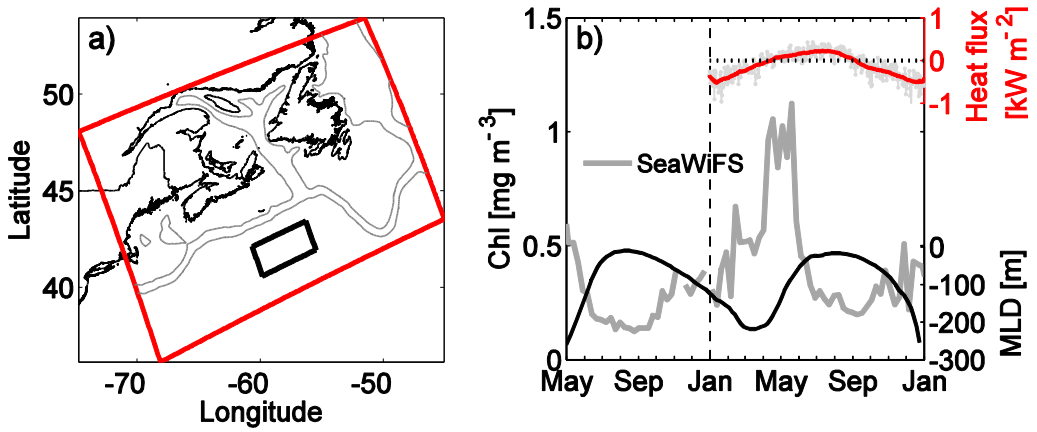


Figure 7: (a) Biological model domain (red box) and averaging area (black box) with the 200 and 1500 m isobaths. (b) Time series of satellite SeaWiFS chlorophyll from 1999 to 2000 spatially averaged in the area of shown in (a) (grey line); gaps indicate missing data due to cloud coverage over the entire region. Right axes show the mixed layer depth (black line, bottom axis) and the surface net heat flux for year 2000 (red line shows smoothed daily data in light grey; top axis). Model spin-up period (January to April 1999) is not shown. The dashed vertical line indicates 1 January 2000 for reference.

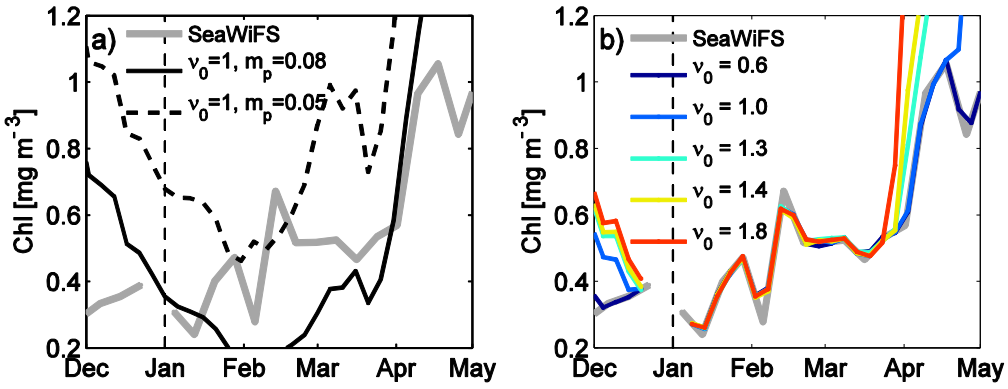


Figure 8: (a) Observed (grey line) and simulated (black dashed and solid lines) chlorophyll time series for two simulations with constant parameters. (b) Five optimized model simulations (with constant growth parameter v0 and time-varying mortality mp) and observations again in grey. The dashed vertical lines indicate 1 January 2000 for reference. Each coloured line in (b) shows the winter optimization using a different value of the growth parameter v0.

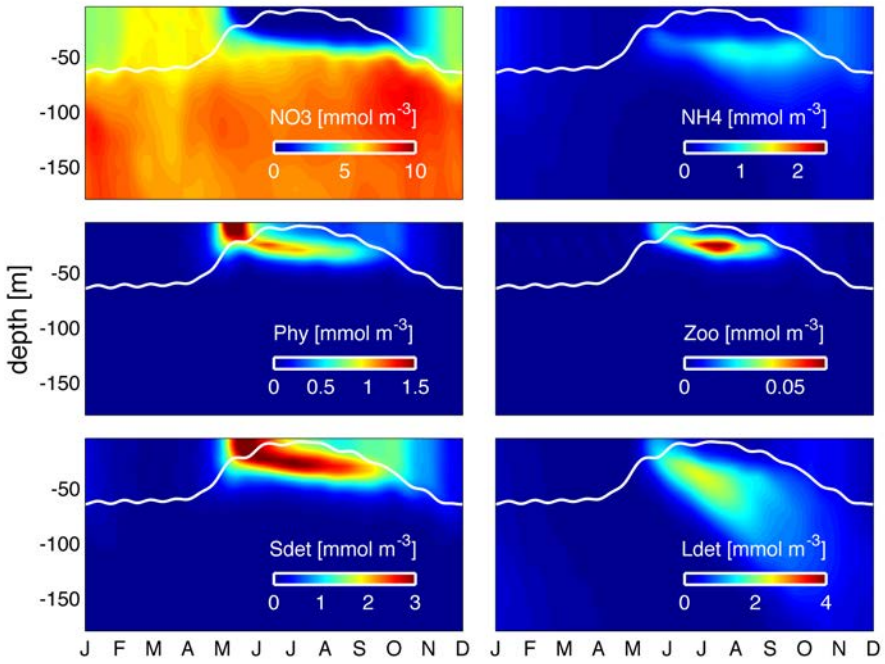


Figure 9: Time-series extracted from the MD4 biological model as station 1 (see Fig. 6 above). The white line is the climatological mixed layer depth.

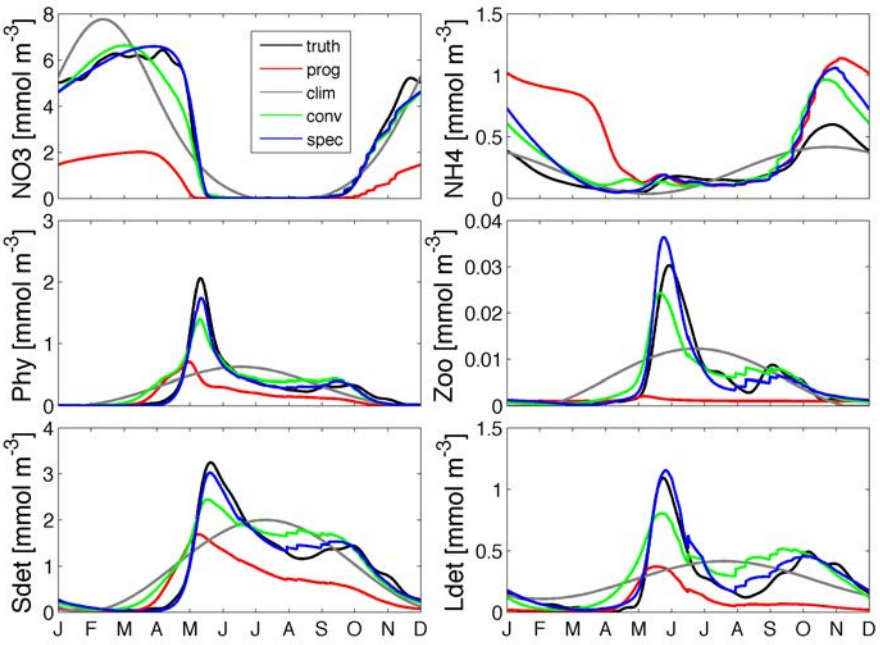


Figure 10: Surface values of the biological variables assumed to be the thruth (black), the corresponding climatology (grey), a prognostic simulation without any nudging (red), and two nudged model simulations, a conventionally nudged simulation (green) and a spectrally nudged simulation (blue).

Assessment of performance of the different models using a wide array of observations.

Performance assessment of submodel SD1 (based on OPA) was completed and results were presented in our recent by publication by Urrego-Blanco and Sheng (2012).

For submodel SD2 based on DalCoast, we first assessed the skill of the model in simulating seasonal cycles of temperature and salinity by using the averaged absoluate difference defined as

$$AAD = \frac{1}{12}\sum_{m=1}^{12}|O_m - M_m|$$

where O_m is the observed monthly-mean climatology of temperature or salinity, and M_m is its simulated counterpart (monthly-mean temperature or salinity averaged over the last four years of the simulation). The black coutour lines in Fig. 11 represent AAD values. It can be seen the the AAD values are generally small everywhere except for the shelf break region, indicating submodel SD2 has resasonal skills in simulating the seasonal cycles of temperature and salinity, which is due to the use of the spectral nudging method and the semi-prognostic method.

We also compared the vertical profiles of simulated temperature and salinity with profiles of observed temperature and salinity in 2001 (Figs. 12 and 13) at 5 AZMP stations (at Rimouski, Anticosti, Gaspe, Shedic and Station 2 of Halifax Line). We found submodel SD2 also has reasonal skills in simulating the seasonal and sub-seasonal variability of temperature and salinity in the Gulf of St. Lawrence and Scotian Shelf.

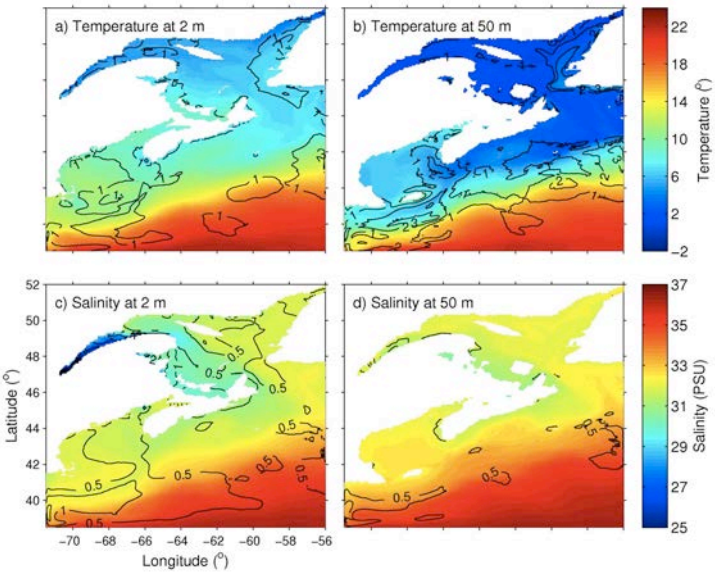


Figure 11. Color images represent the annual mean near-surface (a,c) and sub-surface (b,d) temperature and salinity calculated from monthly means during 2000-2003 of the model run generated by DalCoast. Black contour lines represent the averaged absolute difference (AAD) in monthly means between the climatology and model results. The contour interval is 1°C for temperature AAD and 0.5 PSU for salinity AAD.

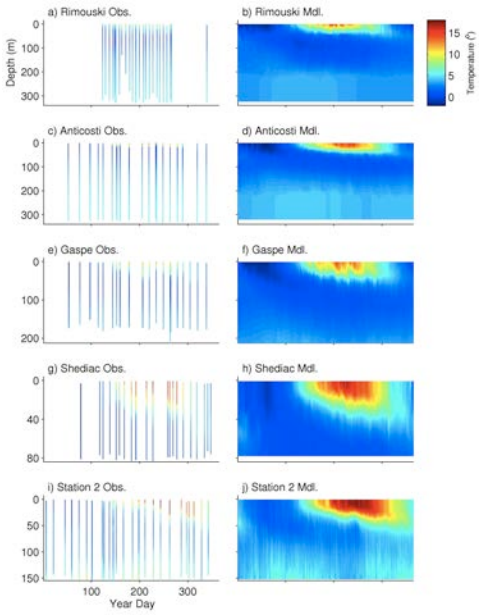


Figure 12. Comparsion of observed (left) and simulated (right) temperatures in 2001 at five AZMP stations in the Gulf of St. Lawrence and Scotian Shelf.

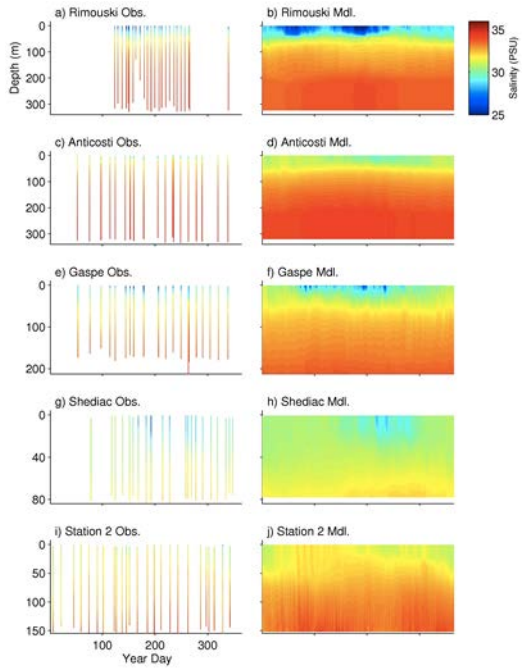


Figure 13. Similar to Figure 12, but for salinity.

In addition to obtaining biological observations from traditional sources Karl Lagman has begun analysis of light data from grey seal tags in order to derive estimates of phytoplankton biomass. Phytoplankton is a major contributor to vertical light attenuation, thus it should be possible to infer changes in phytoplankton biomass from changes in the light attenuation coefficients determined from the seal tags. So far data from 33 tags that were deployed between September 2009 and December 2010 on grey seals by project I.2.4 were used (the tags continuously measured pressure, temperature and light). On the Scotian Shelf grey seals prey on demersal fish and thus dive frequently (see Fig. 14). Pre-processing of light data obtained between local 10am and 2pm revealed systematic differences in measured irradiance between the ascent and descent phase of the dives due to changes in the orientation of the light sensor (Fig. 15). Attenuation coefficients in the mixed layer were estimated from irradiance profiles obtained

during the ascent phase and show promise as a plankton biomass proxy. In order to validate and intercalibrate sensors and to establish a proxy relationship between attenuation coefficients and phytoplankton biomass the tags were also deployed on a sampling device with a full suite of bio-optical measurements (Fig.16) and coincident with bottle sampling in Bedford Basin (with support from project I.1.1). This weekly sampling began in March 2012 and continues to date.

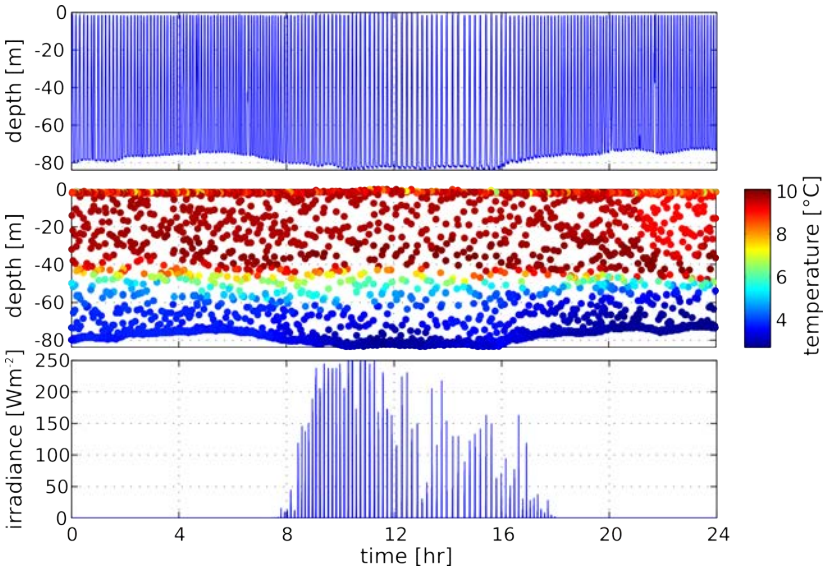


Figure 14: Depth (top), temperature (middle) and irradiance (bottom) measured by a seal tag over the course of 1 day.

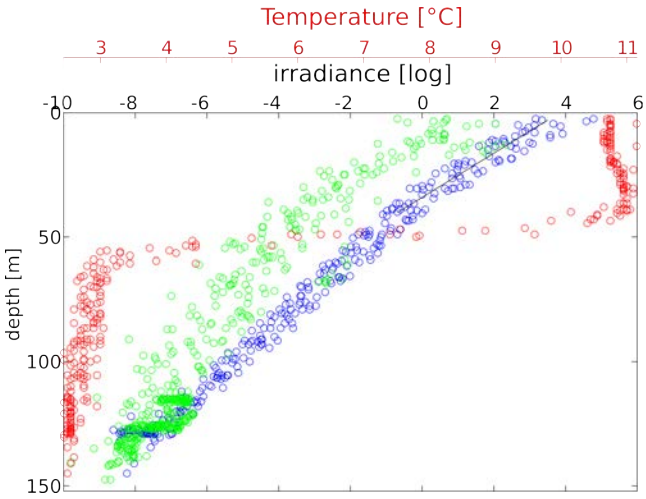


Figure 15: Irradiance profile for the ascent (blue circles) and descent (green circles) phase, and temperature (red circles) for one day.

Figure 16: Sampling rosette with temperature, pressure and irradiance sensors and 5 seal tags mounted on a board.

2. Time-dependent, 3D currents and temperature, salinity, nitrate, ammonium, phytoplankton biomass, chlorophyll and O_2 fields from a non-assimilative hindcast from 2002 to date (~2012) for the Atlantic arena (to be used directly by projects ***I.2.1*** *Atlantic Salmon****, I.2.4*** *Grey Seals, and* ***I.2.5*** *Sea Turtles*).

   Time-dependent, 3D currents, temperature and salinity fields from MD1 and MD2 are available to all OTN investigators.

   Preliminary time-dependent, 3D currents, temperature, salinity and biological variables (excluding oxygen) from MD4 are available to all OTN investigators as well.

3. Studies of key physical and biological processes over the eastern Canadian shelf seas and of the dynamic interactions of shelf processes and deep-water circulation of the northwest Atlantic Ocean (to be used directly by project ***I.2.2*** *American Eels*). Sensitivity studies to changes in initial conditions, surface fluxes and open boundary conditions (e.g. variation in freshwater input from the St. Lawrence estuary).

Dr. Kyoko Ohashi and Dr. Jinyu sheng investigated the effect of the freshwater discharge on the circulation on the Gulf of St. Lawrence and Scotia Shelf based on two numerical experiments produced by DalCoast with very high (wet run) and very low (dry run) river discharge from the St. Lawrence River. They found that the salinity and circulation in the St. Lawrence Estuary, western Gulf of St. Lawrence and inner scotia Shelf are affected significantly by the seasonal and interannual variability of freshwater discharge from the St. Lawrence (Figs. 2 and 17).

Mr. Shilaing Shang and Dr. Jinyu sheng examined main physical processes affecting the 3DD circulation over the shelf break of the Scotian Shelf (Fig. 18) and found that the circulation and hydrography are affect significantly by wind, net surface heat fluxes in the upper water column and by the Labrador Current, tides and local topography in the lower water column of the region.

Dr. Yaoming Song examined the effect of tidal energy extraction in the Mias passage on the large-scale circulation and hydrography over the Gulf of Maine and Scoian Shelf. It was found that small-scale frontal structure is more affected by the energy extraction than the large-scale features over the regions.

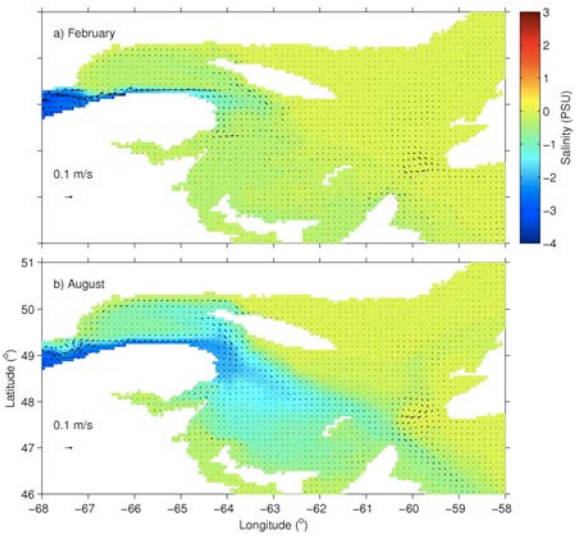


Figure 17: Difference between the wet and dry runs (wet run minus dry run) in monthly-mean salinity and currents in February and August (averaged over the last four years of the control run) at the 2-m depth in the GSL.

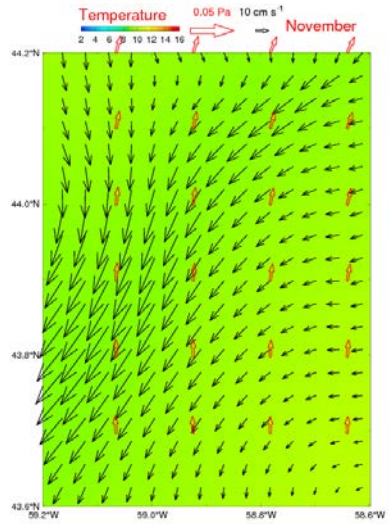


Figure 18: Monthly-means of near-surface currents, temperature and wind stress over the eastern shelf break of the Scotian Shelf produced by the inner-model submodel of the nested-grid modelling system developed by shiliang Shan.

4. Derived products that include suitable habitat with respect to O_2 conditions and a characterization of food supply (plankton biomass) for migratory fish (to be used directly by project ***I.2.1*** *Atlantic Salmon*).

Progress is on track to producing these products in year 4.

Coordination and Integration

The projects co-leads Dr. Sheng and Dr. Fennel are working together closely in all aspects of model implementation and validation. For example, all models use the same data sets for atmospheric forcing, river inputs and climatologies, and the ROMS MD4 model implemented in Dr. Fennel's group is using larger-scale model outputs produced by MD1 in Dr. Sheng's group.

Both, Dr. Sheng and Dr. Fennel, collaborate closely with Dr. Thompson (lead of project I.1.3 *Assimilation Component*) and his group and held joint meetings that included the three investigators and their HQP. Karl Lagman, PhD student with Dr. Fennel is working closely with Dr. Thompson on the

implementation of the spectral nudging method for a biological model. Shiliang Shan collaborated with Dr. Thompson on the development of a new methodology to examine the impact of environmental perferences on the movemens and distribution of marine animals and the effect of physical conditions on the migration of American eels from the eastern Canadian shelf to the Sargasso Sea. In addition to these meetings and individual interactions, HQP from this project and Dr. Thompson's project interact frequently on topics ranging from available data sets to scripts for model validation.

Dr. Sheng and Dr. Fennel, also collaborate closely with collaborators from project I.1.1 Advanced Observation Component, specifically with Dr. Cullen on the use of glider data in model validation and Dr. Smith and Dr. Greenan in the analysis and interpretation of ADCP observations from the OTN moorings on the Halifax Line. In fact, Dr. Sheng and Dr. Smith are co-supervising PhD student Mathieu Dever who is funded through project I.1.1 and Dr. Fennel is a member of his supervisory committee.

Scientific and/or Engineering Significance of Results

Development of the suite of coupled physical-biological models for the northwest Atlantic Ocean is of scientific significance for predicting the time-varying and three-dimensional physical, biological and ecological conditions on animal migrations. These models are state-of-the-art research tools for use by the OTN community and beyond.

By using the nested-grid modelling system and the combination of the spectral budging method and semiprognotic method, we were able to produce most reliable time-varying, 3D currents and hydrography over the Gulf of St. Lawrnece, Scotian Shelf and Gulf of Maine. These mdoel results are available to OTN scientists upon request.

Our recent work on particle movements carried by the ocean currents is also scientifically important for quantifying the effect of physical conditions on the migration and distribution of American eels in the Gulf of St. Lawrence.

Low oxygen concentrations, whether natural or anthropogenically induced, can severely affect coastal marine ecosystems. A deeper understanding of oxygen dynamics is required in order to improve numerical models that predict the timing and severity of hypoxia. As described in the comparative study by Bianucci et al. (2012) inclusion of sediment denitrification in models of wide, passive-margin shelf systems such as the northwestern North Atlantic is important to capture the stabilizing effect that this process has on bottom water oxygen concentrations.

Optimization of selected biological parameters of a 3D model was accomplished with the help of an emulator technique. This is a significant accomplishment. Traditionally biological parameters have been optimized with variational methods that are computationally too demanding to be applied to 3D models. The optimized model reproduced the relatively high chlorophyll concentrations observed in the northwestern North Atlantic in winter and was used to assess the underlying factors. Results suggest that the dilution-recoupling mechanism, proposed recently by Behrenfeld (2010), is not necessary to explain this behavior, at least in the simulation. A manuscript describing the results has been submitted.

The utility of spectral nudging for biological models was assessed for a simplified 1D framework. Counter to expectation spectral nudging provided only modest improvements over the traditional nudging method for reducing model bias and drift. These results are being prepared for publication.

An initial assessement of whether light attenuation estimates from electronic seal tags can be used as phytoplankton proxy on the Scotian Shelf was made with encouraging results. When relationships between attenuation and biomass are established it will be possible to monitor spatial and temporal

changes in phytoplankton biomass on the Scotian Shelf from seals and to assimilate these derived products into biological models.

7. Difficulties encountered

None.

8. Networking and outreach

Intra-Network Collaboration and Partner Meetings

PIs and collaborators attended the Atlantic Arena Meeting in April 2012 in Halifax (organized by PI Fennel with help from the OTN administrative assisstants). The meeting brought together most PIs working in the Atlantic arena. The format included brief presentations from all Atlantic Arena PIs about their project results obtained so far, about avenues for integration with other OTN projects and proposed activities for the OTN Phase II proposal. Talks were followed by extensive discussions about project integration and future work. The arena leaders from the Arctic and Pacific Arena joined in the discussion part via conference call.

PIs, collaborators and HQP attended the Annual OTN Meeting in June 2012 in Halifax as well as some of the OTN workshops that were held in conjunction. All project HQP presented their work. Many opportunities for informal discussions arose.

Both PIs frequently meet with the PIs of projects I.1.1 and I.1.3 and PIs from all three Theme 1 projects are involved in the guidance of HQP, for example by serving on students committees.

Dr. Julian Dodson, Dr. Martin Castonguay and Dr. Melanie Beguer visited Dalhousie and collaborated with our group in modelling the migration of American eels from the St. Lawrence Estuary to the Sargasso Sea.

Dr. Fennel and Karl Lagman regularily interact with PIs and HQP of project I.2.4 *Grey Seals* to discuss the seal tag data analysis and sampling and its use for modeling.

The above list should be taken as an illustration rather than an exhaustive account of the many interactions within the Network.

Interaction/Outreach to Broader Community

Interaction and outreach to the broader community occurred through conference presentations, targeted visits and participation of the PIs in working groups and scientific steering committees.

The conference presentations are listed in detail in sections 9c and 9d. Examples of targeted visits and steering committees follow below.

Dr. Fennel was part of a delegation (consisting of Canadian government, industry and academic representatives) that went to Rio de Janeiro in May 2012 for the first Canada-Brazil Joint Workshop on Ocean Science and Technology. Dr. Fennel gave a presentation to Brazilian colleagues from government, industry and academia about Canadian expertise in ocean science and technology highlighting OTN (Brasil is likely to become a partner in OTN Global).

Dr. Fennel took part in the visit by German Chancellor Angela Merkel to Dalhousie in August 2012, gave a 3 min presentation about OTN-related work to the Chancellor and participated in a 30 min discussion focused on how collaborations with German colleagues can be strengthend.

Dr. Fennel served on the scientific organizing committee of the 46th Annual CMOS Congress in May 2012 in Montreal and organized a session at the international 2012 Ocean Sciences conference in Salt Lake City, Utah, thus facilitating the showcasing of Network results to the broader national and international community.

Dr. Fennel is co-applicant on a proposal for a SCOR working group with the objective of identifying essential ocean variables for monitoring change in marine ecosystems. The working group would focus on defining indicators of the status of marine ecosystems (and how they may be changing) that are required for marine ecosystem management. If funded this working group would be an obvious avenue for outreach by OTN.

Dr. Sheng served on the scientific organizing committee for the 4th International Workshop on Modeling the Ocean (IWMO2012) held in Japan.

Dr. Jinyu Sheng was the co-convener for the special session of "coastal Oceanography and Inland Water" of the 46th annaual CMOS Congress in 2012 in Montreal.

9. Dissemination of information and results

Refereed Journal Articles (3 total)- Accepted/published

Bianucci, L., Fennel, K., and Denman, K., 2012. Role of sediment denitrification in water column oxygen dynamics: comparison of the North American East and West coasts, *Biogeosciences*, **9**, 2673-2682, doi:10.5194/bg-9-2673-2012.

Urrego Blanco, J., and J. Sheng, 2012. Numerical investigation of interannual variability of circulation and hydrography over the eastern Canadian Shelf. Atmosphere-Ocean. 50, 277-300.

Shan, S., and J. Sheng, 2012. Examination of circulation, flushing time and dispersion in Halifax Harbour of Nova Scotia, Canada, Water Quality Research Journal of Canada. In press.

Refereed Journal Articles (1 total)- Submitted

Bianucci, L., Fennel, K., Mattern, J.P., What drives phytoplankton growth during deep winter mixing? A model study for the Northwest Atlantic, *Marine Ecology Progress Series* (submitted)

Conference Presentations (1 total) – Invited

Sheng, J., The far-field effect of tidal energy extraction on circulation and hydrography in the Bay of Fundy and Gulf of Maine, 46th Annual CMOS Congress, Montreal, Canada, May, 2012 (invited).

Conference Presentations (8 total) – Contributed

Bianucci, L., Fennel, K., Mattern, J.P., An emulator approach for constraining net phytoplankton growth rates in the North Atlantic in winter. Ocean Sciences Meeting, Febuary 20 - 24, Salt Lake City, UT, 2012 (poster)

Bianucci, L., Fennel, K., Mattern, J.P., Improving ecosystem models to study animal migration in the North Atlantic. ICES/PICES Early Career Scientists Conference 'Oceans of Change', April 23 - 27, Palma de Mallorca, Spain, 2012 (poster)

Bianucci, L., Fennel, K., Mattern, J.P., Temporal and spatial variability of net phytoplankton growth rates in the North Atlantic: a modelling approach. CMOS Congress, May 29 - June 1, Montreal, QC, 2012 (oral)

Lagman, K., Fennel, K., Bianucci, L., Bowen, D., Cullen, J., Davies, R., Lidgard, D., Iverson, S., Can light attenuation estimates from electronic seal tags be used as phytoplankton proxies on the Scotian Shelf? *CMOS Congress*, May 29 - June 1, Montreal, 2012 (poster)

Urrego-Blanco, J., and Sheng, J., Numerical study of circulation, hydrography and sea-ice conditions in the Gulf of St. Lawrence and Scotian Shelf using a coupled ocean-ice model, 46th Annual CMOS Congress, Montreal, Canada, May, 2012.

Shan, S., Sheng, J., and Greennan, B., Shelfbreak frontal circulation near the Sable Gully of Nova Scotia, 46th Annual CMOS Congress, Montreal, Canada, May, 2012.

Urrego-Blanco, J., and Sheng, J., Numerical study of circulation, hydrography and sea-ice conditions in the Gulf of St. Lawrence and Scotian Shelf using a coupled ocean-ice model, JONSMOD Meeting, Brest, France, May, 2012.

Shan, S., Sheng, J., and Greennan, B., Shelfbreak frontal circulation near the Sable Gully of Nova Scotia, JONSMOD Meeting, Brest, France, May, 2012.

10. Other contributions and deliverables

Invited or contributed presentation/contribution at a workshop.

As mentioned already above, Dr. Fennel was part of a delegation (consisting of Canadian government, industry and academic representatives) that went to Rio de Janeiro in May 2012 for the first Canada-Brazil Joint Workshop on Ocean Science and Technology. Dr. Fennel gave a presentation to Brazilian colleagues from government, industry and academia about Canadian expertise in ocean science and technology highlighting OTN.

Sheng, J., The far-field effect of tidal energy extraction on circulation and hydrography in the Bay of Fundy and Gulf of Maine: Numerical Study using the Princeton Ocean Model, 4th International Workshop on Modelling the Ocean, Yokohama, Japan, May, 2012 (invited).

Invited or contributed consultation with an agency; public or private

Dr. Fennel is serving as member of the IMBER/LOICZ Continental Margins Task Team (CMTT), which is part the International Geosphere Biosphere Program (IGBP). She participated in the June 2012 CMTT meeting in Halifax, which allowed showcasing of OTN science to international guests. Dr. Fennel also serves as a member of the Working Group for Model Development within the international Climate Variability and Predictability (CLIVAR) project, which was established by World Climate Research Program (WCRP). She was invited with the expressed objective of involving ecosystem modeler in a group traditionally dominated by atmospheric and physical oceanography scientists.

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

Ongoing OTN research was an important lever in the successful application for a Network of Centers of Excellence entitled “Marine Environmental Observation, Prediction and Response” (MEOPAR). Both, Dr. Fennel and Dr. Sheng, are heavily involved in this new network and act as project leaders. The MEOPAR research will complement and benefit OTN activities.

As mentioned above, Dr. Fennel is co-applicant on a proposal for a SCOR working group with the objective of identifying essential ocean variables for monitoring change in marine ecosystems. The working group would focus on defining indicators of the status of marine ecosystems (and how they may be changing) that are required for marine ecosystem management.

11. Collaborations with Industrial and Government Partners

DFO scientists Dr. Peter Smith, Dr. Blair Greenan and Dr. David Hebert are actively involved in this project making available observations form the Halifax Line and other DFO monitoring programs (e.g. AZMP) and a PhD student (Mathieu Dever) is jointly supervised. In turn our research products will be available to scientist and managers at DFO with interactions facilitated by our DFO collaborators.

12. Expenditures and Support

Year 3 (2012)

See the Year 3 financial report in Project I.1.1 for the amalgamated expenses for all three Oceanography (I.1) projects.

Year 4 (2013)

1) Salaries and benefits
   a) Two PhD students will be supported in year 4 @ $20,498/yr.
      i) one PhD student will focus primarily on physical model development and collaborate in assimilation of physical data;
      ii) one PhD student will focus on coupled physical-biological modelling and collaborate in the assimilation of interdisciplinary data;
   b) Two Post-Doctoral fellows (@ $45,000/yr) will be supported in year 4
      i) One Post-Doctoral fellow will work on physical model development and analysis.
      ii) One Post-Doctoral fellow will work on biological model development and analysis.
2) Equipment or Facility
   b) This budget line includes costs of minor computer hardware and software upgrades ($2000/yr).
4) Travel
   a) This will cover conference participation for students and Post-Doctoral fellows (2 trips total)
5) Dissemination costs
   a) This will cover page charges of $2,500/yr. This amount is likely not sufficient to cover 2 papers; page charge costs will be supplemented from other sources.

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$42 000	$40 996		2%
b) Postdoctoral Fellows	$90 000	$90 000		0%
c) Technical/Professional	$0	$0		
d) Other	$0	$0		
2) Equipment or Facility				
a) Purchase or Rental	$0	$0		
b) Operations/Maintenance	$2 000	$2 000		0%
c) User Fees	$0	$0		
3) Material and Supplies				
a) Materials and Supplies	$0	$0		
4) Travel				
a) Conferences	$4 000	$4 000		0%
b) Field Work	$0	$0		
c) Collaboration/Consultation	$0	$0		
5) Dissemination				
a) Publications	$2 500	$2 500		0%
b) Other	$0	$0		
6) Other (specify)				
a) Other	$0	$0		
b) Other	$0	$0		
Totals				
Totals	$140 500	$139 496		

Deviation between the Original and Revised year 4 budget

We request no deviations.

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

I. Atlantic Arena

1. Project Number: I.1.3

2. Project Title: Data Assimilation

3. Project Leader: K. Thompson (Dalhousie University)

Collaborators: J. Sheng, K. Fennel and J. Cullen

4. Public Summary of Report

In order to better understand how ocean ecosystems work, and how they respond to climate change, OTN is making point measurements of the passage of tagged animals across fixed lines of underwater acoustic receivers. To interpret these data they must be related to changes in the physical, biological and chemical characteristics of the ocean. A major challenge is the synthesis of a relatively small number of physical, biological and chemical observations in order to generate a dynamically consistent, time-varying, three-dimensional view of the ocean that can be used to explain and predict the observed movement of tagged animals. Coupled physical-biogeochemical models have an important role to play in synthesizing ocean observations and visualizing change in the ocean. It is generally recognized that all ocean models have errors and, if they are used to reconstruct past changes or make projections about possible future states, they must be blended with observations in order to remain close to reality. The process of sequentially blending observations with model states is known as data assimilation. In addition to improving predictions, data assimilation has other useful practical applications such as helping design fixed observing systems. This project has developed new assimilation schemes and models that will be essential in reconstructing past variations of the time-varying, three-dimensional physical, biological and chemical state of the ocean, and also providing initial conditions for projections of future states. Historical reconstructions are being used to interpret the movement of marine animals monitored by OTN's acoustic receivers, and will be used to project how their movement may change in the future.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Anna Katavouta	PhD	100%	100%	September 2010 to September 2014 (planned)
Thesis topic: Downscaling of Ocean Conditions				
Vasily Korabel	Research Associate	100%	100%	February, 2011 to September 2014 (planned)

No technical staff is supported by this project.

6. Progress towards Objectives/Milestones (1 Oct 2011 – 30 Sep 2012)

The goal of this project is to develop effective and efficient methods for assimilating physical, biological and chemical data, collected by fixed and mobile observing platforms, into realistic models of the shelf and the open ocean. The time scales of interest are hours to decades, and space scales of interest are 1 to 10^3 km. The physical data to be assimilated include remotely sensed surface temperature, coastal sea level and measurements of bottom pressure, current, temperature and salinity from the Halifax Line. We also plan to assimilate physical data from gliders and bioprobes as they become available.

This project has the following deliverables:

1) Development of modular FORTRAN codes for assimilating a wide range of physical, biological and chemical data into shelf and deep ocean models;

2) Assessment of the performance of the assimilation schemes;

3) Generation of realistic historical reconstructions (and climatologies) of currents, temperature, salinity, nitrate, ammonium, phytoplankton biomass, chlorophyll and oxygen fields from an assimilative hindcast from 2002 to date through assimilation of various observations.

The milestones for years 2 and 3 are (from the submitted proposal)

"Develop and validate methods for assimilating satellite measurements of surface color and in situ biological and chemical data from fixed platforms into models MD4 then MD5, building on experience gained from assimilation of physical data. We will also develop and evaluate schemes for assimilating physical, biological and chemical data from moving platforms (gliders and bioprobes) into the higher resolution models centered on the Halifax Line (MD3 and MD5)."

Note the MD2 model covers the Scotian Shelf, Gulf of Maine, and Gulf of St Lawrence; the MD3 model domain is embedded within MD2 and centered on the Halifax Line.

Development of a data assimilative model of the Northwest Atlantic and adjacent shelf seas: In order to predict the influence of the adjacent North Atlantic on the circulation and hydrographic state of the adjacent shelf seas, and also model the impact of ocean conditions on the basin scale migrations of animals such as the American Eel, Research Associate Vasily Korabel is developing a data assimilative model of the North Atlantic. The model covers the whole of the North Atlantic with a horizontal resolution of ¼ degree and has a high resolution, nested sub-model (resolution of 1/12 degree) covering the Northwest Atlantic. (The resolution of the coarse grid is eddy permitting and the resolution of the high-resolution nest is eddy resolving, which is important for accurate modeling of the currents in coastal regions.) The model is based on the NEMO code (developed in France). The assimilation scheme is a form of multivariate ensemble optimal interpolation, EnOI. (Long runs of the model are used to generate an "ensemble" of ocean states from which correlations amongst ocean variables are calculated and used to interpolate information from observations across the model grid.)

The main objectives of Dr Korabel's work are (1) assimilate a variety of data streams (e.g., sea surface height, vertical profiles of temperature and salinity measured by Argo floats, sea surface temperature from satellites) into the North Atlantic model; (2) assess the impact of the assimilation of observations into the coarse model on the predictive skill of the nested fine model, and vice versa. The following progress has been made over the last year.

1. Spectral nudging has been implemented in order to suppress systematic mean errors (biases) in the models temperature and salinity fields. Such biases are common in ocean models and spectral

nudging (Thompson et al., 2006, Ocean Modelling, 13, p109-125) solves the problem by nudging the model towards observed seasonall climatologies (thus removing the bias) while leaving the variability at other frequencies to evolve freely. In the previous year we used the WOA05 climatology but discovered it is also biased. A new temperature and salinity climatology (HPC2.0) has replaced the biased climatology and this had led to significantly better predictions.

2. A massively-parallel implementation of EnOI has been developed and tested extensively. The system is capable of assimilating several types of remotely sensed surface data such as sea surface temperature and sea surface height, and additional in situ observations including vertical profiles of temperature and salinity from Argo floats.
3. Several improvements have been made to the EnOI scheme. Comparison of model predictions with Argo profiles showed that vertical correlations of temperature and salinity decreased more slowly with depth than the ensemble-based correlations. A new way of tailoring the ensemble to overcome this problem was developed and has resulted in much more reasonable correlation structures and, most importantly, more accurate predictions of independent observations that were not assimilated.
4. Many data assimilation experiments have been performed over the last year to evaluate the performance of the EnOI data assimilation scheme. Different combinations of data were assimilated (e.g., sea surface temperature alone, surface height alone) and their effect on the model's ability to predict the independent Argo profiles were assessed. These results clearly show the effectiveness of the modified EnOI scheme for the Northwest Atlantic.

A manuscript entitled "An Ensemble Optimal Interpolation Scheme With Improved Vertical Correlations for Surface Data Assimilation" is being finalized for submission to the journal "Ocean Modeling" within a month.

Ocean Downscaling: Marine animals respond to their local physical environment and yet this physical environment is often controlled by factors operating on large, sometimes global, scales. To illustrate, the physical conditions observed on the Halifax Line that cuts across the Scotian Shelf are controlled, in large part, by conditions over the Gulf of St Lawrence, the Labrador Sea (through the Labrador Current that flows southward, along the other edge of the Scotian Shelf), and the adjacent North Atlantic. This leads to a difficult modeling challenge: it is necessary to model large parts of the ocean (the North Atlantic in this example) in order to obtain useful predictive models, but also develop a "zoom" capability to provide much higher resolution (scales of order one kilometer) in order to explain, and ultimately predict, animal movement. This zoom process is usually called downscaling, particularly by atmospheric modellers. We use the term in the rest of this document.

PhD candidate Anna Katavouta is working on downscaling conditions on the Scotian Shelf, where many OTN measurements are being made, from conditions predicted by the North Atlantic model outlined above. Specifically, Anna has developed a new downscaling method, based on data assimilation, that takes advantage of the non-linear coupling of different length scales of ocean variability generated by nonlinear dynamics. In Anna's method, the large scale variability (predicted by a larger-scale, coarser-resolution model) is assimilated into a high resolution model in order to recover the small scale variability, taking advantage of the model's non-linear dynamics. The method has been tested extensively using an idealized (quasi-geostrophic) ocean model and the results suggest that using Anna's approach can indeed recover much of the small scale variability. The top left panel of Figure 1 shows a snapshot of sea surface height from a multi-decadal run of the model that we will treat as the "truth" run. This snapshot shows that the model is highly nonlinear and can support a mean ocean circulation and

also ocean eddies. The middle panel shows that a forecast made with a slightly different initial condition leads to a very different result. The top right panel shows that assimilating the large scales from the truth run does indeed improve the forecast, even though the initial condition is in error.

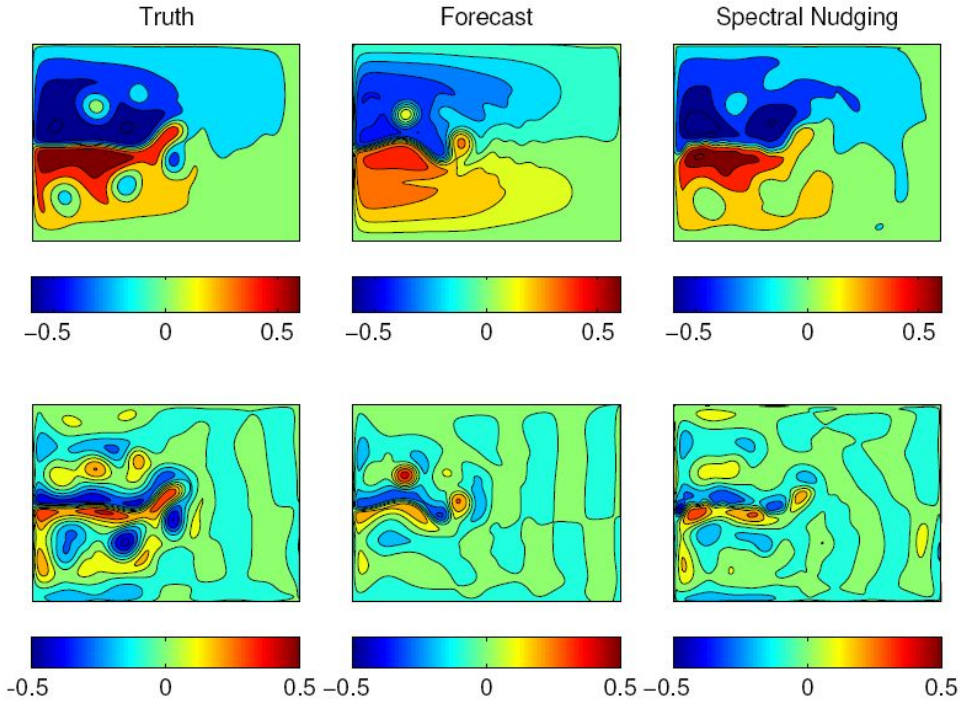


Figure 1: Snapshots of the sea level (m) for the truth (left) run, the forecast (middle) run with an erroneous initial condition, and the downscaling (right) run where the true large scales are assimilated. The output time of all the fields is the same. The small scale variability of each of the fields is displayed in the lower panels. In this example the small scales were characterized as structures with length scales shorter than 450 km.

Anna has spent most of the last year working on an extension of the downscaling technique that allows more of the small scale variability to be recovered if additional oceanographic observations are available. The practical application of this work will be to downscale the predictions of the North Atlantic model (see above) by assimilating additional physical observations such as current and glider measurement made on the Halifax Line. The extension involves an additional step that follows the downscaling: EnOI is used to assimilate the new observations into the downscaled fields. Anna has both developed and tested this new hybrid scheme in the context of the quasi-geostrophic model, using only a small number of observations from the truth run. Figure 2 illustrates the improvement in the fields that can result from assimilating only a small number of additional observations using EnOI. The hybrid (right panel) clearly gives a much improved prediction of the truth (left panel) than can be obtained from downcaling alone (middle panel).

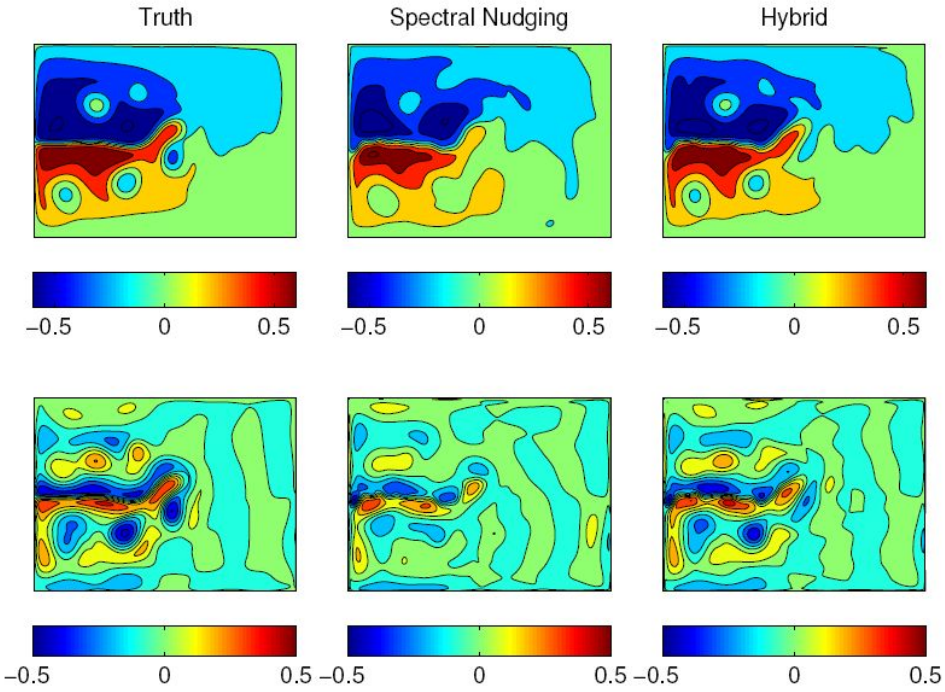


Figure 2: Snapshots of the sea level (m) for the truth, the run with the assimilation of the large scales (middle), and the hybrid run with assimilation of the large scales and the point observations (right). The format is the same as Figure 1.

The time variation of the error in predicting the truth given a wrong initial condition are plotted in Figure 3. The dotted line shows the errors of a run with no assimilation. The remaining three lines shows show the time variation in the errors resulting from the assimilation of a small number of observations (light grey line), downscaling (dashed line) and the hybrid (black line). This figure shows clearly that sparse observations can improve significantly the recovery of the small scales if used in addition with the assimilation of the large scales. These results are encouraging in terms of extracting useful information on the physical conditions on the Scotian Shelf from the limited point observations from moorings and gliders.

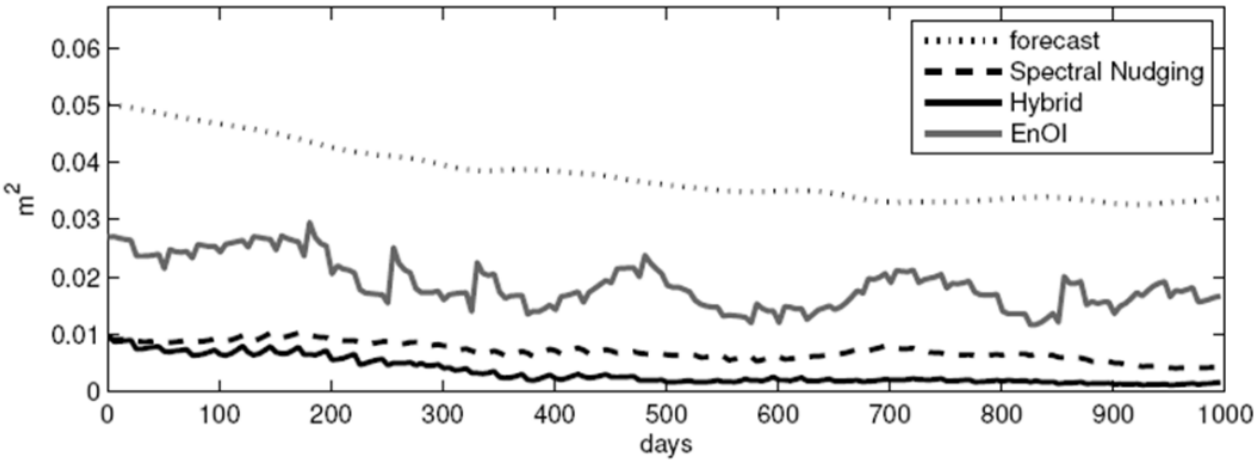


Figure 3: Mean square error (MSE) of the forecast (no assimilation) and three assimilation runs relative to the truth. The lines shows the MSE of the forecast (dotted), downscaling (dashed), assimilation of sparse point-observations (EnOI), and the hybrid (black line).

A paper based on the dynamical downscaling and the hybrid approach is almost complete and will be submitted to "Ocean Modeling" with a month.

The next stage of Anna's research is to apply the above method to the realistic, high resolution model of the Northwest Atlantic and Scotian Shelf already developed by Dr Vasily Korabel. These large scale fields have include inaccuracies, particularly on the fine scales relevant to OTN, due for example to the relatively crude representation of non-linear processes. Observations being gathered by the OTN will be assimilated into the high resolution model to correct such errors and improve the realism of the model's small scale variability. This new model will be used for additional particle release experiments with behavioral constraints in order to infer the trajectories of tagged fish, taking advantage of archived measurements of acceleration, temperature and depth. This line of research will be undertaken in collaboration with Franziska Broell, an OTN graduate student under the supervision of Professor Chris Taggart.

Assimilation of Biogeochemical Data: One of this project's milestones year 3 is to develop and test ways of assimilating biogeochemical data, building on experience gained from assimilation of physical data. In the original proposal it was stated that this activity would be carried out in close collaboration with Professor Katja Fennel (one of the co-leads of project I.1.2). Two relevant activities have been initiated during the present reporting year, both in close collaboration with Professor Katja Fennel.

The first initiative involves the development of a new way of suppressing the systematic errors that are sometimes detected in biogeochemical models of the ocean. Such biases can degrade the quality of ocean hindcasts. Under this new initiative, spectral nudging (described above) is being adapted for use with biogeochemical models. The bulk of the work is being carried out by Karl Lagman, a PhD student under the supervision of Professor Katja Fennel. Keith Thompson is a member of the supervisory committee for this student and is actively involved in implementing spectral nudging. The technique involves the assimilation of monthly climatologies of biogeochemical variables such as nitrate, phytoplankton, zooplankton and detritus. The results obtained to date are encouraging in the sense that the bias errors of a relatively simple, one dimensional biogeochemical model have been suppressed for the mean and annual cycle, leading to a more realistic reconstruction of the higher frequency variability.

A paper is being written on the application of the technique to biogeochemical models with graduate student Karl Lagman as lead author. The next step in the research will be to implement the scheme in more realistic biogeochemical models of the Northwest Atlantic and adjacent shelf seas, and assess its impact on the multi-year hindcasts planned for the region.

A second initiative involves the assimilation of time-varying observations of biogeochemical variables (e.g., remotely sensed observations of ocean color). The idea is to evaluate the multivariate ensemble-based optimal interpolation scheme that has already been implemented for physical variables by Dr Vasily Korabel (EnOI, see above). The work is being carried out by Dr Paul Mattern who is supervised by Professor Katja Fennel. Initial results show that the physical submodel does have significant biases that first need to be suppressed by spectral nudging. Work is also underway on the assimilation of biogeochemical data, specifically the generation of the ensemble of model states needed to assimilate the ocean color observations. Keith Thompson is actively collaborating in this research and this is strengthening significantly the ties between projects I.1.2 and I.1.3.

Modeling the movement of the American Eel: An active collaboration has continued over the last reporting year involving Keith Thompson, PhD student Shiliang Shan (Dalhousie University) and researchers from project I.2.2 who are working on the estuarine and oceanic migrations of the juvenile and reproductive stages of the American Eel. The main collaborators from project 1.2.2 are Professors Julian Dodson and Martin Castonguay, and postdoctoral fellow Dr Mélanie Beguer.

The goal of this collaboration is to obtain a better understanding of how the American Eel migrates from the coast of North America to its spawning grounds in the Sargasso Sea. In an initial theoretical study, Shan and Thompson have focused on the joint effect of ocean currents and the environmental preferences of marine animals (e.g., specific light level, water temperature) on the animals' overall movement and distribution. Animal position is calculated using a particle tracking algorithm that has been modified to allow for the environmental preferences (e.g., range of water temperatures, swimming direction). The ocean currents and physical environmental conditions experienced by the marine animals have been calculated using results from the realistic model of the North Atlantic developed by Dr Vasily Korabel (see above). Figure 4 illustrates one set of calculations where particles were released on the Scotian Shelf (43° N, 58° W) and the nearby Gulf Stream (41° N, 58° W), without behavior (top panels) and with behavior (bottom panels). A patch of over 1000 particles was released at each initial location and tracked for 100 days at a depth of 16 m. The release was repeated 18 times at a 5-day interval. The simulated distribution of particles originating from these two locations from the Northwest Atlantic Ocean shows the importance of the North Atlantic current system in controlling the movement of particles (top panels). The bottom panels show that relatively weak motion associated with an environmental preference can have an order one impact on the mean movement and distribution of the animals.

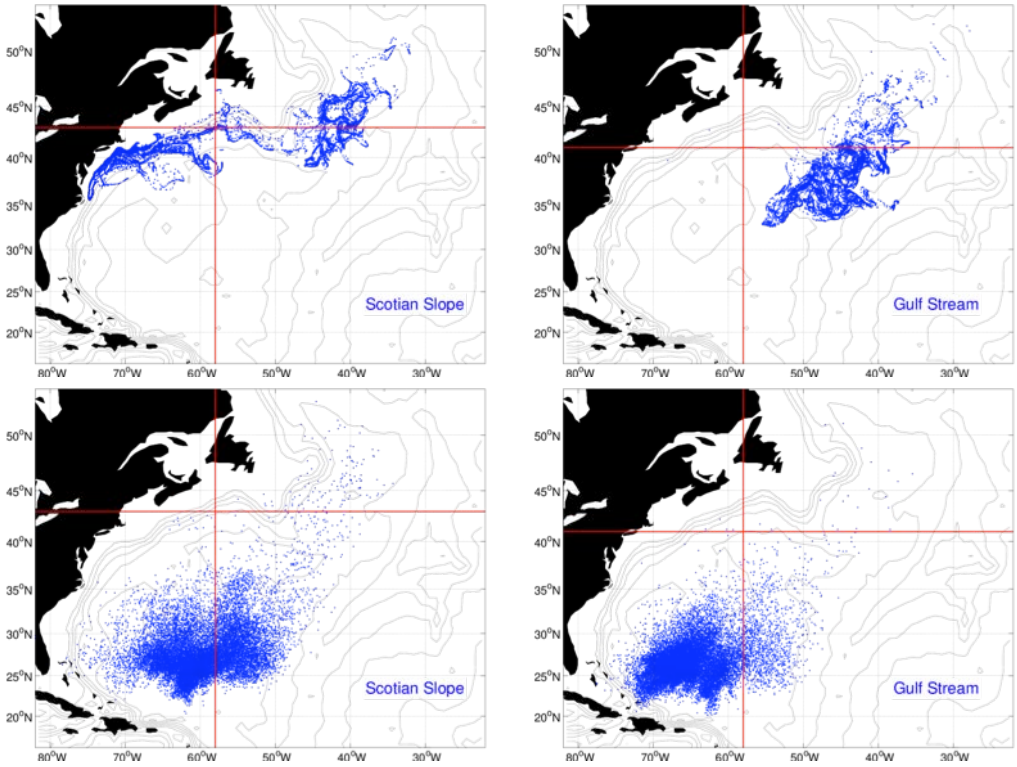


Figure 4: The distribution of a patch of particles released from Scotian Slope and Gulf Stream without (top panels, passive drift) and with biological behavior (weak swimming toward the Sargasso Sea). The 200, 1000, 2000, 3000, 4000 m isobaths are shown. The intersection of the two red lines shows the release point.

Shiliang Shan and Keith Thompson are working closely with Project I.2.2 on the application of the particle tracking techniques described above to the study of the migration of the American Eel from the Gulf of St Lawrence to their spawning grounds in the Sargasso Sea. Much of the research over the last reporting year has focused on ways of inferring the environmental preferences of the marine animals given their initial and final locations, and the physical environment they experience on the way. A two day workshop was held at Dalhousie in July, 2012 attended by researchers Thompson, Shan, Sheng, Ohashi, Dodson, Castonguay and Beguer. Based on these discussions we are using the following criteria to infer environmental preferences: (i) probability of arriving at a given spawning area within a prescribed time window (ii) energy cost of making the journey. By evaluating these criteria for a wide range of environmental preferences (each corresponding to a run of the particle tracking model for multiple particles, such as that shown in Figure 4) it is possible to rank each preference.

A methodological paper ("Impact of Environmental Preferences on the Distribution of Marine Animals") by Shan and Thompson is in the final stages of preparation and will be submitted to the Journal of Marine Systems for publication within the month. A paper involving Shan, Begeur, Thompson, Dodson and Castonguay ("How Does the American Eel Migrate to the Sargasso Sea? An Exploration of Possible Strategies Using a Coupled Physical-Biological Model") is presently being drafted and should be submitted for publication before December, 2012.

Significant Deviations from the Original Objectives or Plans

Overall the project is on track and the original plans are being followed. Some new initiatives have begun (e.g., the development of the hybrid assimilation scheme, spectral nudging applied to biogeochemical models, work on the American Eel in collaboration project I.2.2).

Coordination and Integration

Principal investigator Keith Thompson is in daily contact with Research Associate Vasily Korabel and graduate student Anna Katavouta. Regular meetings are also held (at least weekly) with Professors Sheng and Fennel (project I.1.2). As illustrated above, the collaborations with Professor Katja Fennel are taking place primarily through graduate student Karl Lagman and postdoctoral fellow Paul Mattern.

Coordination and integration with project I.1.1 has taken place primarily through technicians.

An OTN modeling validation group was created last year by the members of projects I.1.2 (modeling) and I.1.3 (assimilation). This group is planning to meet with a similarly created OTN observation group made up primarily of members of project I.1.1. A joint modeling and observation group meeting is presently been arranged to increase the collaboration of these two groups (and the sharing and synthesis of observations and model output).

Scientific and/or Engineering Significance of Results

1. Improved ocean data assimilation scheme for the North Atlantic based on a new way of tailoring the ensemble of model states needed for EnOI.
2. New hybrid scheme for "zooming" the oceanographic conditions predicted by models down to the fine spatial scales relevant to marine animal movement.
3. Better understanding of the role of environmental preference on the movement and distribution of marine animals.
4. A methodology for inferring the environmental preferences of marine animals from their initial and final locations, and the ambient oceanographic conditions.

7. Difficulties encountered

No major problems occurred over the present reporting period.

8. Networking and outreach

Intra-Network Collaboration and Partner Meetings

Close ties have been maintained with the modeling project 1.1.2 led by Professors Fennel and Sheng.

Collaboration with the American Eel project 1.2.2 led by Professors Dodson and Castonguay have strengthened significantly over the last year. A two day workshop was held at Dalhousie University in July, 2012. One day was dedicated to modeling the movement of the American Eel across the North Atlantic from the Scotian Shelf to the Sargasso Sea. This part of the workshop was attend by Thompson and Shan (Dalhousie) and Dodson, Castonguay and Begeur (University of Laval).

9. Dissemination of information and results

It was noted in the SAC's review of last year's annual report that

> *Science report: A question of measures of research productivity (based on information on page 71) was raised in comparison to the other projects that show a higher number of publications. It was emphasized that deliverables are equally important in the evaluation of the project's productivity. However, it was also recognized that there is a difference in time scales for published outputs between observational and modeling studies such as this one.*

I understand this concern. Part of the explanation is that Research Associate Vasily Korabel did not start until February 2011 for the reasons given above. An effort has been made to accelerate the publications. The present situation is that, as explained in the Science Report, five papers are very close to being submitted (one with Anna Katavouta on ocean downscaling, one on ocean data assimilation with Vasily Korabel, two on the American Eel with Shiliang Shan and collaborators at Dalhousie University and Laval, and one on spectral nudging of biogeochemical models with Karl Lagman and Katja Fennel).

Conference Presentations (5 total) *– Contributed*

Anna Katavouta and Keith Thompson. Downscaling ocean conditions: initial test of a new method using a quasi-geostrophic ocean model, Contributed presentation at the 46th CMOS Congress, Montreal, May 29-June 1st 2012.

Anna Katavouta and Keith Thompson. Downscaling ocean conditions: initial test of a new method using a quasi-geostrophic ocean model, Contributed presentation at the Second OTN Symposium, Halifax June 4-6 2012.

Anna Katavouta and Keith Thompson. Downscaling ocean conditions: Can we take advantage of the non-linear coupling between the length scales? Contributed presentation at CDOGS (Conference of the Dalhousie Oceanography Graduates Students), 2012 conference, March 2012.

Vasily Korabel, Keith Thompson, Shiliang Shan, Frederic Dupont. Assimilation of sea-surface temperature observations during 2004 into an eddy permitting model of the North Atlantic Ocean. 46th CMOS Congress, Montreal, May 29-June 1st 2012.

Mélanie Béguer, José Benchetrit, Martin Castonguay, Daniel Hatin, Guy Verreault, Michel Legault, Mélanie Dionne, Pierre Dumont, Yves Mailhot, Jean-Francois Bourque, Ian Jonsen, Keith Thompson, Jinyu Sheng and Julian J. Dodson. Multiple approaches to elucidate the migration of the American eel (Anguilla rostrata) from the St-Lawrence River to the Sargasso Sea, Ocean Sciences Meeting, 2012.

10. Other contributions and deliverables

None.

11. Collaborations with Industrial and Government Partners

None.

12. Expenditures and Support

Please note that Professor Katja Fennel has signing authority on the account.

Year 3 (2012)

See the Year 3 financial report in Project I.1.1 for the expenses for all three Oceanography (I.1) projects.

Year 4 (2013)

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$21 000	$20 498		2%
b) Postdoctoral Fellows	$45 000	$45 000		0%
c) Technical/Professional	$0	$0		
d) Other	$0	$0		
2) Equipment or Facility				
a) Purchase or Rental	$0	$0		
b) Operations/Maintenance	$1 000	$1 000		0%
c) User Fees	$0	$0		
3) Material and Supplies				
a) Materials and Supplies	$0	$0		
4) Travel				
a) Conferences	$2 000	$2 000		0%
b) Field Work	$0	$0		
c) Collaboration/Consultation	$0	$0		
5) Dissemination				
a) Publications	$2 000	$2 000		0%
b) Other	$0	$0		
6) Other (specify)				
a) Other	$0	$0		
b) Other	$0	$0		
Totals				
Totals	$71 000	$70 498		

1) Salaries and benefits

b) One PhD student to be supported in year 4 @ $20,498/yr (Anna Katavouta). The student will work on physical model development and assimilation of physical data.

c) One Post-Doctoral fellow (@ $45,000/yr) to be supported in year 4 (Dr Vasily Korabel) to work on data assimilation.

2) Equipment or Facility

a) Cost of minor computer hardware and software upgrades ($1000).

4) Travel

a) Conferences: $2000 for the two HQP to attend CMOS.

5) Dissemination costs

a) $2000 for publication fees.

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

I. Atlantic Arena

1. Project Number: I.2.1

2. Project Title: Atlantic salmon (*Salmo salar*): migration, distribution, and oceanographic features

3. Project Leaders: S. Iverson[1] (Dalhousie), I. Fleming (Memorial), B. Hatcher (Cape Breton)

Collaborators: M. Robertson, C. Pennel, L. Fudge, J. Gibson (DFO), D. Reddin, P. Downton (DFO retired), D. Ruzzante, G. Crossin, I. Jonsen (Dalhousie), M. Stokesbury (Acadia), J. Carr (Atlantic Salmon Federation), S. Denny (Eskasoni First Nation, UINR), J. Hart (Margaree Salmon Association), S. Porter (CSI), D. Webber (VEMCO), La Have Salmon Assosciation, St. Mary's River Salmon Association, Club Hill Camp, Inc., Nova Scotia Salmon Association, Atlantic Salmon Federation, Nova Scotia Salmon Association, Bras d'Or Biosphere Reserve Association.

4. Public Summary of Report

Atlantic salmon populations are in decline throughout much of their Canadian range, and it appears that mortality occurring in the ocean is a primary cause. To identify when, where and how salmon die while at sea, we used acoustic telemetry to follow juvenile salmon as they exited four Nova Scotian rivers. Pairing this technology with statistical modelling, data on predator populations in the area and a mathematical models describing salmon population dynamics, we were able to identify estuaries as period of high mortality, identify predation as a likely vector and show that this mortality is substantial enough to affect long-term population viability. We are also experimenting with the use of ocean autonomous vehicles as mobile tracking devices. In parallel, work in Newfoundland developed the world's smallest archival tags, which may open up new opportunities to study smolts at sea. Technical difficulties with the mounting of these tags proved a major hurdle, and will be resolved in the future. There are also ongoing studies exploring the behaviour of salmon kelts at sea, with the aim of linking it to potential genomic/physiological signatures.

In Cape Breton, an array of 25 acoustic receivers has been installed in all the main channels and passages of the Bras d'Or "Lakes. Range testing and calibration of the receiver array was undertaken to quantify the probability of detection of tagged fish moving among the major basins of the complex estuary, and between the estuary and the NW Atlantic Ocean. Twenty Atlantic salmon smolt were tagged and released in the largest salmon river in the watershed as a pilot study of the capacity of the array to detect the timing and patterns of smolt movement, and to quantify the proportion of smolt successfully leaving their natal river, and leaving the estuary for the open ocean. Based on the

[1] Note: Iverson helps to lead this project through co-supervision of PhD student Edmund Halfyard and managing his graduate program and research at Dalhousie.

preliminary results, slightly more than half of the tagged smolt entered the estuary. Revisions to tagging proceedures and array design will be undertaken prior to next year's smolt run.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Corinne Conway	RA	47%	47%	1 Oct 2011 – 30 Sep 2012
Melissa Evans	PDF	93%	93%	16 Apr 2012 – 30 Sep 2012
Edmund Halfyard	PhD	100%	100%	1 Oct 2011 – Dec 2012
Thesis topic: The Marine Survival of Atlantic Salmon: Timing, Location, Causes and Potential Mitigative Strategies				
Kim Whoriskey	BSC	100%	0%	May 2012 – Aug 2012
Martin Lequizamon	RA	25%	25%	1 Oct 2011 – 5 Jun 2012
Qi Xu	BSc	25%	100%	15 May 2012 – 26 Aug 2012

Subcomponents 1 and 3, centered at Dalhousie University, provided training to a PhD student (E. Halfyard), and an NSERC Summer Undergraduate Research Award holder (K. Whoriskey). In addition to normal supervisory training activities, Mr. Halfyard attended workshops on the use of the Platform for Ocean Knowledge Management software for visualization and analysis of tracking data. OTN has provided training on strategies for communicating with media, hands-on training with the operation and maintenance of scientific equipment and has facilitated collaboration between Mr. Halfyard and researchers from several other Canadian and international research institutes. Further, the OTN has provided a platform to discuss his research with world leaders in environmental policy, such as the recent visit from the German Chancellor, Dr. Angela Merkel. Ms. Whoriskey was trained in the operation of rotary screw fish traps (smolt wheels), and in the implantation of tags in Atlantic salmon smolts, and operated a tagging program contributing to the Wave Glider mission in the Gulf of St. Lawrence. She also worked with the OTN data analysis and visualization group on a variety of data sets.

Subcomponent 2, centred out of Memorial, continued to provide a breadth of training to research assistants and technical staff, including Corinne Conway of MUN, DFO technical staff (e.g. Lloyd Fudge, Curtis Pennel) and technical staff from the local communities operating the salmon counting fences at Trepassey, Campbellton and Western Arm Brook, Newfoundland. Dr. Melissa Evans, postdoctoral fellow, joined the team in April 2012 and is leading the research to integrate salmon tagging studies with genomic studies to further understand factors that may be shaping behavior and survival of salmon at sea. Dr. Evans brings expertise in genomics, which is being complemented by a new and developing skill set in the use and analysis of archival tags (data storage tags). Collaborative interactions between university and government researchers and technical staff provide the cross-fertilization of ideas, techniques and knowledge creating a positive training environment within the subcomponent.

6. Progress towards Objectives/Milestones (1 Jan 2010 – 30 Sept 2012)

This project has four subcomponents:

1. *Documentation of migration pathways of Atlantic salmon from different regional groupings.* The objective is to implement tagging programs for Atlantic salmon populations from differing regions to see if these fish use different migration pathways and parts of the ocean, or whether they

ultimately link up with the previously described Gulf of St. Lawrence fish in a single mixed Atlantic salmon ocean feeding group.

2. *Use of novel technologies to document how Atlantic salmon make use of the oceans.* The objective is to field test the new archival tags, which we will deploy on kelts leaving the Campbellton River. The tags will be recovered from returning adults and the data compared to the results from previous work with large archival tags to evaluate the reliability of the new tags. In a second experiment, smolts will be fitted with the miniaturized version of the tags, and recovered data will be used to document the conditions they experience in the ocean, and geolocation data analyzed in an attempt to determine if it provides sensible information about the movements of the fish in the ocean.
3. *Are ocean distributions of Atlantic salmon associated with particular and predictable oceanographic conditions?* The objective is to combine the modeling capacity of the oceanographers (see **I.1**) with associated fieldwork on salmon. Models will be developed to provide descriptions of the places in the ocean that have favourable conditions for Atlantic salmon, which will be compared to the actual areas occupied by the salmon. Discrepancies between predicted and actual distributions will become the focus of future research.
4. *Do Atlantic salmon close their life cycle in the Bras d'Or ecosystem of Cape Breton?* Objective is to test a nested set of hypotheses having progressively greater generality and lower certainty: Salmon exiting the mouths of four known spawning rivers in the Bras d'Or watershed 1) do not subsequently leave the sub-basin into which the river drains, 2) do not subsequently exit the estuary to the NW Atlantic ocean, 3) do not make their way back into the Bras d'Or estuary or its rivers, and 4) do not survive to return to those rivers to spawn in subsequent years. Ingress to the Bras d'Or estuary of salmon tagged elsewhere in the North West Atlantic Ocean will also be tracked.

Specifically, in this study we have three 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 migration strategies, what are the physiological pros and cons of these strategies with respect to patterns of reproductive allocation, migratory and spawning behaviour, and future survival? We will test the hypothesis that 1SW or locally migrating fish will have smaller sizes at maturity, lower somatic energy concentrations, and lower mass specific fecundities than 2SW fish, but that overwinter survival will be higher in 1SW fish, with a potential sex bias towards males. Concurrently collected data from oceanographic and ecological studies of the Bras d'Or estuary will be used to generate hypotheses about causal factors affecting migration strategies and their outcomes for Bras d'Or salmon populations both within the complex estuary and between it and the adjacent oceans. 3) Why are the Bras d'Or salmon populations in decline, and how do they differ from other Atlantic salmon populations with high inter-annual survival and return rates? The physiological and environmental correlates of post-spawning and overwinter migration mortality are of great value to the conservation of these salmon populations, because large adult fish presumably contribute the major egg supply to the population. Information from these studies will feed into federal, provincial, regional, and aboriginal conservation and management activities

Subcomponent 1: The field data required to meet all project objectives has been collected. E. Halfyard continued to progress satisfactorily in his PhD research. This had for objectives to 1) Identify the timing, location and magnitude of mortality for Atlantic salmon in estuaries, 2) Evaluate predation as potential

mortality vector, 3) Evaluate impact of estuarine mortality on population viability, 4) In an effort to evaluate the efficacy of this program, describe the behavior of adult Atlantic salmon raised and released into rivers as a strategy to mitigate low marine survival.

Mr Halfyard has completed the analysis of most of his data, and is continuing to analyze the remainder. Two manuscripts from the project have been submitted for publication, one of which has been accepted. Several additional papers will be submitted in the upcoming year.

Subcomponent 2: Having focused on the development and testing of different tag shapes, attachment mechanisms and tagging methodologies for fitting salmon smolts with miniaturized geolocation archival tags during the first period of the study, a full scale field experiment with the new technology was undertaken at the Campbellton River with the tagging and release of 215 smolts (fork length 21.2 ± 2.1 cm; total weight 99.1 ± 28.5 g) in May 2011. One of the tagged smolts (fork length 25.5 cm; total weight 143.7 g), released on 28 May 2011, was recaptured three weeks later on 18 June 2011, off of Black Cliff near Newstead, NL. This is approximately 15 km north of the mouth of the Campbellton River. The fish was recorded as being in good shape, with no signs of wear or infection. A second smolt (fork length 28.5 cm; total weight 223.3 g), also released on 28 May 2011, was recaptured almost 2.5 months later on 11 August 2011(ca. length 38-41 cm) in Fourth Pond in the Campbellton watershed. Thus, we have geolocation and habitat use data (temperature and depth use) for a total of 76 days downloaded from this tag. This smolt is considered a precocial postsmolt, having spent only a few weeks at sea before returning to freshwater. These early results indicate that the smolts were able to handle the tags and that the tagging methodology was effective. However, despite annual smolt-to-adult (grilse) survival rates for the Campbellton River that range from 4-12%, with a mean of ca. 7%, no tags were recovered from the one-sea-winter (grilse) salmon that returned in the summer-fall 2012, when most of the tag returns would have been expected. This result is disappointing. Indications, based on subsequent experiments in California with steelhead trout and Chinook salmon (unpubl.), are that there was an issue associated with corrosion of the tag attachment wire at the point where it was imbedded into the tag potting (i.e. mechanical issue associated with tag construction). We are addressing this issue with the manufacturer and hope to have a solution.

In the spring of 2012, we began a new study building on our earlier research about Atlantic salmon kelts (repeat breeders) at sea (Reddin et al. 2011 Fisheries Oceanography 20: 174-191), to integrate information on marine migratory behaviour with functional genomics to explore profiles associated with successful return and interpopulation differences. To that end, we tagged 81 Atlantic salmon kelts from the NE Trepassey (n=13), Campbellton (n=34), and Western Arm Brook (n=34) populations in Newfoundland with Lotek 2810 geolocation tags. These tags were surgically implanted into the abdomens of the kelts. In addition, we also implanted acoustic tags (VR9 or VR13) in 10 and nine of the kelts from Campbellton and Western Arm Brook, respectively. Any acoustic tag data will be used to confirm the accuracy of the Lotek geolocation tag data. Tissue biopsies from the lateral muscle were collected for future gene expression work and from the adipose fin for future population genetic analysis. In addition to the individuals included in the geolocation study, an additional 25 and 18 kelts from the Campbellton and Western Arm Brook populations, respectively, were sampled for tissues only. These individuals were marked with Floy tags for future identification. During the out migration, five of the 10 kelts that were also acoustically tagged were register at receivers off of Twillingate, Newfoundland (50 km or more north from the mouth of the Campbellton River and out in the open ocean). More records may become available once these and others are downloaded again. Returns of Atlantic salmon kelts on each of the rivers were monitored at counting fences by Fisheries and Oceans Canada (DFO) staff beginning in June 2012. However, due to historically low rainfall levels this summer, each of the rivers showed low water levels and thus delayed kelt returns. Due to DFO

budgetary restrictions, the salmon counting fences were removed from each river by Fisheries and Oceans in early September. As of early September 2012, eight Atlantic salmon kelts bearing geolocation tags had returned to the Campbellton River. For each of these individuals we have successfully retrieved geolocation data and habitat use data (temperature, depth) from the tags. Of the kelts sampled for tissues and marked with a Floy-tag, three individuals had returned to the Campbellton River. No geolocation-tagged kelts or kelts sampled for tissues only had returned as of early September to the NE Trepassey or Western Arm Brook rivers. There is a good chance of recovering kelts that may have migrated up the rivers after the counting fences had been removed during their spring migration back to sea in 2013 (see Reddin et al. 2011).

Subcomponent 3: A major effort was put into advancing the use of autonomous vehicles as mobile receiver platforms to detect migratory marine animals, including Atlantic salmon, and to link them to oceanographic conditions. In previous years, two attempts were made to use Slocum Electric Gliders to conduct this work. Both failed when missions were aborted due to technical malfunctions of the gliders. In 2012, work focused on configuring a Liquid Robotics Wave Glider to conduct the work. This vehicle has both surface and submerged components, which meant that the glider could maintain near constant communication with its controllers via satellite, and report data in near real time. Significant engineering collaborations were required between Liquid Robotics, and VEMCO to incorporate the VEMCO receiver into the onboard systems of the glider. Both companies invested in making this happen. Originally, we had intended to launch the mission in the Gulf of St. Lawrence in early June, at the time and near the point where the tagged Atlantic salmon smolts were entering the Gulf. Engineering problems in melding the VEMCO and Liquid Robotics technologies delayed the launch. Salmon had already started their migration across the Gulf, and we had to estimate their approximate position to determine a new launch point for the mission. Unfortunately, we believe we underestimated the smolt cohort's position and launched the glider behind the migration of the majority of the tagged fish on their movement to the Strait of Belle Isle. Nevertheless, the glider was guided on a 30 d, problem-free, 3500 km mission, and detected one tagged Atlantic salmon kelt from the Miramichi River, tagged cod, and was flown over a number of fixed OTN sentinel tags to assist with the calibration of the detection capability of the glider. The glider was also fitted with oceanographic sensors, and provided a continuous real-time record of thid data, which was posted to a web site made accessible to scientists and the general public. This is a successful proof of concept, and are now working to obtain Wave Gliders for permanent use by the OTN in the future.

Subcomponent 4: Twenty-five acoustic receivers in eight lines and three stations are now in position in the Bras d'Or Lakes following an extensive, two-year program of testing and calibration. A series of oceanographic measurements were made using velocity, temperature and salinity profilers in those channels where tag-receiver performance was compromised by environmental conditions. The Bras d'Or array complements other lines have been established in the Atlantic arena (i.e. the Cabot Strait line, Strait of Belle Isle line, Halifax line, etc.), in association with OTN Global. Fish tagging and telemetry observations began in early spring of 2012 with the successful tagging and release of 14 salmon smolt in the Middle River, 8 of which were subsequently detected in the Bras d'Or array within 15 days of release.

Significant Deviations from the Original Objectives or Plans

Subcomponent 1: The project is on track, and has addressed its original objectives.

Subcomponent 2: There were no major deviations to report beyond the potential mechanical issues with the smolt tags. Our plans to incorporate a genomics aspect to the kelt study is a new component and does

not require new funding, but will involve redirecting some existing funds from the "Equipment or Facility" to "Material and Supplies." It is also facilitated by carryover of funds in these categories from previous years. The addition of acoustic tags to the kelt study was facilitated by tags made available from other sources within the Fleming lab, as well as a donation of tags from DFO.

Subcomponent 3: The project is back on track after technical problems with the autonomous vehicles in previous years, and has addressed its original objectives.

Subcomponent 4: The only significant deviations from the original project plans were the relocations of two receivers and the addition of 11 receivers in the array in order to increase the probability of tag detection.

Coordination and Integration

Subcomponent 1: Regular supervisory committee meetings were conducted to evaluate the progress of E. Halfyard in his thesis research.

Subcomponent 2: Biological and engineering expertise of Memorial, DFO (NF) and private industry (Lotek Wireless) was brought together in the development of miniaturize data storage tags and appropriate tagging methodologies. This was done through laboratory experiments at the Ocean Sciences Centre examining the effects of tags and tagging methodologies on smolts and their growth. There were several joint meetings to design, execute and review findings from the experiments. This all led to the joint tagging of 215 smolts in Spring 2011 and subsequent recovery effort between Memorial and DFO. A similar collaborative approach (design, execution and analysis) was used in the release of 81 kelt across three rivers system in Newfoundland during Spring 2012. The close integration of efforts of university and government will continue as the research progress.

Subcomponent 3: Regular planning and technical meetings were conducted to prepare for and oversee the Wave Glider mission. These included industry representatives (VEMCO and Liquid Robotics), as well as the OTN glider and data teams.

Subcomponent 4: An array design workshop and a fish tagging workshop were held to train collaborators and optimize the allocation of resources. The OTN annual and Atlantic Arena meetings provided mechanisms for integration with other researchers in the project. Dalhousie scientists also travelled to Cape Breton on multiple occasions to coordinate activities with salmon work there under the direction of B. Hatcher, and to share expertise.

Scientific and/or Engineering Significance of Results

Subcomponent 1: The research of Mr. Halfyard is helping to elucidate the causes of marine mortality of Atlantic salmon. This is considered a critical variable that is presently contributing to sharp declines in Atlantic salmon populations, to the point that large numbers of them in Canada have been recommended by COSEWICs for listing as endangered under SARA. The work will assist in the design of recovery plans for some of these endangered populations.

Subcomponent 2

- Miniaturization of a data storage tag for use in tagging smolts. This, to the best of our knowledge, is the first attempt to design a tag and tagging methodology for use of a geo-location data storage tag on smolts.
- Development of an effective tagging methodology.
- Development of a tag shape suitable for external attachment to smolts.

- Field trials indicated that the smolts could handle the tags and that the tagging methodology was effective. However, an apparent corrosion (mechanical) issue with the tag attachment mechanism likely underlies the absence of tag returns of one-sea-winter salmon.
- Building on our earlier research about Atlantic salmon kelts (repeat breeders) at sea (Reddin et al. 2011 Fisheries Oceanography 20: 174-191), we are now investigating genomic signatures that may relate to marine migratory behaviour and survival to explore factors underlying successful return and interpopulation differences.

Subcomponent 3: The engineering work on the Wave Glider project has fostered a continuing collaboration between a Canadian company and an international industrial partner, and created a new product that both of these companies will be jointly marketing.

The proof of concept for the use of a Wave Glider as a mobile receiver platform provides an exciting advance in receiver technologies that could significantly expand the capabilities of the OTN to track animals into areas that for various reasons (e.g., extensive fishing pressure) are presently not suitable for the deployment of moored receivers.

Subcomponent 4: The establishment of the complete array was accomplished this year. Results of range testing demonstrate substantial improvements in tag detection over the 2010-11 results. The mechanisms by which high current velocities, water column stratification and local topography compromise tag-receiver performance are being elucidated and appropriate adjustments being made.

The first successful acoustic tagging and recapture of Atlantic salmon in the Bras d'Or lakes was accomplished in the Spring of 2012. A total of 19 salmon smolt were operated on for tag emplacement in May, five of which suffered tagging-induced mortality (26% of those tags attempted). A total of 14 smolt had VEMCO V-8 acoustic tags implanted, were released, and were not physically recovered. Nine of these tagged fish were subsequently detected in the river and one in the delta in Nyanza Bay up to 24th May 2012 using a VR-100 portable receiver, suggesting that another four died subsequent to tagging and release.

Of these 10 smolts, 5 were subsequently detected by at least one of the three VR-2W receivers located in the line across the mouth of Nyanza Bay up until the 30th of May 2012 (when the data were last downloaded), and another three fish that were not detected in the river or delta were also detected at the mouth of the Bay. All 8 of these fish were on the move (i.e. they were detected by more than one receiver).

Thus, of the 14 fish tagged and released successfully, 8 (57%) made it at least as far as the mouth of the Bay into which their natal river flows. A 'natural' mortality rate of 43% (i.e. 6 of 14 tagged fish) may reasonably be assumed to have occurred between the point of release and the mouth of the Bay. This is in addition to the immediate, tag-induced mortalities (5 fish) described above, for a total mortality of rate in our Middle River Smolt Tagging Program of 58% (i.e. 11 of 19 fish). If delayed, tag-induced morbidity lead to subsequent mortalities (e.g. due to reduced predator avoidance capability), then the true natural mortality rate may be less than the 43% estimated above.

These initial results are being built up to refine the smolt tagging program.

7. Difficulties encountered

Subcomponent 1: No problems.

Subcomponent 2: As mentioned above, the absence of returns of one-sea-winter salmon from the smolt tags may be in large part related to mechanical failure of the tag attachment mechanism. This conclusion is based on subsequent experiments in California with steelhead trout and Chinook salmon (unpubl.) that indicated an issue associated with corrosion of the tag attachment wire at the point where it was imbedded into the tag potting (i.e. mechanical issue associated with tag construction). We are addressing this issue with the manufacturer and hope to have a solution.

Subcomponent 3: An engineering delay caused a delayed launch of the Wave Glider mission, otherwise no problems.

Subcomponent 4: The positioning of acoustic receivers in some of the Bras d'Or array still needs refinement to maximize tag detection efficiency. This refinement will be based on hydroacoustic profiles and further range testing.

Research Associate Martin LeGuizamon left the project in June to undertake graduate studies at Dalhousie University for a year. He cannot be replaced, but will return to the project in September 2013.

Skilled personnel from Dalhousie trained undergraduate students and local collaborators in fish tagging, which facilitated the establishment of a small, local pool of fish taggers.

The weakness of the Middle River smolt run this year and problems with the operation of the smolt wheel limited the number of fish that were captured for tagging.

8. Networking and outreach

Intra-Network Collaboration and Partner Meetings

Subcomponent 1: Multiple planning and coordination meetings were held between the Dalhousie salmon team and the Cape Breton University salmon team. Dalhousie staff assisted with the capture and tagging of salmon in the Bras d'Or region, and OTN technicians and staff assisted with the planning and deployment of the receiver network that was placed into the Bras d'Or Lakes. We also assisted with the training of Eskasoni First Nation staff, who are partners in the Cape Breton project, in techniques for handling and marking salmon with acoustic tags, and will be conducting an additional training session for them on the aging of salmon.

Subcomponent 2: The network continues to play an instrumental role in the undertaking of this subcomponent, allowing us to tap into knowledge from several areas, including animal behaviour and ecology, oceanography (which is critical to the analysis of the geolocation data) and engineering (tag development). We have benefitted from our discussions with others in the salmon components of the Ocean Tracking Network (both in the East and West Coast Arenas) with regards to tagging techniques and experimental design (data collection) as well as the integration of genomics. It is anticipated that these discussions will continue and lead to an integrated understanding of salmon behaviour at sea. Moreover, they are fostering novel ideas and experiments to better understand salmon behaviour at sea. These outcomes are being realized as we move forward into the second phase of OTN (years 5-7), where several cross-Arena project ideas involving integrative salmonid research are being planned.

Subcomponent 3: The primary networking for this component was in meetings between industry representatives and university technical and sciece teams as the Wave Glider mission was planned.

Subcomponent 4

The project has benefited greatly from increased collaboration with co-investigators and collaborators from Dalhousie University, VEMCO Ltd. and the Unama'ki Institute of Natural Resources (UINR). Valuable guidance and assistance was provided by F. Whoriskey, G. Crossin, J. Lindley and Dale Webber in the re-design and expansion of the receiver array.

G. Crossin and student K Whoriskey provided essential training and leadership to all partners in fish tagging. S. Denny and several staff from the UINR operated the smolt wheel and assisted with tagging and tracking. Both investigators and students participated in, and benefitted from the OTN science meeting.

Interaction/Outreach to Broader Community

Subcomponent 1: Our expertise in salmon and telemetry has lead in the past year to collaboration with Norwegian researchers. Dr. Steve Cooke from the Pacific Arena, and Dr. Fred Whoriskey from the Atlantic Arena, are participating in a research project funded by the Research Council of Norway entitled "Survival behavior and welfare of Atlantic salmon after catch and release" (PI-Dr. Eva Thorstad, Norwegian Institute of Nature Research (NINA) and also involving other collaborators from NINA and the Norwegian Institute of Veterinary Science).

Subcomponent 2: There has been extensive networking among academia (Memorial), government (DFO) and industry (Lotek Wireless). This resulted in the development of a first-generation, geolocation data storage tag and tagging methodoly applicable for large Atlantic salmon smolts. It has fostered the production of an industry (Lotek) pamphlet entitled "Attaching Lotek geolocation archival (LAT2900) to salmon smolts," as well as two articles in industry related publications (*Oceans Advance* and *International Ocean Systems*). We have also been working with the local communities near Campbellton, Western Arm Brook and NE Trepassey Rivers with regards to the recovery of tags from the salmon either captured at counting fences or during fisheries.

Subcomponent 3: There was broad interest in the Wave Glider mission leading to extensive TV, radio and print media coverage. In addition, and interactive website was set up and people were able to log in and follow the movements and fish detections by the Wave Glider during the course of its mission.

Subcomponent 4: The project has attracted considerable interest in the broader community. Two newspaper articles and one radio interview have been done. The P.I. and R.A. presented a paper at the special OTN session of the Ocean Science Meetings in February 2012.

9. Dissemination of information and results

a) ***Refereed Journal Articles (4 total)***- *Accepted/published*

E.A., Halfyard, D.E. Ruzzante, M.J.W. Stokesbury, A.J.F. Gibson and F.G. Whoriskey. Estuarine Migratory Behaviour and Survival of Atlantic Salmon Smolts from the Southern Upland, Nova Scotia, Canada. J. Fish Biology (In press).

Thorstad E.B., Whoriskey F.G., Rikardsen A.H., Aarestrup K., 2011a. Aquatic nomads: the life and migrations of the Atlantic salmon. In: Aas, Ø., Einum, S., Klemetsen, A., Skurdal, J. (Eds.), Atlantic Salmon Ecology. Wiley-Blackwell, pp. 1-32.

Thorstad, E.B., Whoriskey, F., Uglem, I., Moore, A., Rikardsen, A.H., Finstad, B., 2012. A critical life stage of the Atlantic salmon *Salmo salar*: behaviour and survival during the smolt and initial post-smolt migration. Journal of Fish Biology 81:500-542.

Lefèvre, M. A. , Michael J. W. Stokesbury, Frederick G. Whoriskey and Michael J. Dadswell. In press. Atlantic Salmon Post-Smolt Migration Routes in the Gulf of St. Lawrence. ICES Journal of Marine Science. In press

b) ***Refereed Journal Articles (2 total)- Submitted***

E.A., Halfyard, D.E. Ruzzante, M.J.W. Stokesbury, A.J.F. Gibson and F.G. Whoriskey. Correlates of estuarine survival of Atlantic salmon post-smolts from the Southern Upland, Nova Scotia, Canada. Submitted. Can. J. Fish. Aquat. Sci.

Lefèvre, M. A. , Michael J. W. Stokesbury, Frederick G. Whoriskey and Michael J. Dadswell. Migration of Atlantic Salmon Smolts and Post-smolts in the Rivière Saint-Jean, QC North Shore: Timing of the Smolt Run, Diel and Tidal Influence on Swimming Rates, from Riverine to Marine Ecosystems. Environmental Biology of Fishes

c) ***Conference Presentations (0 total) – Invited***

d) ***Conference Presentations (7 total) – Contributed***

- Evans, M.L., I.A. Fleming, M. Robertson, D.G. Reddin and P. Downton. Linking behaviour and ecological genomics in Newfoundland Atlantic salmon. Ocean Tracking Network Annual Symposium, Halifax, Canada. (June 2012)
- Fleming, I.A., Reddin, D.G., P. Dowton, L.P. Hansen and A. Mahon. Behavioural ecology at sea of Atlantic salmon kelts from a Newfoundland (Canada) river. Salmon Summit – Salmon at sea: scientific advances and their implications for management. LaRochelle, France. (October 2011)
- Jacobsen, J. A., D.G. Reddin, L.P. Hansen, V. Bakkestuen, I. Russell, J. White, E.C.E. Potter, T.F. Sheehan, N. Ó Maoiléidigh, J.B. Dempson, G.W. Smith, A. Isaksson, M. Fowler, L. Karlsson, S. Oskarsson, K.A. Mork, P. Amiro and S. Pedersen. Analysis of historical tagging data from the salmon fisheries at West Greenland and the Faroe Islands. Salmon Summit – Salmon at sea: scientific advances and their implications for management. LaRochelle, France. (October 2011)
- Sheehan, T. F., D.G. Reddin, G. Chaput and M.D. Renkawitz. SALSEA North America: A pelagic ecosystem survey targeting Atlantic salmon in the Northwest Atlantic. Salmon Summit – Salmon at sea: scientific advances and their implications for management. LaRochelle, France. (October 2011)
- Renkawitz, M.D., T.F. Sheehan, D.G. Reddin and G. Chaput. Atlantic salmon foraging ecology in the Northwest Atlantic. Salmon Summit – Salmon at sea: scientific advances and their implications for management. LaRochelle, France. (October 2011)
- Hatcher, B. G., and M. E. Leguizamon Valex. Plugging the holes. Evaluations and designs for acoustic array integrity in a complex coastal Ecosystem. 2012 Ocean Sciences Meeting, Salt Lake City. (February 2012)

- Whoriskey, F. G. Sonic tracking of Atlantic salmon smolts to sea: correlates of survival and lessons on the migration pathway. Salmon Summit – Salmon at sea: scientific advances and their implications for management. LaRochelle, France. (October 2011)

10. Other contributions and deliverables

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

- CBC TV, Here & Now (St John's, NL), August 2012 (Fleming)
- CBC television interviews on the Wave Glider mission, August 2012 (http://www.cbc.ca/news/canada/nova-scotia/story/2012/08/22/ns-wave-glider-fish-robot.html
- http://www.cbc.ca/player/News/Canada/NS/ID/2271466061/ OTN spot beings at 14:20
- Global television interview on the Wave Glider mission, August 2012 (Global Maritimes: http://www.globalmaritimes.com/video/salmon+glider/video.html?v=2271643247&p=1&s=dd#video)
- Three CBC radio interviews on the status and operation of the wave glider mission (June,July and August 2012
- NY Times online coverage of Wave Glider mission July 10 2012. (http://green.blogs.nytimes.come/2012/07/10/a-new-way-to-track-fish)
- Article in the Chronicle Herald (Halifax NS) on the Wave Glider mission, August 2012 (http://thechronicleherald.ca/novascotia/129191-high-tech-tracker-hits-the-waves)
- Article posted on CBC website regarding the Wave Glider mission (http://ca.news.yahoo.com/solar-powered-fish-tracking-drone-recovered-off-n-212125613.html)
- 1 – CBC Radio interview on the Bras d'Or project

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

- A milestone in miniaturization. *International Ocean Systems* 16: 18-21. (Fleming)
- E. A. Halfyard, Oral Presentation: "Marine Mortality in Atlantic Salmon: Causes, Correlates and Mitigation Options"
  Acadia University, Biology Lecture Series – December, 2011 - Wolfville, NS, Canada
- E. A. Halfyard, Oral Presentation: "Salmon and Trout in Nova Scotian Estuaries: A Peek Into Complex Systems." King Country Wildlife Association - March 2012 - Kentville, NS, Canada
- E. A. Halfyard, Oral Presentation: "Impacts of Predators on Atlantic Salmon Smolt in the Southern Upland" St. Mary's River Association - May 2012 - Sherbrooke, NS, Canada
- F. G. Whoriskey. Le deployment d'un réseau de télérepérage des mammiferès et poisons marins du Golfe du Saint-Laurent. Fédération Québecoise pour le saumon atlantique. April 2012.

- F. G. Whoriskey. Oceean Tracking Network (OTN) overview. Ocean Scences Meeting, Salt Lake City. Feburary, 2012**.**
- F. G. Whoriskey. Sonic telemetry, the Ocean Tracking Network, and Atlantic salmon. Westmount school, Halifax. February, 2012
- F. G. Whoriskey. Sonic tracking of Atlantic salmon smolts at sea. LaHave Salmon Association, March 2012.

*c) Invited or contributed presentation/contribution at a workshop***.**

- F. G. Whoriskey. Insights into Atlantic salmon from telemetry. International Oceans Institute, Dalhousie University. June 2012.
- B. Hatcher, CEPI Steering Committee meeting

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

- B. Hatcher, Cape Breton Naturalists Society

*e) Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, Glider runs, and/or data deposition to an agency/database (e.g., MEDS, GenBank, OBIS, etc.), as well as a contribution to a larger piece of work in any of the former***.**

- Windsor, M.L., P. Hutchinson, L.P. Hansen and D.G. Reddin. 2012. Atlantic salmon at sea: Findings from recent research and their implications for management. NASCO document CNL(12)60. Edinburgh, UK. 20pp.
- Metadata and data submitted to the OTN data warehouse on tagging of Atlantic salmon in the Margaree River.
- Metatdata and data submitted to the OTN data warehouse on tagging of Atlantic salmon in the Riviere St. Jean (Quebec North Shore)
- 1 – 24 CTD cast records, 3 ADCP records – Bras d'Or Institute

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

- Expert Panel on Ocean Climate Change and Marine Biodiversity, Royal Society of Canada (Fleming).
- IUCN Salmonid Specialist Group (Fleming).

- House of Commons Standing Committee on Fisheries and Oceans, Canada (Fleming).

g) Books

Whoriskey, F. G. 2012. Ontogeny of a sonic telemetry program for Atlantic salmon *Salmo salar*. pp. 413-424 in Adams, N. S., J. W. Beeman and J. H. Eiler (eds). Telemetry techniques: A users guide for Fisheries Research. American Fisheries Society, Bethesda, Maryland

h) Reference or training tools/materials

- Lotek Wireless leaflet 2011 – " Attaching Lotek geolocation archival (LAT2900) tags to salmon smolts. (Fleming)

i) Internet publishing, portal, blog, electronic publications

- Oceans Advance – Lotek achieves breakthrough with miniature "message in a bottle" (Fleming)

j) Anything else that isn't a primary publication that has you communicating (specify) with others (specify).

- Hatcher: Guest lecture in Marine Biology class. Articles in Cape Breton Post and Inverness

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

- Salmon research undertaken through OTN has helped to leverage another research initiative related to quantifying the migratory behaviour wild and escaped farm Atlantic cod (acoustic tracking). This research is part of MUN MSc student, Emily Zimmermann's thesis and is about to be submitted for publication. The data has become part of the OTN data repository.
- Hatcher: CBU Application for an NSERC Engage Grant (pending)

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

- A spin-off opportunity that has arisen is the development of a small scale collaboration among MUN, the local DFO office in St. Anthony and the Save Our Char Society of St. Anthony to explore the migratory behaviour of a local, threaten char population (one of the southern most anadromous char populations in the Northwest Atlantic).
- Dalhousie worked with VEMCO and Liquid Robotics to develop a Wave Glider that had new onboard acoustic receiver capabilities to permit the mobile tracking of fish
- CBU conducted measurements of hydrodynamic regimes in Bras d'Or Channels that contributed to tidal energy research initiatives.

m) 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.

- Development of miniaturize geolocation data storage tag and tagging methodology suitable for large Atlantic salmon smolts.
- A beta trial and proof of concept mission of the new Wave Glider was run in the Gulf of St. Lawrence in 2012.

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

- Field test the deployment of the miniaturize geolocation data storage tag with mixed success.
- The work is assisting on establishing the migraton routes, timing and survival of a variety of Atlantic salmon populations under present environmental conditions. These will provide a basis for evaluating future changes in migration and survival for a species that is believed will be greatly influenced by climate change.

11. Collaborations with Industrial and Government Partners

Fisheries and Oceans Canada, Salmonid Section, Newfoundland and Labrador Region – provided tagging expertise, 7 acoustic VR13 tags, collaborated in project design, execution and analyses, and provided field support at the Campellton River, NE Trepassey River and Western Arm Brook salmon counting fences.

Lotek Wireless, St. John's Office – provided the engineering expertise for tag development and worked closely with the researchers on tag shape and tagging methodologies.

VEMCO: Consults on design of design of acoustic arrays, performance of equipment in field conditions, and analysis of problematic detection files. Invests in R and D to assist with the creation of new products that meet network needs. This includes the present work with the Wave Glider, and in the development of new generation of tags and receivers.

Liquid Robotics: Invested in R and D to assist in the creation of a new mobile receiver platform.

VEMCO Ltd. designs and manufactures acoustic tags and receivers. Technical staff participated in array design and range testing for the Bras d'Or array.

Fisheries and Oceans Canada (DFO) is responsible for monitoring Atlantic salmon abundance and habitat in the Bras d'Or watershed. Local Area Office participated in licensing and training of work here.

Offshore Energy and Environment Research agency (OEER) supports research into the environmental effects of marine energy development. OEER supported oceanographic measurements in major channels of the Bras d'Or array.

Unama'ki Institute of Natural Resources (UINR) supports salmon conservation in First Nations communities of the Bras d'Or watershed. Scientific staff participated in smolt tagging and release.

Bras d'Or Lake Biosphere Reserve Association (BLBRA) is responsible for the management of the UNESCO Biosphere Reserve. BLBRA participated in dissemination of results.

Collaborative Environmental Planning Initiative (CEPI) integrates all empowered agencies in provising management advice for the Bras d'Or. CEPI participated in dissemination of results.

Cash and in-kind contributions from partners for year 3.

Subcomponent 2

Name of supporting organization:	**Fisheries & Oceans Canada**	**Memorial University (Fleming laboratory)**
Cash contributions to direct costs of research		
In-kind contributions to direct costs of research		
7) Salaries for scientific and technical staff	15,000*	
8) Donation of equipment, software	3,100**	3,600#
9) Donation of material		
10) Field work logistics	1,000	
11) Provision of services		
12) Other (specify): _____		
In-kind contributions to indirect costs of research		
4) Use of organization's facilities	4,000***	
5) Salaries of managerial and administrative staff		
6) Other (specify): _____		
Total of all in-kind contributions	23,100	3,600
Is this new funding (acquired during this reporting period)?	Yes	

***** Estimated salaries of DFO personnel for their involvement in the project Martha Robertson, Lloyd Fudge and Curtis Pennel, as well as that of the personnel operating the local counting fences at NE Trepassey, Campbellton and Western Arm Brook.

****** Donation of tagging materials, including needles, sutures, anaesthetic, etc., as well as 7 VR13 acoustic tags.

******* Using of trapping facilities at NE Trepassey, Campbellton and Western Arm Brook.

[#] 12 VR9 acoustic tags

Subcomponents 1 and 3

Name of supporting organization:	Atlantic Salmon Federation	VEMCO	Liquid Robotics	ClubHill Camp Inc
Cash contributions to direct costs of research				
In-kind contributions to direct costs of research				
1) Salaries for scientific and technical staff				2,000
2) Donation of equipment, software	115,000[1]		15,000[3]	
3) Donation of material				
4) Field work logistics				13,000
5) Provision of services		25,000[2]		
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	115,000	25,000	15,000	15,000[4]
Is this new funding (acquired during this reporting period)?	Yes			

[1]Tags for Atlantic salmon, and support of Strait of Belle Isle receiver array in collaboration with OTN
[2]Estimated R and D to the Wave Glider project; we await confirmation of the figures from the VEMCO
[3]Estimated R and D to the Wave Glider project; we await confirmation of the figures from Liquid Robotics
[4]Support of field team to tag Atlantic salmon for tracking with Wave Glider

Subcomponent 4

Name of supporting organization:	Offshore Energy and Environment Research	Unama'ki Institute of Natural Resources (UINR)	VEMCO
Cash contributions to direct costs of research	8,342		
In-kind contributions to direct costs of research			
1) Salaries for scientific and technical staff		6,500	1, 050
2) Donation of equipment, software			
3) Donation of material		4,800	
4) Field work logistics		1,580	646
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	8,342	21,880	1,696
Is this new funding (acquired during this reporting period)?	Yes		

12. Expenditures and Support

Year 3 (2012)

Subcomponent 2

Budget Item	Year 3 (2012)				
	Proposed*	**Actual Expenditures** 1 Jan - 30 Sep 2012	**Total Balance** 30 Sep 2012	**Projected Balance** 31 Dec 2012	**Deviation**
1) Salaries and Benefits					
a) Students	$0	$0	$0	$0	
b) Postdoctoral Fellows	$42 000	$18 577	$23 423	$10 846	26%
c) Technical/Professional	$20 000	$18 028	$1 972	-$1 484	-7%
d) Other	$0	$0	$0	$0	
2) Equipment or Facility					
a) Purchase or Rental	$500	$500	$0	$0	0%
b) Operations/Maintenance	$1 000	$1 000	$0	$0	0%
c) User Fees	$0	$0	$0	$0	
3) Material and Supplies					
a) Materials and Supplies	$2 000	$3 066	-$1 066	-$2 066	-103%
4) Travel					
a) Conferences	$2 000	$1 031	$969	$969	48%
b) Field Work	$1 883	$2 326	-$443	-$433	-23%
c) Collaboration/Consultation	$500	$0	$500	$500	100%
5) Dissemination					
a) Publications	$1 000	$0	$1 000	$1 000	100%
b) Other	$0	$0	$0	$0	
6) Other (specify)					
a) reward for tag returns	$0	$175	-$175	-$275	
b) Other	$0	$0	$0	$0	
Totals					
Totals	$70 883	$44 703	$26 180	$9 057	

*These number are based on the approved "revised year 3 (2012)" budget submitted last year.

As approved by the Reprofiling Committee and NSERC in 2011, there was a reallocation of funds from a PhD student (3.5 yrs) to a postdoctoral fellow (2 yrs) that will continue through year 4 (2013). In year 3 (2012), the salary expenditure on the postdoctoral fellow was lower than anticipated because she was unable to begin in the position until mid-April 2012.

The following table for subcomponent 2 indicates a total carry over from years 1-3. This carry over is directed towards three items: (1) salary for the postdoctoral fellow as approved by the Reprofiling Committee and NSERC; (2) materials and supplies as required for the genomics research, which by its very nature is expensive and can only occur late in the project once fish have been recaptured; and (3) conference travel, which was redirected from field work travel that was less than anticipated. With regards to the conference travel, it will be used to fund the attendance of either PI and postdoctoral fellow at the Second International Conference on Fish Telemetry in Grahamstown, South Africa. This

will represent a significant and appropriate opportunity to present key findings from the research, for knowledge transfer/gain, professional exposure (pdf) and development of collaborations. There is really no other conference at this time that will provide a more appropriate venue for the research, the exchange of telemetry knowledge and furthering of international collaboration for this project.

Actual expenses for year 2 during October-December were on target with the forecast and any deviation was < 20%.

The travel budget in year 3 was used to provide partial support ($1030.85) for the PI's (Fleming) attendance at the Salmon Summit – Salmon at sea: scientific advances and their implications for management in LaRochelle, France, during October 2011. The request for travel support during year 4, as explained above, is primarily for attendance of the PI (Fleming) and postdoctoral fellow (Evans) at the Second International Conference on Fish Telemetry in Grahamstown, South Africa. This represents an excellent venue to present our results to the international community, to exchange ideas and potentially develop new collaborations. Also, the timing is excellent as it occurs at the culmination of phase I of OTN and just prior to the initiation of phase II.

Subcomponents 1 and 3

Budget Item	Year 3 (2012)				
	Proposed	**Actual Expenditures** 1 Jan - 30 Sep 2012	**Total Balance** 30 Sep 2012	**Projected Balance** 31 Dec 2012	**Deviation**
1) Salaries and Benefits					
a) Students	$21 000	$17 300	$3 700	$0	0%
b) Postdoctoral Fellows	$0	$0	$0	$0	
c) Technical/Professional	$0	$0	$0	$0	
d) Other	$0	$0	$0	$0	
2) Equipment or Facility					
a) Purchase or Rental	$0	$0	$0	$0	
b) Operations/Maintenance	$23 000	$29 220	-$6 220	$0	27%
c) User Fees	$0	$0	$0	$0	
3) Material and Supplies					
a) Materials and Supplies	$9 865	$1 121	$8 744	$1 000	10%
4) Travel					
a) Conferences	$2 000	$0	$2 000	$0	0%
b) Field Work	$3 750	$2 909	$841	$0	0%
c) Collaboration/Consultation	$1 000	$0	$1 000	$0	0%
5) Dissemination					
a) Publications	$500	$0	$500	$0	0%
b) Other	$0	$0	$0	$0	
6) Other (specify)					
a) Other	$0	$0	$0	$0	
b) Other	$0	$0	$0	$0	
Totals					
Totals	$61 115	$50 549	$10 566	$1 000	

Most budget categories for this component of the project are being expended as planned. Salary support for graduate student E. Halfyard is as budgeted. Operations and maintenance costs were budgeted at $ 23,000 and were principally for approved replacement VR2W receivers. Due to price increases since the original budgeting, the cost for the approved numbers of receivers has increased and the cost of this budget item as of September is $ 29, 200 (Deficit of $6,220; 27% above original budget). The deficit for this cost has been applied to the Materials and Supplies budget (originally budgeted at $9, 865). The Materials and Supplies category after applying this additional charge are projected to finish the year with a small surplus ($1000, approximately 10% of budget). Unforeseen circumstances could reduce this. Remaining travel funds for field work and consultation are expected to be expended by the completion of the calendar year. The unexpended conference budget is being held for E. Halfyard to attend a scientific conference. Plans for this have not yet been finalized. Modest dissemination costs ($500) have also not yet been spent. E Halfyard is now submitting papers to peer-reviewed journals, and we expect that some of them will have associated charges.

Remaining budgeted conference travel and dissemination funds will be used to support the completion of E. Halfyard's thesis program. Surplus funds will roll back to the grant.

Actual expenses for year 2 during October-December were on target with the forecast and any deviation was < 20%.

Conference funds are reserved for PhD candidate E. Halfyard, whose salary is supported 100% by the network. He will attend the Canadian Conference on Freshwater Fisheries Resarch in January 2013. At any conference he attends, he will present the results from his OTN research. This will help publicize the OTN scientific activity, which is the value-add for the network.

Subcomponent 4

Budget Item	Year 3 (2012)			
	Proposed	**Actual Expenditures** 1 Jan - 31 Dec 2012	**Total Balance** 31 Dec 2012	**Deviation**
1) Salaries and Benefits				
a) Students	$7 200	$8 653	-$1 453	-20%
b) Postdoctoral Fellows	$0	$0	$0	
c) Technical/Professional	$5 000	$1 072	$3 928	79%
d) Other	$0	$0	$0	
2) Equipment or Facility				
a) Purchase or Rental	$1 500	$2 722	-$1 222	-81%
b) Operations/Maintenance	$5 000	$5 131	-$131	-3%
c) User Fees	$0	$0	$0	
3) Material and Supplies				
a) Materials and Supplies	$2 000	$3 555	-$1 555	-78%
4) Travel				
a) Conferences	$2 100	$2 459	-$359	-17%
b) Field Work	$4 400	$4 865	-$465	-11%
c) Collaboration/Consultation	$2 000	$948	$1 052	53%
5) Dissemination				
a) Publications	$500	$368	$132	26%
b) Other	$0	$0	$0	
6) Other (specify)				
a) Other	$0	$0	$0	
b) Other	$0	$0	$0	
Totals				
Totals	$29 700	$29 773	-$73	

Significant deviations to Year 3 expenses:

1) Extra students were employed to work the Smolt Wheel, increasing the student portion. A portion of the Technical assistant fees was paid in 2011, so less was paid in 2012.
2) Extra mooring, diving, and computer equipment and boat rental was required to install and manage the expanded (30%) receiver array resulting from the re-design in February of 2012.
3) Installation of the expanded receiver array and extensive range testing required materials for 10 extra moorings and more consumable materials for boat work and diving.
4) Travel to the Ocean Science Meeting cost more than budgeted, but this was offset by reduced collaboration costs because this happened at the one week meeting.
5) The only dissemination costs were posters prepared for conferences.

The remainder of the Year 3 budget will be spent on consumables, salaries, operational expenses and travel.

Year 2 (2011) actual expenses for October-December were approximately on target with that forecast in last year's report.

Hatcher & LeGuizanmon Velez present paper at special OTN session of Ocean Science Meeting in Salt Lake City, February 2012. Hatcher, LeGuizamon, Xu participate in OTN annual meeting in Halifax, June 2012.

Year 4 (2013)

Subcomponents 1, 3, and 4

As requested by the SAC, the funds for Subcomponents 1, 3, and 4 will be held at Dalhousie University and reported together.

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$7 200	$7 200		0%
b) Postdoctoral Fellows	$0	$0		
c) Technical/Professional	$0	$6 400		
d) Other	$6 400	$0		100%
2) Equipment or Facility				
a) Purchase or Rental	$750	$700		7%
b) Operations/Maintenance	$8 600	$8 600		0%
c) User Fees	$0	$0		
3) Material and Supplies				
a) Materials and Supplies	$11 500	$11 500		0%
4) Travel				
a) Conferences	$5 100	$2 500		51%
b) Field Work	$7 000	$7 000		0%
c) Collaboration/Consultation	$2 667	$5 267		-97%
5) Dissemination				
a) Publications	$1 000	$1 000		0%
b) Other	$0	$0		
6) Other (specify)				
a) Other	$0	$0		
b) Other	$0	$0		
Totals	0			
Totals	$50 217	$50 167		

Subcomponents 1 and 3 are mostly complete. The remaining funds will be directed to wrapping up these projects and supporting the work of Subcomponent 4. These costs include:

1) Salaries and benefits

c) technical assistants/summer students to support Subcomponent 4 (moved from 1d) ($6400), possibly including experienced technical assistance from a part time research associate with acoustic oceanography for tag range testing in narrow channels. Experienced resident anglers and holders of local ecological knowledge to locate fish, capture and tag them. The amount

assumes tagging at 4 sites in year 4 of the project, with 2 persons spending 5d/site. The fee rate is $80/d cash with no benefits.

2) Equipment or Facility

equipment and materials to support Subcomponent 4 ($3300)

3) Material and Supplies

a) surgical supplies to support Subcomponent 4 ($9300)

4) Travel

a) Conferences

HQP E. Halfyard to attend the ICES Annual conference in Iceland in Sept 2013 ($2500)

c) Collaboration/consultation

increased travel budget for new co-PI Crossin and assistants to travel between Halifax and Bras d'Or ($4267)

5) Dissemination costs

a) Publication costs ($500)

For **Subcomponent 4**:

1) Salaries and benefits

a) One senior undergraduate (B.Sc.) student will work in each year of the project.

The amount is the standard UG student stipend, which includes full-time work during the summer and part-time during the academic year. 12% benefits is included.

2) Equipment or Facility

a) Exposure - floatation suits for students @$500/ y

b) Supplies and service materials for tag and receiver deployment, battery change, defouling & recovery @ 10 sites. Batteries for receivers $80 each per annum. Field equipment and mooring maintenance & repair @ $1000/ y ($5500).

3) Material and Supplies

a) Angling supplies for fish capture and surgical supplies to place tags in fish ($2000 / y in Years 1, 2, 3 & 4).

4) Travel

b) Receiver deployment, data download and service (3500km @ $0.40/km plus 20d per diem @ $40 = $2200/y). Fish Tagging (3500km @ $0.40/km plus 20d per diem @ $40 = $2200/y).

c) Travel to Halifax for Hatcher to meet with Crossin (1000km @ $0.40/km plus hotel plus per diem * 3 = $1800).

Consultations with local communities around the Bras d'Or periodically during the project. Travel to and catering of 4 meetings in different locations each time @ $500/meeting ($2000).

5) Dissemination costs

a) Graphics preparations ($500).

Subcomponent 2

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over*	Deviation
1) Salaries and Benefits				
a) Students	$21 000	$0	$7 000	100%
b) Postdoctoral Fellows	$0	$45 000	$10 846	
c) Technical/Professional	$20 000	$17 000	$3 175	15%
d) Other	$0	$0	$0	
2) Equipment or Facility				
a) Purchase or Rental	$250	$250	$33	0%
b) Operations/Maintenance	$2 000	$1 000	$3 500	50%
c) User Fees	$0	$0	$0	
3) Material and Supplies				
a) Materials and Supplies	$3 500	$15 458	$2 978	-342%
4) Travel				
a) Conferences	$0	$7 000	$1 279	
b) Field Work	$4 750	$4 750	$6 164	0%
c) Collaboration/Consultation	$1 333	$1 333	$2 833	0%
5) Dissemination				
a) Publications	$1 000	$1 000	$1 500	0%
b) Other	$0	$0	$0	
6) Other (specify)				
a) reward for tag returns	$0	$0	-$350	
b) Other	$0	$0	$0	
Totals				
Totals	$53 833	$92 791	$38 958	

*total carry over from start (Years 1-3)

The budget for year 4 is similar to that originally proposed, with differences reflecting carry over of funds from years 1-3. As stated previously, the Year 4 budget table for subcomponent 2 indicates that the total carry over from years 1-3 will be directed towards three items: (1) salary for the postdoctoral fellow as approved by the Reprofiling Committee and NSERC; (2) materials and supplies as required for the genomics research (ca. 75%), which by its very nature is expensive and can only occur late in the project once fish have been recaptured; and (3) conference travel, which was redirected from field work travel that was less than anticipated. With regards to the conference travel, it will be used to partially fund (80%) the attendance of the PI and postdoctoral fellow at the Second International Conference on Fish Telemetry in Grahamstown, South Africa (14-20 July 2013). This will represent a significant and appropriate opportunity to present key findings from the research, for knowledge transfer/gain, professional exposure (pdf) and development of collaborations. There is really no other conference at this time that will provide a more appropriate venue for the research, the exchange of telemetry knowledge and furthering of international collaboration for this project. Finally, the timing is excellent as it occurs at the culmination of phase I of OTN and just prior to the initiation of phase II.

Genomics costs (comparing 8 survivors to 8 non-survivors per population for 2 populations):

a) RNA extraction
    - Trizol - $500
    - Chloroform $300
    - RNA cleanup kits $1500
    - DNAse 1 $200
b) Microarrays: $375 per individual on an array (includes RNA amp kits, labeling reactions, microarray chips) = $12,000
c) qPCR anticipated: $5,000

Conference travel:

a) Flight (St. John's to Port Elizabeth, South Africa): ca. $2,800 x 2 = $5,600
b) Accommodation (7 nights @ ca. $140): ca. $980 x 2 = $1,960
c) Per diem (8 days @ $55): $440 x 2 = $880
d) Local travel (e.g. taxi): $150 x 2 = $300

Deviation from the original and revised year 4 budget are related principally to the carry over of funds from years 1-3 and is explained in the preceding section. The justification is also contained therein. Approval for reallocation of funds for the postdoctoral salary has been approved previously by the Reprofiling Committee and NSERC. Redistribution of funds from carryover has gone principally to material and supplies to allow the coupling of behaviour and survival with genomic signatures to explore factors underlying successful return and interpopulation differences. Funding for this novel aspect will be supplemented from other sources as well. Finally, carryover from earlier conference travel plus redistribution of travel for field work will be used to partially fund (80%) the travel of the PI and the postdoctoral to attend the Second International Conference on Fish Telemetry in Grahamstown, South Africa (14-20 July 2013). To date, only $1,031 has been spent on conference travel to present project results (>50% of that travel to attend the Salmon Summit – Salmon at sea: scientific advances and their implications for management in LaRochelle, France, during October 2011 came from other sources).

The total, 4-year cost of the project remains unchanged.

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

I. Atlantic Arena

1. Project Number: I.2.2

2. Project Title: Estuarine and Oceanic migration of the juvenile and reproductive stages of the American eel (*Anguilla rostrata*)

3. Project Leaders: J. Dodson (Laval), M. Castonguay (DFO)

Collaborators: D. Hatin, M. Dionne, P. Dumont, M. Legault, G. Verreault, Y. Mailhot, J. Dussureault (Ministry of Natural Resources and Wildlife–MNRF); J.-F. Bourque, V. Tremblay (AECOM); K.R. Thompson, J. Sheng, S. Shan, K. Ohashi, R. Apostle, D. Vanderzwaag (Dalhousie); D. Cairns, S. Campana (Fisheries and Oceans Canada –DFO); M. Stokesbury (Acadia University); P. Sirois (University of Quebec at Chicoutimi)

4. Public Summary of Report

The migration of the American eel from its feeding areas in continental waters to the spawning grounds in the Sargasso Sea remains one of the great mysteries in animal biology. This project aims to elucidate how mature American eels migrate through the St. Lawrence River, across the Gulf of St. Lawrence and across the vast expanses of the North Atlantic Ocean to attain their spawning grounds in early spring. Using a combination of acoustic pingers and moored hydrophones, we have demonstrated considerable variation in migratory behavior within the St. Lawrence River. Downstream migration occurs at night during the ebbing tide and picks up speed later in the year. Eels exhibit stop and go behavior, with some eels suspending movement for weeks in different parts of the river before resuming their migration. The moored array of hydrophones at Cabot Strait recorded outmigrating eels in December, but also indicated a very low survival of eels migrating from the Gulf of St. Lawrence. One possible cause of this is predation. The tracking of large silver eels in the Gulf of St. Lawrence using satellite tags that record depth and temperature before being released from tagged eels on a pre-determined date revealed an unexpectedly high predation rate from porbeagle sharks. This raises the possibility that that eels may represent a reliable, predictable food resource for porbeagle sharks.

The development of coupled physical-biological models of the eel migration is another way of exploring the variety of behaviours that could be adopted by eels under specific conditions of oceanic circulation and temperature. These models provide researchers with plausible migration scenarios that may then be tested using direct observations of migratory behavior. To obtain this detailed tracking data from the North Atlantic Ocean, while at the same time attempting to avoid the high levels of predation with the Gulf of St. Lawrence, our research team will pursue the satellite tagging of eels from release sites in Nova Scotia. The team aims to successfully record the oceanic movements of eels to the Sargasso Sea and, in combination with physical-biological models, describe the mechanisms employed by eels to complete their spectacular migrations.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Mélanie Béguer	PDF	100	100	1 Oct 2011 – 30 Sep 2012
José Benchetrit	M.Sc.	100	100	1 Oct 2011 – 30 Sep 2012
Thesis topic: Chronologies of yellow eel in-river migrations using acoustic telemetry and multi-elemental analysis of otoliths				

The role of Mélanie Béguer (PDF) is to facilitate and maintain communication among all project collaborators, to lead in the data analysis as well as contribute to the supervision of the M.Sc. student. She is also involved in the field work by participating in eel tagging, deployment, checking and retrieving acoustic receivers, and X-tag experiments and deployment.

José Benchetrit is a M.Sc. student. The aim of his project is to retrace the environmental history and movement patterns of yellow eels at the scale of the St. Lawrence River, using both telemetry data and otolith microchemistry analyses. As a result, he is involved in both eel tagging and in the management of acoustic receiver arrays. Moreover, he is being trained to use techniques involved in the analysis of trace element concentrations in otoliths using Laser Ablation Inductively-Coupled Plasma Mass Spectrometry (LA ICP-MS). This work is supervised by Professor Pascal Sirois, professor at the University of Quebec at Chicoutimi.

6. Progress towards Objectives/Milestones (1 Oct 2011 – 30 Sep 2012)

The aim of the project is to establish the migration routes of the American eel, *Anguilla rostrata*, in the St. Lawrence system and beyond to the Cabot Strait and the Atlantic Ocean and to identify the abiotic and biotic conditions that prevail along these pathways. Two stages of the species lifecycle are being investigated: yellow-stage eels (juveniles) and silver-stage eels (reproductive adults). To study both life-history stages, we conduct a system-wide effort to capture and acoustically tag a total of 300 eels from the Saint Lawrence River with V9 and V13 pingers (depending on fish size). We first hypothesize that yellow eels exhibit periodic migrations to feed in the estuary. This hypothesis is tested by exploiting fixed arrays of acoustic receivers deployed along the St. Lawrence River and Estuary to track movements of tagged fish. To complement these telemetry efforts, environmental history and potential alternative patterns of habitat-use of yellow eels will be studied through the analysis of otolith microchemistry. Otoliths will be used to determine the age of individuals and the use of microchemistry techniques will enable us to establish chronologies of habitats used by the eel during its continental growth stage.

Migration routes of the silver eel stage en route towards the presumed spawning site in the Sargasso Sea will also be determined using V13 pingers. As nothing is known of the migration of silver eels, no hypotheses may be formulated. Furthermore, several silver eels are fitted with archival tags (X-tags, Microwave Telemetry) to track, for the first time, their diel horizontal and vertical migrations to the spawning site in the Sargasso Sea. Data on the eel's oceanic migration obtained from those archival tags and results from a reconstruction of the physical state of the Northwest Atlantic Ocean developed by OTN colleagues will be used to interpret the silver-eel movements from the St-Lawrence to the spawning site. Physical data and models will also provide projections of the possible impact of climate change on eel migration.

Acoustic tracking: In November 2011, all acoustic receivers (103) that were deployed along 12 arrays from Montréal to Ouelle River in April/May 2011 were retrieved. Data were downloaded and a total of 52 656 detections corresponding to tagged eels were recorded by the St. Lawrence arrays. In October 2011, 36 silver eels were tagged at Rivière-du-Loup by our partner from MRNF Rivière-du-Loup with tags bought by OPG –Ontario Power Generation-. With the previously tagged eels (during summer 2010 and summer 2011), a total of 180 silver eels were tagged during the two years of the projet. In 2011, 98.5% of the silver eels tagged upstream of Rivière-du-Loup were detected by our acoustic arrays. A total of 67 yellow eels were tagged during this project: 25 in 2010 and 42 in 2011. 43 tagged yellow eels were detected by the fluvial and estuarine arrays. This represented a great amount of data that were analyzed from winter 2011 though to fall 2012.

In April 2012, Martin Castonguay and Guy Verreault participated in downloading the VR2W from Cabot Strait array. The detections corresponding to tagged eels were retrieved and analysed during summer 2012. For the first time, we detected the out-migration of silver eels through the Cabot Strait (see below).

A publication about the acoustic tracking of silver eels is currently in preparation. Another one about the acoustic tracking and ototith analysis of yellow eels will be prepared during the fall 2012.

Satellite tracking: In early October 2011, 8 large silver eels were equipped with archival pop-up tags (X-tags from Microwave Telemetry). Those eels were released in the St. Lawrence estuary at Mont-Joli. Tags were programmed to be automatically released for pop-up on 15 March 2012 but they all popped-up prematurely (before December 2011) as a consequence of an unexpectedly high predation rate. Archival data were retrieved via Argos and sent to Microwave telemetry for interpretation. Data were then analysed during the first semester of 2012. The statistical comparison of the vertical migration profiles of the eel-predators with two potential predators allowed us to identify the porbeagle shark as most likely being responsible for the predation. These unexpected and interesting results are the subject of a paper that was accepted for publication in September 2012 in PLoSOne. In this paper, we discuss evidence suggesting that predation of silver-stage American eels by porbeagle sharks may represent a significant source of mortality inside the Gulf of St. Lawrence despite the fact that the tagging itself may contribute to increasing the eel's susceptibility to predation. It raises the possibility that eels may represent a reliable, predictable food resource for porbeagle sharks.

As was planned last year, more eels will be equipped with X-tags this fall. But given the previous surprising results, it was decided to tag and release eels outside the Gulf of St.Lawrence in order to avoid predation in this area and to follow the migration as far as possible in the open Ocean. The deployment of 15 X-tags is planned for October (2012) and data will be analysed in 2012 (tags will be programmed to pop-up in March 2013). The tagged eels will be from Nova Scotia, the difficulty here being to find eels large enough for tagging. We have identified two sources for large eels, one at Cheticamp and the second in SW Nova Scotia.

Modeling collaboration: In January 2012, Dr Mélanie Béguer visited the research OTN team of Theme I.1 (Kyoko Ohashi, Jinyu Sheng, Shiliang Shan and Keith R. Thompson from the Department of Oceanography) at Dalhousie University to start the collaboration about modeling of eel movements. The physical models were introduced to Mélanie and she presented the current state of knowledge about silver eel migration patterns and our expectations from the modeling excercise. Two projects for papers and thus two different physical-biological models were targeted for completion in 2012. The first model is a particle tracking model that will simulate the eel migration from Québec to Cabot Strait, i.e. the migration in the Gulf of St. Lawrence. It is based on Dalcoast, the oceanographic model developed by Kyoko Ohashi. The objective of this first physical-biological model is to better understand the ways

migrating eels succeed in escaping the Gulf of St. Lawrence during their spawning migration. The coupled physical-biological model is based on the first observations from the field (X-tags results) in order to evaluate the range of behaviors that allow adults to reach the Cabot Strait.

The second physical-biological model will simulate the migration from the Atlantic coasts (4 different locations, including Cabot Strait and Nova Scotia) to the spawning grounds in the Sargasso Sea. The main objective of this model is to explore different behavioural strategies and associated environmental cues that allow the American eel to reach the Sargasso Sea in time for reproduction. The success of the different strategies will be evaluated by calculating the probability of arriving at the spawning area within a prescribed time window with sufficient energy stores to permit reproduction. The physical model used will be NEMO, a particle advection scheme and associated probability density functions developed by Shiliang Shan and Keith Thompson. It is based on their previous work.

For both modeling projects, the parameters values and the scenarios to be tested have been discussed several times, during intra-team (J.Dodson, M.Castonguay and M. Béguer) and inter-team meetings in Halifax (January 2012, June and July 2012). A detailed plan for each paper was established this summer. We conducted a literature review this spring and summer, in order to set some parameter values for the simulations. We developed the energy expenditure part of the model based on a literature review. It will be included in the physical-biological model by Shilian Shan and Keith Thompson. The particle tracking is currently being developed and tested by the oceanographers. The first simulations should be run this fall and will provide the first results. The collaboration will continue during 2013, to finalize these two projects and eventually to develop other projects based on the results of our field tracking (X-tags October 2012- March 2013).

Otolith analysis: A total of 129 eels were sampled from various locations in the Saint Lawrence River and Lake Champlain between the fall of 2010 and the fall of 2011. The otoliths of 114 eels were sectioned at the Quebec City laboratory of the Quebec Ministry of Wildlife and Natural Resources over 3 weeks in January 2012. Once sectioned, they were analyzed at LabMater, the geochemical laboratory at the University of Quebec at Chicoutimi. There, a LA ICP-MS was used to run transects across the surface of each of these otoliths over the course of 3 days in February 2012. The concentrations of 30 minor and trace elements were obtained across each transect for the 114 otoliths sampled. Analyses of elemental profiles are underway in an attempt to retrace environmental histories and possible movements undertaken during the residence of eels in the system.

Significant Deviations

Since the detection rate of silver eels at Cabot Strait was very low (possibly due to high mortality), it was decided to suspend the original acoustic tagging planned with 50 acoustic tags (V13) at Rivière-du-Loup in October 2012. Rather, 5 more satellite tags (X-tags) were purchased, representing a total of 15 eels that will be equipped with these tags in the fall of 2012 instead of the 10 originally planned. We estimated that these tags can generate more information (vertical behavior, predation) and provide additional chances to follow adults in the open ocean, the part of the migration that still remains a complete mystery. Thus, no acoustic arrays were deployed this year in the St.Lawrence River and Estuary for our project.

Furthermore, OPG – Ontario Power Generation -, in collaboration with our partners from MRNF Rivière-du-Loup- plan on tagging 75 silver eels with V13T pingers in October 2012. They are interested in the detection rate at Cabot Strait Line. Their tagged eels will provide important data for our project.

Coordination and Integration

The particular roles of each partner have been determined and assigned based on their location and their skills. Our partners from **AECOM**, a private consulting company, were in charge, with our assistance, of one acoustic array in 2011. They also provided technical expertise (boat captain) to verify 3 other arrays. Our partners from the **Quebec Ministry of Natural Resources –MRNF-** were in charge of an additional 5 arrays (3 upstream arrays and 2 arrays in the middle estuary). Our partners from Fisheries and Ocean Canada were in charge of the last downstream array at Ouelle River/Montmagny. All those partners provided material, technical and logistical support to our core team to manage the acoustic arrays and retrieve them during November 2011. Furthermore, partners from the MRNF also deployed additional acoustic receivers in the regions of Gentilly and Montmagny, for their specific projects about the movement of striped bass and walleye. Those receivers thus provided additional information on eel movements. At the same time, our arrays served in their studies. In October 2011, tagging efforts at Rivière-Du-Loup were led by the MRNF.

On March 21st 2012, a meeting was held at Laval University bringing together all co-investigators and collaborators involved in the acoustic telemetry part of the project. Both year's results were presented and discussed. Goals for summer 2012 were discussed. Since the data from Cabot Strait array were not available at that time, it was decided to pursue the discussion via email and telephone. A report of the meeting was sent to all partners several weeks after the meeting.

Dr. Mélanie Béguer visited Kyoko Ohashi, Jinyu Sheng, Shiliang Shan and Keith R. Thompson from the Department of Oceanography at Dalhousie University (**OTN research team of Theme I.1**) in January 2012, during 4 days, to start the collaboration on the modeling of eel movements. The discussion was continued via email. Progress was discussed in June 2012 at Halifax during the OTN annual meeting. Another meeting was then scheduled to continue the collaboration in July 2012. Drs. Martin Castonguay, Julian Dodson and Mélanie Beguer visited Dalhousie University during 2 days in early July 2012 to finalize the physical and behavioural scenarios to be modelled.

We are also collaborating with social scientists and lawyers within OTN who are working on the science and governance dimensions of the eel fishery. David Vanderzwaag, from Dalhousie's Law School, is providing the overall lead for the lawyers and social scientists involved. Dr. Richard Apostle visited Martin Castonguay in July 2012 to pursue discussions about the collaboration. Drs. Dodson and Castonguay attended the governance work shop during the 2012 OTN meeting to discuss the preparation of a paper.

Scientific or Engineering Significance of Results

Acoustic telemetry: Very significant and novel results have emerged from the acoustic tracking conducted in 2010 and 2011 and analyzed in 2012. Basically, results from 2010 were confirmed in 2011. We consider that this part of the project to have been a total success.

In 2010, 39 hydrophones distributed in 6 lines were deployed in the St. Lawrence River and Estuary from middle August to early November. In 2011, several lines were added and a total of 103 hydrophones distributed in 12 lines were deployed in the St. Lawrence River and Estuary from April-May to November. The Cabot Strait line was ca. 28 % covered in 2010 while it was 100% covered in 2011 allowing us a first estimate of the escapment rate from the Gulf of St. Lawrence during fall-winter 2011-2012.

Large silver eels: A total of 180 silver eels were tagged: 67 in 2010 and 113 in 2011 (including 36 eels tagged by OPG). 105,436 signals corresponding to codes of tagged silver eels were detected within the river and estuary (65,548 in 2010 and 39,888 in 2011). It corresponds to a total of 121 silver tagged eels that were detected across the system (river, fluvial and brackish estuary). This represents 79.1% of the eels tagged in 2010 and 98.5% of the eels tagged in 2011 that were detected. This allowed us to obtain detailed information about silver eel migration which had previously never been studied at this scale. Various behaviors were determined according to the indidual profiles revealed by the acoustic records in the fluvial and brackish sections of the St. Lawrence. Only 10 eels were non-migrants while 97.7 % of the detected eels had migrated (81.6% of the tagged eels). Except for 4 eels, all migrant eels exhibited unidirectional, downstream movements with no return observed toward upstream sections. An important variability in individual profiles was found, with eels spending more time at various section of the estuary (Fig. 1). At each array, eels were recorded during 3.4 days on average but most eels were recorded between 11.4 min and 7.9 hours. No significant differences in morphology of eels were detected in relation to migratory behavior. The individual rate of displacement calculated between each array increased significantly with the date of passage for each section. No individual's morphometric characteristics measured such as total length or body condition were correlated with the rate of displacement. Most eels were detected for the first time at arrays at night during ebb tide, indicating that migrating silver eels from the St. Lawrence are using active tidal stream transport to assist downstream displacement.

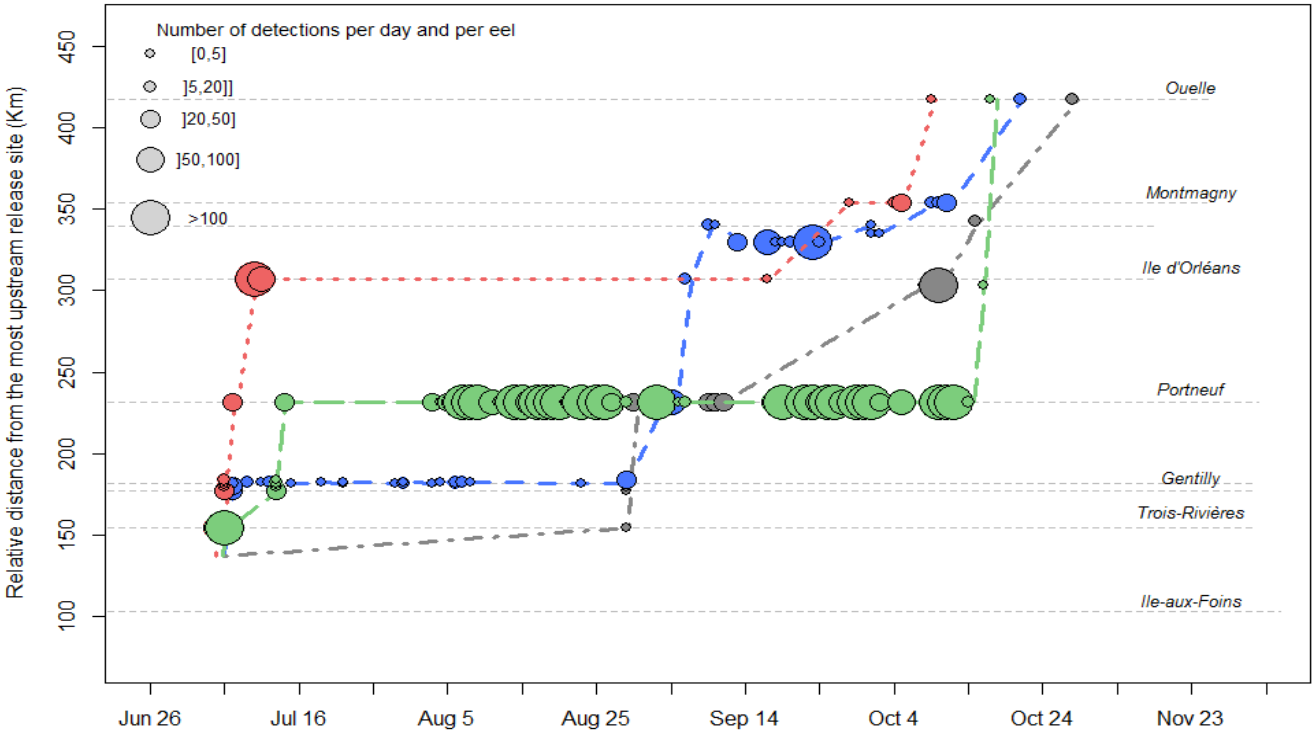


Figure 1. Examples of four migration patterns of 4 silver American eels, shown by acoustic telemetry within the freshwater and brackish sections of the St. Lawrence estuary, demonstrating the variability of the profiles. The four eels were caught, tagged and released in Lac St-Pierre in 2011.

For both years, no eels were detected at Canso Strait. In 2010-11, no eels were detected at Cabot Strait that was only ca. 28% covered. In 2011-12, only four large silver eels were detected at Cabot Strait which was entirely covered by acoustic receivers. All detected eels were eels caught near Kamouraska

and tagged and released at Rivière-du-Loup. Thus, the escapement rate from the Gulf of St. Lawrence was less than 4% ! This very surprising low detection rate at Cabot Strait may be related to a high mortality rate in the Gulf of St. Lawrence (by predation? See results from X-tag tagging below), or low detection probability in deep waters. Some eels may have stopped migrating while in the Gulf and continued their migration the following year. Even with a very low detection rate at Cabot Strait, we have obtained the first estimates of migration duration in the Gulf and thus the net migration speed. Combined with the results from X-tags experiments (see below), it represents a significant step forward in understanding the course and speed of the Gulf of St. Lawrence phase of the eel migration.

Small silver eels: In 2011, 52 small silver eels were tagged: 12 at Cap Santé by our team and the remaining at Rivière-du-Loup by OPG. These eels originate from a stocking program involving glass eels caught in Nova Scotia and released in the Richelieu River. Our goal was to compare their migration with the larger, naturally-recruited conspecifics. Of the 8 eels tagged at Cap Santé that were detected, only one migrated beyond Ouelle river. The remaining eels were non-migrants, recorded at the Portneuf array. So no statistical comparison of their migration could be done. Eleven small silver eels were recorded at the Cabot Strait array, representing an escapement rate of 21 % and thus demonstrating that these stocked eels can migrate to the North Atlantic. Nevertheless the detection rate was still low.

Yellow eels: A total of 67 yellow eels (juveniles) were acoustically tagged during our project: 25 in 2010 and 42 in 2011. 40.0% were detected by the fluvial and brackish acoustic arrays of the St. Lawrence in 2010 and 78.6 % in 2011. The majority of yellow eels (86.5%) were detected at a single array suggesting that movements are more restricted at this scale. 13.4% were migrant, i.e detected at several successive arrays but no return movement was observed during the season. These migrant yellow eels may have resided in the brackish section of the estuary for several years. Furthermore, the otolith analysis of 114 eels showed that 10 individuals exhibited evidence of having used the estuary at some point during their lifetime. These individuals were sampled at sites 80-210 km upstream from the brackish estuary. This suggests that a proportion of the juvenile American eels in the St. Lawrence River do undertake movements involving distance at least as great as this. Three patterns of estuarine residence were observed. Further work using barium, gallium and manganese are underway that are likely to elucidate movements within the freshwater section where Strontium profiles are less useful.

Satellite-tags: In an attempt to document the migratory pathways and the environmental conditions encountered by American eels during their oceanic migration to the Sargasso Sea, we tagged 8 silver eels with miniature satellite pop-up tags (X-tags from Microwave Telemetry) during their migration from the St. Lawrence River in Québec, Canada, in early October 2011 (a tagged eel is illustrated in Fig 2). Surprisingly, of the 7 tags that successfully transmitted archived data, six were ingested by warm-gutted predators, as observed by a sudden increase in water temperature illustrated in Fig 3. Gut temperatures were in the range of 20 to 25°C—too cold for marine mammals but within the range of endothermic fish. In order to identify the eel predators, we compared their vertical migratory behavior with those of satellite-tagged porbeagle shark and bluefin tuna, the only endothermic fishes occurring in the Gulf of St. Lawrence. We accurately distinguished between tuna and shark by using the behavioral criteria generated by comparing the diving behavior of these two species with those of our unknown predators. Depth profile characteristics of most eel predators more closely resembled those of sharks than those of tuna. During the first days following tagging, all eels remained in surface waters and did not exhibit diel vertical migrations. Three eels were eaten at this time. Two eels exhibited inverse diel vertical migrations (at surface during the day) during several days prior to predation. This work was accepted for publication in September 2012 in PLoSOne. Although tagging itself may contribute to increasing the eel's susceptibility to predation, we discuss evidence suggesting that predation of silver-

stage American eels by porbeagle sharks may represent a significant source of mortality inside the Gulf of St. Lawrence and raises the possibility that eels may be targeted by porbeagle sharks.

These satellite-tagging efforts provided the first significant pieces of information detailing the behavior of American eels in the Gulf of Saint Lawrence. As observed for other Anguillid eels, tagged eels exhibited daily vertical migrations. Furthermore, based on recorded depth and temperature data, individuals appear to follow the deep Laurentian Channel while transiting the Gulf.

Figure 2: A wild eel (circa 1 meter long) equipped with an X-tag and released on October 2011, near Mont-Joli, in the St. Lawrence estuary

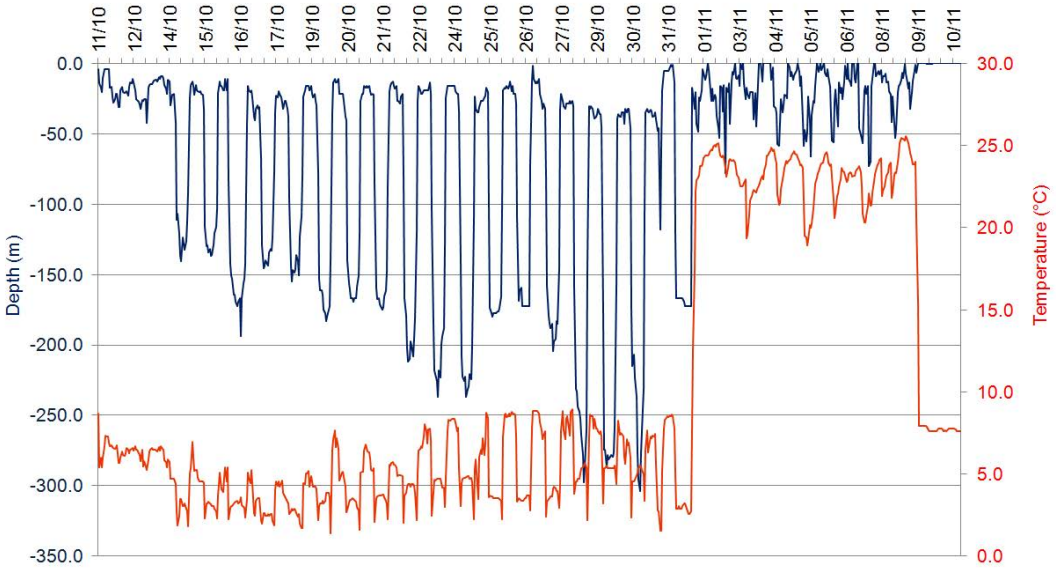


Figure 3: Vertical profile (depth & temperature) of a tagged eel (#110 617) illustrating the predation event and subsequent change in recorded temperature and depth

Modeling the migration of silver eels: Two projects of modeling the migration of silver eels are currently in progress in collaboration with oceanographers from the OTN team (Kyoko Ohashi, Jinyu Sheng, Shiliang Shan and Keith R. Thompson from the Department of Oceanography). The first project is a particle tracking model that will simulate the eel migration from Québec to Cabot Strait. It is based on Dalcoast, the oceanographic model developed by Kyoko Ohashi. The objective of this first physical-biological model is to better understand how migrating eels succeed in escaping the Gulf of St. Lawrence during their spawning migration. The coupled physical-biological model is based on the first observations from the field (X-tags results) in order to evaluate the range of behaviors that allow adults to reach the Cabot Strait. The second physical-biological model will simulate the migration from the Atlantic coasts (4 different locations, including Cabot Strait and Nova Scotia) to the spawning grounds in the Sargasso Sea. The main objective of this model is to explore different kind of behavioural strategies and associated environmental cues that allow the American eel to reach the Sargasso Sea on

time. The success of the different strategies will be evaluated following the probability of arriving at the spawning area within a prescribed time window with sufficient energy for spawning. The physical model used will be NEMO, a particle advection scheme and associated probability density functions developed by Shiliang Shan and Keith Thompson.

For both modeling projects, the parameter values and the scenarios to be tested were agreed upon during the summer of 2012. A literature review on the state of knowledge of silver eel migration was conducted and the energy expenditure part of the model was developed based on a literature review. The particle tracking is currently being developed and tested by the oceanographers. The first simulations will be completed this fall. The collaboration will continue during 2013, to finalize these two projects and eventually to develop other projects based on the results of our field tracking (X-tags October 2012-March 2013).

7. Difficulties encountered

No problem encountered.

8. Networking and outreach

Intra-Network Collaboration and Partner Meetings

We have been collaborating with **Michael J.W. Stokesbury from Acadia University** for our work on X-tags data that was accepted for publication in PlosOne in September 2012: "Shark predation on migrating adult American eels (Anguilla rostrata) in the Gulf of St.Lawrence". Mike's bluefin tuna data from 2010 were used to compare the vertical migration behavior of tagged eels following predation with that of its satellite-tagged tuna in order to identify the unknown eel predators.

An important objective of our project is to attempt to link physical and oceanographic factors with eel migration routes. This requires the use of the physical environment models developed within **Theme I.1**. Physical data and models will be used to project the potential impacts of the climate change on the eel migration. Furthermore, a modified version of DalCoast (Theme I.1) that provides realistic circulation and hydrographic distributions over the Gulf of St. Lawrence will also be useful to understand eel migration in the Gulf of St. Lawrence.

We are also collaborating with **social scientists and lawyers within OTN** who are working on the governance dimensions of the eel fishery. Following a summer meeting between Castonguay and Apostle, we continue to collaborate on a search for information to build a socio-economic impact assessment of eel restoration measures and actions taken by countries having habitats for eel.

Interaction/Outreach to Broader Community

We have been collaborating with **Steven Campana**, from DFO, for our publication about the shark predation on migrating adult American eels in the Gulf of St. Lawrence. Steven Campana provided us with vertical migration profiles of satellite-tagged porbeagle sharks enabling us to identify the eel predators. Dr Campana visited us in March 2012 to provide us the data and discuss the preparation of the publication.

David Cairns, from DFO, helped us in finding large silver eels from Novia Scotia for this fall's X-tag deployment (October 2012) in Nova Sotia. He provided us many contacts, helped us with the logistics and eventually will be participating in field tagging in October 2012.

We collaborate with the **MRNF of Quebec** which is actually working on the acoustic tracking of various fish species such as the striped bass, the yellow walleye and the Lake sturgeon. For instance, our arrays are providing information on the spawning migration and dispersal of the striped bass following their reintroduction in the Saint Lawrence system. The additional acoustic receivers they deployed for their own project provides us additional data about eel movement.

We participated in the **working group on eel biology (CESWoG)** that was held in November 2011 at Montreal, allowing us to contribute to the development of a national plan for eel management. We will also participate in the upcoming CESWoG meeting that will be held in Ottawa next November 2012. 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

Refereed Journal Articles (1 total)- *Accepted/published*

Mélanie Béguer-Pon, José Benchetrit, Martin Castonguay, Kim Aarestrup, Steven E. Campana, Michael J.W. Stokesbury and Julian J. Dodson. Shark predation on migrating adult American eels (*Anguilla rostrata*) in the Gulf of St. Lawrence. **PLoS One**, **PONE-D-12-18264R1**, accepted on 5th September 2012, should be on line in a few weeks.

Conference Presentations (6 total) *– Contributed*

1. Benchetrit J, Béguer-Pon M, Sirois P, Castonguay M, and J.J. Dodson. Reconstructuring the environmental histories of American eels in the Saint Lawrence River using multi-element profiles of otoliths. Oral communication at the 2012 ICES Annual Science Conference that was held in Bergen, Norway, 17-21 September 2012.

2. Béguer-Pon M, Benchetrit J, Castonguay M, Hatin D, Verreault G, Legault M, Dionne M, Dumont P, Mailhot Y, Bourque J-F, Tremblay V and J.J. Dodson. Migration Patterns of the American Eel from the Saint Lawrence River to the Atlantic Ocean Using Acoustic and Satellite Technology. Oral communication during the second OTN annual meeting, June 2011, Halifax, Nova Scotia, Canada.

3. Benchetrit J, Béguer-Pon M, Sirois P, Castonguay M, and J.J. Dodson. Combining Acoustic Telemetry and Otolith Microchemistry to Understand Movement Patterns of American Eels in the Saint Lawrence River. Poster presented at the second OTN annual meeting, June 2011, Halifax, Nova Scotia, Canada.

4. Béguer-Pon M, Benchetrit J, Castonguay M, Hatin D, Verreault G, Legault M, Dionne M, Dumont P, Mailhot Y, Bourque J-F, Ohashi K, Thompson K, Shang S and Dodson JJ, 2012. Multiple approaches to elucidate the migration of the American eel (Anguilla rostrata) from the St Lawrence River to the Sargasso Sea. Oral communication at the 6th World Fisheries Congress, Edinburgh, Scotland, 7-11th May 2012.

5. Béguer-Pon M, Benchetrit J, Castonguay M, Hatin D, Verreault G, Legault M, Dionne M, Dumont P, Mailhot Y, Bourque J-F, Ohashi K, Thompson K, Shan S and Dodson JJ. 2012. Multiple approaches to elucidate the migration of the American eel (Anguilla rostrata) from the St Lawrence River to the Sargasso Sea. Oral communication at the Ocean Sciences Meeting 2012, 20-24 February 2012, Salt Lake City, Utah, USA.

6. Béguer-Pon M, Benchetrit J, Castonguay M and Dodson JJ. 2011. Suivi des mouvements de l'anguille d'Amérique dans le St-Laurent: description du projet et premiers résultats. Oral

communication at the 10th Annual General meeting of Québec Ocean, Manoir du Lac Delage, November 17th-18th 2011.

10. Other contributions and deliverables

Invited or contributed presentation/contribution at a workshop.

1. Béguer-Pon M, Benchetrit J, Castonguay M, Aarestrup K and Dodson JJ. 2012. Using X-tags to unravel the American eel's mysterious migration from the St-Lawrence estuary to the Sargasso Sea. Oral communication at the 2012 MTI (Microwave Telemetry) Avian and Marine Tracking Conference, March 27-30, 2012, Columbia, MD, USA.

2. Béguer-Pon M, Benchetrit J, Castonguay M, Hatin D, Verreault G, Legault M, Dionne M, Dumont P, Mailhot Y, Bourque J-F, Tremblay V and Dodson JJ. 2011. Tracking the movements of the American eel in the St-Lawrence River: Project overview and first results. Oral communivation at the 9th annual meeting of the Canadian eel science working group (CesWog), Montréal, Québec, Canada.

Internet publishing, portal, blog, electronic publications

A post entitled "Migrating eels often make meals" was published in Nature News Blog website on 23rd February 2012: http://blogs.nature.com/news/2012/02/migrating-eels-often-make-meals.html

11. Collaborations with Industrial and Government Partners

In November 2011, our partners from AECOM, a private consulting company, and partners from the Quebec Ministry of Narural Resources –MRNF- were in charge of retrieving the arrays deployed in the St. Lawrence River and Estuary since April-May 2011. Our partner from Fisheries and Ocean Canada in Mont-Joli was in charge of retrieving the last downstream array at Ouelle/La Malbaie. All those partners provided material, technical and logistical support to our core team to retrieve the acoustic data and the receivers at the end of the season 2011 (November). Partners from the MNRF also deployed additional acoustics receivers in the St. Lawrence for their specific projects about the movement of striped bass and walleye. Those receivers thus provided us additional information on eel movements. In the same time, our arrays served in their studies.

In 2012, there was no acoustic array specifically deployed for studying American eel movement in our project. Nevertheless, partners from MRNF, still continue working on migratory species such as the striped bass and the Lake sturgeon. Approximately 88 acoustic receivers were deployed in the St. Lawrence system, from April 2012 to November/December 2012, not systematically distributed in arrays but rather dispersed, to study the movement of other fish species (striped bass, sturgeon.). Only a small number of deployed VR2Ws was provided by OTN, partners having invested in the purchase of their own equipment. AECOM was also in charge of one array this year. Furthermore, approximately 50 American eels were tagged upstream in the St. Lawrence to assess mortality in the turbines of major dams located upstream of Lac St. Pierre. This is a collaboration between MRNF and OPG – Ontario Power generation. In addition, these same two partners plan on tagging 75 silver American eels, in October 2012, near Rivière-Du-Loup. They are interested in the detections that can be recorded at Cabot Strait Line. They will provide us the tagging metadata that we will transmit to OTN data managers. Their results will provide us further information on the escapement of eels from the Gulf of St. Lawrence.

We also collaborate with partners from DFO. David Cairns helped us in finding large silver eels in Nova Scotia and will provide us logistical help during the field planned next October (2012). As previously mentioned above, Steven Campana, from DFO, provided us with shark data helping us to identify the eel predators responsible for eating the X-tag fitted eels in October-November 2011.

Cash and in-kind contributions from partners for year 3

Name of supporting organization: **MRNF**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$20 000
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$2 500
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$22 500
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **POC (DFO)**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$20 000
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$3 000
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	$10 000
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$33 000
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **AECOM**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$1 500
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$750
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	$2 250
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **Québec-Océan**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
Salaries for scientific and technical staff	$1 000
Donation of equipment, software	
Donation of material	
Field work logistics	
Provision of services	
Other (specify): *scholarship for conference*	$1 400
In-kind contributions to indirect costs of research	
Use of organization's facilities	
Salaries of managerial and administrative staff	
Other (specify): _____	
Total of all in-kind contributions	$2 400
Is this new funding (acquired during this reporting period)?	No

12. Expenditures and Support

Year 3 (2012)

Budget Item	Year 3 (2012)				
	Proposed	**Actual Expenditures** 1 Jan - 30 Sep 2012	**Total Balance** 30 Sep 2012	**Projected Balance** 31 Dec 2012	**Deviation**
1) Salaries and Benefits					
a) Students	$23 500	$12 250	$11 250	$5 948	25%
b) Postdoctoral Fellows	$45 000	$33 750	$11 250	$0	0%
c) Technical/Professional	$10 000	$3 998	$6 002	$2 000	20%
d) Other	$0	$0	$0	$0	0%
2) Equipment or Facility					
a) Purchase or Rental	$3 000	$0	$3 000	$3 000	100%
b) Operations/Maintenance	$12 000	$2 649	$9 351	$351	3%
c) User Fees	$0	$0	$0	$0	0%
3) Material and Supplies					
a) Materials and Supplies	$0	$0	$0	$0	0%
4) Travel					
a) Conferences	$4 000	$6 030	-$2 030	-$2 030	-51%
b) Field Work	$11 250	$2 802	$8 448	$448	4%
c) Collaboration/Consultation	$4 000	$4 896	-$896	-$896	-22%
5) Dissemination					
a) Publications	$0	$1 286	-$1 286	-$1 286	
b) Other	$0	$0	$0	$0	0%
6) Other (specify)					
a) Other	$0	$0	$0	$0	0%
b) Other	$0	$0	$0	$0	0%
Totals					
Totals	**$112 750**	**$67 661**	**$45 089**	**$7 535**	

Given the early start of the fiscal year (January) and the relatively late acquisition of tracking results (late fall), our field planning and budget projections occur several months before we have results of the current year's efforts in hand. As in 2011, we once again found ourselves in the situation of finalizing plans for the 2012 fiscal year before having the 2011 results in hand. Downloading of acoustic receivers in October 2011 and the radio satellite tagging results obtained in Nov-Dec 2011 led us to reconsider our research objectives in early 2012. First and foremost, we decided to suspend the acoustic tagging of silver eels for two major reasons; (1) the 2011 field season was very successful and, with the results of the 2010 tracking season, provided us with a clear picture of silver and yellow eel migratory behavior in the lower St. Lawrence R. and upper estuary. (2) We initially planned to deploy our last acoustic tags for detection at the Cabot Strait line. However, the very low recapture rate (4%) of acoustic signals at Cabot indicated that the release of another 50 acoustic pingers on silver eels in the St. Lawrence estuary was a waste of resources. In addition, in early 2012, Ontario Power Corporation announced their intention of tagging (V9 and V13 pingers) and releasing 75 silver eels at Rivière-du-Loup for eventual detection at the Cabot Strait line (we assume the responsibility of archiving this data with the OTN metadata base). We thus applied to OTN for the permission to suspend the purchase of our remaining acoustic tags and

to invest our allocation of CFI finds in the purchase of satellite tags (15) to pursue the oceanic migration phase of the eel. In addition, our partners from MRNF and AECOM took over the responsibility of maintaining the VR2s deployed in the St. Lawrence River and estuary entirely within the context of their own projects. In addition, we invested more time and effort in our collaboration with Dal researchers on our modeling efforts of the eel migration and we attended three major international conferences (4 contributions) to share our findings with the international community. These decisions had significant impacts on several budget line items.

1 (a). As we suspended acoustic tagging operations in the summer of 2012, we did not hire a summer student (5, 948$). Thus we spent 25% less than anticipated on this line item.

2 (a). The installation of the middle estuary acoustic receivers was taken over by MRNF, thus precluding the necessity to hire a boat and captain (3, 000$) to do so.

4 (a). We attended 3 international conferences rather than one, involving 4 presentations rather than 2 as originally planned. We thus overspent this line item.

4 (c). We spent more time collaborating with the Dal researchers (Thompson and Sheng laboratories) in the development of coupled physical-biological models of eel migration. Mélanie Béguer visited Halifax in January 2012 and we all participated in a 2-day workshop in Halifax. Although Dal assumed part of the costs, we overspent this line item in our budget.

5 (a). We did not budget for publication costs. However, we failed to account for free-access publication fees. As we hope to disseminate as widely and as quickly as possible our shark predation findings, we chose to publish in PLoS ONE.

How the remaining Projected Balance of your Year 3 on 31 Dec 2012 will be spent

1 (a) The final three months of one M.Sc. student stipend (José Benchatrit), with a balance of 5 948$.

1 (b) The final three months of one postdoctoral fellow (Mélanie Béguer), with zero balance.

1 (c) One month of technical assistance in the field (3000$) and periodical professional assistance in statistics (1000$), with a balance of 2000$.

2 (a) No further expenditures, with a balance of 3000$.

2 (b) Argos satellite charges (5000$), purchase of eels (4000$), with a balance of 351$.

4 (a). No further expenditures, with a deficit of 4 568 $.

4 (b). All our field work is planned for October 2012 (eel tagging with X-tags in Nova Scotia). Expenses (1 month) for truck rental, gas, lodging and food for four, purchase of eels, expendables (8000$), with a balance of 448$.

4 (c). No further expenses, with a deficit of 896$.

Whether year 2 (2011) actual expenses for October-December were on target with what was forecast in last year's report

Category	Projected expenses	Real expenses	Deviation	Justification
1(a)	$3800	$4302	-13%	
1(b)	$11955	$12971	-9%	
1(c)	$7000	$6464	8%	
2(a)	$731	$1369	-87%	exorbitant price for eels
2(b)	$3500	$3115	11%	
4(a)	$1061	$952	10%	
4(b)	$2949	$2884	2%	
4(c)	$1642	$0	100%	Trip planned for the fall was postponed until Jan. 2012. This contributed to the deficit of this line item in 2012 (see above)).
Total	$32638	$32058	1.2%	

Conference travel budget justifications

Conference	Location	Traveller	Fees			
			Regist.	Travel	Accom.	Food
6th World Fisheries Congress	Edinburgh, Scotland,	Dr Mélanie Béguer*	$479	$575	$786	$469
Ocean Sciences Meeting 2012	Salt Lake City, Utah, USA	Dr Mélanie Béguer	$378	$790	$607	$248
ICES 2012	Bergen, Norway	José Benchetrit*	$180	$614	$654	$250

* MB and JB's travel expenses were partially subsidized by Québec-Océan

The year 2012 provided exceptional opportunities to present our work to an international audience. The World Fisheries Congress (with a dedicated eel session) and Ocean Sciences Meeting (with a dedicated OTN session) are scheduled only once every two years whereas ICES is an annual conference that provides access to a unique mix of fishery scientists and managers. The ICES meeting also provided an opportunity for José to present the results of his master's project before graduating in December 2012. The value added to the Network involves exposure of OTN research to multiple international audiences and provides the opportunity to interact with and profit from the knowledge of international researchers.

Year 4 (2013)

The original year 4 budget does not take into account any of the changes made to the project in 2010 and 2011. The 4th year of the project is dedicated to completing the modeling exercises, obtaining and analyzing satellite transmission data from our 2012 release of X-tags and publishing our findings. The only field activity planned is to conduct, in the fall of 2013, preliminary experiments with a new generation of pop-up tags. This activity will be carried out by Dodson, Castonguay, Béguer and one professional assistant during one month. As such, our year 4 request bears little resemblance to the original year 4 budget. All line items retained deviate by more than 20% of the original budget. As such, each budget line item will be discussed below.

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$42 300	$0	$0	100%
b) Postdoctoral Fellows	$0	$0	$0	
c) Technical/Professional	$0	$0	$0	
d) Other	$0	$0	$0	
2) Equipment or Facility				
a) Purchase or Rental	$3 000	$1 000	$0	67%
b) Operations/Maintenance	$5 200	$5 200	$0	0%
c) User Fees	$0	$0	$0	
3) Material and Supplies				
a) Materials and Supplies	$0	$0	$0	
4) Travel				
a) Conferences	$6 000	$8 000	$0	-33%
b) Field Work	$11 250	$3 000	$0	73%
c) Collaboration/Consultation	$2 000	$5 000	$0	-150%
5) Dissemination				
a) Publications	$0	$2 500	$0	
b) Other	$0	$0	$0	
6) Other (specify)				
a) Other	$0	$0	$0	
b) Other	$0	$0	$0	
Totals				
Totals	**$69 750**	**$24 700**		

Deviations between the Original and Revised year 4 budget

1 (a) As stated in our 2011 report, the recruitment of additional graduate students was suspended due to unexpected large expenditures in 2010 and 2011. The present graduate student (José Benchetrit) will finish his M.Sc. program in December 2012. No new students will be recruited in 2013 as it is the final year of this phase of the project. No funds are thus needed in this line item.

2 (a) We request $1000 for eel purchase for fall tagging.

2 (b) We request $5200 for Argos satellite fees to cover expenses of satellite tags released in the fall of 2013 (see below).

4 (a) We request additional funds to attend 2 international conferences for three presentations by the principal researchers and the post-doctoral fellow.

4 (b) We require $3000 to cover the expenses of a limited field work effort (car rental, lodging, food for 1 week on the St. Lawrence estuary).

4 (c) We request additional funds to insure continued collaboration with the laboratories of Thompson and Sheng. The initial request was far too low, given our expenses for collaboration in 2012.

5 (a) We request publication costs to cover the publication of 2 open-access publications in 2013.

a) In summary, we request 24 $700 for year 4.

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

I. Atlantic Arena

1. Project Number: I.2.3

2. Project Title: Atlantic sturgeon on the east coast of Canada: migratory behaviour and origin, and the potential for tidal power impacts

3. Project Leaders: M. Stokesbury (Acadia), M. Litvak (Mount Allison), M. Dadswell (Acadia)

Collaborators: P. Smith, R. Bradford, J. Gibson (BIO DFO), J. Sheng, C. Taggart (Dalhousie), R. Karsten (Acadia), A. Redden (ACER, Acadia), D. Fox (U Delaware), S. Laporte (NOAA, NMFS), I. Wirgin (NYU, NY), T. King (USGS), M. Fast (UPEI Veterinary Collage), S. Cooke (Carleton U)

4. Public Summary of Report

We are tagging Atlantic sturgeon from the stock present in the Saint John River, New Brunswick and from the mixed stock aggregation that migrates every summer through Minas Basin, Nova Scotia, with acoustic coded-pingers. We have characterized the timing, extent, and habitat use during the spawning migration in the Saint John River. For the summer feeding aggregation of Atlantic sturgeon in the Minas Basin we have determined their main prey species and quantified feeding, searching and directed migration behaviour. We have determined survival, post catch and release, by otter trawl and this information is now being used to inform management organizations as they determine regulations for endangered species legislation. Also, to guide engineering and mitigate possible negative impacts of turbine operation on species of concern, we are describing sturgeon spatial and temporal behaviour including depth preferences in the Minas Passage, and area targeted for instream tidal power turbine deployment.

Ongoing objectives include answering fundamental questions such as: Do Atlantic sturgeon show fidelity to certain spawning grounds? What is the timing of their spawning migrations, and are there sex differences associated with spawning migrations? What is the population structure and origin(s) of the Atlantic sturgeon that migrate through the Minas Basin and the Saint John River system on a seasonal basis? What areas in the Saint John River, the Bay of Fundy and the inshore coastal shelf water constitute critical habitat for Atlantic sturgeon populations of Canadian and USA origins? What are the characteristics of the water column selected by sturgeon in the areas of aggregation along the Canadian and USA Atlantic seaboard? What is the potential impact of tidal power development in Minas Channel, inner Bay of Fundy, Nova Scotia? The answers to these questions are crucial to developing a better understanding of the ecology of this species which will lead to their protection and management.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Montana McLean (Acadia)	MSc	100%	100%	1 Oct 2011 – 30 Sep 2012
Thesis topic: Quantifying Movement Patterns and feeding behaviour of Atlantic sturgeon (*Acipenser oxyrinchus*) in the Minas Basin, Bay of Fundy, Canada				
Jeffrey Beardsall (Acadia)	MSc	100%	0%	1 Oct 2011 – 30 Sep 2012
Thesis topic: Consequences of Incidental Otter Trawl Capture on Survival and Physiological Status of Threatened Atlantic Sturgeon (*Acipenser oxyrinchus*)				
Colin Burhiliwalla (Acadia)	MSc	20%	0%	1 Jun 2012 – 15 Sep 2012
Thesis topic: Stripped bass distribution and behaviour determined through tracking using acoustic telemetry				
Samuel Andrews (Acadia)	RA	20%	0%	1 May 2012 – 1 Sep 2012
Project topic: Acoustic hydrophone deployed on Atlantic sturgeon bioprobe				
Laura Logan-Chesney (Acadia)	RA (Honours)	100%	0%	1 May 2012 – 1 Sep 2012
Thesis topic: Acoustic hydrophone deployed on Atlantic sturgeon bioprobes				
Andrew Taylor (Mt. Allison)	M.Sc.	100%	50%	1 Oct 2011 – 30 Sep 2012
Thesis topic: Seasonal distribution, movement patterns and habitat use of Atlantic sturgeon, *Acipenser oxyrinchus*, from the Saint John River, New Brunswick, Canada				
Sima Usvyatsov (UNBSJ/Mt. A.)	Ph.D.	10%	10%	1 Oct 2011 – 1 Jun 2012
Thesis topic: Modeling the habitat use of shortnose sturgeon (*A. brevirostrum*) throughout the species' life history				
Sima Usvyatsov (UNBSJ/Mt. A.)	Postdoc	10%	0%	1 Jun 2012 – 31 Aug 2012
Kevin Isherwood (Mt. Allison)	RA	100%	100%	1 May 2012 – 31 Aug 2012
Alicia Cassidy (Mount Allison)	RA	10%	0%	1 Jul 2012 – 31 Aug 2012
Allison Byrne (Mount Allison)	RA	15%	0%	1 May 2012 – 31 Aug 2012
Ainslie Oland (Mount Allison)	RA	10%	0%	1 May 2012 – 31 Aug 2012
Christine Gilroy (Mt. Allison)	RA	10%	0%	29 Aug 2012 – 30 Sep 2012
Project topic (Usvyatsov, Isherwood, Cassidy, Byrne, Oland, Gilroy): Seasonal distribution, movement patterns and habitat use of Atlantic sturgeon, *Acipenser oxyrinchus*, from the Saint John River, New Brunswick, Canada				

Our HQP's are completely integrated into every facet of this study. They prepare and deploy receivers. They operate on and acoustically tag sturgeon. They have developed new harness systems that have proven very reliable for keeping PAT (MK10 and mini-PAT) tags attached to free ranging sturgeon. They sample sturgeon for morphological characteristics (length, weight, etc), assist in blood collection for stress analysis, collect samples for DNA analysis, stable isotope analysis, larval sampling and observe and help collect parasites. They are involved in active and passive tracking of Atlantic sturgeon. They assist in record keeping and data analysis, including submission of meta-data to the OTN data centre. Most HQP's have attended workshops on using the Platform for Ocean Knowledge Management (POKM) and 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 two recently submitted publications with HQPs as first authors). They present results at international and local scientific meetings from portions of the study for which they are responsible.

HQP McLean (Acadia) was a visiting student at James Cooke University to learn advanced data analysis techniques from OTN Global researchers Heuple and Simpendorfer. Also, Beardsall (Acadia)

completed field work and trained in sampling blood indicators of stress at the University of Tasmania with Tracey.

6. Progress towards Objectives/Milestones (1 Oct 2011 – 30 Sept 2012)

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 Basin and the population characteristics 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. Increase our understanding of the biology of Atlantic sturgeon and how this knowledge may assist in determining the status of east coast Atlantic sturgeon stocks and provide managers with information that can assist in the sustainable exploitation of these stocks.
7. Improve scientific information on the existence and movements of Atlantic sturgeon stocks in eastern Canada
8. 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
9. Determine large and fine scale movement patterns, seasonal distribution and habitat use of Atlantic sturgeon from the Saint John River, NB, Canada.
10. 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.
11. Communicate our findings locally, nationally and internationally through meetings, presentations and publications.

During the time period of this report (1 Oct 2011 to 30 Sept 2012) a total of 35 Atlantic sturgeon were tagged with pressure sensitive acoustic tags in Minas Basin. In addition 9 sturgeon were tagged with either MK10 or Mini-PAT tags. A total of 43 VR2w acoustic receivers were deployed in Minas Basin and Channel. Ten intertidal receivers (3 contributed by NMFS), 6 in an array around the Nova Scotia Power tidal turbine and), 12 across the Minas Channel (contributed by ACER), and 14 across Minas Channel (contributed through OTN) were deployed to study migratory corridors, seasonality, environmental preferences (including depth) and survival of sturgeon as they move between the Minas Basin and outer Bay of Fundy in an area targeted for installation of tidal power turbines in 2013.

The intertidal array of receivers off Kingsport observed sturgeon exploiting the soft-sediments of the inter-tidal zone during high tide for feeding. A total of 10 sturgeon tagged in 2010 and 18 tagged during 2011 were acoustically recaptured between April and August 2011 within the array. Food recovered from captured individuals by gastric lavage indicated the sturgeon were feeding on soft-bodied

invertebrates such as polychaetes and amphipods *(Corophium* sp) which are common members of the intertidal infauna of Minas Basin.

Our results indicate an aggregation of juvenile and sub adult Atlantic sturgeon occurs in Minas Basin of the inner Bay of Fundy during April to September. Tag-recapture data indicate the aggregation contains approximately 6,000 - 9000 sturgeon. Mean size and range is 135cm FL and 56 - 219cm FL and ages range from 6-60 yr. External tag and acoustic tag recoveries during 2010 2011 and 2012 indicate the aggregation apparently feeds in the inner portions of Minas Basin over soft sediments mainly in the intertidal zone at high tide on polycheates (McLean et al. submitted) and moves slowly in a clockwise pattern around the Basin from the northern shore in spring to the southern shore by late summer. Sturgeon enter and exit Minas Basin through Minas Passage where deployment of tidal turbines is planned. Early results from pressure sensitive tags indicates sturgeon move through the passage at mid-depths and would encounter the turbines.

The sturgeon aggregation in Minas Basin is composed of multiple stocks from Canada and the USA. Government agencies from both nations have recently recognized Atlantic sturgeon as threatened or endangered due to overfishing and habitat degradation. Many (thousands) sturgeon are captured as bycatch in fisheries targeting other species but it is difficult to determine the extent to which bycatch is contributing to population declines. In Beardsall et al. (submitted) we characterize the effects of capture and release by otter trawl on Atlantic sturgeon by calculating a minimum rate of survival for fish post-catch and release using acoustic telemetry and examined physiological indicators of stress. Minimum post-release survival rate from otter trawl capture events was high (94% survival). Results also demonstrated that the magnitude of blood lactate in trawl captures relative to experimental controls increased with longer handling times. We suggest that minimizing handling time (i.e. time on deck) should be a priority in trawl fisheries that capture Atlantic sturgeon as bycatch. Results of this study will be very important to conservation strategies put in place by managing organizations in Canada and the US for trawl fishery management.

During 2011-2012, a total of six sturgeon were tagged in the Saint John River estuary with pressure sensitive acoustic tags and seven were tagged with pop-up satellite tags. A total of 25 acoustic receivers were deployed in the Saint John River estuary. Twenty-three receivers were deployed throughout the river to gather information on large-scale movement patterns, while two receivers were deployed below the Reversing Falls at the Saint John Harbour, to determine timing of exit from the river in relation to tide fluctuation. Using a VR100 acoustic receiver with an omni-directional and directional hydrophone attached, active tracking methods were used to triangulate fish position to determine fine-scale habitat use and movement. All tagged fish were acoustically recovered during 2012, and the majority has been observed exiting the Saint John River estuary by mid-September. Capture stress of gill net fishing was tested and will be compared to weir and trawl fishing capture stress in the Minas Basin.

Acoustically tagged fish in the Saint John River have been found aggregating in lower river reaches, primarily over sandy substrate. Individuals are exploiting all areas of the water column, with a mean depth of 5.44 ± 0.4 meters in 2011. Throughout the summer tagged fish undertake localized movement within the lower 50km of the river. Occasional rapid upstream migrations occur up to kilometer 110 of the river.

D-frame drift nets were used in the Saint John River to sample for larvae in suspected spawning areas. In July 2011, four Atlantic sturgeon larvae were captured, the first confirmed Atlantic sturgeon larvae found in the Saint John River. No Atlantic sturgeon larvae were captured in 2012 despite extensive sampling.

During tagging trips in the Saint John River and the Minas Basin, blood samples were taken to be used in stable isotope analysis. Stable isotopes will be used to determine diets and habitat utilization.

A total of 23 Atlantic sturgeon of 30 tagged in Minas Basin during 2010 were acoustically recovered in Minas Basin during 2011 for a known survival rate of 77% over one year at large. Four Atlantic sturgeon tagged in Minas Basin with only dart tags were recovered in the Saint John River estuary during 2010, 2011 and 2012 and three sturgeon dart tagged in the Saint John were recovered in the Minas Basin. Six Atlantic sturgeon acoustically tagged in the Saint John River have been passively tracked with VR2W's in the Minas Basin, one in September 2010 and five in May-July 2011. In addition, one tagged sturgeon from the Saint John River was picked up by a VR2 located near Musquash, NB, shortly after it was identified acoustically in the Minas Basin in June 2011. Two Atlantic sturgeon tagged in the Saint John River were detected on receivers on the Halifax line in October and November 2011. One of these Atlantic sturgeon returned to the Saint John River in November 2011 where it remained for approximately 1 week before exiting the river.

Six of seven pop-up satellite tags deployed in the Saint John River in August 2011 were released from fish in the Bay of Fundy in June 2012. Data recovered from the pop-up satellite tags is currently being analyzed.

Two of three pop-up tags deployed in the Minas Basin successfully disengaged from tagged sturgeon and reported on the appropriate pop-up date. Data analysis (by Beardsall) has begun on this data set. Ten more pop-up tags were also deployed in 2012 for pop-up schedules in 2013

During tagging trips in Minas Basin Atlantic sturgeon were examined in an on-going collaboration between Acadia and UPEI for external and blood parasites by two researchers, Jeffrey Beardsall (Acadia) and Mark Fast (UPEI Veterinary School).

181 Atlantic sturgeons were sampled for DNA analysis at the laboratories of Isaac Wirgin (NYU) and Tim King (USGS) during tagging trips in Minas Basin. Stock analysis using Microsatellites and Mitochondrial DNA indicated that 61% were Saint John River, New Brunswick stock, 34% were from the Kennebec River, Maine, 4% were from the Hudson River, NY and 1% was identified to the James River, Virginia. Dadswell and Wehrell from Acadia and OTN Canada were co-authors on this study (Wirgin et al. 2012) published in the Transactions of the American Fisheries Society.

Dadswell was involved with the Atlantic States Marine Fisheries Commission in an assessment of the endangered listing of Atlantic sturgeon in the USA.

Presentations on our findings were given at two international and two regional scientific meetings by project leaders and HQP personal. The Lions Club sturgeon derby was used as a public outreach event during which fishers captured sturgeon to be tagged, measured and weighed. Overall the event promoted communication with the recreational fishing sector of the Maritimes.

Significant Deviations from the Original Objectives or Plans

There has been no significant deviation from the original objectives or plans. However, the project has become more complex and multifaceted. For example, we are now working on blood indicators of stress (cortisol, lactate, glucose) to determine the least stressful sampling and tagging methods for sturgeon. This is in collaboration with Steve Cooke, Carleton University and OTNC Pacific. Also, we have examined DNA for population structure in collaboration with Isaac Wirgin (New York University) and Tim King (USGS), external, gill and blood parasites with Samantha Munroe (Acadia) and Mark

Fast (UPEI Veterinary College). Litvak's lab is also using blood samples to examine stable isotopes for diet and habitat use for Atlantic sturgeon caught in the Saint John River and the Minas Basin.

We have begun planning for acoustic tagging of sturgeon during 2013 in the Mira Estuary, Cape Breton, a little studied region of the Atlantic coastal environment, and other Maritime rivers (Petitcodiac, Miramichi, etc). This work will broaden our study towards the realization of our primary objective to determine the migratory behavior and origin of eastern Canada sturgeon stocks. This expansion should exploit the existence of the two OTN receiver lines off Halifax and northern Cape Breton. 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. 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 to Atlantic Canada.

Coordination and Integration

Co-ordination of field work during the 2011-2012 field season was the responsibility of each research unit (Minas Basin and Saint John Estuary). Dadswell and Stokesbury worked together with their HQP personnel (McLean – Funded by OTNC, Beardsall and Burhiliwalla, Logan-Chesney, Andrews – Funded by other funds to MJWS and MJD) to deploy receivers and tag sturgeon in Minas Basin. They also coordinated with and assisted Redden and Broome (ACER) in deployment of the additional receivers in Minas Basin. Litvak and his HQP personnel deployed receivers, tagged, sampled and tracked sturgeon in the Saint John River and estuary. Fast and his student (Donovan – Funded by UPEI) joined us and our HQP personnel during sturgeon tagging in weirs and onboard ship. DNA samples were shipped to Wirgin (NYU) and King (USCS) and MJD is using the information discovered to enter the debate in the United States on the status of US Atlantic sturgeon stocks (NMFS) and possible threats to the health of their population in light of possible mortalities from Tidal Power development in Canada and commercial fishing bycatch along the Atlantic coast.

Scientific and/or Engineering Significance of Results

We have determined the foillowing previously unknown facts.

Scientific:

- That a summer aggregation of about 6000-9000 Atlantic sturgeon occurs in Minas Basin each year consisting of mainly sub adults and adults from 100- 200cm and 10-25 years of age.
- These sturgeon enter Minas Basin in spring and move through the Basin feeding over soft sediments. Movement is in a clockwise pattern from the northern portion of the Basin to the southern. Sturgeon exit the Basin in late summer.
- Passage into and out of the Basin occurs at mid-depths in Minas Passage.

- Sturgeon occurring in Minas Basin in summer consist of fish from stocks in at least four spawning rivers; the Saint John R, NB, the Kennebec in Maine, the Hudson in NY and the James River in Virginia.
- Sturgeon return to Minas Basin in successive years and survival of acoustically tagged individuals is excellent (77+% plus those that move to natal rivers to spawn).
- Sturgeon parasite loads can be heavy but do not seem to harm their health. A complete list of external parasites for Atlantic sturgeon at any locality in eastern Canada has been compiled for the first time.
- Sturgeon have high survival after capture by otter trawl (> 94%) and increases in stress indicators from blood samples reveal that sturgeon returned quickly to the water suffer minimal stress.
- Sturgeon feed on soft-bodied invertebrates while in the southern bight of the Minas Basin, were others has predicted that they mainly feed on *Crophium* (mud shrimp).
- Sturgeon passing through the Minas Passage, and area scheduled for tidal turbine deployment, move throughout the water column mainly between depths of 10 to 50 M. This is critical as we define what areas of the water column might be affected by tidal turbine deployment.
- In the Saint John River Atlantic sturgeon remain primarily in the lower reaches during the summer. We described daily activity schedules, fine scale movements of these tagged fish and habitat utilization.
- Timing of exit from the Saint John River is from early August to late September. The Atlantic sturgeon seem to time their exit based on tidal flow.
- Four Atlantic sturgeon larvae were caught in the Saint John River in late July 2011. This provides us an indication of upstream spawning location.
- Fish tagged in the Saint John River have been found in the Minas Basin, Musquash estuary, and passing the Halifax line.

Engineering:

- In collaboration with VEMCO we have demonstrated that the VEMCO VPS 3-D acoustic tracking array design is effective for accurate 3-D tracking fish with minimal error (metres) on a scale of kilometers in a Macro Tidal Estuary.
- In the Stokesbury lab we have developed a method for leadering popup archival tags to Atlantic sturgeon that will reduce premature detachment of tags.
- 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.
- Taggart, Litvak, and HQP are working with to combine pop-up archival tag ability with the capacity to measure acceleration. If successful this will create an innovative solution to determining long term energy (and therefore somatic and reproductive potential) budgets for highly mobile animals. Creation of this tag would not only be of high significance to the scientific community but also of great interest to the Canadian and international animal tracking industry.

- Tagged sturgeon moving through the Minas Passage, an area scheduled for Tidal Power turbine infrastructure deployment in 2012, have provided information on seasonality, depth preferences and tidal transport. This information is central to the design, deployment and operation of hydro power turbines in the Minas passage. Information will also inform mitigation measures for the industry to reach conservation targets for species of concern.
- Definition of critical river reaches of Atlantic sturgeon within the Saint John River are required to manage flow rates at NB Power's hydroelectric facilities. Information on habitat utilization can be used to inform decision makers on management of water flow at the Maqtaquac dam that will minimize impact on Atlantic sturgeon.

7. Difficulties encountered

In 2012, two tagged Atlantic sturgeon were captured and harvested by commercial fishers shortly after the tagging event. Tags were redeployed later in the summer in an effort to avoid recapture. This caused interference with data collection as well as creating additional expenses and labor.

Difficulties recovering pop-off tags in Bay of Fundy because of transmission failures and fog.

8. Networking and outreach

Intra-Network Collaboration and Partner Meetings

This work could not be completed without the Network approach. Research projects are discussed and moved forward by all PI's in the program. Student input in experimental design is incorporated. The research performed in this program is centred around building on capacity of OTNC and OTN Global. Technology is discussed with OTNG technicians, and data collection and storage with OTNG data management. Large scale arrays that add important added value to our research are provided by other OTN collaborators. Questions fundamental to diadromous life history are now being developed with assistance of other OTNC arenas including animal trackers, oceanographers, and social scientists. The network approach has not only significantly accelerated our learning curve with respect to the biology and migration of Atlantic sturgeon, it is facilitating scientific enquiry on a broader scale that would not be possible without the OTN Network.

New Synergies and research opportunities – Stokesbury's student (Beardsall M Sc) travelled to Quebec in 2011 to perform field work and be trained in blood chemistry sampling and analysis with Dr. Steve Cooke's lab at Carleton university. Beardsall has returned that knowledge in 2011 and now 2012 to the Stokesbury and Litvak labs where he has trained other students in sampling techniques. Steve Cooke is on Beardsall's committee and more interaction between labs will be forthcoming. Stokesbury and Dadswell are working with Fast and his student (Donovan – Funded by UPEI) to examine parasite load and blood indicators of vitality for Atlantic sturgeon. In addition, DNA samples were shipped to Wirgin (NYU) and King (USCS) and they are using the information discovered to enter the debate in the United States on the status of US Atlantic sturgeon stocks (NMFS),

Litvak and his M.Sc. student, A. Taylor (Mount Allison University, OTN Atlantic), and Beardsall and Logan-Chesney (Acadia HQP) developed linkages with Broell (M.Sc. Dal, OTN Atlantic) and Taggart (Dal, OTN Atlantic). They jointly carried out a series of accelerometer swim trials on shortnose sturgeon at the Mactaquac Hatchery (DFO, New Brunswick; Litvak's lab has 200+ sturgeon there) in May/June 2011. Also, they deployed accelerometers on sturgeon in connection with an NSERC Engage grant (Stokesbury Acadia and Woods Instrument Concepts Inc.) in the Minas Basin. This work could not have

been accomplished without this collaborative effort. Broell was provided access to these fish and the facilities rented by the Litvak lab. Litvak's lab also provided a field assistant during the swim trials and field work, while Broell provided the necessary accelerometer equipment, expertise of equipment usage and experimental protocol. The high-resolution accelerometer data on activity, swimming and burst acceleration collected will be used to determine optimal sampling frequencies for shortnose and Atlantic sturgeon for certain parameters of interest (size-at-age scaling parameter, parameters for activity patterns and energy budgets).

This linkage between two groups within OTNC provides the opportunity to develop a larger collaborative effort. We are working on the development a longer-duration tag with the optimal frequency for the field to be used for tagging Atlantic sturgeon in the Saint John River. For this collaboration between Litvak, Broell, Taggart, and Taylor (M.Sc. student Litvak's lab) are using Pop-up Satellite Tags (Desert Star Systems, LLC) in combination with accelerometer tags and V9 tags to assess activity patterns and movement of sturgeon species in the Saint John River. They used these tags for short-term field trials on shortnose sturgeon prior to attachment for a longer study on Atlantic sturgeon. This collaboration benefits both labs. Broell's studies will be able to test the size-at-age and acceleration hypothesis as well as the relations between acceleration and activity/energy budgets. Taylor and Litvak's work will benefit from this novel application by adding information to sturgeon behavior that was previously limited to migration routes, and location detection. With the use of accelerometers more in-depth behavior (swimming, bursting activity, feeding, spawning etc.) can be developed to better understand habitat utilization and migration.

Since we became part of the OTN network other researchers discovered our work through web sites, meetings and publications and asked to collaborate in the study. This has dramatically expanded the scope of our work with little extra effort and led to numerous cross disciplinary relationships. We have provided these researchers with samples and/or ship time for them to sample and this has expanded all our research and publication opportunities. Ours and their students have benefited in the planning and coordination of the combined research activities and have expanded the exchange of information and data: our students learned about parasites and DNA research; and their students saw how to sample and acoustically tag what seemed to them were extremely large fish, and handle them in a research atmosphere.

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. The OTN was meant to provide a framework for collaborative research that would be expanded and provide an economy of scale of infrastructure to allow researchers to answer important questions. Our project continues to expand research collaborations and answer important questions relevant to OTNs original goals.

Nationally 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), and the industrial level (see above, i.e. McLean VPS tracking, Litvak and Taggart tag development). 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., McLean term in Australia, Heuple and Simpendorfer at James Cooke University and Beardsall term in Australia with Sean Tracey at the University of Tasmania).

The OTNC sturgeon project has deployed infrastructure in the Saint John River, the Minas Passage and the Minas Basin. This has provided information for researchers to reach objectives of the sturgeon project; it has also positively impacted other projects as we have gained tracking information on Spiny Dogfish (Campana, DFO), striped bass and American eels (Broome and Redden, Acadia) The Saint John array has also served other researchers tracking fish on the on the Saint John River. We were pleased to report tag information to Rod Bradford (DFO) and Allen Curry (UNB) for their tracking programs on striped bass. We have also formed collaborations with UPEI Veterinary school (Dr. Fast, parasites), New York University (Dr. Wirgin Microsatellites DNA) and the USGS (Dr. King mitochondrial DNA) and the Atlantic States Marine Fisheries Commission (Status of Atlantic sturgeon in the USA).

International:

Stokesbury, M. J. W. 2012. Electronic tagging of giant Atlantic bluefin tuna in the Gulf of St. Lawrence, Canada, in collaboration with the global Ocean Tracking Network. Invited Lecture, University of Cadiz, Spain, May 2012

National:

Beardsall, J.B., M.F. McLean, S.J. Cooke, B.C. Wilson, M.J. Dadswell, A.M. Redden, and M.J.W. Stokesbury. (2012) Consequences of Incidental Otter Trawl on Atlantic Sturgeon *Acipenser oxyrinchus* in Minas Basin. Abstract accepted for poster presentation at opening of the Acadia Tidal Institute, Wolfville, Nova Scotia.

Beardsall, J.B., S.J. Cooke, and M.J.W. Stokesbury. (2012) Consequences of Capture on Survival and Physiological Status of Atlantic Sturgeon in Minas Basin, Nova Scotia. Abstract accepted for oral presentation at 2nd Annual Ocean Tracking Network Canada Symposium.

McLean, M.F., Simpendorfer, C.A., Heupel, M.R., Dadswell, M.J., Stokesbury, M.J.W. (2012) Movement patterns of tagged Atlantic sturgeon: what are those fish up to? Abstract accepted for oral presentation at the 2nd Annual Ocean Tracking Network Canada Symposium, Halifax, Nova Scotia

McLean, M.F., Stokesbury, M.J.W., Dadswell, M.J., Smith, F. (2012) Movement, behaviour, and diet of Atlantic sturgeon tagged with acoustic transmitters in the Minas Basin, Bay of Fundy. Abstract accepted for oral presentation at the Canadian Conference for Fisheries Research, Moncton, New Brunswick.

McLean, M.F., Stokesbury, M.J.W., Smith, F., Dadswell, M.J. (2011) Movement, behaviour and diet of Atlantic sturgeon, *Acipenser oxyrinchus*, tagged with acoustic transmitters in the Minas Basin, Bay of Fundy, Canada. Extended abstract accepted for oral presentation at Proceedings of the 9th BoFEP Bay of Fundy Science Workshop, Saint John, New Brunswick and publication In: Protecting the Watersheds and Estuaries of the Bay of Fundy: Issues, Science and Management. T.Wickers, J.A. Percy, P.G. Wells, and S.J. Rolston (Eds). pp. 74-79

Taylor, A.S., S. Usvyatsov and M.K. Litvak (2012). Morphometric differences of shortnose sturgeon and Atlantic sturgeon larvae during early ontogeny. Poster presentation: Canadian Society of Zoologists, Sackville, NB, May 7-11.

*Taylor A., and M.K. Litvak (2012). River-wide movements and fine-scale habitat use of Atlantic sturgeon during spawning migration in the Saint John River, New Brunswick, Canada. Oral presentation: Canadian Conference for Fisheries Research, Moncton, NB. January 5-7.

*Litvak, M., S. Usvyatsov, A. Taylor, S. Blair, and M. Power (2012). The past, present, and future of sturgeons: an elemental analytic approach to better understand and protect. Oral presentation: Canadian Conference for Fisheries Research, Moncton, NB. January 5-7.

+Taylor, A. (2011). Movement patterns, seasonal distribution and habitat use of Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus,* from the Saint John River, NB, Canada. Recipient of the best graduate talk award at the 9th Bay of Fundy Science Workshop, Saint John, NB.

OTNC Regional:

Taylor, A. D., and Litvak, M.K. 2012. Movement and seasonal distribution of Atlantic sturgeon, *Acipenser oxyrinchus*, from the Saint John River, NB, Canada. OTN's second annual conference. June 2012. (Oral presentation)

As noted above, knowledge and HQP transfer has occurred between the OTNC sturgeon project and OTNG international partners (i.e., McLean term in Australia, Heuple and Simpendorfer at James Cooke University and Beardsall term in Australia with Sean Tracey at the University of Tasmania.

Stokesbury was invited to present a lecture at the University of Cadiz on Global OTN, and possibilities for international collaboration in the tagging of Atlantic Bluefin tuna.

As indicated previously, an active collaboration between the Taggart and Litvak labs was developed. Without OTN, we would not have been in the position to initiate this collaboration. The focus of this work is on the development of high-resolution accelerometer data on activity, swimming and burst acceleration. The collected data will be used to determine optimal sampling frequencies for shortnose and Atlantic sturgeons for certain parameters of interest (size-at-age scaling parameter, parameters for activity patterns and energy budgets).

HQP personnel working with Dadswell and Stokesbury worked with HQP personnel of Redden (ACER) and Bradford (DFO) to tag fishes.

Dadswell, Stokesbury and Litvak had 6 extensive telephone conferences to discuss overall objectives and methods for handling the internal acoustic tagging of sturgeon.

Litvak's lab takes the weights and lengths for the Lion's Club Sturgeon Derby which occurs every fall on the Kennebecasis River. This provides us with an opportunity to talk to the public about our work tracking these fish.

9. Dissemination of information and results

Refereed Journal Articles (1 total)- *Accepted/published*

Wirgin, I., Meada, L., Waldman, J. R., Wehrell, S., Dadswell, M. J., and T King. 2012. Stock origin of migratory Atlantic sturgeon in the Minas Basin, inner Bay of Fundy, Canada determined by microsatellite and mitochondrial DNA analysis. Trans. Amer. Fish. Soc. 141: 1389-1398.

Refereed Journal Articles (2 total)- *Submitted*

Beardsall, J. W., McLean, M. F., Cooke, S. J., Wilson, B., Dadswell, M. J., Redden, A. R., and M. J. W. Stokesbury. Submitted. Consequences of incidental otter Trawl capture on survival and physiological Status of threatened Atlantic Sturgeon *Acipenser oxyrinchus.* Transactions of the American Fisheries Society, Submitted August 2012

McLean, M. F., Dadswell, M. J., and M. J. W. Stokesbury. Submitted. Feeding Ecology of Atlantic sturgeon, *Acipenser oxyrinchus* Mitchill, 1815 on the Infauna of Intertidal Mudflats of Minas Basin, Bay of Fundy. Journal of Applied Ichthyology, 21 August 2012

Conference Presentations (11 total) *– Contributed*

Taylor, A. D., and Litvak, M.K. 2012. Movement and seasonal distribution of Atlantic sturgeon, *Acipenser oxyrinchus*, from the Saint John River, NB, Canada. OTN's second annual conference. June 2012. (Oral presentation)

Taylor, A. D., Usvyatsov, S. and Litvak, M.K. 2012. Preliminary results of morphometric differences of shortnose and Atlantic sturgeon larvae during early ontogeny. Canadian society of zoology symposium. May 2012. (Poster presentation)

Taylor, A. D., and Litvak, M.K. 2012. Movement patterns, habitat use, and seasonal distribution of Atlantic sturgeon, *Acipenser oxyrinchus*, from the Saint John River, NB, Canada. Canadian conference for fisheries research. January 2012. (Oral presentation)

Beardsall, J.B., S.J. Cooke, and M.J.W. Stokesbury. (2012) Consequences of Capture on Survival and Physiological Status of Atlantic Sturgeon in Minas Basin, Nova Scotia. Abstract accepted for oral presentation at 2nd Annual Ocean Tracking Network Canada Symposium, June 2012, Halifax, Nova Scotia.

McLean, M.F., Simpendorfer, C.A., Heupel, M.R., Dadswell, M.J., Stokesbury, M.J.W. (2012) Movement patterns of tagged Atlantic sturgeon: what are those fish up to? Abstract accepted for oral presentation at the 2nd Annual Ocean Tracking Network Canada Symposium, June 2012, Halifax, Nova Scotia

McLean, M.F., Stokesbury, M.J.W., Dadswell, M.J., Smith, F. (2012) Movement, behaviour, and diet of Atlantic sturgeon tagged with acoustic transmitters in the Minas Basin, Bay of Fundy. Abstract accepted for oral presentation at the Canadian Conference for Fisheries Research, January 2012, Moncton, New Brunswick.

10. Other contributions and deliverables

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

Stokesbury is a featured scientist in a new National Film Board Documentary. It is currently being filmed and due to be released in 2013. The main focus of this documentary is bluefin tuna but OTNC sturgeon project has been discussed at length.

Invited or contributed open-to-public presentation/contribution.

Litvak's lab participated in the Lions Club annual sturgeon derby on the Kennebecasis River, during which he had the opportunity to talk to the local fishers and sturgeon enthusiasts, and to promote this project and its results.

Stokesbury gave an invited lecture in Cadiz, Spain on OTNG and OTNC.

Internet publishing, portal, blog, electronic publications

Webpages:

- Stokesbury Lab (http://www.acadiau.ca/~mstokesb/)

- Litvak Lab webpage (http://sites.google.com/site/litvaklabsite/Home

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

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

In the Stokesbury lab we have developed a method for leadering popup archival tags to Atlantic sturgeon that will reduce premature detachment of tags.

Litvak and HQP Taylor have developed a procedure that allow 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.

Litvak, Taggart and HQP are working with to combine pop-up archival tag ability with the capacity to measure acceleration. If successful this will create an innovative solution to determining long term energy (and therefore somatic and reproductive potential) budgets for highly mobile animals. Creation of this tag would not only be of high significance to the scientific community but also of great interest to the Canadian and international animal tracking industry.

Tagged sturgeon moving through the Minas Passage, an area scheduled for Tidal Power turbine infrastructure deployment in 2012, have provided information on seasonality, depth preferences and tidal transport. This information is central to the design, deployment and operation of hydro power turbines in the Minas passage. Information will also inform mitigation measures for the industry to reach conservation targets for species of concern.

*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, Taggart and HQP are working with to combine pop-up archival tag ability with the capacity to measure acceleration. If successful this will create an innovative solution to determining long term energy (and therefore somatic and reproductive potential) budgets for highly mobile animals. Creation of this tag would not only be of high significance to the scientific community but also of great interest to the Canadian and international animal tracking industry.

A proof of concept in relation to any of the above

McLean and Stokesbury in collaboration with VEMCO we have demonstrated that the VEMCO VPS 3-D acoustic tracking array design is effective for accurate 3-D tracking fish with minimal error (metres) on a scale of kilometers in a Macro Tidal Estuary.

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.

Analysis of DNA with Dr. Wirgin (NYU, as stated above). Quantification of parasite load and effect on sturgeon vitality with Dr. Fast (UPEI Veterinary College, as above).

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.
- 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. In addition the PI's and HQP have given multiple public presentations on our results and progress. Also, McLean, Roberts and Beardsall (Acadia) have gone from house to house in the entire community of Kingsport to inform residents of our project and to have the opportunity to answer any questions. When deploying large amounts of equipment off a public beach community involvement and input it central to the successful completion of the project.

Civic (e.g. water commission), provincial (e.g. parks), territorial, national and First Nations (e.g. hunter-trapper associations) monitoring/regulatory agencies (e.g. Environment Canada, Fisheries and Oceans, Transport Canada, Parks Canada, etc.) and their scientific, statistical and management branches.

The OTNC sturgeon project provides information on animal behaviour to the Offshore Education and Environmental Research group. OEER is an arms-length provincial government body that provincial that invests in environmental research for ocean energy. Stokesbury is a member of the OEER Environmental Mitigation Advisory Committee, which has monthly meetings for reporting on progress of research.

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 NOAA meeting in Virginia (detailed above) for providing advice to regulators in the US regarding the status of Atlantic sturgeon populations.

Private (e.g. technology firms), corporate (e.g. offshore oil & gas) and NGO (e.g. CPAWS, WWF, etc.) organizations. Describe how the project has helped advance the interests, capabilities, and/or insights of these organizations, including *the betterment of the Canadian economy".*

The Fundy Ocean Research Centre for the Environment (FORCE) board of directors includes CEO's of companies investing in tidal power, scientists, and government representatives. The results of OTNC sturgeon have been presented to this group many times.

Print-media contribution: international, national, local, university, etc.

- News story of research conducted on Atlantic sturgeon in the Saint John River:

  http://www.cbc.ca/news/canada/new-brunswick/story/2012/07/27/nb-monster-fish-sturgeon-research.html. Also published in the Telegraph Journal and the Times and Transcript.

11. Collaborations with Industrial and Government Partners

- Dadswell, Stokesbury and Litvak are all actively involved in research on fish migrations, sturgeon biology and knowledge transfer. Dadswell has been actively involved in research of the effects of hydraulic turbines on fishes. All three partners are teaching undergraduates and supervising graduate students totaling 3 MSc.
- Dadswell, Stokesbury and Redden assist fisheries managers at DFO (Smith, Bradford and Gibson) on questions concerning stock composition of migratory fish species and migration routes.
- Partners include the Acadia Center for Estuarine Research (Anna Redden) which is involved with studying the movements of fishes within Minas Basin and along the NA Atlantic coast and the potential effects of tidal power.
- Dadswell has been involved with the Threatened Resources Section of the NMFS-NOAA in Gloucester, MA (Sarah Laporte and Atlantic States Marine Fisheries Commission) who are examining the coastal movements of Atlantic sturgeon and the status of the species in the United States and whether it should be listed as threatened or endangered.
- Stokesbury is part of the Environmental Monitoring Advisory Committee (EMAC) for in-stream hydropower installations in the Minas Passage. Including Industry and government partners whom have provided funds for tagging of Atlantic sturgeon in the Minas Passage.
- Litvak is a PI on an NSERC strategic grant titled "Historical and current uses of sturgeon: an elemental analytic approach (https://sites.google.com/site/sturgeonecology/home)" using stable isotopes to examine First Nations diets from archeological finds and effect of climate change on sturgeon distributions over the last 4000 years in collaboration with Drs. Sue Blair (UNBF Archeology) and Mike Powers (Department of biology University of Waterloo). Currently, they are working on the following:
    - Collaborating with Breviro and Target Marine sturgeon aquaculture facilities to distinguish between sturgeon products, such as caviar and smoked meat of shortnose, Atlantic and white sturgeon, from wild and aquaculture sturgeon stocks
    - Collaborating with Metepengiag First Nation to acquire specimens of sturgeon remains from ancient settlements in Atlantic Canada in order to characterize First Peoples diet (4000 years before present) and climate change.
- Litvak is currently discussing the possibility of a joint project with the Eel Ground First Nation to examine Atlantic sturgeon past and current distribution in the Miramichi River.
    - Representatives from Fort Folly and Eel Ground First Nation First Nations groups came to be trained in working with sturgeon during the 2012 field season. This will hopefully lead to a larger collaborative effort.

Cash and in-kind contributions from partners for Year 3

Name of supporting organization: **CFI (OTNG)**	**Year 3** 2012
Cash contributions to direct costs of research	$69 800
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$69 800
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **CFI (LOF - Stokesbury)**	**Year 3** 2012
Cash contributions to direct costs of research	$29 000
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$29 000
Is this new funding (acquired during this reporting period)?	

Name of supporting organization: **Acadia University**	**Year 3** 2012
Cash contributions to direct costs of research	$4 500
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	$2 000
4) Field work logistics	$4 000
5) Provision of services	$1 000
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	$6 000
2) Salaries of managerial and administrative staff	$2 500
3) Other (specify): _____	
Total of all in-kind contributions	$20 000
Is this new funding (acquired during this reporting period)?	

Name of supporting organization: **OEER/FORCE**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$5 600
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	$5 600
Is this new funding (acquired during this reporting period)?	

Name of supporting organization: **Mount Allison University**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$13 200
2) Donation of equipment, software	
3) Donation of material	$2 000
4) Field work logistics	$4 000
5) Provision of services	$1 000
6) Other (specify): _____	$42 000
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	$4 000
2) Salaries of managerial and administrative staff	$2 500
3) Other (specify): _____	
Total of all in-kind contributions	$68 700
Is this new funding (acquired during this reporting period)?	

12. Expenditures and Support

Year 3 (2012)

Budget Item	Year 3 (2012)				
	Proposed	**Actual Expenditures** 1 Jan - 30 Sep 2012*	**Total Balance** 30 Sep 2012*	**Projected Balance** 31 Dec 2012**	**Deviation**
1) Salaries and Benefits					
a) Students	$35 460	$22 162	$13 298	$7 616	21%
b) Postdoctoral Fellows	$2 840	$0	$2 840	$2 840	100%
c) Technical/Professional	$0	$0	$0	$0	
d) Other	$0	$0	$0	$0	
2) Equipment or Facility					
a) Purchase or Rental	$1 521	$5 997	-$4 476	-$4 476	-294%
b) Operations/Maintenance	$2 500	$3 947	-$1 447	-$1 447	-58%
c) User Fees	$0	$0	$0	$0	
3) Material and Supplies					
a) Materials and Supplies	$2 000	$1 776	$224	$224	11%
4) Travel					
a) Conferences	$0	$91	-$91	-$91	
b) Field Work	$10 000	$10 112	-$112	-$112	-1%
c) Collaboration/Consultation	$0	$0	$0	$0	
5) Dissemination					
a) Publications	$1 000	$0	$1 000	$1 000	100%
b) Other	$0	$0	$0	$0	
6) Other (specify)					
a) Other	$0	$3 460	-$3 460	-$3 460	
b) Other	$0	$0	$0	$0	
Totals					
Totals	$55 321	$47 544	$7 777	$2 094	

The increase in projected costs of fieldwork reflects the expanded scope of this research and still means that we need to find other funds to cover fieldwork as our costs will still exceed this amount. We did exceed 20% changes in 5 areas of the project. We did not know that we had to submit requests for re-profiling for this grant. We will attempt to do so in the future. All of the changes were executed to ensure the effective execution of the research. This work is time sensitive and it is difficult to track funds while in the field.

1) Salaries and benefits

a) Students – Deviation 21%. Mount Allison--Andrew Taylor received an NSERC PGSM allowing us to allocate more funds from the Mount Allison portion of the salaries and benefits to other cost centers in support of his OTN sponsored M.Sc. research.

b) Postdocs – Deviation 100%. Mount Allison--Sima Usvyatsov (Postdoc) was paid out of another grant rather than OTN. The $2840 was reallocated to other cost centers in support of Andrew Taylor's research.

2) Equipment and facility

a) Purchase and rental – Deviation -294%.

Acadia – We spent more than anticipated on equipment, mostly due to buying equipment to properly describe movement and physical variables of the water column in Minas Basin. This was critical to achieve objectives in the sturgeon VPS study.

Mount Allison – We purchased 3 range test pingers from VEMCO to calibrate the VPS system we set-up in the Saint John River ($937). We also purchased another PIT tag reader and tags to place in the sturgeon.

b) Operations and Maintenance – Deviation -58%. Litvak (Mount Allison) had to spend $1717.08 on repairs to the second boat (Logic 110/130HP) we used for the recovery of the PSAT tags in the Bay of Fundy. This was an unanticipated but welcomed expenditure as we recently came into possession of this boat that allows us to recover PSAT tags when they are released off shore. The repairs were done to make the boat seaworthy and to repair the trailer after a minor boating launch accident while working on the OTN project in the Bay of Fundy.

4) Dissemination Costs

100%. We did not spend this $1000 on publication costs and would like to reallocate this to other cost centers in this project.

6) Other – No deviation seemed to show in the formula because the proposed was 0 (see spreadsheet formula). However, we would like to explain the expense. Litvak (MTA) hired a commercial fisher to help Andrew Taylor and his RA's to catch Atlantic sturgeon on the Saint John River. This was crucial to our ability to capture and tag fish in the Saint John River.

How the remaining Projected Balance of Year 3 on 31 Dec 2012 will be spent

$2094 is left from 2012 that will be carried over to 2013.

Whether Year 2 (2011) actual expenses for October-December were on target with what was forecast in last year's report

There was a greater than 20% deviation in student salary (app $7k) and purchase or rental (app $6k). We had predicted that we would have a carryover but virtually all funds were spent on time as originally planned. Costs were greater for student support at both Acadia and MTA. This was due to increased demand for student time to deal with large amounts of metadata submission and data storage, and less departmental support for graduate students than predicted; this was due to increased numbers of graduate student in Biology and therefore diminishing resources per student. Purchase costs were larger than predicted as increased amounts of oceanographic sampling equipment were purchased to provide physical data sets to correlate with movement behavior.

Cconference travel budget justifications

We had a cost of $91 for conferences. $60.31 was spent on printing a poster on OTN work that Andrew Taylor presented at the Canadian Society of Zoologists in May 2012. The remainder was spent on dinner for Sima Usvyatsov (Postdoc) and Andrew Taylor (M.Sc.) at the POKM workshop at Dal.

Year 4 (2013)

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$17 300	$19 394	$0	-12%
b) Postdoctoral Fellows	$0	$0		
c) Technical/Professional	$0	$0		
d) Other	$0	$0		
2) Equipment or Facility				
a) Purchase or Rental	$0	$0		
b) Operations/Maintenance	$1 900	$1 900	$0	0%
c) User Fees	$0	$0		
3) Material and Supplies				
a) Materials and Supplies	$1 000	$1 000	$0	0%
4) Travel				
a) Conferences	$2 000	$2 000	$0	0%
b) Field Work	$8 000	$8 000	$0	0%
c) Collaboration/Consultation	$0	$0		
5) Dissemination				
a) Publications	$1 000	$1 000		0%
b) Other	$0	$0		
6) Other (specify)				
a) Other	$0	$0		
b) Other	$0	$0		
Totals				
Totals	$31 200	$33 294		

Acadia - Salaries and benefits – Students - One M.Sc. student at Acadia University in Year 4 funded for 6 months ($8,650). This student will continue with field work and analysis of data from years 1-3 and assist in writing up a manuscript on sturgeon environmental preferences (including depth) as they move through the Minas Passage, an area scheduled for tidal power turbine deployment and operation **(Total = $8,650).**

Acadia - Operations and maintenance - Batteries for Atlantic sturgeon receivers ($950/year). We have 3 years worth of tagged sturgeon (100+) with acoustic tags still active so hydrophone deployment and operation must continue through year four **(Total = $950)**

Acadia - Materials and Supplies – Ink for printer ($400) paper for printer ($100). **(Total = $500)**

Acadia –Travel - Conferences – Montana McLean will present sturgeon project tagging results at the Canadian Conference For Fisheries Research meeting in Ontario in 2013 **(Total = $1,000)**

Acadia – Field work - Housing in Five Islands for 6 weeks = $1,000; Food $800; Mileage $1,000; Fuel (truck rental and fuel) = $1,200. (**Total = $4,000)**

Acadia – Publication cost- Page charges and color figure charges for Marine Ecology Progress series submission concerning sturgeon movement through Minas Passage. **(Total = $500)**

Mount Allison - Salaries and benefits – Students - One M.Sc. student at Mount Allison University in Year 4 funded for 6 months ($8,650). This student will continue with field work and analysis of data from years 1-3 and will finish writing manuscripts on river and ocean movements of Atlantic sturgeon from the Saint John River. Partial funding of 1 undergraduate assistant to help in the field ($2094) **(Total = $10,746).**

Mount Allison - Operations and maintenance - Batteries for Atlantic sturgeon receivers ($950/year). We have tagged Atlantic sturgeon over the past 3 years during their spawning runs. We need to keep monitoring the river to be able to detect if these fish come back to spawn during year 4 of the project. This information is key to understanding their spawning periodicity. Thus hydrophone deployment, operation and tracking must continue through year four **(Total = $950)**

Mount Allison - Materials and Supplies – Rope, weights and locks for deployment of receivers. **(Total = $500)**

Mount Allison –Travel - Conferences – Andrew Taylor will present at the World Sturgeon Conservation Society meeting in Victoria, BC, during July 2013. **(Total = $1,000; Litvak will find the rest from other funds)**

Mount Allison – Field work – Mileage, gas for boat, food and camping costs (**Total = 4,000).**

Mount Allison – Publication cost- Page charges for Transactions of the American Fisheries Society publication. **(Total = $500)**

Deviations between the Original and Revised year 4 budget

No large deviations from original budget justification needed. However, while less than a 20% deviation, we do report an increase of $2094 to be carried over from 2012 to 2013 in salaries. This will be directed to MTA to help to defray a portion of the salary for a student research assistant during the summer.

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

I. Atlantic Arena

1. Project Numbers: I.2.4 and I.2.5

2. Project Titles: Grey seals (*Halichoerus grypus*) as Bioprobes: Predicting Impacts on their Ecosystems, and, Design Principles for OTN and Climate Change Impacts on Leatherback Turtle (*Dermochelys coriacea*) Foraging and Distribution.

3. Project Leaders: S. Iverson, J. Mills Flemming (Dalhousie), D. Bowen (BIO-DFO Dalhousie)
Collaborators: L. Comeau (DFO NB), K. Fennel, J. Sheng, K. Thompson (Dalhousie), M. Hammil, D. Swain (DFO Gulf Region), M. James (BIO-DFO)

4. Public Summary of Report

The prey of top marine predators such as seals is patchily distributed. The way in which such predators search for this food is not well understood but has important implications for understanding the impact predators may have on their prey. This study is concerned with examining interactions between the Atlantic grey seal and two fish species of conservation, i.e. Atlantic salmon, and commercial interest, i.e. Atlantic cod, using acoustic telemetry. Each year between 2009 and 2012, 15-20 grey seals have been tagged on Sable Island with acoustic transceivers and GPS tags, for a total 74 individuals. The acoustic transceiver transmits a unique acoustic code and records unique codes from other acoustically tagged animals, such as other seals and fish. The GPS tag records the geographic location of the animal, but also records light level, sea temperature, and depth during diving. During the same period, 427 Atlantic cod were tagged on the Eastern Scotian Shelf and in the southern Gulf of St. Lawrence with acoustic transmitters. Of the 74 grey seals equipped with tags, data have been retrieved from 49 and a further nineteen seals will be recaptured in December 2012. Encounters between grey seals and three species of fish, namely Atlantic cod, Atlantic salmon and Atlantic bluefin tuna have been recorded. None of these encounters indicated predation, but do indicate co-occurrence that provides the opportunity for predation or feeding on similar prey.

Surprisingly, approximately 4,000 detections have been recorded among tagged seals implying that grey seals are associating with one another while at sea. This result was entirely unexpected, given that it has been assumed that grey seals forage independently, and may have important implications for our understanding of the spatial distribution of grey seal predation. Because of the spatial and temporal nature of these interactions, the analysis of these types of data is difficult and has required the development of new statistical and visualization tools. These tools are being developed and to date have demonstrated a link between the spatial distribution of seal-seal encounters, water depth and distance from Sable Island.

Understanding the detection performance of the acoustic transceivers is critical to the interpretation of the spatial and temporal pattern of seal-seal and seal-prey interactions. Preliminary examination of the detection range of the acoustic receivers indicates that most occur at distances of between 200 m and 325 m, although there is substantial variability. The bottom depth and the seals' travel rate appear to

have little influence on detection rates. The intention is to examine the influence of other environmental and behavioural variables. A better understanding of detection distance and the factors influencing detection distance are needed as input to simulation studies aimed to improve the design of OTN tagging studies. The use of grey seals as bioprobes, equipped with acoustic telemetry and GPS tags, has proven to be an effective new tool to better understanding their foraging ecology and interactions with prey species in an otherwise inaccessible environment.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Laurie Baker	MSc	100%	60%	1 Sept 2012 – 30 Sep 2012
Thesis topic: examination of factors that influence VMT detection efficiency				
Stuart Carson	MSc - PhD	80%	50%	1 Oct 2011 – 30 Sep 2012
Thesis topic: Spatial point process analysis of at sea seal encounters				
Joey Hartling	BSc	75%	88%	1 Oct 2011 – 30 Dec 2011
Thesis topic: Seal-Cod Interaction simulation using the R programming language				
Susan Heaslip	PhD	15%	0%*	1 Oct 2011 – 30 Sep 2012
Thesis topic: optimal foraging ecology of grey seals				
Ian Jonsen	RA	100%	80%	1 Oct 2011 – 30 Sep 2012
Topic: detection efficiency of VMTs, monitoring and analysis of receiver line efficiency, mark-recapture models for tagged Atlantic salmon, modeling animal-tracking data				
Shelley Lang	PDF/RA	20%	20%	1 Oct 2011 – 30 Sep 2012
Topic: combining dietary data and grey seal habitat use				
Damian Lidgard	PDF/RA	80%	80%	1 Oct 2011 – 30 Sep 2012
Topic: encounters between grey seals and their prey and at-sea social interactions amongst grey seals				
Sarah AL Shaghay	Technical Assistant	33%	33%	1 Oct 2011 – 30 Sep 2012
Priyanka Varkey	BSC Honours	50%	0%	1 Sept 2012 – 30 Sep 2012
Thesis topic: movement patterns of cod using detections from acoustic receiver lines				
Kim Whoriskey	USRA	50%	0%	1 Jun 2012 – 31 Aug 2012
Thesis topic: compiling and summarizing environmental data collected by grey seals				

***Note: S. Heaslip held a NSERC PSG2 Fellowship providing full external stipend.*

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

6. Progress towards Objectives/Milestones (1 Jan 2010 – 30 Sept 2012)

The objectives stated in the original SNG proposal over a 7-year period were as follows, with some aimed to be achieved in Phase I of this SNG and others to be achieved in Phase II:

1) To examine the hypothesis that grey seals are responsible for the high levels of natural mortality among adults in two declining and depleted Atlantic cod stocks, southern Gulf of St. Lawrence and Eastern Scotian Shelf;
2) To determine the extent to which grey seals contribute to ocean mortality of Atlantic salmon smolts;

3) To provide data on grey seal foraging locations to help validate behavioural state space switching models;
4) To collect fine (<500m) and meso-scale information on the distribution and movements of prey species that have been tagged with coded acoustic tags;
5) To test the hypothesis that grey seal movements and search/foraging behaviour are conditioned by oceanographic current field;
6) To determine what oceanographic features are associated with habitats heavily used by grey seals;
7) To determine how much of the seasonal changes in sex-specific habitat use by seals is explained by seasonal changes in oceanography; and
8) To develop predictive models of habitat use that incorporate physical/biological oceanographic features such as temperature, bathymetry, currents, prey biomass and diversity;
9) To predict the probabilities of encounter between grey seal bioprobes and acoustic-tagged species (e.g. Atlantic cod, Atlantic salmon) using a spatially-explicit simulation model;
10) To estimate encounter rates and spatial density of acoustic-tagged species;
11) To develop statistical (e.g. mark-recapture) methods for estimating movement rates and survival of acoustic-tagged species;
12) To estimate functional relationships between leatherback turtle movement behaviours and the bio-physical environment. (*Note: this component has been currently suspended due to withdrawal of collaborators from the Canadian Sea Turtle Network*.)

During the period covered by this report, progress was made toward the objectives 1 – 11.

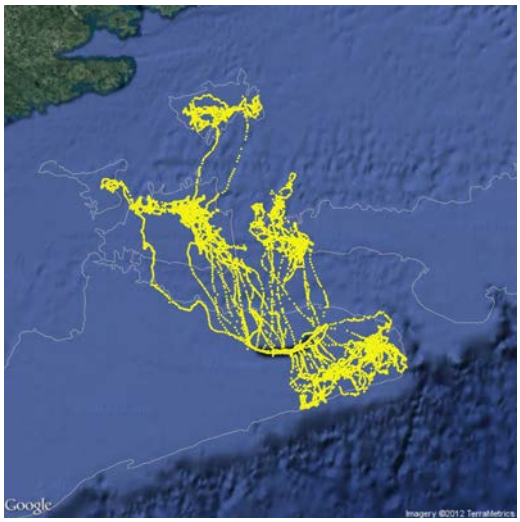
1) To examine the hypothesis that grey seals are responsible for the high levels of natural mortality among adults in two declining and depleted Atlantic cod stocks, southern Gulf of St. Lawrence and Eastern Scotian Shelf;

2) To determine the extent to which grey seals contribute to ocean mortality of Atlantic salmon smolts;

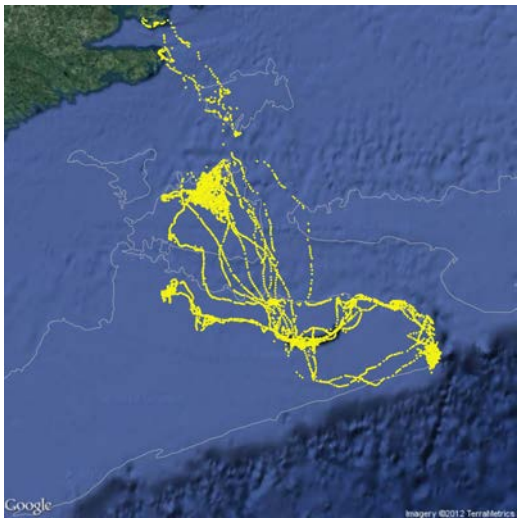
3) To provide data on grey seal foraging locations to help validate behavioural state space switching models;

In June 2011, we deployed VEMCO Mobile Transceivers (VMT) and Wildlife Computer Satellite-GPS transmitters on 20 female grey seals on Sable Island. The deployment was much earlier than in previous years (October in 2009 and September in 2010), to provide a longer period of data collection to allow us to examine seasonal changes in behaviour. Between December 2011 and January 2012, 16 seals were recaptured and instruments recovered, while four individuals did not return to Sable Island and thus could not be recaptured. Data from the satellite-GPS tags support our previous observations that grey seals focus their foraging activity on offshore banks on the Eastern Scotian Shelf (Fig. 1).

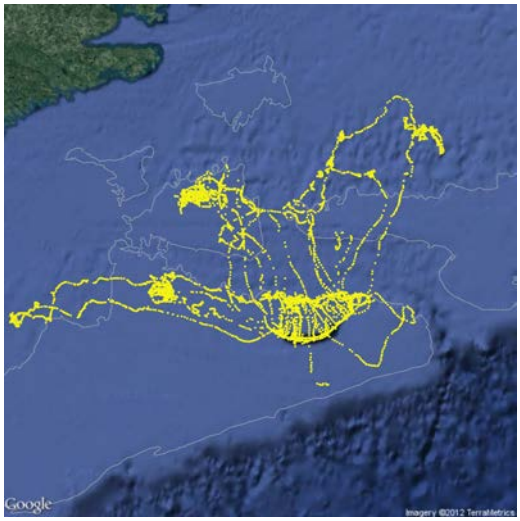
Once again, S. Heaslip spent several weeks on Sable Island in January learning techniques for handling a large marine mammal and deploying scientific devices. D. Lidgard and S. Lang participated in and helped run both field camp seasons. Data from the VMT tags showed detections from several species of acoustically tagged fish (Table 1, Fig. 2), namely Atlantic cod (tagged by Sean Smith and Éliane Aubry, DFO), blue fin tuna (tagged by B. Block, Stanford University) and salmon (both smolts and kelts, tagged by J. Carr, Atlantic Salmon Federation).



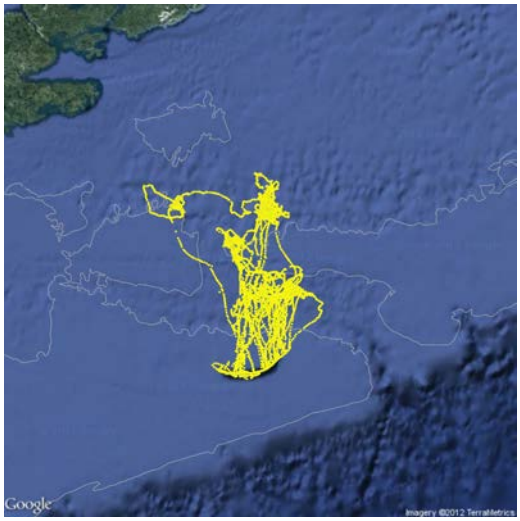
Seal S0756



Seal K11



Seal S0757



Seal S0753

Figure 1. Movement paths of four female grey seals between June 2011 and January 2012. Canso peninsula is shown in the upper left corner of each figure.

Table 1 Species and number of fish detected by tagged grey seals on Sable Island 2011

Date of deployment	Seal Id	Species detected	Number of fish detected	Number of detections
June-2011	S0751	Atlantic salmon	3	38
		Atlantic cod	3	5
		Bluefin tuna	2	8
June-2011	E87	Atlantic cod	1	13
June-2011	K11	Atlantic cod	7	50

These seal-fish encounters, along with those from 2010, not only strengthen the proof of concept for this new technology but also provide novel data on seal-fish interactions. Firstly, the patterns of seal-fish detections suggest that seals did not predate on the tagged fish providing support to previous and concurrent diet studies that show cod are in general a minor component of the grey seal diet. Results from the 2013 recoveries in addition to future planned deployments of seals and cod, as well as other potential prey, will provide important insight into these debates. Secondly, the detection of blue fin tuna by grey seals tagged in 2010 and 2011 suggests that these two species may share common prey or foraging areas. Interestingly, one of the tuna was detected in both years by two different seals. Another interesting seal-fish encounter involved an Atlantic salmon kelt, which was detected on multiple occasions during a one month period, again suggesting the sharing of a common resource. However, it is acknowledged that these sample sizes are small and that it is not yet possible to generate firm conclusions. Nevertheless, these data open the door to better understanding predator-prey dynamics, as well as providing new insight into the distribution of tagged fish such as salmon and cod in areas where fixed receiver arrays are not present.

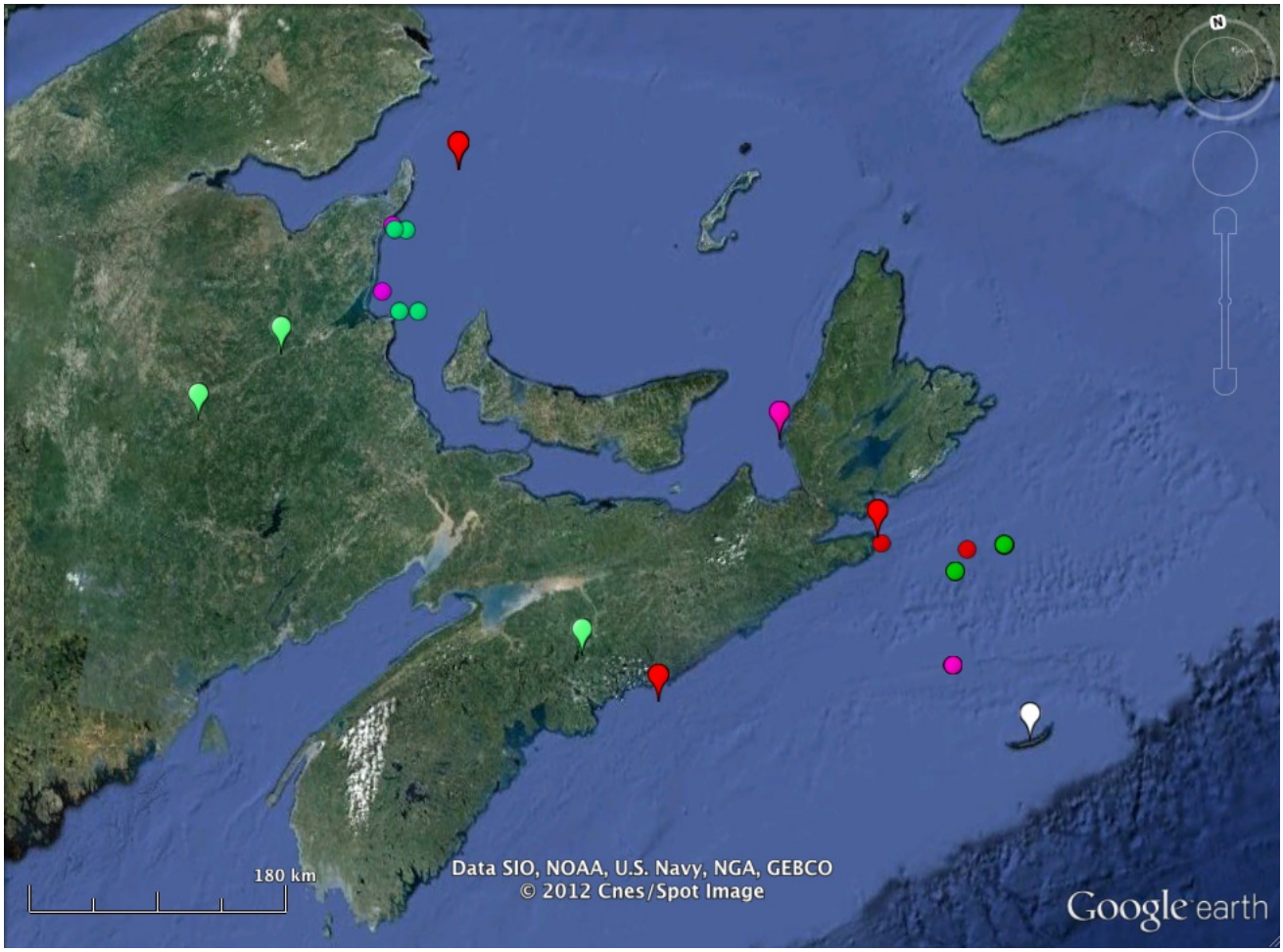


Figure 2. Location of fish tagging (coloured balloons) and seal-fish encounters (coloured dots) for grey seals tagged on Sable Island (white balloon) in 2010 and 2011. Legend: red – Atlantic cod; purple – bluefin tuna; green - Atlantic salmon

The VMTs also collected more data on seal-seal associations (n = 933) and supported our observations from 2009 and 2010 that seal-seal associations are aggregated around offshore banks. These data are very novel and suggest that grey seals either engage in social interactions at foraging spots, perhaps to enhance foraging success, or that competition for food at these spots is sufficiently high to generate chance meetings of two or multiple seals from a pool of thousands of individuals. At the onset of this study we did not expect to discover that seals associate with each other while at sea. These data add important value to this project through contributing toward our understanding of the dynamics of seal foraging behaviour and the spatial-temporal impact on or interactions with their prey resources. A manuscript focused on seal-seal associations from the first year of deployment (2009-2010) will be published in Nov 2012 by the scientific journal Plos ONE.

In June 2012, we deployed six grey seal males and 11 females on Sable Island with the same configuration of tags as in previous years and these will be re-captured in December 2012/January 2013 to retrieve instruments and download data. From examination of ARGOS data, four of these females have spent considerable time in the southern Gulf of St. Lawrence and thus have the potential of encountering the 200 cod tagged in 2009-2010 for this study.

In early October 2012, we will deploy three prototype Bluetooth enabled VMTs and GPS-satellite tags on three adult females. These tags were developed this year through collaboration between PIs, Co-PIs and HQP, and VEMCO and the Sea Mammal Research Unit (SMRU), St. Andrews, Scotland. The tags differ from those deployed to date in that the detection data from the VMT can be remotely transferred, via Bluetooth technology, to the GPS-satellite tag and then uploaded by orbiting ARGOS satellites for data retrieval. The advantage of this configuration is that there is no requirement to retrieve the tags to recover the data which will allow us to deploy VMTs on seals from locations other than Sable Island where one is unable to recapture seals during the breeding season or other parts of the year, e.g. Hay Island, Cape Breton or the southern Gulf of St. Lawrence. These future deployments will broaden our geographic coverage of seal-fish and seal-seal associations to form a dataset that is better representative of the grey seal population. Given that 80% of the grey seal population resides on Sable Island, in future years we will continue with deployments from there in addition to these new sites. The disadvantage of this configuration is that there is a limited bandwidth for uploading data from the tag to satellites. The outcome of this restriction is that uploads will comprise of summaries of the detection data rather than the archived raw data which is obtained upon tag retrieval. To evaluate the extent of loss in detail and potential consequences, we intend to recover the three Bluetooth enabled instruments during the 2013 breeding season on Sable Island and compare the archived data with that uploaded via satellite. Due to the nature of this project it is unlikely that this loss of detail will impact our understanding of seal-fish interactions. Nevertheless, the comparisons of archived and satellite uploaded data will allow evaluation and perhaps calibration of uploaded data quality for future deployments. It is also planned that this beta-testing will provide input and encouragement to industry suppliers (VEMCO and SMRU) to develop fully integrated VMT tags, which will allow this "bioprobe" technology to be used in other marine species (both within OTN Canada and beyond) that are large enough to carry these instruments (e.g., sturgeon, sharks, other seal and marine mammal species).

Two hundred Atlantic cod have been tagged with V13 transmitters in the Southern Gulf of St. Lawrence (in 2009 and 2010 by Doug Swain, DFO Gulf region and Luke Comeau, DFO NB), and 200 have been tagged on the Scotian Shelf (in 2010 and 2011 by Sean Smith, DFO Atlantic region). In March 2012 another 25 cod were tagged (by Sean Smith) close to Canso Bank and in November 2012 we intend to deploy another 150 V13 tags. The location for tagging cod has been influenced to a great extent by the costs of ship time, likelihood of capturing cod (from previous surveys or local knowledge), and the likelihood of tagged seals encountering the cod.

Another ten V13 VEMCO acoustic transmitters were deployed and anchored in place (Canso Bank) to allow us to better understand the performance of the VMTs with respect to detecting acoustic tags. VMTs from six seals collected 207 detections from four of the eight V13 transmitters anchored on Middle Bank (deployed in 2010). We expect more detections to be collected in future seal deployments to form a dataset of sufficient size for an analysis on VMT detection performance, again to provide calibration information for current and future studies using VMTs as either fixed receivers (e.g. in the Arctic, projects II) or as roaming receivers attached to bioprobes or roboprobes (gliders); see also below (9)).

4) To collect fine (<500m) and meso-scale information on the distribution and movements of prey species that have been tagged with coded acoustic tags;

In addition to the detections of Atlantic cod collected by VMTs deployed on seals, ~164,000 detections have been collected by fixed receiver arrays on the eastern Scotian Shelf, mostly from the Cabot Strait Line, since 2009. These data are currently being analysed by P. Varkey (Dalhousie Biology honours student) to reveal movement patterns of Atlantic cod on the eastern Scotian Shelf and southern Gulf of

St. Lawrence, according to the time of year and oceanographic variables. Given the paucity of data on cod movement, particularly on the eastern Scotian Shelf, these data are extremely valuable and will contribute toward understanding the distribution of cod, relative to that of grey seals, as well as cod stock structure.

5) To test the hypothesis that grey seal movements and search/foraging behaviour are conditioned by oceanographic current field;

6) To determine what oceanographic features are associated with habitats heavily used by grey seals;

Stuart Carson's M.Sc. research proposed modeling the seal encounters as spatial point patterns. This work successfully demonstrated the effectiveness of these techniques for formally testing biological/ecological hypotheses of interest (e.g. do certain grey seals show a preference to forage on particular areas of the Scotia Shelf, very shallow banks, for example?).

7) To determine how much of the seasonal changes in sex- specific habitat use by seals is explained by seasonal changes in oceanography; and

8) To develop predictive models of habitat use that incorporate physical/biological oceanographic features such as temperature, bathymetry, currents, prey biomass and diversity;

These four objectives rely on the availability of fine-scale oceanographic data from the eastern Scotian Shelf and southern Gulf of St. Lawrence. These data are being generated from the GPS-satellite tags carried by the seals. Each tag records sea temperature, light, and depth every 10 seconds for the entire deployment period, thus collecting detailed oceanographic data during the course of their movement history. To address the four questions above, these data along with data on seal movements and habitat use, need to be incorporated into oceanographic models. To achieve this, the sensors on the tags must be calibrated against standard oceanographic equipment. In collaboration with PhD student Karl Bryan Lagman, Richard Davis, Katja Fennel and John Cullen (projects I.1) from the Department of Oceanography, Dalhousie, five of the GPS-satellite tags have been deployed in the Bedford Basin alongside a sampling device collecting a full suite of bio-optical measurements. Day-long deployments occur on a weekly schedule that began in March 2012 with the objective to calibrate the tag sensors. K.B. Lagman is currently examining these data and testing whether data from seal tags can be used as a proxy for primary production (I.1.2), the techniques of which will eventually be used in Phase II to add ocean productivity data to inform measurements of animal movements.

9) To predict the probabilities of encounter between grey seal bioprobes and acoustic-tagged species (eg. Atlantic cod, Atlantic salmon) using a spatially-explicit simulation model

Led by I. Jonsen, we are examining the detection efficiency of VMT's through analysis of both the VMT detection data and GPS tracking data obtained from tagged grey seals. The high-resolution GPS data provide an expected number of seal-to-seal (or VMT-to-VMT) detections that are compared to the actual seal-to-seal detections obtained via the deployed VMT's (Fig. 3). We fit preliminary models (GAMMs) to the observed vs. expected detection data to understand how detection efficiency varies as a function of seals' travel rate, distance between VMTs and bottom depth. These preliminary models indicate that the proportion of observed detections declines predictably with distance between VMT's (within an assumed detection radius of 0.6 km in 2009 or 1.0 km in 2010) and that bottom depth and the seals' travel rate have little influence on detection rates (Fig. 4).

Significant Deviations from the Original Objectives or Plans

At the onset of this study we did not expect to discover that seals associate with each other while at sea. These unexpected data offer new insights into our understanding of the dynamics of seal foraging behaviour and the spatial-temporal pattern of interactions with prey. We intend to develop this aspect of the project further in Phase II. It is also anticipated that a significant portion of L. Baker's MSc and S. Carson's PhD thesis will be devoted to calibrating VMT performance. The need for this research was not fully appreciated, but it is considered essential to draw reliable ecological/biological conclusions from VMT data. The results from this research will have cross-cutting application to all of OTN.

Coordination and Integration

Regular monthly meetings have been held throughout with co-investigators and all HQP involved in the bioprobe project to formalize all future and expanding aspects of collaborative efforts (authorships, precise division of interrelated projects, etc.).

D. Swain (DFO, Gulf Region) and L. Comeau (DFO, Gulf Region) organized and conducted the surgery on cod in the Gulf of St. Lawrence in 2009 and 2010. S. Smith and D. Bowen (DFO, Maritime Region) were responsible for organizing the cod tagging and Sean Smith conducted the surgery to implant the tags in Atlantic cod on the eastern Scotian Shelf.

Through collaboration between PIs, Co-PIs and HQP, and VEMCO and the Sea Mammal Research Unit, St. Andrews, Scotland a Bluetooth enabled VMT has been developed. This tag differs from those deployed to date in that the detection data from the VMT can be remotely transferred, via Bluetooth technology, to the GPS-satellite tag and then uploaded by orbiting ARGOS satellites for data retrieval. The advantage of this configuration is that there is no requirement to retrieve the tags to recover the data which will allow us to deploy VMTs on seals from locations other than Sable Island where one is unable to recapture seals during the breeding season or other parts of the year. These future deployments will broaden our geographic coverage of seal-fish and seal-seal associations to form a dataset that is better representative of the grey seal population.

J. Mills Flemming is leading a collaboration with W. Oldford (University of Waterloo), an expert in data visualization. W. Oldford visited Dalhousie in January 2012 and presented some initial work on simultaneously visualizing data streams obtained from the VMT and Wildlife Computers SPLASH tag for particular seals. With some formal graduate student support now arranged for a student to be co-supervised by J. Mills Flemming, I. Jonsen and W. Oldfold, this work is anticipated to ramp up again in early 2013.

J. Mills Flemming and I. Jonsen are intending to develop a collaborative research project with S. Bonner (University of Kentucky) to develop mark-recapture models based on acoustic detections from VMTs and receiver lines.

S. Carson's initial PhD research will focus on extending the spatial point modeling to handle temporal dependence of the observations (i.e., acoustic detections). Presently he is learning the R package "INLA" that was developed by Janine Illian (University of St. Andrews) and will attend a course at Dalhousie by the developers. S. Carson, J. Mills Flemming and I. Jonsen will all be in attendance. Concurrent with the above S. Carson will also be investigating the possibility of using spatial point process approaches with data that have been collected by C. Taggart (project I.1.1).

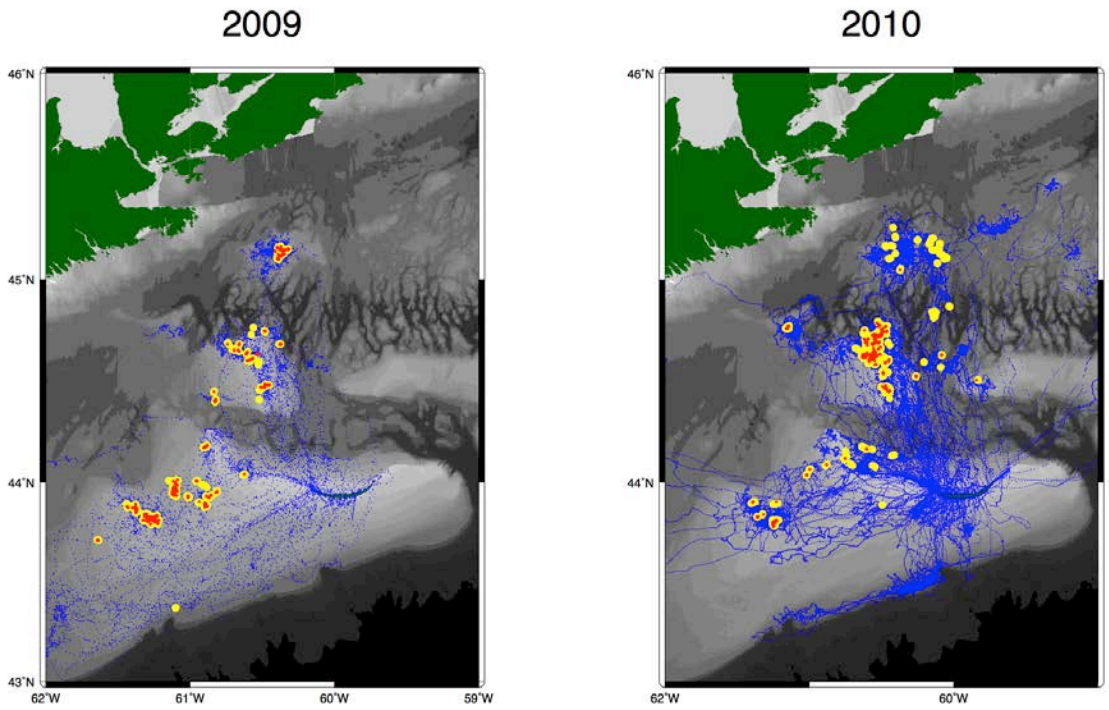


Figure 3. Spatial distribution of observed (red) versus expected (yellow) VMT-to-VMT detections in 2009 and 2010, overlaid on observed GPS locations (hourly resolution in 2009 and 15 min resolution in 2010). To calculate the expected detection from the GPS data, we assumed detection ranges of the VMT's were 600 m (2009) and 1000 m (2010), based on the distances between VMT's that recorded detections.

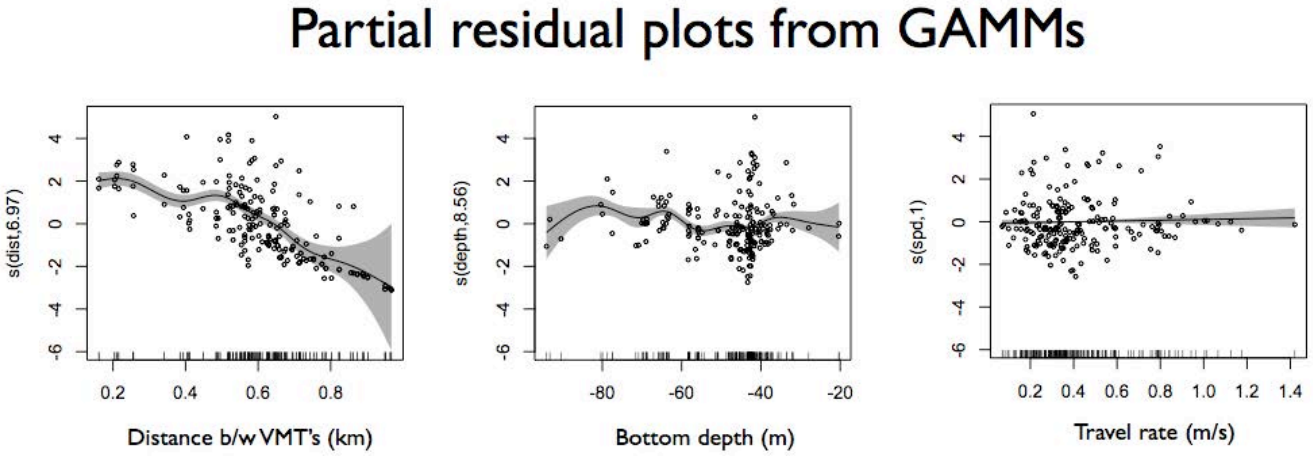


Figure 4. Relationships between the proportion of all potential detections actually recorded by VMT's and the distance between VMT's, the bottom depth at VMT locations, and the travel rate of VMT-equipped seals in 2010. The response and predictors are daily aggregates.

We are currently expanding these models to include likely environmental and behavioural predictors of detection efficiency (i.e. depth of thermocline relative to seals, daily average wind speed, behavioural state of seals - travelling vs. foraging). To this end, K. Whoriskey (NSERC USRA) worked on

compiling and summarizing environmental data collected by the seals via the Wildlife Computers MK10 satellite tags. Our new MSc student, L. Baker, will work on incorporating the summarized environmental and other potential predictors into expanded models that will allow us to better understand the factors that influence VMT detection efficiency. We anticipate a manuscript to be submitted by December 2012.

In 2013, L. Baker will work on general simulation scenarios, informed by results of the VMT detection efficiency study, to explore general principles for deployment of VMTs and acoustic-tags for studying species interactions. Together, these studies provide further important information to current and future studies using VMTs as either fixed receivers (e.g. in the Arctic, projects II) or as roaming receivers attached to bioprobes or roboprobes (gliders).

10) To estimate encounter rates and spatial density of acoustic-tagged species;

Point pattern data analysis techniques enabled MSc student S. Carson (now PhD student) and J. Mills Flemming to link the spatial distribution of the seal encounters, to water depth and to distance from Sable Island. They succeeded in providing statistical evidence of close associations between the locations where seals encounter one another, the distance from their land habitat, and the topography of the ocean floor. They also provided statistical evidence of a sex based difference in clustering behavior. By providing a method by which to not only estimate a mean for the rate at which the seal encounters occur, but to gain some insight into how the seals react to one another when encountered; and to tie these encounters to the physical environment in which they occurred, they clearly demonstrate utility of the approach. This work (S. Carson's MSc thesis) has been submitted to Environmetrics for publication. A second paper, presenting a full analysis of multiple years of encounter data (2009-2012) will be prepared early in 2013.

S. Carson commenced his PhD program on 1 January 2012 and successfully completed his qualifying exams in May of the same year. He then attended a workshop on animal movement modeling in June of 2012 at the University of St Andrews, Scotland that brought together leading researchers within the areas of modeling and analyzing animal movement data. The goal of the workshop was to further research in these areas by developing interesting and novel statistical techniques.

S. Carson's initial PhD research will focus on extending the modeling efforts detailed above so as to handle temporal dependence. Presently he is learning the R package "INLA" that was developed by Janine Illian at the University of St. Andrews. On 22 November 2012 a free INLA course will be offered here at Dalhousie by the developers. S. Carson, J. Mills Flemming and I. Jonsen will all be in attendance. Concurrent with the above, S. Carson will also be investigating the possibility of using spatial point process approaches with data that have been collected by Chris Taggart (project I.1.1). A full PhD thesis proposal will be available in January of 2013.

Undergraduate honours student J. Hartling designed a "Seal-Cod" Interaction simulation using the R programming language. This work was completed in December of 2011. The simulation run time was substantially reduced by re-coding certain portions using the C programming language and dynamically linking it with R. Although much was learned about efficiently performing simulations like these, it is unclear whether this simulation tool will prove particularly useful going forward. More will be known in this regard once L. Baker starts work on the simulation scenarios discussed in (9).

Wayne Oldford (Waterloo) visited Dalhousie in January of 2012 and gave a talk on Data Visualization in which he presented some initial work on simultaneously visualizing data streams obtained from the VMT and Wildlife Computers SPLASH tag for particular seals. With some formal graduate student support now arranged for a student to be co-supervised by J. Mills Flemming, I. Jonsen and W. Oldfold,

this work is anticipated to ramp up again in early 2013. In the interim, the bioprobe team will meet to formalize the biological/ecological requirements of the visualization tools to be developed/extended.

J. Mills Flemming gave a keynote lecture at the International Statistical Ecology Conference in Olso, Norway, in July of 2012. This was an extremely interesting conference and allowed J. Mills Flemming the opportunity to meet face-to-face with a number of leading researchers in statistical ecology including Steve Buckland, Toby Patterson, Len Thomas, Andy Royle, Perry de Valpine, Byron Morgan, Richard Barker Ruth King and Janine Illian. J. Mills Flemming has been in correspondence with a number of these researchers since that time.

11) To develop statistical (e.g. mark-recapture) methods for estimating movement rates and survival of acoustic-tagged species

In collaboration with Fred Whoriskey (1.2.1), I. Jonsen implemented a Bayesian Cormack-Jolly-Seber (CJS) mark-recapture model to estimate out-migration survival rates of Atlantic salmon postsmolts tagged on 3 New Brunswick rivers (Cascapedia, Miramichi, and Restigouche) from 2007 to 2010. The postsmolts cross (or potentially cross) 3 acoustic receiver lines during their seaward migration, the last being the Strait of Belle Isle (SoBI).

Estimating survival during this last leg of their seaward migration is critical to understanding patterns of mortality during this phase of the species' life history, but estimation of survival at the last point of observation is confounded by detection rate in the classic CJS model. To overcome this we take advantage of independent (sentinel tagging) data on the detection efficiency of the SoBI receiver line. We used the detection rate of the sentinel tags as proxies for the detection rate of postsmolts crossing the SoBI line, thereby enabling estimation of postsmolt survival out to this line. In general, survival rates out to the SoBI line were high, but variable across the 4 years of tagging and among the 3 populations (Fig. 5). We anticipate submitting this work to ICES Journal of Marine Science.

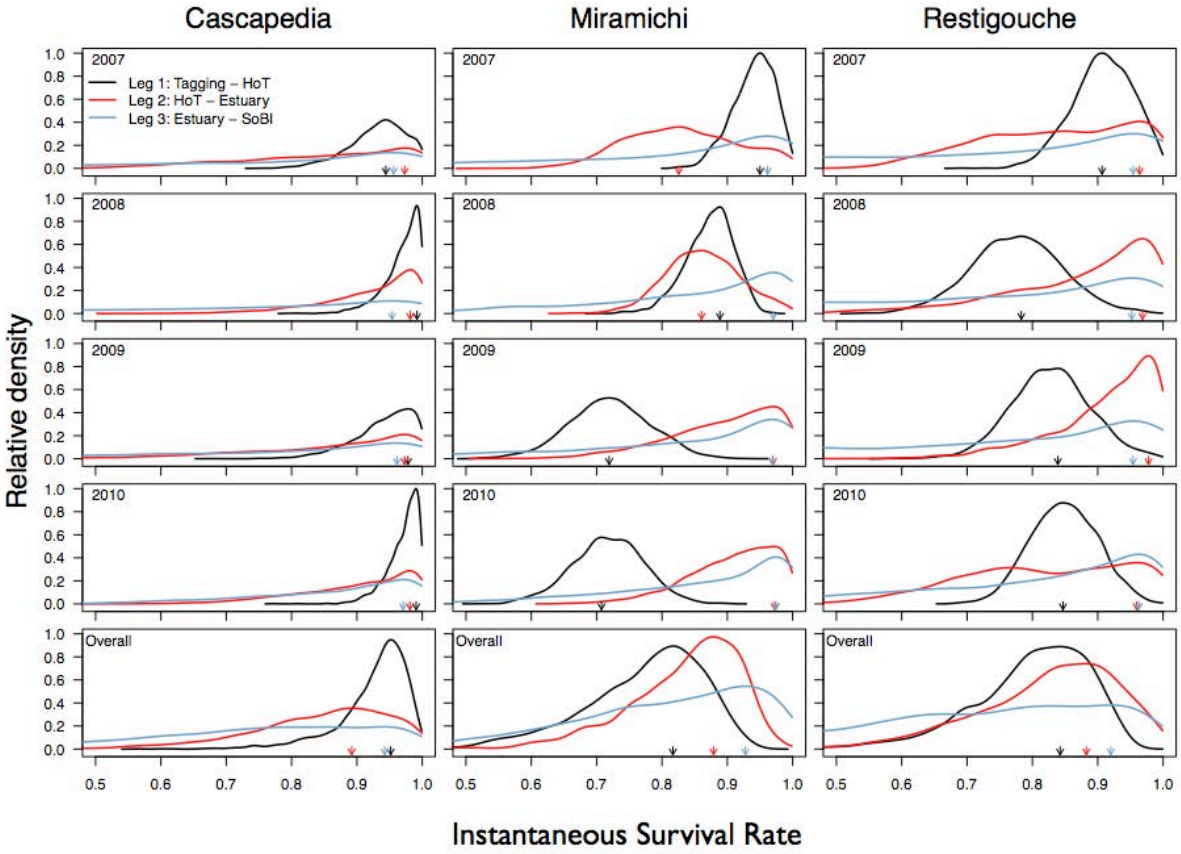


Figure 5. Survival rate estimates from a Bayesian CJS mark-recapture model fit to Atlantic salmon postsmolts acoustically tagged on the Cascapedia, Miramichi and Restigouche rivers in New Brunswick.

J. Mills Flemming has been invited to visit with Simon Bonner at the University of Kentucky in early 2013. S. Bonner is still extremely keen to be involved in the OTN and is an expert in mark-recapture methods. With this in mind, J. Mills Flemming and I. Jonsen are still intending to develop a potential collaborative research project targeted at this objective.

Significant Deviations from the Original Objectives or Plans

N/A

Coordination and Integration

Regular monthly meetings have been held throughout the year with co-investigators and all HQP involved in the bioprobe project to formalize all future and expanding aspects of collaborative efforts (authorships, precise division of interrelated projects, etc.). Joint meetings including oceanography collaborators occur every two months.

Doug Swain (DFO, Gulf Region) and Luke Comeau (DFO, Gulf Region) organized and conducted the surgery on cod in the Gulf of St. Lawrence in 2009 and 2010. Sean Smith and D. Bowen (DFO,

Maritime Region) were responsible for organizing the cod tagging and Sean Smith conducted the surgery to implant the tags in Atlantic cod on the eastern Scotian Shelf.

D. Lidgard, D. Bowen, I. Jonsen and S. Iverson have been in regular discussions with VEMCO and the Sea Mammal Research Unit, St. Andrews, Scotland on the development of a Bluetooth enabled VMT and GPS-satellite tag. The first model of these tags is available for deployment in October 2012.

J. Mills Flemmeing, I Jonsen and S. Iverson regularly meet on the development of the data visualization team and interactions with the HQP involved in this effort.

Network Benefits

As in previous years, the success and development of this project has been greatly enhanced through the efforts of our collaborations that this network provides and also with our other collaborators within the Network. This work and its success would not be possible without the integrated support of this network. DFO continues to provide their expertise and logistical support for the successful tagging of adult grey seals on Sable Island and of Atlantic cod. Their support will become even more vital as we broaden the geographical area for seal deployments with the use of the Bluetooth enabled hardware. S. Heaslip, PhD student, has also benefited greatly from this collaboration through the unique opportunity of being able to work with knowledgeable researchers and gain valuable experience in fieldwork, handling large mammals and in the deployment of telemetry instruments. As in 2010 and 2011, S. Heaslip passed this knowledge on to undergraduates through giving a lecture for the SEASIDE summer course on Field Methods in Marine Mammal Ecology, and D. Lidgard achieved the same through his role as co-instructor for this course. D. Lidgard is also co-supervising S. Iverson's 2011/2012 Honours student (P. Varkey) in examining the detection data from the Halifax and Cabot Strait receiver lines. Thanks to the efforts and support of DFO, more cod were deployed on the eastern Scotian Shelf. DFO is contributing financially toward these deployments (i.e., ship time), as well as providing the logistical support (access to fishermen) and knowledge and expertise required. Collaborations continue between the grey seal bioprobe project (1.2.4) and Atlantic salmon project (1.2.1), thus contributing toward a better understanding of the predator–prey dynamics between grey seals and Atlantic salmon as well as the movement of salmon in the Atlantic Ocean. D. Lidgard, D. Bowen, I. Jonsen and S. Iverson have been in collaboration with our oceanographic partners (projects 1.1; PhD candidate K.B. Lagman, R. Davis, K. Fennel and J. Cullen) to validate and calibrate the oceanographic sensors on the GPS-satellite tags deployed on grey seals with the objective for using these data in oceanographic models and to tackle objectives 5 - 8. Lastly, D. Lidgard and S. Iverson have been working with social science collaborators (D. VanderZwaag and R. Apostle), but especially with Tsafrir Gazit and Katie Sykes on the publication of a scientific paper "Changing Environments: Culling Grey Seals to Save Atlantic Cod? Tracking the Scientific, Socio-political, Legal, and Ethical Currents" for a special volume in the Journal of International Wildlife Law and Policy, to be entitled "Tracking and Protecting Marine Species at Risk: Scientific Advances, Sea of Governance Challenges" focused on OTN Canada work and species. This paper will be a valuable contribution toward elucidating the conflict between grey seals and cod, as well as between marine mammals and fisheries generally. Finally, the development of a Bluetooth enabled VMT for communication with Bluetooth enabled GPS-satellite transmitters was the product of working in a collaborative environment. Dalhousie University and DFO were integral to encouraging VEMCO and the Sea Mammal Research Unit, Scotland to develop this product.

Scientific and/or Engineering Significance of Results

As the number of fish tagged with acoustic transmitters continues to build, we are seeing an increase in the number of seal-fish detections providing confirmation that using top marine predators, such as grey seals, as mobile receivers to collect data on species interactions in addition to their own distribution clearly works. These data, along with those collected by the fixed OTN arrays, will provide a better understanding of species interaction dynamics and serve as a template for designing studies in other ecosystems and employing other large predators. Acoustic encounters between seals were not expected at the start of this project. However the large number of detections collected to date (~4,000) will provide a significant contribution toward understanding grey seal foraging behaviour and the potential impacts of seal predation on prey resources, as well as strengthening the approach of using top-marine predators as mobile receivers. Through a multi-group collaborative effort (*see 5b above*) the development of a Bluetooth enabled VMT for communication with Bluetooth enabled GPS satellite transmitters will allow us to deploy VMTs on seals in areas where recapture of the seal and tag retrieval is not possible. The significance of this development is that VMTs will be deployed at sites other than Sable Island thus broadening the geographic reach of the project and contributing toward a dataset that is better representative of the eastern Canadian grey seal population.

Evaluation of VMT detection efficiency and development of design principles for OTN VMT tracking studies is critical for ensuring that current and future studies are conducted efficiently by maximizing the detection rate of species carrying acoustic tags.

Development of mark-recapture modelling tools for OTN data will enable estimation of migration, survival and line detection rates (efficiency) for a variety of acoustically tagged species. Estimation of survival rates during migration is of particular importance as it provides a direct measure to guide management and conservation efforts.

It is anticipated that a significant portion of both the graduate research of L. Baker and S. Carson will be devoted in some sense, at least, to calibrating VMT performance. This was not anticipated but is essential before one can draw substantive ecological/biological conclusions from VMT data.

7. Difficulties encountered

Scientific problems/difficulties

Increasing the number of fish tagged that move through or within the Scotian Shelf and Gulf of St. Lawrence continues to be an important need for the bioprobe studies. It would be important scientifically, to tag both other known key prey species of grey seals, as well as more cod in critical areas. However, unfortunately budgets on the CFI grant are mostly committed and given DFO's greatly reduced budgets, there are limited resources to best support the optimal scientific plans. However, as more groups, both with OTN Canada and external to the network (e.g. US agencies) tag more animals, these needs will be met, but it nevertheless remains an issue.

8. Networking and outreach

S. Iverson co-hosted a special session on OTN at the February 2012 Ocean Sciences Conference in Salt Lake City, Utah, entitled "Integrating Oceanography and Animal Tracking - the Ocean Tracking Network" at which she also gave a lecture on the bioprobe work entitled "Bioprobes and Recievers in the Ocean Tracking Network (OTN): Grey Seals as Biological and Oceanographic Samplers".

S. Iverson, testified before the Senate Committee on Fisheries and Oceans (29 March 2012) about our ongoing study for the Senate's review of the management of the grey seal population off Canada's East Coast. Her testimony included the bioprobe team's most recent findings from the successful use of VEMCO Mobile Transceivers (VMTs) to directly assess grey-seal cod interactions in the open ocean.

All bioprobe co-PIs and HQP, and many collaborators, attended the 2nd Annual OTN Canada-wide Symposium in Halifax, as well as some of the OTN workshops that were held in conjunction, in June 2012. Both D. Lidgard and S. Carson (HQPs) gave presentations at the Symposium.

J. Mills Flemming and I. Jonsen co-lead a data visualization and modelling workshop as part of the 2012 OTN June Symposium, which was attended by all OTN Canada co-PIs and HQP.

J. Mills Flemming gave a plenary lecture at the OTN Canada June Symposium titled "OTN: A Statistician's Perspective on Complex Marine Observations" in which she reviewed the mandate OTN and proposed that visualization and modeling be recognized as cross-cutting activities so as to create greater synergy among OTN Canada participants so as to build additional capacity across all of OTN. In this spirit, I. Jonsen and J. Mills Flemming submitted a proposal for Phase II, that would formalize this effort.

D. Lidgard along with Tsafrir Gazit and Katie Sykes gave a presentation for the social and governance theme workshop during the 2nd Annual OTN Symposium on interactions between grey seals and Atlantic cod. Presentations given at this workshop formed the outline for the special volume being produced in the Journal of International Wildlife Law and Policy entitled, "Tracking and Protecting Marine Species at Risk: Scientific Advances, Sea of Governance Challenges"

Katja Fennel and one of her PhD students (Karl Lagman) from oceanography project I.1.2 are now regularly attending the bioprobe project's team meetings. This will move ahead the incorporation of oceanographic data into both visualization tools and accompanying models of predator and prey movements.

J. Mills Flemming has been invited to give a lecture on methods in Statistical Ecology at the Canadian Math Society Winter Meeting that is taking place in Montreal in December 2012. She will also give an invited lecture at the Statistical Society of Canada Meetings in the Spring of 2013 and will focus on some statistical science developments that are taking place to support the OTN.

I. Jonsen is collaborating with F. Whoriskey on mark-recapture analyses of acoustically tagged Atlantic salmon postsmolts. The goal of these analyses is to estimate migration survival of postsmolts as they travel from natal rivers to sea. The analysis tools developed here will relevance to other OTN research projects aiming to estimate survival of acoustically tagged species.

I. Jonsen is collaborating with E. Halfyard (HQP of Iverson, Whoriskey), Bob Branton (OTN Data Manager), and Chris Taggart (Oceanography project I.1) on analyses of OTN receiver line performance. The aim of this work is to determine the key environmental (and other) factors that influence receiver line detection efficiency. A manuscript is in preparation.

I. Jonsen is developing a strategy for monitoring and analysis of OTN receiver line efficiency to be implemented on all global OTN receiver lines. As part of this work, a suite of data fetching and analysis tools will be developed so that standard line efficiency reports can be generated automatically and published online for use by OTN researchers and the broader scientific community.

I. Jonsen collaborated with an international group of ecological modellers on a manuscript reviewing the current state-of-the-art in analysis tools for animal tracking data. The aim of the manuscript was to provide sufficient background information and advice for ecologists wishing to use such tools to analyze their own electronic tracking data. The manuscript was published online in July 2012.

I. Jonsen collaborated with researchers at Stanford University, NOAA Pacific Fisheries Research Center, and UC Santa Cruz to explore how the habitat and distribution of top predators in the northwest Pacific may change over the next century. This research combined predictions from IPCC-assessed global ocean models with animal tracking data in a series of habitat models to generate new predictions of the percent change and distribution of species' core habitat. This work was published online in Nature Climate Change in September 2012.

S. Iverson was asked to be a co-convener of a special session accepted for the 2013 ICES meeting in Iceland in Sept 2013, entitled: "'Hi-tech Tagging': Advances in Studying Spatial Distribution", at which she is also the invited keynote speaker.

8. Dissemination of information and results

Note: Deliverables from collaborators are listed in their respective reports and not repeated here.

Refereed Journal Articles (7 total) - *Accepted/Published*

Breed GA, Costa DP, Jonsen ID, Robinson PW, Mills Flemming JE (2012) State-space methods for more completely capturing behavioural dynamics from animal tracks. Ecological Modelling 235/236:49-58

Hazen EL, Jorgensen S, Rykaczewski RR, Bograd SJ, Foley DG, Jonsen ID, Shaffer SA, Dunne JP, Costa DP, Crowder LB, Block BA (2012) Predicted habitat shifts of Pacific top predators in a changing climate. Nature Climate Change. DOI: 10.1038/nclimate1686

Jonsen ID, Basson M, Bestley S, Bravington M, Patterson TA, Pedersen MW, Thomson R, Thygesen U, Wotherspoon S (2012) State-space models for biologgers: a methodological road map. Deep Sea Research II DOI: 10.1016/j.dsr2.2012.07.008

Lidgard, D.C., Bowen, W.D., Jonsen, I.D. and Iverson, S.J. (2012) A novel approach to studying at-sea associations in marine predators. PlosOne.

Lidgard, D.C., Sykes, K. and Gazit, T. (accepted) Changing Environments: Culling Grey Seals to Save Atlantic Cod? Tracking the Scientific, Socio-political, Legal, and Ethical Currents. *In:* Tracking and Protecting Marine Species at Risk: Scientific Advances, Sea of Governance Challenges. Journal of International Wildlife Law and Policy. Special Edition.

Winship AJ, Jorgensen SJ, Shaffer SA, Jonsen ID, Robinson PW, Costa DP, Block BA (2012) State-space framework for estimating measurement error from double-tagging telemetry experiments. Methods in Ecology and Evolution 3:291-302

Cooke, S.J., Iverson, S.J., Stokesbury, M.J.W, Hinch, S.G., Fisk, A.T., VanderZwaag, D.L., Apostle, R. and Whoriskey, F. (2011) Ocean Tracking Network Canada: A network approach to addressing critical issues in fisheries and resource management with implications for ocean governance. Fisheries **36**(12): 583-592.

Refereed Journal Articles (3 total)- *Submitted*

Bestley S, Jonsen ID, Hindell MA, Guinet C, Charrassin J-B. Integrative modeling of animal movement: Incorporating in-situ habitat and behavioural information for a migratory marine predator. Proceedings of the Royal Society B, in review.

Carson, S. and Mills Flemming, J. Seal Encounters at Sea: A Spatial Point Pattern Approach. Envirometrics, in review.

Lidgard, D.C., Bowen, W.D., Jonsen, I.D. and Iverson, S.J. (submitted) Piscivore meets pisces: interactions between grey seals and fish on the Eastern Scotian Shelf and Southern Gulf of St. Lawrence. Marine Ecology Progress Series

Invited Conference and Seminar Presentations (4 total)

Mills Flemming, J. (2012a) The Ocean Tracking Network - Visualization tools and novel analyses for acoustic tracking data. International Statistical Ecology Conference, Olso, Norway June 2012.

Mills Flemming, J. (2012b) OTN: A Statisticians' Perspective on Complex Marine Observations, Ocean Tracking Network 2nd Annual Canada Annual Symposium, June 2012.

Jonsen ID (2012) Performance of OTN receiver lines & VMT's (Bioprobes), Ocean Tracking Network Canada, 2nd Annual Symposium, June 2012, Halifax, NS.

Iverson, S.J. (2012) What marine predators can tell us about ocean ecosystems and climate change. Dalhousie 2012 Homecoming Lecture, Sept 2012, Hailfax, NS.

Contributed Conference Presentations (3 total)

Carson, S. (2012) Spatial Point Process Analysis of at Sea Seal Interactions, Ocean Tracking Network Canada, 2nd Annual Symposium, June 2012, Halifax, NS.

Iverson, S.J., Lidgard, D.C., Bowen, W.D., Jonsen, I.D., Fennel, K. (2012) Bioprobes and receivers in the Ocean Tracking Network (OTN): Grey seals as biological and oceanographic samplers, 2012 Ocean Sciences Meeting, February 20 – 24, Salt Lake City, UT.

Lidgard, D.C., Bowen, W.D., Jonsen, I.D. and Iverson, S.J. (2012) Pisces meets Piscivore: novel approach to studying the foraging ecology of a marine predator. 2nd OTN Canada Symposium, June 2012, Halifax, NS.

9. Other contributions and deliverables

Production of a video, blog, webinar, podcast, webpage, etc.

- Contributed summary of grey seal and cod project with results to date for OTN website and DFO review of the Center for Marine Mammal Expertise.
- Contributed to the on-going development of a web-based data-fetching, visualization, analysis and collaboration platform (Platform for Ocean Knowledge Management; POKM)

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

- CBC, Close to Home, Carmen Klassen: phone interview, Sable Island, brief discussion on the use of grey seals as bioprobes
- Rural Report for Northern Tasmania: radio interview associated with Bio-logging conference; discussed the role of OTN in advancing our understanding of marine animal movement patterns and the potential influence of climate change on these patterns

Invited or contributed presentation/contribution at a seminar series.

- S. Iverson June 2011. Keynote Lecture at Ocean Power Public Lecture Series, Dalhousie University Oceans Week, June 2011, Hailfax, NS.

Invited or contributed presentation/contribution at a conference.

- Marine Mammal Society Conference, Tampa, Nov. 2011: Presentation contribution on use of acoustic technology to understand foraging ecology of grey seals
- OTN Symposium, Halifax, June 2011: Presentation of results from first year of data, on use of acoustic technology to understand foraging ecology of grey seals
- 4th International Science Symposium on Bio-logging, Hobart, AU, March 2011: Keynote presentation on quantitative approaches for animal movement ecology

Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, Glider runs, and/or data deposition to an agency/database (e.g., MEDS, GenBank, OBIS, etc.), as well as a contribution to a larger piece of work in any of the former.

- Preparation of a manuscript for a peer-reviewed journal on the use of grey seals as bioprobes.

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

- We are in discussion with VEMCO and the Sea Mammal Research Unit, Scotland to develop a VMT that is capable of communicating with satellite- GPS tags to remove the need to re-capture seals for recovery of data. This will increase the number of potential sites for deploying seals with acoustic transceivers.

10. Collaborations with Industrial and Government Partners

The Department of Fisheries and Oceans, Canada continues to be integral to the deployment of telemetry and data-logging instruments on grey seals through arranging fieldwork on Sable Island and providing the equipment necessary for deployment. Their logistical and knowledge support will be extremely valuable when deploying VMTs and satellite transmitters on at sites other than Sable Island. VEMCO have manufactured the VEMCO Mobile Transceivers, had them ready in ample time for deployment and have improved the firmware based on data obtained from 2010 and 2011. PIs, Co-PIs and HQP have been working with VEMCO and the Sea Mammal Research Unit, Scotland to develop a Bluetooth enabled VMT which will allow the transfer of data from the VMT to ARGOS satellites for data download and thus remove the necessity of capturing animals to retrieve data. Three prototypes will be deployed in October 2012.

Name of supporting organization: **DFO**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$35 000
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$10 000
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	$2 000
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$47 00
Is this new funding (acquired during this reporting period)?	

Name of supporting organization: **CFI**	**Year 3** 2012
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	$171 150
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	$171 150
Is this new funding (acquired during this reporting period)?	

12.Expenditures and Support

Year 3 (2012)

Budget Item	Year 3 (2012)				
	Proposed	**Actual Expenditures** 1 Jan - 30 Sep 2012	**Total Balance** 30 Sep 2012	**Projected Balance** 31 Dec 2012	**Deviation**
1) Salaries and Benefits					
a) Students	$42 000	$17 375	$24 625	$12 625	30%
b) Postdoctoral Fellows	$90 000	$73 731	$16 269	-$5 641	-6%
c) Technical/Professional	$15 900	$9 793	$6 107	$0	0%
d) Other	$0	$0	$0	$0	
2) Equipment or Facility					
a) Purchase or Rental	$6 365	$5 798	$567	$0	0%
b) Operations/Maintenance	$29 722	$27 075	$2 647	$0	0%
c) User Fees	$0	$0	$0	$0	
3) Material and Supplies					
a) Materials and Supplies	$12 564	$11 445	$1 119	$0	0%
4) Travel					
a) Conferences	$11 000	$0	$11 000	$11 000	100%
b) Field Work	$24 720	$22 518	$2 202	$0	0%
c) Collaboration/Consultation	$0	$0	$0	$0	
5) Dissemination					
a) Publications	$5 120	$0	$5 120	$2 000	39%
b) Other	$0	$0	$0	$0	
6) Other (specify)					
a) Other	$0	$0	$0	$0	
b) Other	$0	$0	$0	$0	
Totals					
Totals	**$237 391**	**$167 736**	**$69 655**	**$19 984**	

The original year 3 budget listed in the table encompasses the following as was contained in the 2011 Annual report:

1) Salaries and benefits

a) Students

Stuart Carson completed his MSc thesis in year 3 on initiating spatial point analysis work on the bioprobe data and then started his PhD research, focusing on extending this work to handle temporal dependence and other issues (see below). Laurie Baker (MSc, partial support from a Dal fellowship) began her MSc in Sept 2012 to work on general simulation scenarios, informed by results of the VMT detection efficiency study, to explore general principles for deployment of VMTs and acoustic-tags for studying species interactions.

b) Postdoctoral fellows

Two post doctoral fellow/RA positions: D. Lidgard (80%) and S. Land (20%) and I. Jonsen projects included examining the spatial and temporal patterns of predator and prey encounters and predation rates on tagged fish species by grey seals, developing statistical methods for estimation of encounter probabilities, and analyzing detection efficiency of VMT receivers to help scale expected detection rates in simulations aimed at improving the design of OTN tagging studies throughout all of OTN Canada Arenas, but also to provide information for other OTN Global tagging studies being developed. D. Lidgard and S. Lang led all field studies and their organization.

c) Technical/professional assistants

Technical and laboratory assistance with the bioprobe projects is required for analysis of collected grey seal and prey samples for diet analyses, organization and upkeep of the prey database, and support of fieldwork.

2) Equipment or facility a) Purchase or rental

a) Purchase of grey seal VHF transmitters (~$318/unit = $6,365/yr) to locate instrumented animals when they return to Sable Island.

b) Operations and maintenance costs

ARGOS satellite fees for grey seal satellite tags for Year 3 at $8.74/d x 170d x 20 units.

3) Materials and supplies

Grey seal fieldwork supplies includes 15-20 doses of Telazol; syringes, needles, biopsy tools, scintillations vials, vacutainers, cryovials, 5-min epoxy at $500/yr. Protective clothing for HQP in the field (oilskins, boots, anorak, gloves) at $500/yr. Food for two students on Sable Island for 30 days in January for instrument recovery ($1,080/yr); (note: for any Gulf of St. Lawrence work implemented in Year 3, support for HQP would come from that allocated above). ATV running cost on Sable Island at $30/d/bike for the two seasons for two students. Fatty acid analyses at 80/yr and $75/sample; stable isotope analysis at 40/yr at $15/sample. Office supplies including printer cartridges, paper, media.

4) Travel

***a) Conferences

Travel was budgeted for four HQP to attend one conference each and funding to bring in/or visit collaborators in data visualization work. We did not spend this budget as we did not feel there were appropriate conferences for them to attend relevant to OTN Canada in 2012 – and with the recognition that there are several important conferences coming up in 2013, one in South Africa that are important for OTN Canada HQP to attend – so we are requesting to carry this conference budget over to 2013.

b) Field work

Grey seal field work: one 212 helicopter flight out and one return from Sable Island in June to instrument adults at $5,500/flight plus Sable Island landing fees at $500/flight. One 212 out and back in January to recover instruments at $5,500/flight plus Sable Island landing fees at $500/flight. (All other flights for these two field trips - approximately 6 out and 4 return - are covered by DFO.)

5) Dissemination costs a) Publication costs

Page and colour figure charges for 4-5 publications for years 3.

Significant deviations from the proposed expenditures

As described above, we wish to carry over the conference budget to 2013 to allow attendance at several conferences, including the 2nd Annual International Conference on Fish Telemetry in South Africa at which a special OTN session is being held.

We also wish to carry over publication costs as several papers are being submitted in early 2013.

Year 4 (2013)

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$63 000	$30 000		52%
b) Postdoctoral Fellows	$45 000	$88 000		-96%
c) Technical/Professional	$16 400	$10 000		39%
d) Other	$0	$0		
2) Equipment or Facility				
a) Purchase or Rental	$9 056	$7 860		13%
b) Operations/Maintenance	$49 440	$29 716		40%
c) User Fees	$0	$0		
3) Material and Supplies				
a) Materials and Supplies	$12 911	$11911		8%
4) Travel				
a) Conferences	$3 000	$5 000		-167%
b) Field Work	$24 720	$24 000		3%
c) Collaboration/Consultation	$0	$3 000		
5) Dissemination				
a) Publications	$5 184	$5 184		
b) Other	$0	$0		
6) Other (specify)				
a) Other	$0	$0		
b) Other	$0	$0		
Totals				
Totals	$228 711	$214 671		

There only major proposed changes to the original budget in the approved SNG for year 4, is switching some student salary to PDF/RA salary to allow the work initiated by D. Lidgard and I. Jonsen to continue. Two students are still supported from the grant in year 4, but one has partial support from a Dal A- fellowship. Technician time has been reduced to accommodate these changes, as have some field and supply costs. This is further described below for information and reference:

1) Salaries and benefits

a) Students

Stuart Carson's initial PhD research (started in Year 3) will focus on extending the spatial point analysis work completed for his MSc to handle temporal dependence. S. Carson will also be investigating the possibility of using spatial point process approaches with data that have been collected by Chris Taggart (project I.1.1). Laurie Baker (MSc, partial support from a Dal fellowship) will work on general simulation scenarios, informed by results of the VMT detection efficiency study, to explore general principles for deployment of VMTs and acoustic-tags for studying species interactions.

b) Postdoctoral fellows

Two post doctoral fellow/RA positions: D. Lidgard and I. Jonsen will continue their initiated work examining the spatial and temporal patterns of predator and prey encounters and predation rates on tagged fish species by grey seals, developing statistical methods for estimation of encounter probabilities, and analyzing detection efficiency of VMT receivers to help scale expected detection rates in simulations aimed at improving the design of OTN tagging studies throughout all of OTN Canada Arenas, but also to provide information for other OTN Global tagging studies being developed.

c) Technical/professional assistants

Technical and laboratory assistance with the bioprobe projects and for analysis of collected grey seal and prey samples for diet analyses, organization and upkeep of the prey database, and support of fieldwork.

2) Equipment or facility

a) Purchase or rental

Year 4: purchase of 20 grey seal VHF transmitters (~$318/unit = $6,360/yr) to locate instrumented animals when they return to Sable Island. Year 4: A laptop computer ($1500) is needed for a PhD student to examine the extent to which grey seals condition movement patterns and habitat use based on physical and biological oceanographic features on the Scotian Shelf.

b) Operations and maintenance costs

ARGOS satellite fees for grey seal satellite tags for Year 4 at $8.74/d x 170d x 20 units ($29 716/yr).

3) Materials and supplies

Grey seal fieldwork supplies includes 15-20 doses of Telazol; syringes, needles, biopsy tools, scintillations vials, vacutainers, cryovials, 5-min epoxy at $500/yr. Protective clothing for HQP in the field (oilskins, boots, anorak, gloves) at $250/yr. Food for two HQP on Sable Island for 30 days in January for instrument recovery ($1,080/yr). ATV running cost on Sable Island at $30/d/bike for the two seasons for two students ($2,250). Fatty acid analyses at 80/yr and $75/sample ($6,000/yr); stable isotope analysis at 40/yr at $15/sample ($600). Office supplies including printer cartridges, paper, media ($1231).

4) Travel

The increased travel budget includes $5 000 carried over from Year 3's unused travel budget.

a) Conferences

Travel for two HQP to attend one conference each:

$2500 for Laurie Baker (MSc student) to attend the ICES Annual conference in Iceland in Sept 2013 to present her work on estimating VMT at-sea detection efficiency.

$2500 for an additional HQP (to be determined) to attend the ICES Annual conference in Iceland in Sept 2013.

b) Field work

Grey seal field work: one 212 helicopter flight out and one return from Sable Island in June to instrument adults at $5,500/flight plus Sable Island landing fees at $500/flight. One 212 out and back in January to recover instruments at $5,500/flight plus Sable Island landing fees at $500/flight. (All other flights for these two field trips - approximately 6 out and 4 return - are covered by DFO.)

c) Collaboration/consultation

Funding to bring in/or visit collaborators in data visualization research. This would allow us to bring in one person with expertise (Wayne Oldford for example) or allow one of us to go and see what AIMS is doing (as suggested by Rob Harcourt at the ISAC meeting).

5) Dissemination costs

a) Publication costs

Page and colour figure charges for 4-5 publications for year 4.

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

II. Arctic Arena

1. Project Numbers: II.1-5

2. Project Titles:

II.1. Testing and Applying New Technology to the Arctic Marine Ecosystem
II.2. Oceanography of the Arctic Arena
II.3. Movement of Arctic char and Sculpin in relation to physical variables in the Canadian Arctic: Frobisher Bay/Lancaster Sound
II.4. Monitoring Bay- and Basin-Scale Movements of Arctic cod in Relation to Abiotic Habitat across Diverse Time-Scales: Lancaster Sound (Resolute)
II.5. Trophic Interactions and Movements of Arctic Fish and Marine Mammals in a changing Cumberland Sound Ecosystem

3. Project Leaders:

II.1. A. Fisk (Windsor) and S. Vagle (DFO-Victoria, U Victoria)
II.2. S. Vagle (DFO-Victoria, U Victoria)
II.3. A. Fisk (Windsor) and S. Vagle (DFO-Victoria, UVictoria)
II.4. A. Fisk (Windsor), S. Vagle (DFO-Victoria, U Vic.), S. Ferguson (DFO-Winnipeg, U Man.)
II.5. A. Fisk (Windsor), S. Vagle (DFO-Victoria, U Vic.), S. Ferguson (DFO-Winnipeg, U Man.)

Collaborators:

II.1 D. Webber (VEMCO)
II.2 E. Carmack (DFO-Victoria, UBC), D. Turk (Dalhousie-OTN)
II.3 R. Tallman (DFO-Winnipeg)
II.4 R. Crawford (U Windsor)
II.5 K. Hedges (DFO-Winnipeg), M. Treble (DFO-Winnipeg), D. Webber (VEMCO)

4. Public Summary of Report

The third year of the Arctic OTN program was a complete success, building on the initial pilot projects and work done in 2010 and 2011 generating tracking data for commercial, keystone and flagstone marine species using innovative techniques. Research in Cumberland Sound, lower Baffin Island, deployed acoustic receivers for one year at the greatest depths (> 1,000 m) ever used for these instruments, providing new insights on the movements of the deep-water species Greenland halibut, arctic skates and Greenland sharks. This also provides a novel approach that will extend the use of Canadian monitoring equipment in future applications. Greenland halibut are an important commercial flatfish, skate and sharks are by-catch species, and the data collected will help the Government of Nunavut establish effective management plans for Inuit artesian fisheries in and around Baffin Island. Oceanographic instruments were deployed for a full year in this region, and along with dedicated surveys in the summer of 2011 and 2012, will provide one of the most comprehensive oceanography profiles of an arctic marine ecosystem. These data will provide insights into the source of arctic ocean waters in this changing biome, help to understand the fish and marine mammal movements and

contribute to regional and large scale oceanographic models. Satellite tags were deployed on ringed seals in the lower and high Arctic, providing insights on movements in relation to ice and oceanographic conditions. These data are being coupled with detailed movement studies of arctic cod and sculpin, both key arctic fish that link lower and upper trophic levels, in the high arctic region of Resolute Bay. The Arctic component of the Ocean Tracking Network provides the first large scale multidisciplinary research program on the movement of marine species in relation to oceanographic conditions for the region and is providing unique data for regional management.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Emma Murowinsk	PhD	80	0	Jul 2012 – Dec 2012
Thesis topic: Physical Oceanography and Acoustics in Resolute Bay				
Jordan Matley	MSc	100	100	Jan 2012 – Jul 2012
Thesis topic: The ecology of Arctic cod (*Boreogadus saida*) and top predators in the Canadian Arctic				
Steven Kessel	PDF	100	100	Jan 2012 – Sep 2012
Nigel Hussey	PDF	100	100	Jan 2012 – Sep 2012
Dave Yurkowski	MSc	100	25	Jan 2012 – Sep 2012
Thesis topic: Acclimation of an ice-adapted predator in a changing Arctic ecosystem				
Jeannette Bedard	PhD	100	100	Jan 2012 – Sep 2012
Thesis topic: Physical Oceanography and Acoustics in Cumberland Sound and Scott Inlet				
Amy Tanner	BSc	25	20	Jul 2012 – Aug 2012
Thesis topic: Stress response of captured ringed seals				
Iva Peklova	MSc	100	100	Jan 2012 – Aug 2012
Thesis topic: Seasonal movements of Greenland halibut and Arctic skate				
Emma Murowinsk	PhD	80	80	Jul 2012 – Sep 2012
Thesis topic: Physical Oceanography and Acoustics in Resolute Bay				
Rob Cook	BSc	100	100	Jul 2012 – Aug 2012
Thesis topic: Physical Oceanography in Cumberland Sound				
Marianne Marcoux	PDF	20	0	Jan 2012 – Sep 2012
Cortney Watt	PhD	10	0	Jan 2012 – Sept2012
Thesis topic: Movement and feeding ecology of narwhal				
Eric Primeau	undergrad	15	0	Jul 2012 – Aug 2012
Melissa McKinney	PDF	20	0	Jan 2012 – Sept 2012

PDFs and graduate students take a lead in the design and implantation of all research, which has included travelling to the arctic to carry out the research. These HQP are also leading the analysis and interpretation of data, presenting of data at conferences and meetings, and the writing of manuscripts. Technicians and undergraduates have mainly assisted with field logistics but also with technical aspects of the equipment. Advanced HQP (PDFs and PhD) have helped trained undergraduates and MSc students. For example, David Yurkowski has extensive experience working within the Arctic and is fieldwork leader for ringed seal satellite tagging work. He has been training an undergraduate student (Amy Tanner) with proper Arctic fieldwork techniques and methods used to capture and successfully attach satellite transmitters to ringed seals.

6. Progress towards Objectives/Milestones (1 Oct 2011 – 30 Sep 2012)

- Test and apply new acoustic tracking technology to Arctic marine ecosystems that experiences low temperatures, salinity stratified waters and ice;
- 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;
- To study the movement and feeding ecology of arctic cod and shorthorn sculpin, key and abundant fish in the Arctic, in relation to physical variables and predators (beluga, ringed seals and seabirds) in the high arctic ecosystems of Resolute Bay.
- To study the movement and feeding ecology of Arctic charr, the northern most salmonid and important subsistence and commercial fish species.
- Quantify the feeding ecology, dive behavior, 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, satellite tags and chemical tracers.
- Determine how Greenland sharks, apex predators and by-catch species, interact with their environment in the high arctic (Resolute Bay) and lower arctic (Baffin Island) by examining movements, depth and temperature preferences and feeding ecology using acoustic tags and acouistic monitor arrays, pop-off satellite tags and chemical tracers.
- Quantify the seasonal and yearly movement, depth and temperature preferences and feeding ecology of: i) Greenland halibut, an important commercial species for developing fisheries throughout the region, and ii) arctic skate, a by-catch species, in the deepwater habitats of the eastern Arctic.

II.1. Testing and Applying New Technology to the Arctic Marine Ecosystem

Two dedicated range tests (V69 and V180) were deployed in Resolute Bay, one in shallow and one in deep water. Additionally we are working, with Dale Webber from VEMCO, on a novel analysis of sync tag data from the two VPS systems to assess ranges in multiple directions. Preliminary data shows above average/predicted ranges for both 180 and 69 kHz transmitters in the Arctic marine environment. It appears (though more data processing is required) that V6 tags are consistently detected from 300 m and V9 tags from up to 1,000 m. However our 'system' approach to addressing acoustic range has shown range to not be consistent in all planes of field. We feel that this approach of deploying dedicated range test arrays is revolutionary and in future will be incorporated into studies across the field of telemetry. As part of this assessment we are currently working on a review paper on range testing in acoustic studies, in which these observations will become available through the field of marine science. Additionally specific range test results from the Arctic field work is being combined with results from extensive range tests undertaken in Cumberland Sound in 2011 (including a 1000m depth study) and sister studies in both subtropical marine and temperate fresh water, to reveal new information about the characteristics of acoustic range deployments in 'quiet' ecosystems. Here a donut shading effect of high sound-power tags may influence future selection of transmitter power for studies in low ambient noise environments.

II.2. Oceanography of the Arctic Arena

The 2012 oceanographic field season in Cumberland Sound was designed to build on the results from the summer 2011 field season and specifically answer questions on the origin of the water within Cumberland Sound and how water circulates through the Sound. Both oceanographic moorings left in Cumberland Sound in August 2011 were recovered. The time series obtained from these moorings will allow examination of yearly, monthly and daily cycles at multiple depths both at the mouth of the sound and deep within it. The mooring instruments were reset and redeployed in Scott Inlet. A total of 42 CTD casts were made in Cumberland Sound in July and August 2012 along with two cross-mouth transects to capture flow as it enters and exits the sound. For nutrient and oxygen 18 samples were collected from 4 depths at 4 stations for analysis. These will help determine the origins of the water within the sound and help us understand how the ecosystem in the sound may be affected by climate change.

Oceanpgraphic research was also initiated in Resolute Bay in July 2012 by PhD student Emma Murowinsk. More than 50 CTD casts were conducted throughout Resolute Bay during the field season (15^{th} July – 5^{th} August). Additionally two complete benthic pods were deployed for a one-year period in Resolute Bay, one inside the bay and one outside of the mouth. Finally, a 300 kHz Acoustic Doppler Current Profiler (ADCP) was deployed inside the bay to reveal information on water movement, ice movement and ice formation, zooplankton and fish. All moorings will be retrieved in July 2013 and the data will be used to help interprete fish and marine mammal movement data from the acoustic array.

II.3. Movement of Arctic char and sculpin in relation to physical variables in the Canadian Arctic: Frobisher Bay/Lancaster Sound

Due to the retirement of PI Terry Dick (UManitoba) at the end of 2011, this project has made little progress to date. Given this retirement, PI Fisk has taken over this project and established a collaboration with DFO research scientist Ross Tallman. Dr. Tallman initiated seasonal movement studies of arctic charr in land-locked and sea-run populations in lakes near the community of Pangnirtung in Cumberland Sound. A PDF (John Sebastian Moore) will start on the arctic charr project in January 2013, with funding from DFO and Quebec funded PDF awarded to Dr. Moore.

II.4. Monitoring Bay- and Basin-Scale Movements of Arctic Cod in Relation to Abiotic Habitat across Diverse Time-Scales: Lancaster Sound (Resolute Bay)

1) The full acoustic monitor array (30 - V69 and 60 - V180), which includes two VS systems, was deployed in Resolute Bay along with oceanographic equipment and CPODs. The summer monitors were retrieved from the nearshore shallow water (deployed from 28^{th} July – 18^{th} September), downloaded and redeployed in deeper, further offshore, water on the 20th September, well ahead of ice formation. All receivers will be retrieved in July and/or August 2013.
2) All acoustic tags were deployed as planned, 85 Arctic cod and 25 sculpin, in July. From the summer monitor download alone, to date we have collected 65,738 arctic cod and 115,200 sculpin detections. For the sculpin we also have extensive accelerometry and depth reading data.
3) Extensive acoustic profiling of the fish fauna in Resolute Bay was conducted by Richard Crawford in July. Initial data has been submitted to OTN PIs Fisk and Vagle. Crawford will work with PhD student Emma Murowinsk and PDF Steve Kessel to interpret data and use for the assessment of range tests, oceanographic data and fish and marine mammals movements and interactions.
4) Biological samples (fin, muscle, liver and stomach) were collected from several fish species as planned and returned to UWindsor for stable isotope, Hg and stomach content analysis, which will begin in October 2012.

5) Two CPODs were successfully deployed, one inside and one ouside Resolute Bay. Additionally records of beluga presence and kills within and around the bay will be used to truth the CPOD data by collecting data from the Hunters and Trappers Organization and local fisherman/hunters from the community of Resolute Bay.
6) A shallow water longline was set in late July on which two Greenland sharks were tagged, one of which was acoustically tagged. This animal, in addition to the 6 tagged off Maxwell Bay in 2011, will provide insight into their behavior should they enter the bay or pass by the deep water monitors in Lancaster Sound.
7) Three ringed seals, all juveniles (< 2 years old) were equipped with satellite telemetry transmitters near Resolute Bay, the first in July and the second and third in September; efforts to tag more seals will continue until October 1. The seal tagged in July immediately left the Resolute area and is now residing in Peel Sound. The second seal tagged in late September is on the east side of Bathurst Island, and the third seal tagged September 25 is by the east side of Griffith Island. All three tags are providing detailed information on dive and haul-out behavior.

II.5. Trophic Interactions and Movements of Arctic Fish and Marine Mammals in a changing Cumberland Sound and Scott Inlet Ecosystems

1) The full acoustic monitor array (32 – VR2W-69 and 12 - VMTs), oceanographic equipment (2 stations) and marine mammal listening devices (3/4 CPODs and 2 AURALs) were deployed in August 2011 in Cumberland Sound and retrieved in August and September 2012. A total of 14 VR2W-69 and VMTs were deployed to >1000 m, all were functional upon retrieval (and checked by VEMCO engineers) and all contained data. This is the first deployment of VR2W to depths greater than 500 m.
2) More than 100,000 detections were recorded from 90+ individual fish (three species: Greenland halibut, Arctic skate and Greenland shark) and range tests (V9, V13 and V16 tags) from the moorings in deep (> 1000 m) and shallow (< 500 m) water. Although these data have not yet been fully analyzed, seasonal movement trends are obvious from the data and we found 5 Greenland halibut left Cumberland Sound.
3) Three sets of range tests (> 1000 m V69 only, ~500 m and 100 m V69 and V180 systems) were collected from Cumberland Sound. All tags and receivers were recovered, providing a year's worth of range test data under variable ice conditions.
4) A total of 42 CTD casts were made in Cumberland Sound in July and August 2012 along with two cross-mouth transects to capture flow as it enters and exits the sound. For nutrient and oxygen, 18 samples were collected from 4 depths at 4 stations for analysis. These will help determine the origins of the water within the sound.
5) During August 2012, DFO researchers conducted boat-based transects of Cumberland Sound and Clearwater, Shark, Pangnirtung, Kingnait, and Iqalugaju fiords. No transects of Cumberland Sound were completed due to the presence of ice that had entered Cumberland Sound from Davis Strait and blocked access to the southwestern shore for much of the fieldwork period. High winds and rough seas prevented crossings during the final days of the field study. However, transects were carried out twice in all study fiords, with the exception of Iqalugaju, which was done once. This year's effort marks the fourth year of standardized transects in these fiords, enabling comparisons among years to study patterns in the numbers and distribution of marine mammals and seabirds. This information is required to assess population size and growth trends over time.

6) Additional objectives this year included deploying satellite transmitters, collecting biopsies and photographing beluga, bowhead, and killer whales for use in diet, movement, and genetics studies of all three species in the eastern Canadian Arctic. Biopsies were collected from five bowhead whales outside of Kingnait Fiord. No beluga or killer whales were observed during the field trip, but biopsy and tagging equipment were left with Ricky and Mark Kilabuk in case killer whales arrive in Cumberland Sound during the end of August or September.
7) The ring seal tagged with a satellite transmitter in August of 2011 in Cumberland Sound sent data until mid May 2012 (when the tag was likely lost during molting, as expected). The seal, ~ 9 year old male, stayed in the same general area in the north west corner of Cumberland Sound. Dive depths and duration of dives varied with ice cover, with short less frequent dives during the winter months (Jan- March).
8) Over 1,100 ringed seal muscle and liver samples have been collected from several communities spanning the Canadian Arctic. These have been processed for stable isotope analysis to examine temporal changes in seal diets. This work will be compared with satellite tag data from ringed seals.
9) A total of 24 accoustic receivers and 2 oceanographic stations were deployed in and around Scott Inlet on the east coast of Baffin Island in late September 2012. As well 40 V16-4L acoustic tags were deployed in Greenland Halibut and 13 V16-6H in Greenland shark in the Scott Inlet area in late September 2012. Three Greenland sharks were also equiped with MK10 satellite tags for an approximate one-year period to complement tracking work undertaken in Cumberland and Lancaster Sound. More than 10 CTD casts were carried out in this area during this time. Two shallow water and one deep water CPOD and one aural were also deployed to monitor marine mammal precense and feeding behavior.

Significant Deviations from the Original Objectives or Plans

A number of changes to the original objectives or plans occurred in the two main studies areas of the Arctic arena. Most of these changes occurred because of concern from local Inuit communities on the impact of acoustic tags and receivers and boat traffic on marine mammal populations, mainly ringed seals and beluga, and are detailed below. As well, weather conditions, including ice, always play a major role in research activities in the Arctic and often result in day-to-day plan changes.

Plans for arctic charr research have been delayed due to the retirement from OTN of PI Terry Dick (UManitoba). PI Dick was the lead on three of the Arctic OTN projects (II: 1, 3 and 4). Project 1, testing and applying new technology has progressed very well and was not influenced by PI Dick's retirement. Project 3, movement of arctic cod and sculpin, was entirely successful in 2012 under the guidance of PIs Fisk and Vagle and HQP (Kessel, PDF; Hussey PDF; Murowinsk, PhD; Yurkowski, PhD). Project 4, which focuses on Arctic charr, has not begun. However, PI Fisk has recruited DFO scientist Ross Tallman (DFO-Winnipeg) to collaborate on Arctic charr projects at various locations across the Canadian Arctic (Cambridge Bay, Arctic Bay and Cumberland Sound). Significant supporting funds will be brought to this project from DFO and Government of Nunavut in 2013 thru this collaboration with Dr. Tallman, and a PDF (S. Moore) has been recruited to work on this project. Initial Arctic charr acoustic telemetry projects were carried out in 2011-2012 in lakes around the Cumberland Sound. Arctic charr will be a focus of years 5-7 of OTN and will be closely linked to Arctic charr work proposed for the Atlantic arena (PIs: Fleming, MemorialU, and Power, UWaterloo).

The main deviation from the original plan for Project II.4 (Arctic cod and sculpin in the high Arctic) was the relocation of research efforts from Allan Bay to the neighbouring Resolute Bay. There were several

reasons that drove the relocation but these did not change any of the objectives of the project, indeed they enabled the opportunity to assess the influence of large ships on arctic cod and marine mammal movement and behavior because Resolute Bay is used as a anchor site and loading area for cargo ships. The rationale for the change was:

i) On arrival in Resolute, the ice conditions were more favorable in Resolute Bay than Allan Bay,

ii) Preliminary acoustic surveys indicated large biomass of Arctic cod within Resolute Bay,

iii) Resolute Bay was a more manageable size to allow for complete acoustic coverage,

iv) Resolute Bay is an important place for the community as a hunting ground, but is much more widely used by boats, ships and other logistics. Also, the Resolute Bay Hunters and Trappers Organization favored it over Allan Bay,

v) Resolute Bay was much more logistically feasible, in terms of proximity and access to work in, reducing the need for truck and vehicle rental (a significant savings, truck rental range from $200-$300/day).

The main deviation for Project II.5, which focused on fish and marine mammal ecology in Cumberland Sound, was the rejection of continued use of moorings in Cumberland Sound by the Hunters and Trappers Organization and the general community of Pangnirtung. All acoustic telemetry receivers, marine mammal listening devices and oceanography equipment was retrieved in August 2012 and have now been re-deployed in Scott Inlet on the east coast of Baffin Island with the complete approval from the Clyde River community. All attempts by PI Fisk, collaborator Kevin Hedges and DFO and Government of Nunavut staff, including additional trips to Pangnirtung, to get approval failed. It should be noted that other projects unrelated to OTN were also denied approval from this community. With new data from Resolute Bay, which clearly shows seals and whales feeding amongst an extensive array of receivers and acoustic tags, we hope to re-deploy receivers in Cumberland Sound in 2013 with the community approval. This was a very unfortunate event, as the monitors retrieved this year contained a large amount of data and will contribute directly to protection of fish stocks in the Arctic and developmet of an Inuit-based artisian fishery. However, the original objectives of the Cumberland Sound project will be addressed with the current data and efforts to re-depoly receivers and instruments in the future. The movement of instruments to Scott Inlet was going to be a part of this project in years 5-7; the problems encountered in Cumberland Sound have accelerated this objective.

Finally, the original objective was to deploy satellite transmitters on ringed seals in Cumberland Sound. However, due to problems encountered with the Cumberland Sound community (see above), this research was moved to Resolute Bay. This made sense, as acoustic telemetry research is being conducted on Arctic cod (main prey item for ringed seals) in Resolute, and provides an excellent opportunity to study fish and marine mammal interactions. Indeed, three seals have been tagged here and one of the seals has remained in the acoustic array where the Arctic cod have and are being detected.

Coordination and Integration

All co-investigators (A. Fisk, S. Ferguson, S. Vagle), collaborators (Dale Webber, VEMCO, Richard Crawford, Kevin Hedges and Ross Tallman, DFO-Winnipeg) and HQP provided intellectual contributions to develop and establish the research plan for 2012. 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.

Scientific and/or Engineering Significance of Results

The range test deployed in Cumberland Sound and Resolute represent the most comprehensive tests in terms of number of ranges, depths (20 m – 1,100 m), length (1 full year), environmental conditions (open water vs. ice cover) and location (63 – 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.

Deployment of acoustic tags and VR2W receivers (both rated to 500 M) to depths up to 1,300 m expands the range and applications of VEMCO technology. Receivers and tags have been checked and verifed as functioning properly by VEMCO. This also expands the potential to use this technology to study deep-water commercial fish species that previously have been logistically difficult to undertake research on.

Oceanographic data collected in Resolute Bay and Cumberland Sound is among the most intensive ever collected in the Canada Arctic. For example, the last know CTD casts in Cumberland Sound were carried out in 1953. 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.

To date in Resolute Bay, we are only in possession of limited results from the shallow water monitors downloaded and re-deployed last month. However, this has still provided some extremely interesting data on the residency and movements of Arctic cod and sculpin. Preliminary results show the Arctic cod schools to show a strong tendency to take summer residence in Resolute Bay. There was a general trend of increasing detections from east to west and south to north with the greatest number of detections recorded in the northwest. Sculpin appear to have more limited movement and remain relatively benthic with little use of the water column. Priliminary range test data extrapolated from the sync tags shows good performance of both 180 and 69 KHz tags in the Arctic marine system, with above average range records. Records of Beluga and Narwhal presence in and around the bay have been obtained which will later be used to truth the CPOD data. All results obtained so far are preliminary and we will not have a full dataset until we conduct the monitor retreavals and downloads next summer.

The presence of large numbers of beluga and ringed seals within the extensive acoustic monitor array and acoustically tagged fish is evidence that these instruments do not scare marine mammals.

Initial examination of Cumberland Sound monitor data clearly shows a seasonal movement pattern of Greenland halibut from shallower waters in the winter to deeper holes in the summer. This acoustic telemetry work is the first to verify that halibut caught in the northern, winter fishing grounds are from the same population to the south in the summer fishing grounds. Furthermore, tagged Greenland halibut were detected on a monitor at the entrance to Cumbelrand Sound demonstrating this is not a closed population or a population sink as previously suggested. This represents the first deep water (> 1000 m) acoustic study ever conducted and the results have serious and immediate implications for the development of Inuit artesian fisheries in Cumberland Sound. The results also demonstrate that the behavior and movements of arctic skate are different than for Greenland halibut.

7. Difficulties encountered

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

As has been the case throughout OTN, shipment of heavy equipment (weights for moorings) presents a logistic problem. Costs are very high and delivery times are inconvenient for research; most deliveries come late in the summer or early fall as ice conditions become favourable. We also experienced issues with the Benthic Pods, both in terms of assembely (confusing), intiating and deployment (weight), however we were still able to deploy two successfully in Resolute Bay.

Personnel problems:

Arctic OTN is dependent on local fishermen and hunters for carrying out the research; these people provide expertise on the local environment (including polar bear safety) and equipment (mainly boats). Although most of fishermen and hunters we hired were punctual and hardworking, we did have some trouble with some individuals on many days, in which they either showed up late or did not snow up at all. This is a common problem in Nunavut communities and we have therefore tried to developed a network of locals that have proven dependable and hard working.

Other (specify):

As expected, weather in the Arctic created a few issues resulting in numerous days where boat based work could not be conducted. Ice conditions in Cumberland Sound delayed the Government of Nunavut research vessel, resulting in a reduction of time spent in Clyde River from 21 to 8 days. The final issue, as highlighted above, was approval from the Pangnirtung community for work in Cumberland Sound. Despite efforts by PI Fisk, collaborator Kevin Hedges (DFO) and DFO and Government of Nunavut representatives, the community would not allow OTN to redeploy acoustic receivers, marine mammal listening devices and oceanography equipment. Elders felt we had scared away seals and mammals, although younger fisherman stood in support of our work. We are not the only project that faced issues and problems with this community.

8. Networking and outreach

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 Halifax. A number of phone conversation or meetings with OTN collaborators were carried out, these have led to new projects ideas and plans within the OTN umbrella but also with other funding agencies. Specifically:

i) On February 3 2012, PI Fisk had detailed discussion with Pacific OTN PI Steve Cooke about future collaborations and research related to OTN and salmonids, in particularly captured fisheries work on arctic charr in arctic communities. Discussion of surgery techniques and tag insertion in salmonids was also discussed.

ii) On June 21 2012, PI Fisk and PDF Hussey met with Pacific OTN PI Scott Hinch in Windsor to discuss OTN projects and plans and general results and progress to date.

iii) Dale Webber from VEMCO traveled to Windsor for a workshop on acoustic telemetry on June 17 at University of Windsor. During this time PI Fisk and PDFs Hussey and Kessel met with Dr. Webber on several occasions to discuss OTN research, range test designs and collaborative papers.

iv) In July and August, PI Fisk had extensive discussion with Atlantic OTN PI Ian Fleming and future OTN PIs Michael Power (University of Waterloo) and Ross Tallman (DFO-Winnipeg and University of Manitoba) about project proposals on Arctic charr in the Arctic and Atlantic regions.

v) In August 2012, PI Fisk had discussions with Atlantic OTN PI Matt Litvak about possible collaborative projects on sturgeon in the Arctic and Atlantic regions. Also discussion issues related to the tagging of large freshwater and andramous fish.

vi) In August 2012, PI Fisk had discussion and email with Pacific OTN PI Steve Cooke about a collaborative paper on range testing of acoustic tags being led by PDF Steve Kessel.

vii) In September 2012, PDFs Kessel and Hussey held discussions over a review manscuript on the protective status of Greenland sharks given developing fisheries in the Arctic with OTN participants at Dalhouise and the Worm lab.

Interaction/Outreach to Broader Community

The Arctic OTN team has had a number of interactions with boarder scientific community related to OTN research, which has lead to collaborative projects, sharing of data and development of fisheries management plans. These incude:

i) Numerous interactions and positive communication with the Inuit community in Resolute Bay, including face-to-face meetings with the stake-holders of the Hunters and Trappers Organization in July (PDFs Hussey and Kessel and PhD Yurkowski) and September (PDF Kessel). To date four members of the Resolute community have been hired to assist with the field work, and an additional two boats were rented from community members. Many locals (including children) visited us on the shore of the bay to discuss our research and offer input, some even assisted with the tagging process. Finally, arrangements have been made with the local school to talk to the students during our next scheduled visit and for some classes to be brought to the bay to see our research as field trips were set up.

ii) Continued interactions with the Inuit community of Cumberland Sound were held, although research in 2012 was not approved. This included a presentation of data and research plans and open discussion with the community by PI Fisk and collaborator Kevin Hedges (DFO) on June 11 2012. PDF Hussey interacted with fishermen in Cumberland Sound during Septemebr 2012 with regard to plans for future deployments and obtaining approval from the HTO.

iii) On January 24, PI Fisk PDF Hussey and MSc Peklova met with Aaron MacNeil, Australian Marine Institute about statistical analysis of SAT and acoustic tag data. This collaboration will continue.

iv) On March 29, PI Vagle met with the director of NEPTUNE Canada (Kate Moran) to discuss possible collaborations between NEPTUNE Canada and OTN with regards to cabled deployments of acoustic receiver arrays and fish tagging in Cambridge Bay.

v) In April 2012, PI Fisk spoke with Margaret Treble (DFO) regarding tagging techniques for Greenland halibut caught and released through the ice.

vi) On June 8, 2012, MSc Iva Peklova shared ideas and data on arctic skates and tagging method with a Norwegian graduate student.

vii) On June 10 and 11, PI Fisk with Angela Young, Government of Nunavut) about arctic charr tagging projects and methods in lakes in the Cumberland Sound area and linking to OTN activity planned on behavior of arctic charr in the marine environment.

viii) On August 14 2012, PI Fisk, PDF Hussey and collaborator Kevin Hedges had a conference call with Julie Whalen (Fisheries Research Program Manager, Torngat Wildlife, Plants and Fisheries Secretariat, Torngat Joint Fisheries Board) about collaboration for research on the movement and behavior of Greenland halibut in northern Labrador and Quebec.

ix) In September 2012, PDF Hussey worked with Angela Young (Government of Nunavut) to download and pre-process all Arctic charr acoustic telemetry data from lakes surrounding Cumberland Sound

x) In September 2012, PDF Hussey met with Kevin Hedges (DFO) to discuss potential workshop with Pangnirtung fishermen to show data retrieved so far and to place more project responsibility in their hands with a view to obtaining permission to continue work in this area in 2013.

xi) In October 2012, PDF Hussey met with Zoya (???) in Iqualuit to discuss future approval for acoustic receiver deployments from the Pangirtung HTO.

9. Dissemination of information and results

Refereed Journal Articles (5 total)- *Accepted/published*

Hussey, N.E., J.A. Olin, M.J. Kinney, B.C. McMeans and A.T. Fisk. 2012. Lipid extraction effects on stable isotopes values ($\delta^{13}C$ and $\delta^{15}N$) of elasmobranch muscle tissue. J. Exper. Mar. Biol. Ecol. In press.

Peklova, I., N.E. Hussey, K.J. Hedges, M.A. Treble and A.T. Fisk. 2012. Depth and temperature preferences of the deepwater flatfish, Greenland halibut (Reinhardtius hippoglossoides) in an Arctic marine ecosystem. Mar. Ecol. Prog. Ser. In press.

Marcoux, M., B.C. McMeans, A.T. Fisk and S.H. Ferguson. 2012. Composition and temporal variation in the diet of belugas in Cumberland Sound using stable isotopes. Mar. Ecol. Prog. Ser. In press.

Matley, J.K., A.T. Fisk and T.A. Dick. 2012. Seabird predation on Arctic cod (Boreogadus saida) and their interactions during summer in the Canadian Arctic. Mar. Ecol. Progress Ser. 450:219-228.

Matley, J.K., R.E. Crawford, and T.A. Dick. 2012. Observation of common raven (Corvus corax) scavenging Arctic cod (Boreogadus saida) from seabirds in the Canadian High Arctic. Polar Biology 35: 1119-1122.

McKinney, M.A., B.C. McMeans, G.T. Tomy, B. Rosenberg, S.H. Ferguson, A. Morris, D.C.G. Muir and A.T. Fisk. 2012. Trophic transfer of contaminants in a changing arctic marine food web: Cumberland Sound, Nunavut, Canada. Environ. Sci. Technol. 46: 9914-9922.

Tallman R F, Roux M -J and Fisk A. 2012. Management of ecosystem effects, potential and realized, in emerging arctic fisheries in South Baffin Island. In: G H Kruse, H I Browman K L Cochrane, D Evans, G S Jamieson, P A Livingston, D Woodby and C I Zhang (eds.), Global Progress in Ecosystem-Based Fisheries Management. Alaska Sea Grant, University of Alaska Fairbanks.

Refereed Journal Articles (3 total)- *Submitted*

Brown, T. A., S. H. Ferguson, D. J. Yurkowski, N. J. Davison, J. Barnett, P. D. Jepson and S. T. Belt. Regional variation in marine mammal diet determined using IP25 and related highly branched isoprenoid (HBI) diatom biomarkers. Journal of Experimental Marine Biology and Ecology. Submitted (JEMBE-D-12-00402)

Matley, J.K., Fisk, A.T., and Dick, T.A. 2012. The biology and foraging ecology of Arctic cod (Boreogadus saida) in Allen Bay, Canada. Mar. Bio. Submitted Sep 13, 2012, MABI-S-12-00671.

Matley, J.K., Fisk, A.T., and Dick, T.A. 2012. Feeding ecology of Arctic marine mammals near Resolute, Canada. Mar. Mammal Sci. Submitted Sep 13, 2012, MMSCI-3569.

Conference Presentations (1 total) *– Invited*

Hussey, N.E. January 2012 Spatial and temporal movements and trophic ecology of fish: integrating telemetry with stable isotopes for conservation management. Stony Broook University, New York.

Conference Presentations (10 total) *– Contributed*

Bedard, J.M.*, S. Vagle, W. Williams, J.M. Klymak and A. Fisk, February (2012) Temperature Structure and Water Masses in Cumberland Sound. *2012 Ocean Sciences Meeting*, Salt Lake City, Utah. Poster presentation.

Hussey, N.E., Dick, T.A., Hedges, K.J., Vagle, S., Ferguson, S.H. and Fisk, A.T. (2012) The Arctic Ocean Tracking Network: movement and behaviour of fish and marine mammals in relation to oceanographic data across the Canadian Arctic. IPY 2012, Montreal, Canada.

Kessel, S.T., Hussey, N.E., Vagle, S., Ferguson, S. and Fisk, A.T. (2012) Introduction to the Lancaster Sound Arctic OTN component. Ocean Tracking Network Annual Conference, Halifax, Nova Scotia, Canada.

Marcoux et al. (2012) Beluga acoustics. 2012 International Polar Year (International), Montreal, Quebec. Oral presentation.

Peklova, I., Hussey, N.E., Hedges, K., Treble, M. and Fisk, A.T. (2012) Movement of deep water fish in Cumberland Sound, Canadian Arctic using satellite tags. Ocean Tracking Network Annual Conference, Halifax, Nova Scotia, Canada.

Peklova, I., Hussey, N.E., Hedges, K.J., Dick, T.A. and Fisk, A.T. (2012) Depth and temperature preferences of the deep-water benthic flatfish, Greenland Halibut (*Reinhardtius hippoglossoides*), in Cumberland Sound, Baffin Island. IPY 2012, Montreal, Canada.

Yurkowski, D. J.* *et al.* (2012) Feeding ecology of an ice-adapted predator in a changing Arctic ecosystem. *2nd Ocean Tracking Network Symposium (National)*, Halifax, Nova Scotia. Oral presentation.

Yurkowski, D. J.* *et al.* (2012) Behavioural responses of ringed seals (*Pusa hispida*) to environmental variability in a changing Arctic ecosystem. *2012 International Polar Year (International)*, Montreal, Quebec. Oral presentation.

Yurkowski, D. J.* *et al.* November (2011) Capturing ringed seals (*Phoca hispida*) in the Canadian Arctic. *Live catching techniques workshop at the 19th Biennial Conference on the Biology of Marine Mammals (International)*, Tampa, Florida. Oral presentation.

10. Other contributions and deliverables

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

A number of radio interviews have been carried out by Arctic OTN PIs and HQP including:

i) April 18, 2012, PI Fisk was the guest on the program Research Matters on CJAM in Windsor.

ii) A description of the project, its goals and the fieldwork conducted was presented on the HTA radio station in Resolute in September 2012.

iii) June 2012, PDF Hussey was the guest on the program Research Matters on CJAM in Windsor.

iv) September 25, 2012 PDF Nigel Hussey was on CBC-Windsor radio and several local radio stations

v) September 13, 2012, PI Fisk was the guest on the program Research Matters on CJAM in Windsor.

vi) October 2, 2012 PDF Hussey was on CBC-Windsor television along with University of Windsor communications officer Stephen Fields

Invited or contributed open-to-public presentation/contribution.

Fisk, A.T. 2012. Animal Movements in Cumberland Sound. Community Presentation to the Community of Pangnirtung, Nunavut. June 11, 2012.

*Invited or contributed presentation/contribution at a workshop***.**

Yurkowski, D. J.* *et al.* November 2011. Capturing ringed seals (*Phoca hispida*) in the Canadian Arctic. *Live catching techniques workshop at the 19th Biennial Conference on the Biology of Marine Mammals (International)*, Tampa, Florida. Oral presentation.

*Invited or contributed presentation/contribution at a seminar series***.**

Yurkowski, D. J.* *et al.* April 2012. Feeding ecology of an ice-adapted predator in a changing ecosystem. *2012 GLIER Multidisciplinary Graduate Student Symposium (Institutional)*, Windsor, Ontario. Oral presentation.

*Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, Glider runs, and/or data deposition to an agency/database (e.g., MEDS, GenBank, OBIS, etc.), as well as a contribution to a larger piece of work in any of the former***.**

Cory J.D. Matthews, Eric Primeau, Ricky Kilabuk, Mark Kilabuk, David Kilabuk, Eric Kilabuk, Gretchen Freund, Steven H. Ferguson. 2012. Boat-based surveys for marine mammals and seabirds in Cumberland Sound. Fisheries and Oceans Canada. Fieldwork report: August 2012

Invited or contributed consultation with an agency; public or private

PI Fisk and PDF Hussey were invited to a workshop on the development of Inuit fisheries in the Canadian North by the Government of Nunavut. PI Fisk made a presentation on the OTN work in Cumberland Sound and both Fisk and Hussey participated in discussions about future research on commercially important fish species in the Arctic.

Internet publishing, portal, blog, electronic publications

David Yurkowski was interviewed in October 2011 by Steven Fields (Communications Officer - University of Windsor) for the Daily News (University of Windsor) regarding Arctic fieldwork and capturing and tagging ringed seals.

In September 2012, Stephen Fields (University of Windsor communication officer) maintained a blog on his experiences participating in the Ocean Tracking Network fieldwork in the Arctic. Posted on the Uiversity of Windsor website and through CBC-Windsor.

Anything else that isn't a primary publication that has you communicating (specify) with others (specify).

Jeannette Bebard, March 2012, Ocean Networks Canda Ocean Sciences Symposium. Presented to 5 groups of high school students about physical oceanography, working at sea and current work in Arctic.

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

We are exploring the possibility of contributing Arctic cod samples for an Arctic wide DNA database and for toxicology analysis with Derek Muir at Environment Canada, Burlington. We are also in the process of initiating a collaborative research effort with the Vancover Aquarium to run controlled trials on tag retention and stable isotope feeding studies using their housed Arctic cod. This work will complement current work underway in the field in Resolute Bay.

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

We are using sync tag data for multiple direction range testing in Resolute Bay. VEMCO are currently examining the VR2W acoustic receivers deployed in >1000m water and further work is being conducted on the use of this equipment at this depth.

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 are exploring the possibility of contributing Arctic cod samples for an Arctic wide DNA database and for toxicology analysis with Derek Muir at Environment Canada, Burlington.

Ringed seal liver and muscle samples have been collected since 1985 and will be used as a baseline for stable isotope and genetic analyses to determine whether any significant changes have occurred in relation to their diet, feeding behavior and population structure over time.

11. Collaborations with Industrial and Government Partners

Dale Webber from VEMCO had direct involvement with the experimental design and range testing of equipment, which is ongoing. VEMCO are currently involved in the testing of VR2W receivers deployed in water depths >1000m.

We are working closely with DFO and Government of Nunavut on the development of Greenland Halibut Inuit fisheries in Cumberland Sound and Scott Inlet. This has involved consultations (meetings, phone conference calls) about research and management decisions. As well, both DFO and Government of Nunavut have provided direct funding for our research.

We have have received support from the Polar Continential Shelf Project for research in Resolute Bay.

Name of supporting organization: **DFO – Arctic and Central Region**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff (4 meetings with VEMCO staff)	$30 000
2) Donation of equipment, software	
3) Donation of material	$30 000
4) Field work logistics	$25 000
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$85 000
Is this new funding (acquired during this reporting period)?	☐ Yes ☐ No

Name of supporting organization: **Government of Nunavut**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$90 000
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$90 000
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **Polar Continential Shelf Project**	**Year 3** 2012
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	$10 000
3) Donation of material	
4) Field work logistics	$16 000
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$26 000
Is this new funding (acquired during this reporting period)?	Yes

12. Expenditures and Support

Year 3 (2012)

Budget Item	Year 3 (2012)				
	Proposed	**Actual Expenditures** 1 Jan - 30 Sep 2012	**Total Balance** 30 Sep 2012	**Projected Balance** 31 Dec 2012	**Deviation**
1) Salaries and Benefits					
a) Students	$86100	$49625	$36475	$20475	24%
b) Postdoctoral Fellows	$110000	$50518	$59482	$24198	22%
c) Technical/Professional	$15000	$10000	$5000	-$5000	-33%
d) Other	$21200	$25236	-$4036	-$13800	-65%
2) Equipment or Facility					
a) Purchase or Rental	$13125	$4000	$9125	$0	0%
b) Operations/Maintenance	$24040	$5000	$19040	$0	0%
c) User Fees	$0	$0	$0	$0	
3) Material and Supplies					
a) Materials and Supplies	$18500	$0	$18500	$0	0%
4) Travel					
a) Conferences	$4000	$2000	$2000	$0	0%
b) Field Work	$63684	$69082	-$5398	-$5398	-8%
c) Collaboration/Consultation	$0	$0	$0	$0	
5) Dissemination					
a) Publications	$1000	$0	$1000	$0	0%
b) Other Activities	$1000	$0	$1000	$0	0%
6) Other (specify)					
a) Other	$0	$0	$0	$0	
b) Other	$0	$0	$0	$0	
Totals					
Totals	**$357 649**	**$215 461**	**$142 188**	**$20 475**	

In general costs were higher in 2012 because of cost over-runs in 2011 for PI Fisk who covered logistics of former PI Dick research in Resolute Bay in 2011 (he has since retired). These cost over-runs were covered from unused funds from PI Dick at UManitoba that were recently transferred to PI Fisk at UWindsor.

1) Salaries and benefits: Less money was spent on graduate student (**1a**) and PDF salary (2b) and more was spent on technical (**1c**) and other staff (**1d**) salary. The reduction in graduate student stipends was due to one student winning a scholarship (Dave Yurkowski was awarded an OGS scholarship) and a second student, PhD Murowinski, salary was covered by non-OTN funds. The unused student salary ($20,475) will be carried forward to 2013 to cover student salaries at UVictoria and $20,475 less student salary is requested for 2013.

Unused PDF salary resulted from a planned PDF for arctic charr research delaying the start of the PDF until January 1, 2013. Unused PDF salary was spent on technical help in the arctic, mainly hiring more local fisherman and hunters. A technician (Dr. Richard Crawford) was hired ($20,000) to help find, quantify using an echosounder and catch arctic cod in Resolute Bay. Dr. Crawford has 30+ years experience researching arctic cod, catching the cod would have been impossible without his help and he continues to help analyze echosounder data and is involved in the training of HQP (PDF Kessel and PhD Murowinski); he visited UWindsor Nov 15 and 16 to discuss results and plan for 2013. We spent more on local helpers due to problems encountered catching arctic cod and ringed seals in the Resolute Bay area, which required a second trip to Resolute Bay in September 2012 (resulted in 2 more ringed seals being tagged). Weather was also a problem and resulted in more days being used to carry out the research, a common problem in the Arctic.

How the remaining Projected Balance of Year 3 on 31 Dec 2012 will be spent

The remaining budget will be used to cover salaries of HQP and technicians (Dr. Richard Crawford), costs of equipment used in the field in September, and sample analysis for stable isotopes, fatty acids and contaminants.

Whether year 2 (2011) actual expenses for October-December were on target with what was forecast in last year's report

Yes.

Conference travel budget justifications

PhD Bedard travelled to Salt Lake City for the 2012 Ocean Sciences Meeting. PhD Yurkowski and PDF Hussey travelled to Montreal for the 2012 International Polar Year Conference. All HQP made presentations.

Year 4 (2013)

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$98 700	$71 410		28%
b) Postdoctoral Fellows	$45 000	$90 000		-100%
c) Technical/Professional	$45 000	$27 290		39%
d) Other	$24 800	$24 800		0%
2) Equipment or Facility				
a) Purchase or Rental	$10 200	$10 200		0%
b) Operations/Maintenance	$22 710	$22 710		0%
c) User Fees	$0	$0		
3) Material and Supplies				
a) Materials and Supplies	$16 500	$16 500		0%
4) Travel				
a) Conferences	$4 000	$4 000		0%
b) Field Work	$54 128	$56 628		-5%
c) Collaboration/Consultation	$0	$0		
5) Dissemination				
a) Publications	$3 500	$1 000		71%
b) Other	$3 450	$3 450		0%
6) Other (specify)				
a) Other	$0	$0		
b) Other	$0	$0		
Totals				
Totals	**$327 988**	**$327 988**		

As submitted in original proposal see changes to allocation of funds below.

Significant deviation between the Original and Revised year 4 budget

1) Salaries and Benefits:

We have decreased our request for student salaries (**1a)** from $98,700 to $71,410. Part of this reduction is being covered by a $20,475 carry over from 2012 (*see above*). We have increased the PDF salary request (**2b)** from $45,000 to $90,000 and have decreased our technician salary **(1c)** from $45,000 to $27,290.

5) Dissemination costs a) Publication costs have been reduced to $1,000 from $3,500 to make up the difference for the total budget. Given the uncertainty of arctic research and the need for experienced people, it is felt that PDFs (Steve Kessel and Nigel Hussey) are critical for the delivery of the OTN project in the arctic. The total number of HQP supported by the Arctic OTN, including graduate students will meet the original projections of the grant proposal through outside funding (e.g., OGS funds to MSc David Yurkowski and new MSc Amanda Barkley (to start January 2013) and a third PDF (JS Moore; working on arctic charr) who's 2013 salary is covered by a Quebec PDF award and funds from DFO).

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

III. Pacific Arena

1. Project Numbers: III.1 and III.2

2. Project Titles:

III.1. Characterizing oceanographic conditions for out-migrating juvenile and returning adult salmon
III.2. Biology, behaviour and physiology of migrating adult and juvenile Pacific salmon

3. Project Leaders:

III.1. R. Thomson (DFO, UBC), S. Hinch (UBC), S. Cooke (Carleton)
III.2. S. Hinch, T. Farrell (UBC), S. Cooke (Carleton), K. Miller, R. Thomson (DFO, UBC)

Collaborators:

III.1. Dave Patterson (DFO)
III.2. D. Patterson M. Hague (DFO), M. Hague (DFO, PSC), M. Lapointe (PSC), D. Welch (Kintama), B. Riddell (PSF), K. English (LGL), M. Shrimpton (UNBC), T. Clark (Australian Institute of Marine Science) (2012), M. Davis (USA NOAA – retired)

4. Public Summary of Report

The OTN Pacific Arena research is focused on Pacific salmon 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 Pacific salmon migration across large spatial scales. Research has covered several life stages including outmigrating smolts and upriver migrating adults. 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 tested novel telemetry tags that measure tailbeats of fish enabling the estimation of swimming speeds and energy use from the ocean to spawning grounds. 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. The team tested and identified best practices for ensuring that released fish survive. The work conducted in 2011-2012 involved extensive partnerships with Fisheries and Oceans Canada, First Nations Groups, 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.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Erin Rechisky	RA	5	0	1 Oct 2011 – 30 Sep 2012
Eduardo Martins	RA	10	0	1 Oct 2011 – 30 Sep 2012

Personnel	Title	% Time in project	% Support from SNG	Dates
Erica Eliason	PDF	50	25	1 Oct 2011 – 30 Sep 2012
Brad Davis	PDF	10	0	1 Jan 2012 – 30 Sep 2012
Mike Donaldson	PDF	100	100	1 Sep 2012 – 30 Sep 2012
Ken Jeffries	PhD	100	50	1 Apr 2012 – 30 Sep 2012
Thesis topic: Genomics and migration success in Pacific salmon				
Matt Drenner	PhD	100	25	1 Oct 2011 – 30 Sep 2012
Thesis topic: Relationships between oceanographic conditions and adult salmon migration timing and survival				
Graham Raby	PhD	100	0	1 Oct 2011 – 30 Sep 2012
Thesis topic: Effects of capture/release fisheries on salmon migration behaviour, physiology, and RAMP				
Nolan Bett	PhD	20	0	1 Oct 2011 – 30 Sep 2012
Thesis topic: Factors affecting olfaction and homing success in adult salmon				
Natalie Sopinka	PhD	10	0	1 Oct 2011 – 30 Sep 2012
Thesis topic: Effects of stress on survival and fitness of adult salmon				
Mike Donaldson	PhD	100	0	1 Oct 2011 – 30 Aug 2012
Thesis topic: Capture stress and physiology of migrating adult salmon				
Nathan Furey	PhD	100	10	1 Oct 2011 – 30 Sep 2012
Thesis topic: Modelling survival and behaviour of outmigrating salmon smolts				
Alison Collins	MSc	100	100	1 Oct 2011 – 30 Jan 2012
Thesis topic: Effects of tag burden on survival and swim performance of salmon smolts				
Vivian Nguyen	MSc	100	0	1 Oct 2011 – 30 Jun 2012
Thesis topic: User group perceptions and opinions of salmon capture/release and telemetry research				
Kendra Robinson	MSc	100	25	1 Oct 2011 – 30 Sep 2012
Thesis topic: Assisted ventilation as a recovery approach for salmon following capture/release				
Sam Wilson	MSc	100	0	1 Oct 2011 – 30 Sep 2012
Thesis topic: Using accelerometer transmitters to assess migration energetics in adult salmon				
Charlotte Whitney	MSc	10	0	1 Oct 2011 – 30 June 2012
Thesis topic: Effects of incubation temperature on juvenile salmon swim performance				
Marika Gale	MSc	100	25	1 Oct 2011 – 30 Jun 2012
Thesis topic: Survival and travel rates of outmigrating salmon smolts				
Nich Burnett	MSc	100	0	1 June 2012 – 30 Sep 2012
Thesis topic: Comparison of accelerometer loggers and transmitters in assessing migration behaviour of adult salmon				
Matt Casselman	MSc	5	0	1 Apr 2012 – 30 May 2012
Thesis topic: Swimming and cardiac performance of juvenile salmon				
Jessica Taylor	MSc	5	0	1 Sep 2012 – 30 Sep 2012
Thesis topic: Effects of adult migration stress on juvenile salmon oxidative stress				
Marley Bassett	MSc	25	0	1 Apr 2012 – 30 Sep 2012
Thesis topic: Osmoregulatory preparedness of outmigrating salmon smolts				
Collin Middleton	undergrad	100	50	1 May 2012 – 30 Sep 2012
Michael Lawrence	undergrad	100	50	1 Oct 2011 – 30 Apr 2012
Sylvia Chow	undergrad	5	0	1 Oct 2011 – 30 Apr 2012
Andrew Lotto	technician	100	100	1 Oct 2011 – 30 Sep 2012
Darcy McKay	technician	25	0	1 Oct 2011 – 30 Sep 2012
Taylor Nettles	technician	25	25	1 Oct 2011 – 30 Sep 2012
Keith Stampelcoskie	technician	100	0	1 Aug 2012 – 30 Aug 2012

Research on Pacific salmon 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 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. Relying solely on graduate students for stakeholder engagement is not consistent with the need to maintain long-term relationships. 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. Our technical staff serves a critical role as conduits of information from the public and other stakeholder groups to the investigators in our research program. Our technical staff is 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 (1 Oct 2011 – 30 Sep 2012)

Project III.1)

i. Characterize the upper ocean physical, chemical and biological environments encountered by juvenile and adult salmonids in coastal areas to order explore interannual variability in these environments, and obtain data for use in Project III.2 in order to relate ocean conditions to that of fish behavior, physiology, or survival.

Project III.2)

ii. Examine how environmental and anthropogenic conditions experienced by migrating adult salmon en route to natal rivers during the coastal approach and estuarine transition zones varies among individuals depending on population of origin and physiological state.
iii. Examine how environmental, physiological and anthropogenic conditions influence adult salmon survival to the natal rivers and spawning grounds.
iv. Examine the effects of different types of acoustic transmitters and fish sizes on sustained swim speeds, metabolic rate, feeding, and survival in smolting sockeye salmon in both freshwater and saltwater.
v. Examine speed of outmigration, and location and level of mortality in freshwater and coastal areas, for individual sockeye salmon smolts.

Project III.1)

i) Rick Thomson (DFO) and his colleagues from the Institute of Ocean Sciences continue to conduct four oceanic surveys per year in the Salish Sea region from the entrance to Juan de Fuca Strait to the northern Strait of Georgia using the DFO vessel 'Vector'. These seasonal CTD/rosette surveys include profiles of salinity, temperature, chl a, light attenuation, density, and nutrients (P, Si, NO3). The four cruises are meant to define the seasonal cycle and long term trends. These long-term data will be used to link with multi-year tagging data we are now collecting on salmon smolt migration rates and survival through the Salish Sea (PhD student Nathan Furey). Thomson and colleagues continue to collect and process CTD profile data around 10 times per month in the Nanoose Torpedo Test range by the US and Canadian Navies. They continue to maintain current meter moorings to measure currents in the northern

Strait of Georgia, including a long term current, water property and sediment flux measurements from site SOGN (approx. 10 nm south of Cape Mudge) and DPN (in Discovery Passage). Roy Hourston and Maxim Krassovski (DFO technicians with R. Thomson) have been developing models using the hourly data from the northern current meters and from the met buoys in the Strait of Georgia to predict abundance and return timing of adult sockeye salmon.

Matt Drenner (PhD student), Sam Wilson (MSc student) and Collin Middleton (undergrad) collected CTD data in the northern Strait of Georgia during August 2012 in conjunction with telemetry tracking of adult sockeye salmon. CTD casts were made in areas where sockeye were migrating and in areas they were not migrating to assess environmental characteristics preferred by salmon migrants. Sea surface temperature collected from meteorological buoys, sea surface salinity from coastal light-stations, tidal details, and daily volume discharge from the Fraser River will complement the CTD cast data. Additional temperature and salinity data are being provided by the VENUS observatory situated at the Fraser River mouth, and also Environment Canada buoys situated throughout the lower Fraser River.

Project III.2)

i) Analyses are continuing on data collected in 2010 and 2011 which examine the factors affecting behaviour and survival of marine tagged adult sockeye (> 400 fish were captured, biopsy sampled, tagged and tracked from marine areas to natal freshwater areas). Specifically, Drenner has been working with Martins (RA) to quantitatively link thermal experience of coastal migration adult sockeye assessed from ibutton information to oceanographic variables (collected in Project III.1), migration speed and survival. It appears that population origin and fish sex have little effect on marine thermal experience and migrants may be actively selecting their thermal optima during their coastal migration. Analyses relating initial physiological state, including genomic biomarkers, to survival are underway (RA Martins, PDF Davis, PhD Drenner).

In October 2011, we captured and moved 40 adult sockeye to the DFO Cultus Lake Field Laboratory in the Fraser Valley. Individual fish were gastrically implanted with accelerometer transmitters and put through standard respirometry trials which occur at different temperatures and involve cannulated plasma assessments of metabolites (PDF Eliason; MSc Wilson). During winter 2012, these data were used to derive calibrations between accelerometry outputs (x, y, and z movement data from the transmitters) and swim speed and oxygen use based on respirometer results. These calibrations can now be used to convert field obtained accelerometry data (summer/fall 2012) into estimates of swim speeds and energy use, and to develop bioenergetics models of salmon migration.

In August 2012, 60 adult Fraser River sockeye salmon were captured in the northern Strait of Georgia during their homeward migration and implanted gastrically with a depth sensing accelerometer acoustic transmitter (PhD Drenner, MSc Wilson, undergrad Middleton; technicians Lotto, McKay, Thompson). In September 2012, 30 adult Fraser River sockeye salmon were captured in the lower Fraser River by First Nations beach seining (partner Chehalis First Nations) and also implanted gastrically with a depth sensing accelerometer acoustic transmitter (MSc Wilson, PDF Donaldson, MSc Burnett, technicians Lotto, Nettles, McKay). All fish were tissue biopsied and plasma sampled prior to release for assessment of physiological condition. Sentinel acoustic receivers (operated by POST/OTN, Kintama Ltd. and LGL Ltd) situated throughout the Strait of Georgia and lower Fraser River were used to collect data on river entry timing, migration rates, swim speeds and survival. Field work has been completed. DNA analyses to assess stock composition and physiological analyses of tissues will be completed during winter 2013 (technicians Nettles, Hill, McKay, Thompson, Li). Downloading of the acoustic receivers will occur in late fall 2012.

ii) Analyses are continuing on data collected in 2011 (PhD Raby, MSc Robinson, RA Martins) which examine if assisted ventilation approaches (e.g. use of fish bags or manual ram ventilation) influence survival of released adult salmon following angling or commercial capture. The fate and survival of tagged salmon was assessed with a telemetry array set up in partnership with the Pacific Salmon Foundation and LGL Ltd. In one study, 70 summer-run adult sockeye captured in lower Fraser River estuary transition area by volunteer anglers were either tagged and released immediately, tagged then air exposed for one minute prior to release, or tagged then air exposed for one minute then held in fast flowing water in an attempt to accelerate recovery prior to release. Preliminary results suggest that assisted ventilation did not increase survival rates. In a related study, radio tags were applied to 200 Late-run sockeye salmon in the Harrison River which is just upstream of the estuary transition area but still affected by the marine environment. Fish were captured by First Nations beach seining (partner Chehalis First Nations) and then either immediately tagged and released, additionally stressed by swimming to exhaustion in a swim chamber and air exposed for one minute then tagged and released, or stressed as just described then held in fast flowing water in an attempt to accelerate recovery prior to release. Preliminary results suggest that assisted ventilation had no beneficial effect for aiding recovery and survival. The results of all these studies will help elucidate how different fishing handling and release strategies in environmental transition zones influence salmon behaviour and survival. In conjunction with the tagging studies, First Nations fishers (~ 100) were interviewed while they were fishing, using social science survey methods, to gain an understanding of how they viewed telemetry 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 (MSc Nguyen, PhD Sopinka). Over 70% of First Nations fishers had heard about telemetry science but only 1/3rd knew anything about how telemetry science worked. However over 2/3rd 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.

Analyses are also continuing on data collected in 2011 that involved implanting radio tags into 80 adult coho salmon in the lower Fraser River estuary transition area (PhD Raby, MSc Nguyen, MSc Larocque, technician Lotto). Coho salmon were captured as by-catch in First Nations economic opportunity seine fisheries for pink salmon. Half of the tagged fish were immediately released and half were held in mesh flow through recovery bags for 30 minutes prior to release. RAMP (rapid reflex assessment protocol) which is an index of physiological impairment, was used rather than taking a plasma sample to assess condition of fish. Results to date reveal that RAMP measures were highly predictive of delayed mortality thus these simple and quick reflex measures could be used by fishers as a means of knowing whether they should release by-caught coho, or keep them because they will die anyway during subsequent migration. We found that post-release mortality levels were very similar to what was observed the previous year based on a related study. Similar to results from the sockeye work described above, a 30 minute post-capture confinement in recovery bag showed no benefit in terms of subsequent survival following release.

In 2011, we attempted to capture and tag coho in the Strait of Georgia prior to them reaching the estuarine transition area via an angling charter vessel but were unsuccessful. In August 2012, we chartered a commercial purse seine vessel and were able to capture and tag with VEMCO V8 acoustic transmitters 50 coho in Juan de Fuca Strait (PhD student Raby, technicians Stamplecoskie, Hills, Thompson). Because these fish are still feeding at this stage in their marine life, transmitters needed to be externally attached to the fish. This was a novel tagging method for migrating adult salmon, so we simultaneously conducted a tagging validation study using an on-board net pen with 24-h holding trials. Coho salmon bycatch that were tagged with acoustic transmitters were also evaluated for injury and

RAMP in order to link post-release fate with fish condition. Likewise, we were able to compare fish condition with mortality in the on-board 24-h holding study (repeated 4x) in order to bolster our samples sizes for the mortality estimate. This is the first work anywhere on tracking the homeward migration of coho salmon in the marine environment. The fish we tagged were biopsied for DNA and we anticipate that we tagged a mixture of American (Puget Sound) and Canadian (Fraser River) stocks. This project utilized the POST/OTN acoustic receiver lines currently operating in the Juan de Fuca Strait, the Fraser River mouth, the lower Fraser River (Kintama partner line), and likely also American lines operating in Puget Sound. The project was a collaboration with industry partners (Area B Seiner Society), the Pacific Salmon Foundation, and DFO, with the objective of generating a bycatch mortality estimate for coho salmon captured in purse seine fisheries that target sockeye and pink salmon. Telemetry results are all still pending. DNA and plasma analyses are all pending (technicians Nettles, Hill, McKay, Thompson, Li).

We continue to collaborate with electronic engineers in utilizing a novel miniaturized data logger that records heart rate, swim speed, depth and temperature. Loggers are surgically implanted and must be recovered in order to access data (RA/collaborator Clark, PhD Raby, Technician Lotto). In November 2011, we implanted 100 loggers into adult coho salmon that were held at the DFO Cultus Lake Field Laboratory in the Fraser Valley. Fish with loggers were exposed experimentally in large tanks to different techniques of beach seine capture (e.g. varying water depth of capture and time of capture in net) at different temperatures. The purpose was to better understand the physiological responses of salmon to capture technique and use that information to inform management on best fishing practices. Data are being analyzed.

In August 2012, we compared two accelerometer technologies (an external mounted data logger vs an internal implanted VEMCO acoustic transmitter) in a head to head contrast via a pilot study on adult sockeye migrating up to and through a fishway on the Seton River (MSc Burnett, PhD Bett, Technician Lotto, PDF Donaldson). The external loggers are considerably less expensive so if they produced similar data and could be readily retrieved, they may be a preferable option over the more expensive VEMCO model. Results are still pending.

iii. 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' to develop 'best practices' in terms of sizes of transmitters that can be used in field telemetry studies on juvenile salmon. Specifically, we need to know how to minimize effects of tag size on behaviour and survival, and in particular to assess new tag sizes recently brought onto the commercial market. Moreover, there are few tagging effects studies on sockeye salmon, our focal species, and none that assess tag burden influences on fish that are transitioned from freshwater to saltwater.

In 2011 and 2012, we completed several relevant handling effects and review studies, one a global literature review examining how telemetry has been used to study marine migrating salmonids – this review is now published in PloS-1 (PhD Drenner, RA Clark, MSc Whitney, PDF Martins, Hinch and Cooke). Collins (MSc) completed her thesis wherein she assessed the effects of tag burden level and tag type (i.e. VEMCO V9, V7 and V6 designs) on swim performance, growth and survival of juvenile hatchery raised Cultus Lake sockeye salmon in freshwater and saltwater (manuscript accepted in TAFS), and effects of tag presence on standard metabolic rate. Tim Clark (RA/collaborator) assessed effects of tag burden on survival of two-year old wild Chilko sockeye smolts.

In winter 2011/2012, we undertook a tagging effects study in the lab using the new VEMCO V5 tag, their smallest, which enables smaller salmon smolts to be tagged than previously. As with studies using the larger tags, we assesed the effects of specific tag burdens on individual growth and survival (PDF Eliason, PhD Sopinka, MSc Gale, MSc Whitney, Technicians Chow, Lotto). We found that tag burdens which resulted in high survival and growth were similar to what we identified using the larger tags. During March 2012, an experiment was conducted at UBC using lab-raised smolt-sized juvenile sockeye which were surgically implanted with dummy V5 tags (some had small amounts of gill filaments removed; others were non tagged/non clipped controls). After 30 days, none of the tagged fish (with or without gill removal) had died and there were no discernible differences among treatments in fish growth indicating it was feasible to emulate this tagging/handling approach with wild smolts in the field.

iv. Summarization and write-up of results from outmigrating smolt studies from 2010 and 2011 are underway (collaborator Clark; RA Rechisky). The lower Fraser River acoustic receiver array was re-deployed during early April, 2012 by Kintama Ltd. The upper Chilcotin acoustic receiver array was re-deployed during mid April by UBC. Both arrays had receivers positioned in identical locales to previous years. Marine lines are in same locales as in previous years, and were rebatteried/maintained this past winter by Kintama, POST and OTNC. In April and May 2012, acoustic transmitters were implanted into 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 acoustic transmitters (MSc Gale, PDF Jeffries; MSc Casselman, MSc Bassett, technician Lotto). Sentinel acoustic receivers situated near the release site and in the lower Fraser River, and acoustic curtains associated with POST were used to determine travel rates, and locales and levels of mortality. In total 390 fish (120 to 143 mm fork length) were implanted with V7 tags (7 mm diameter, 1.6 g mass in air) which are detectable with 69 kHz VR2W receivers and are identical to tags used in 2010 and 2011. Small gill samples were collected from 195 of these fish to quantify pathogen loads, using newly developed molecular techniques (qPCR). This is the first time the pathogen status of telemetered smolts has been investigated, and we hope to relate these data to acoustic detection data in the river and early marine environments. 199 fish (95 to 119 mm fork length) were implanted with the newly available V5 tags (5 mm diameter, 0.68 g mass in air), which are detectable with 180 kHz VR2W receivers (none of these fish had gill samples removed). This was the first ever mass release of this new type of VEMCO tag. A subset of fish were destructively analyzed for length at age assessments and preliminary results suggest that tagged fish in 2012 were almost exclusively two-year-olds, despite our attempts to tag as many small of fish as tag burden limits with V5 tags would allow. In mid May 2012, 300 1-year old smolts were transported to UBC for holding and observation. In early June 2012, the Chilcotin receivers were retrieved and were downloaded. The lower Fraser array will be downloaded in late October to coincide with the completion of a companion adult sockeye and coho study; the POST/OTNC marine arrays will be downloaded sometime during late fall or early winter as in previous years (pending OTNC officially taking ownership of the lines). Assessments of survival and movement rates are pending the recovery of these receiver lines.

Significant Deviations from the Original Objectives or Plans

The original broad objectives, after being modified and approved in 2010, remain intact. In 2011 and continuing in 2012, we expanded some of our current and planned telemetry projects on adult salmon to include assessing how different types of fishing practices influences survival and behaviour. This is a logical expansion given that assessing investigator 'handling' and 'tagging' effects is a large component of all of our studies, and we acquire all of our fish to be telemetry tagged from various fisheries so having a more rigorous assessment of how these sampling platforms affects our telemetry results is important. Also, this expansion provides better linkages with DFO fisheries management, and with

several stakeholder user groups (e.g. fishing and ENGO groups) who have partnered with us in these studies.

No projects were deleted. We were opportunistically able to conduct the additional pilot study that compared inexpensive biologger accelerometers with acoustic transmitters accelerometers at no additional cost to OTNC as transmitters and HQP time were provided from other sources.

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 among Pacific Arena researchers. The following were the face to face meetings:

- Jan. 11, 2012 – meeting at UBC to review smolt tagging approaches results and plan for field season (Hinch, Eliason, Collins, Gale)
- Feb. 9, 2012 – OTNC Pacific Arena investigator and collaborator annual meeting (Hinch, Cooke, Farrell, Miller, Thomson, Patterson, Riddell, and several other collaborators, all OTNC Pacific graduate students, PDFS, technicians) – held in conjunction with 'Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries', University of British Columbia, Vancouver, BC, Canada
- March 23, 2012 – meeting at UBC to review adult salmon ocean tagging study results and plan for field season (Hinch, Farrell, Miller, Thomson, Drenner, Martins)
- April 3, 2012 – meeting at UBC to review smolt tagging study and plan for field season (Hinch, Eliason, Gale, Jeffries, Lotto, Patterson)
- June 5, 2012 – meeting in Halifax (in conjunction with 2nd OTN Symposium) among OTNC Pacific investigators (Hinch, Cooke, Gale, Drenner, Collins, Wilson, Robinson, Patterson, Ngyuen)
- July 20, 2012 – meeting to discuss planning of adult salmon ocean tagging study (Hinch, Cooke, Patterson, Riddell, others)
- August 8, 2012 - meeting at UBC with OTNC Pacific investigators to discuss upcoming adult salmon tagging studies (Hinch, Patterson, Raby, Wilson, Lotto, Burnett; Cooke on Skype)
- August 23, 2012 – meeting at Kintama Ltd. (Nanaimo, BC) regarding future research for relating smolt migration behaviour and early marine survival to environmental and oceanographic conditions; also discussed the future development of an individual-based model (IBM) for simulating smolt movements (Hinch, Furey, Welch, Rechisky, Trudel)
- Monthly conference calls with project leaders and collaborators occurred (which included personnel from UBC, Carleton, the Pacific Salmon Foundation, the Pacific Salmon Commission, Fisheries and Oceans Canada (Nanaimo and Vancouver), and Kintama Research).
- Project leaders and collaborators were in frequent (weekly) contact on a multitude of issues via conference calls, email and Skype.

Scientific and/or Engineering Significance of Results

1) We conducted the largest ever study for assessing thermal experience of marine migrating salmon. Over the past several years we have implanted temperature loggers (ibuttons - which record thermal experience each hour) into several hundred ocean migrating adult sockeye. In 2012 we analyzed logger data and found that there are no differences between populations or between sexes in marine thermal experience – although hourly thermal experience was widely variable (8-21 C), most of the time thermal experience was ~ 10-13 C. Oceanographic data indicate this thermal range occurred at different depths in the different years suggesting that migrants are actively selecting this temperature range which coincides with their metabolic thermal optima.

2) In 2012 we conducted the first ever large scale study with depth sensing acoustic accelerometer transmitters. Over 100 Fraser River sockeye salmon were captured during their homeward migration in the northern Strait of Georgia and lower Fraser River and implanted gastrically with a depth sensing accelerometer acoustic transmitter. Swim tunnel respirometry experiments with sockeye determined the relationships between accelerometer data, swim speed and oxygen consumption. We are currently using these relationships to assess the swim speeds and energetics of migration from our field tracking studies.

3) We conducted the first ever study tracking coho salmon 'by-catch' following release from a commercial marine fishery. Because these fish are still feeding at this stage in their marine life, acoustic transmitters needed to be externally attached to the fish. This was a novel tagging method for migrating adult salmon, so we simultaneously conducted a tagging validation study using an on-board net pen with 24-h holding trials. We found that ~ 20% of fish perished in net pens, and the same level of mortality was observed using telemetry. This level of mortality is consistent with non-surgical implantation (esophageal) techniques and probably reflects mortality rates associated specifically with the capture-release event.

4) 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' to develop 'best practices' in terms of sizes of transmitters that can be used in field telemetry studies on juvenile salmon. We have identified critical tag burdens (and size limits) that can start to inform 'best practice' procedures for tagging juvenile salmon - it appears that 6-8% tag burden (for 6-9 mm tags) may represent an upper limit for juvenile sockeye salmon. We also assessed in the lab the new VEMCO V5 (5 mm) tag, their smallest, which enables smaller salmon smolts to be tagged than previously. Lastly using a lab study we determined that small amounts of gill filaments could be removed from tagged smolts with no effects on 30 day survival thus groundproofing a technique to assess effects of pathogens and condition on fate of wild tagged and released migrants.

5) We have identified key locales associated with juvenile salmon mortality during outmigration. Ours is the first telemetry study (> 1500 fish tagged) ever on wild juvenile sockeye, and the first large study to use VEMCO V6 and V5 (180 kHz) miniature tags. In all years, including 2012, we recorded significant mortality of Chilko Lake sockeye smolts within the first 100 km (of their 650 km freshwater migration) likely as a result of predation. Overall, survivorship during the freshwater portion of the outmigration was ~ 30-40%; subsequent marine survival through the Strait of Georgia to the northern end of Vancouver Island (to the Queen Charlotte Strait POST acoustic line ~ 240 km) was of similar scale to that in freshwater with a total survival from release to final acoustic line of 3-7%. In 2012, gill samples were taken from 200 outmigrating sockeye smolts that were tagged to assess pathogen status and other biomarkers of condition and relate these to migratory fate. This is the first time the biomarkers have been used in this manner on tagged Pacific salmon - analyses are underway.

7. Difficulties encountered

Scientific Difficulty

Migrating smolts were much smaller and thinner than in the previous two years that we conducted tagging on them (~ 20% smaller), and as such we had difficulty collecting sufficient numbers of fish large enough to bear tags, hence we were unable to reach our tagging quota (about 100 fish short of expectation of 700 tagged). This smaller average size also meant that we were unable to tag 1 year old smolts as expected with the new V5 tags and had to resort to tagging 2 year old smolts as we have in previous years.

8. Networking and outreach

Intra-Network Collaboration and Partner Meetings

- January 2012 – PI Cooke traveled to Windsor to meet with PI Fisk (Arctic Arena) to discuss development of a project in the Arctic on catch-and-release of Arctic charr – also met with OTN PDF Nigel Hussey.
- January 2012 – a fish tagging and surgery training course was put on by Erika Eliason (PDF) and Alison Collins (MSc student). In attendance were Melinda Jacobs (Kintama Ltd), Marika Gale (MSc student), Mike Lawrence (technician), Miki Shimomura (PSC technician) and Adam Goulding (MSc student).
- February 2012 – PI Cooke and PI Flemming (Atlantic Arena) met to discuss opportunities for collaboration within OTN which led to the preparation of two OTN-related projects – one on catch-and-release in the Atlantic region and another on mining existing smolt movement data across years and regions to identify trends.
- February 9, 2012 - Annual Pacific Arena PI meeting involving all PIs Hinch, Cooke, Clarke, Farrell, Miller, Thomson and Patterson to discuss the OTN program and strategize for research in the coming year.
- February 10, 2012 – a meeting between PhD student Drenner, and Farrell, Clark, Miller, Hinch and Thomson took place to discuss Drenners research progress, future directions, data analysis, and interpretation.
- February- September 2012 - PhD student Drenner had numerous meetings and email exchanges with Rick Thomson (DFO) for transfer of oceanographic data from fixed monitoring lines and for mentoring in analysis and interpretation of results. During this time email discussions were also frequent with Clark (RA) re: iButton data analysis.
- March 14, 2012 – meetings were held with PhD student Drenner, Patterson (DFO), Thompson (DFO), and Hills (DFO) to discuss iButton data collection and analysis.
- March 23, 2012 – Miller attended student committee and thesis planning meetings, including with Matt Drenner, a PhD student working on the OTN adult tagging studies.
- March 29, May 28, June 14, July 12, and September 4, 2012 - meetings were held between PhD student Drenner and RA Martins for mentoring in analysis of iButton, oceanographic and physiology data.

- April 2012 – a meeting was held between Drenner and LGL scientist Robichaud about iButton data collection.
- June 2012 – Martins (RA) met with Joanna Mills-Flemming and Ian Jonsen (both from OTN Atlantic Arena - Dalhousie University) to discuss the application of state-space models to analyze fine-scale movement data of bull trout and burbot in the forebay of a large hydropower facility in BC (related to a HydroNET project that Marints is involved with). Martins will meet with them again in November of 2012 to work on data analysis. The training on state-space models acquired by Martins will benefit current and future projects in the Pacific Arena related to movement of salmon. Early in the coming year, he will work closely with Drenner (PhD student) on the application of state-space models to the analysis of sockeye salmon tracking data collected in the Fraser River estuary in 2011.
- June 2012 – PhD student Drenner had numerous meetings with MSc student Sam Wilson to mentor her in logistics for upcoming field work and to train in operation of field equipment (CTD, VEMCO VR2W receivers, VUE software, Ruskin software).
- August 1- 15, 2012 - PhD student Drenner assisted and mentored Wilson in the field with her ocean tracking research.
- August-September 2012- PhD student Drenner communicated with Nikki Beauchamp in regards to creating video footage of research, and conducting self-interview about OTN and research. This footage was taken while in the field with Sam Wilson during August of 2012. Video footage and photos of research were sent to Beauchamp for use by OTN.
- Winter 2012-present - Martins (RA) has been actively mentoring all of the MSc and PhD students in the Pacific Arena on data analysis (e.g. survival analysis, mixed models) and/or R software skills. Students that have benefitted from his mentoring include Marika Gale (MSc), Alison Collins (MSc), Kendra Robinson (MSc), Charlotte Whitney (MSc), Jenn Burt (MSc), Samantha Wilson (MSc), Vivian Nguyen (MSc), Ken Jeffries (PhD) and Matt Drenner (PhD).
- August 23 2012 - Meeting at Kintama Ltd. (Nanaimo, BC) regarding future research for relating smolt migration behaviour and early marine survival to environmental and oceanographic conditions; and also discussed the future development of an individual-based model (IBM) for simulating smolt movements. Both projects require collaboration (Nathan Furey [PhD student], Scott Hinch, David Welch, Erin Rechisky, Marc Trudel).
- Fall 2012 to present – Cooke, Hinch, and Fisk (along with several HQP) are working on a collaborative article for the Social Science case study special issue.

<u>Interaction/Outreach to Broader Community</u>

- November, 2011 – MSc student Robinson met with Stu LePage (DFO Fraser Sockeye Stock Assessment Senior Technician) regarding her 2011 Harrison River radio tagging results ; DFO is planning a telemetry study which will be modelled after hers and was looking for feedback on study design and logistics.
- December 7, 2011 – MSc student Robinson met with Nicole Trouton (DFO Fraser River Stock Assessment Biologist) at DFO Kamloops office regarding our 2011 Harrison River radio telemetry study. DFO is preparing a proposal to conduct a radio tag study on Chinook salmon in the Harrison River the following year and are using our results to guide them in logistic and budgetary planning.

- December 12, 2011 - Hinch made presentation on 'Overview of the Canada Ocean Tracking Network' to a workshop on the use of acoustic telemetry and the future of POST at the DFO Pacific Regional Headquarters, Vancouver, BC. Hinch represented OTN at this meeting which included senior DFO officials from Ottawa, stakeholders, ENGOs and local DFO scientists. A report based on this meeting was used by senior DFO officials in their planning for future involvements with OTN.
- December 15, 2011 - Miller testified at the Cohen Commission of Inquiry hearings (extra sessions dealing with ISA disease). There was a significant media interest in this final evidentiary hearing, with resultant media coverage from The Vancouver sun, The Globe and Mail, The Montreal Gazette, Toronto Sun, The Province, Toronto Star, and The National Post, CTV news, CTV Calgary, KPLU radio, CBC news, BBC news, and Nature Volume 483.
- January 2012 to September 2012 – Cooke is President of the Canadian Aquatic Resources Section (CARS) of the American Fisheries Society and has been able to discuss OTN program and projects at section meetings with CARS members.
- January 2012 to September 2012 – MSc student Robinson became a founding member and treasurer of the American Fisheries Society British Columbia Student Subunit (AFS-BC). The mission statement of this subunit is to unite undergraduate and graduate student in fisheries research at universities and colleges throughout British Columbia while operating under the larger mission statement of the American Fisheries Society (AFS). In this role she has been able to communicate OTN mission objectives and project results to a broad student audience.
- January 17, 2012 – a workshop entitled, Fraser sockeye future directions, was hosted by the Pacific Salmon Commission. Miller and Patterson attended and contributed to discussions pertaining to research combining acoustic tracking and physiological and genomic assessments of individuals.
- January 24, 2012 - Miller gave a 30 minute presentation at the Genome BC Winter Symposium hosted in Vancouver which provided an overview of the salmon genomics research findings to date, including two studies that combined OTN funded acoustic/radio tracking and genomics in adult salmon. She also presented new data on microbe profiling of these same samples that suggests that a novel salmon virus recently discovered by her lab is correlated with premature mortality in one Fraser River salmon stock.
- February 6, 2012 - Miller participated in a DFO led Climate Change Workshop that aimed to plot a strategic direction for integrated research on climate change for the department. Genomic assessments of health that included information on fate gained from tracking data were part of the discussion.
- February, 2012 – Discussions continued between Robinson and Nicole Trouton (DFO Fraser River Stock Assessment Biologist) which were initiated last fall continue regarding advice for a DFO tagging study.
- February 14, 2012 - MSc student Robinson, made a presentation to the Annual meeting of the Pacific Salmon Commission Fraser River Panel, Sheraton Wall Centre, Vancouver, BC, Canada, entitled Facilitated recovery of sockeye salmon following capture.

- February 16, 2012 - Miller was interviewed by a Communications student at University of Toronto about the research associated with the 2011 Science paper who wrote an article for the school paper.
- February 23, 2012 - Miller attended a meeting with social scientists from University of Victoria that was set up by Genome BC to discuss ways in which to engage stakeholders in applied salmon genomics research. A strategy was developed that was taken forward into the development of a new Genome BC co-funded project on salmon microbes. This project is linked with the OTN in that some of the fish analysed will include the smolts and adults tracked in OTN studies.
- June 2012 - Cooke along with two new Dalhousie Biology Department hires prepared a proposal to Marine Ecology Progress Series journal on "Tracking the Fitness of Marine Animals" which was accepted as a special issue. Papers are due in November 2012 and the majority of contributions are from OTN Canada or OTN Global. Cooke will serve as one of the co-editors.
- February 2012 – Cooke participated in the Great Lakes Acoustic Telemetry Observation System workshop where he shared information on OTN activities.
- February 2012 – Cooke traveled to Puerto Rico to work with Dr. Andy Danylchuk on development of a telemetry array that will become part of OTN Global.
- March 2011 to present – MSc student Robinson was a member of the organizing committee for the 33rd annual Pacific Ecology and Evolution Conference held March 2-4, 2012 at Bamfield, British Columbia. This is a conference for graduate, post-doctoral, and advanced undergraduate students conducting ecological and evolutionary research at Western Canadian and American Universities. OTN research was presented at this conference.
- March 2012. Martins (RA) made a presentation entitled 'Predicting the entrainment vulnerability of fish in hydropower reservoirs' to NSERC HydroNet 2nd Annual Symposium, Burnaby, BC.
- March 17, 2012: Brad Davis (PDF) gave a talk at the Annual Salmon Ocean Ecology Meetings in Oregon that overviewed the genomics research on Pacific Salmon smolts, and touched on the OTN-genomic research approaches being used within our OTN collaborative team.
- March 23, 2012 - Oral presentation given by PhD student Donaldson on the effects of fisheries-related exercise stress on Pacific salmon migrations to scientists at the Pacific Northwest National Laboratory in Richland, Washington.
- April 2012 - "Magnificent Migrations: Pacific salmon physiology"; Farrell Invited speaker, Hopkins Marine Station, Stanford University, USA.
- April 27, 2012 - Thomson presented an invited 30 minute talk to the Pacific Salmon Commission Fraser River Panel in Victoria on "New Approaches for Forecasting Timing and Diversion Rates of Fraser River Sock Sockeye Salmon".
- April 2012 – Cooke traveled to Australia to work with Dr. Tim Clark (honorary RA and collaborator) on unique heart rate and acceleration biologgers (technology exchange) for measuring fish physiology and behaviour.
- May 03, 2012 – PhD student Donaldson made presentation to representatives of the First Nations, recreational, and commercial fisheries sectors and fisheries managers at the Fisheries and Oceans Canada Integrated Harvest Planning Committee meeting on salmon in Richmond, B.C.

- May 14/15, 2012 - Thomson attended the annual meeting of the NSF-funded Pacific Northwest Harmful Toxic Algae program (PNWTOX) examining physical and biogeochemical factors affecting the impact of toxic algal blooms on the shellfish industry along the west coast of Washington and Oregon. He presented an invited talk on the ongoing observational program and physical processes affecting plankton blooms along the BC-Washington coast. "PNWTOX- The Columbia River plume and HABs in the Pacific Northwest: bioreactor, barrier or conduit?"
- June 18, 2012 – MSc student Gale and Hinch submit report to Pacific Salmon Foundation summarizing research dealing with outmigrating smolts.
- June 23, 2011 - Thomson met with the lawyers of the Cohen Commission of Inquiry ISA hearings in Vancouver to discuss how physical oceanographic conditions may have contributed to the poor return of Fraser River Sockeye salmon in 2009.
- June 2012 – Hinch and Cooke, and PhD student Raby conducted a conference call with ENGO and DFO stakeholders related to a project on bycatch of coho salmon in purse seine fisheries in order to develop project ideas, receive feedback, and initiate acquisition of additional sources of research funding.
- July 13, 2012 - Skype meeting between Raby, MSc student Wilson and Captain Mike Griswold (commercial fisherman) about logistics of field work and ideas for deployment of VEMCO VR2Ws and tags from his troll fishing vessel.
- August 2012 –Cooke traveled to Denmark to meet with Dr. Kim Aarestrup from OTN Global to discuss application of satellite tags to eels.
- August 2012 – PhD student Raby met with Paul Brajcich (commercial fisherman and owner of a purse seine vessel) and Chris Ashton (head of Area B Seine Society) in order to develop and refine project ideas related to ocean tagging research.
- August 1-15, 2012 – PhD student Drenner communicated with commercial, aboriginal, and sport fisherman in regards to research while in the field.
- September 14, 2012 - DFO (PBS Nanaimo, BC) hosted a meeting on Kintama's TEFFS (The Effects of Fish Farms on Salmon) proposal that utilizes the former POST lines in a study to assess potential impacts of open net aquaculture on health and survival of wild fish. In attendance representing OTN were Miller, Hinch and Farrell. DFO had solicited feedback within the departmental scientists on the strengths and weaknesses of the proposal, and the meeting was meant to go over the issues in question and to discuss ways to move forward. The meeting was quite positive, and new approaches to get around the potential for negatively impacting farms in the study design were proposed.

9. Dissemination of information and results

Refereed Journal Articles Accepted/Published (total 21)

Burd, B.J., and R.E. Thomson. 2012. Estimating zooplankton biomass distribution in the water column near Endeavour Ridge using acoustic backscatter and concurrently towed nets. Oceanography 25(1): 269-276.

Collins AL, Hinch SG, Welch DW, Cooke SJ and Clark TD. Accepted. Intracoelomic tagging of juvenile sockeye salmon: swimming performance, growth, survival, and post-surgical wound

healing in freshwater and during a transition to seawater. Transactions of the American Fisheries Society.

Cooke, S.J., and E.B. Thorstad. 2012. Is radio telemetry getting washed downstream? The changing role of radio telemetry in studies of freshwater ichthyofauna relative to other tagging and telemetry technology. American Fisheries Society Symposium 76:349-369.

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

Cooke, SJ, Hinch, SG, Donaldson, MR, Clark, TD, Eliason, EJ, Crossin, GT, Raby, GD, Jeffries, KM, Lapointe, M, Miller, KM, Patterson, DA and Farrell, AP. 2012. Conservation physiology in practice: how physiological knowledge has improved our ability to sustainably manage Pacific salmon during up-river migration. Philosophical Transactions of the Royal Society of London B – Biological Sciences 367, 1757-1769.

Donaldson, M.R., S.G. Hinch, G.D. Raby, D.A. Patterson, A.P. Farrell, and S.J. Cooke. In press. Population-specific consequences of fisheries-related stressors on adult sockeye salmon. Physiological and Biochemical Zoology.

Donaldson, M.R., G.D. Raby, V.N. Nguyen, S.G. Hinch, D.A. Patterson, A.P. Farrell, M. Rudd, L.A. Thompson, C.M. O'Connor, A.H. Colotelo, S.H. McConnachie, K.V. Cook, D. Robichaud, K.K. English, and S.J. Cooke. In Press. Evaluation of a simple technique for recovering Pacific salmon from capture stress: integrating comparative physiology, biotelemetry, and social science to solve a conservation problem. Canadian Journal of Fisheries and Aquatic Sciences.

Drenner, SM, Clark TD, Whitney, CK, Martins, EG, Cooke, SJ and Hinch, SG. 2012. A synthesis of tagging studies examining the behaviour and survival of anadromous salmonids in marine environments. *PLoS ONE* 7(3), e31311.

Hammill, E., Curtis, J.M.R., Patterson, D.A., Farrell, A.P., Sierocinski, T., Pavlidis, P., Hinch, S.G., Miller, K. 2012. Comparison of techniques for correlating survival and gene expression data from wild salmon. Ecology of Freshwater Fish 21: 189-199.

Hinch, S.G., S.J. Cooke, A.P. Farrell, K.M. Miller, M. Lapointe, and D.A. Patterson. 2012. Dead fish swimming: early migration and premature mortality in adult Fraser River sockeye salmon. Journal of Fish Biology 81:576-599.

Johnson, J. E., Patterson, D. A., Martins, E. G., Cooke, S. J. and Hinch S. G. 2012. Quantitative methods for analyzing cumulative effects on fish migration success: a review. Journal of Fish Biology 81: 600-631.

Jeffries, K. M., Hinch, S. G., Martins, E. G., Clark, T. D., Lotto, A. G., Patterson, D. A., Cooke, S. J., Farrell, A. P. and Miller, K. M. 2012. Sex and proximity to reproductive maturity influence survival, final maturation, and blood physiology of Pacific salmon when exposed to high temperature during a simulated migration. Physiological and Biochemical Zoology 85, 62-73.

Jeffries, KM, Hinch, SG, Sierocinski, T, Clark, TD, Eliason, EJ, Donaldson, MR, Li, S, Pavlidis, P and Miller, KM. 2012. Consequences of high temperatures and premature mortality on the transcriptome and blood physiology of wild adult sockeye salmon (*Oncorhynchus nerka*). Ecology and Evolution 2, 1747-1764.

Jeffries, KM, Hinch, SG, Sierocinski, T, Clark, TD, Eliason, EJ, Donaldson, MR, Li, S, Pavlidis, P, Miller, KM. Accepted. Consequences of high temperatures and premature mortality on the transcriptome and blood physiology of wild adult sockeye salmon (*Oncorhynchus nerka*). Molecular Ecology.

Martins, E. G., Hinch, S. G., Cooke, S. J. and Patterson, D. A. In press. Climate effects on growth, phenology and survival of sockeye salmon (*Oncorhynchus nerka*): a synthesis of the current state of knowledge and future research directions. Reviews in Fish Biology and Fisheries.

Martins, E. G., Hinch, S. G., Patterson, D. A., Hague, M. J., Cooke, S. J., Miller, K. M., Robichaud, D., English, K. K. and Farrell, A. P. 2012. High river temperature reduces survival of sockeye salmon (*Oncorhynchus nerka*) approaching spawning grounds and exacerbates female mortality. Canadian Journal of Fisheries and Aquatic Sciences 69, 330-342.

McConnachie, S.H., K.V. Cook, D.A. Patterson, K.M. Gilmour, S.G. Hinch, A.P. Farrell, and S.J. Cooke. In Press. Consequences of acute stress and cortisol manipulation on the physiology, behavior, and reproductive outcome of female Pacific salmon on spawning grounds. Hormones and Behaviour.

Nguyen, V.M., M. Rudd, S.J. Cooke and S.G. Hinch. 2012. Differences in information use and preferences among recreational salmon anglers: implications for management initiatives to promote responsible fishing. Human Dimensions of Wildlife 17:248-256.

Nielsen, J.K., G.H. Niezgoda, S.J. Taggart, S.J. Cooke, P. Anson, C.T. Hasler, K.C. Hanson, and G. Carl. 2012. Mobile positioning of tagged aquatic animals using acoustic telemetry with a synthetic hydrophone array (SYNAPS: Synthetic Aperture Positioning System). American Fisheries Society Symposium Proceedings 76:233-250.

Raby, G.D., M.R. Donaldson, S.G. Hinch, D.A. Patterson, A.G. Lotto, D. Robichaud, K.K. English, W.G. Willmore, A.P. Farrell, M.W. Davis, and S.J. Cooke. 2012. Validation of reflex indicators for measuring vitality and predicting the delayed mortality of wild coho salmon bycatch released from fishing gears. Journal of Applied Ecology 49:90-98

Thomson, R.E., R.J. Beamish, T.D. Beacham, M. Trudel, P.H. Whitfield, and R.A.S. Hourston. 2012. Anomalous ocean conditions may explain extreme variability in Fraser River sockeye salmon production, *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystems Science,* 4: 415-437.

Refereed Journal Articles Submitted (total 8)

Donaldson, M.R., S.G. Hinch, K.M. Jeffries, D.A. Patterson, S.J. Cooke, A.P. Farrell, and K.M. Miller. Responses and recovery of wild, mature adult Pacific salmon to exercise stress. Submitted to Comparative Biochemistry and Physiology A.

Eliason, E.J., S.M. Wilson, A.P. Farrell, S.J. Cooke, and S.G. Hinch. Low cardiac and aerobic scope in a coastal population of sockeye salmon with a short upriver migration. Submitted to Journal of Fish Biology.

Nguyen, V.M., Rudd, M.A., Hinch, S.G., and Cooke, S.J. Recreational anglers' attitudes, beliefs, and behaviors related to catch-and-release practices of Pacific salmon in British Columbia with implications for conservation and management. Submitted to Journal of Environmental Management.

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., Scott, S.G., and Cooke, S.G. 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. Submitted to Physiological and Biochemical Zoology.

Nguyen, V.M., Raby, G.D., Hinch, S.G., and Cooke, S.J. Aboriginal fisher perspectives on use of biotelemetry technology to study adult Pacific salmon. Submitted to Knowledge and Management of Aquatic Ecosystems.

Raby, G.D., S.J. Cooke, K.V. Cook, S.H. McConnachie, S.G. Hinch, M.R. Donaldson, C.K. Whitney, S.M. Drenner, D.A. Patterson, T.D. Clark, and A.P. Farrell. Resilience of pink salmon and chum salmon to simulated capture stress incurred upon arrival at spawning grounds. Submitted to Transactions of the American Fisheries Society.

Sopinka, N.M., Lotto, A.G. and Hinch S.G. Does among-population variation in burst swim performance of sockeye salmon fry reflect difficulty of early life migrations? Submitted to Journal of Fish Biology.

Wilson, S.M., Eliason, E.J., Farrell, A.P., Hinch, S.G., and S.J. Cooke. Calibrating acoustic accelerometer transmitters for estimating energy use by wild adult sockeye salmon. Submitted to Methods in Ecology and Evolution.

Conference Presentations Invited (total 6)

Cooke, S.J., J. Thiem, S. Wilson, G.D. Raby, M.K. Taylor, J. Brownscombe, S.G. Hinch, A.J. Danylchuk and T.D. Clark. Measuring the Energetics of Wild Fish Using Biotelemetry and Biologging Tools. AFS Annual Meeting – Symposium on GLATOS. Minneapolis, MN. Aug 2012.

Farrell, A.P. "Getting to the heart of physiological research in fish", Keynote Speaker, Canadian Association of Laboratory Animal Science, Vancouver, BC. June 2012

Farrell, A.P. "Magnificent Migrations: Pacific salmon behaviour, physiology and transcriptomics"; co-authors - E. Eliason, S. Hinch, K. Miller, S. Cooke, Keynote Speaker, 1st International Conference on Integrative Salmonid Biology, Oslo, Norway. June 2012

Farrell, A.P. "Cardiorespiratory tailoring among sockeye salmon populations for river migrations & its relevance to conservation"; co-authors- Erika Eliason, Mike Donaldson, Kristi Miller, Steve Cooke & Scott Hinch , Invited speaker, Society of Experimental Biology, Salzburg, Austria. July 2012

Hinch, S.G., V.M. Nguyen, D.A. Patterson. Integrating biological and social sciences into management actions: success and future challenges with adult Pacific salmon. Ocean Tracking Network Symposium. Plenary talk**.** Halifax, Nova Scotia, Canada. June 4-6, 2012

Sopinka, N.M., C.K. Whitney, A.G. Lotto, and S.G. Hinch. 2012. Does intraspecific variation in burst swim capacity reflect early life history in sockeye salmon? Future Forestry Leaders Symposium. Vancouver, BC, Canada February 24, 2012.

Conference Presentations– Contributed (16 total)

Donaldson, M.R., S.G. Hinch, S.J. Cooke, D.A. Patterson, K.M. Miller, G.D. Raby, V.M. Nyguyen, and A.P. Farrell. 2012. Understanding how Pacific salmon respond to fisheries-related stress in a

changing climate. 65th Canadian Conference for Fisheries Research, Moncton, New Brunswick, January 2012.

Drenner, S.M., T.D. Clark, L.A. Thompson, D.A. Patterson, R.E. Thomson, S.G. Hinch. 2012. Ocean temperature experience during early stages of sockeye salmon homeward migration. The 2nd Ocean Tracking Network (OTN) Canada Symposium, Dalhousie University, Halifax, NS, Canada.

Furey NB, SJ Cooke, DW Welch, and SG Hinch. Use of spatially explicit individual-based models to investigate population-level hypotheses regarding salmonid migrations and survival. Poster Presentation at the Annual Ocean Tracking Network Meeting, Halifax, Nova Scotia. July 2012.

Gale, M., T.D. Clark, D. Welch, S.G. Hinch. 2012. Behaviour and survival of outmigrating tagged juvenile sockeye salmon. The 2nd Ocean Tracking Network (OTN) Canada Symposium, Dalhousie University, Halifax, NS, Canada.

Hinch, S.G., S. J. Cooke, A.P. Farrell, K.M. Miller, and D.A. Patterson. Physiological drivers of adult salmon migrations and consequences of different migration behaviour. Ecological and Evolutionary Ethology of Fishes, Windsor, ON, Canada, June 17-21, 2012

Nguyen, V.M., E.G. Martins, G.D. Raby, M.R. Donaldson, A.G. Lotto, D.A. Patterson, D. Robichaud, K.K. English, A.P. Farrell, W.G. Willmore, S.G. Hinch, S.J. Cooke. (2012) The relative roles of stress, injury, and recovery on the migratory behaviour and success of sockeye salmon captured and released in the lower Fraser River. *6th World Fisheries Congress*. Edinburgh, Scotland, UK. May 7-11, 2012

Nguyen, V.M., M.A. Rudd, S.G. Hinch, S.J. Cooke (2012) Adopting responsible fishing in a British Columbia recreational salmon fishery: a look at angler behaviour, communication preferences, perceived threats, and support for angler education programmes. 6th World Fisheries Congress. Edinburgh, Scotland, UK. May 7-11, 2012

Raby, G.D., M.W. Davis, M.R. Donaldson, V.M. Nguyen, S.G. Hinch, D.A. Patterson, A.P. Farrell, and S.J. Cooke. 2012. Using simple reflex actions to predict post-release mortality in Pacific salmon: a synopsis of 3 years of research. 6th World Fisheries Congress, Edinburgh, Scotland, UK, May 7-11, 2012.

Raby, G.D., T.D. Clark, D.A. Patterson, A.P. Farrell, S.J. Cooke, and S.G. Hinch. 2012. Using biotelemetry, physiology, and heart-rate biologgers to study capture and release of coho salmon. 2nd Annual OTNC Canada Symposium, Dalhousie University, June 4-6, 2012.

Robinson, K.A., S.G. Hinch, M.K. Gale, and S.J. Cooke. 2012. Facilitated recovery of sockeye salmon following capture. Pacific Ecology and Evolution Conference, Bamfield Marine Science Centre, Bamfield, BC, Canada. March 2-4, 2012.

Robinson, K.A., S.G. Hinch, M.K. Gale, and S.J. Cooke. Effect of facilitated recovery on post-release survival of sockeye salmon recently transitioned from saltwater to freshwater. Ocean Tracking Network Canada Symposium, Dalhousie University, Halifax, Nova Scotia. June 5, 2012.

Robinson, K.A., S.G. Hinch, M.K. Gale, and S.J. Cooke. Effect of facilitated recovery on post-release survival of sockeye salmon. World Fisheries Congress, Edinburgh International Conference Centre, Edinburgh, Scotland. May 11, 2012.

Sopinka, N.M., C.K. Whitney, A.G. Lotto, and S.G. Hinch. 2012. Does intraspecific variation in burst swim capacity reflect early life history in sockeye salmon? Pacific Ecology and Evolution Conference. Bamfield, Canada. March 3, 2012.

Sopinka, N.M., Middleton, C.T., Patterson, D.A. & Hinch, S.G. 2012. Stressed out salmon: effects of parental stress on sockeye salmon offspring. Ecological and Evolutionary Ethology of Fishes, Windsor, ON, Canada, June 17-21, 2012. *won R. Jan F. Smith Conservation Award for Best Application of Behaviour to Fish Conservation

Whitney, C.K., S.G. Hinch, and D.A. Patterson. 2012. Provenance matters: Variable effects of climate change of juvenile sockeye salmon. Pacific Ecology and Evolution Conference. Bamfield, Canada. March 3, 2012.

Whitney, C.K., S.G. Hinch, and D.A. Patterson. Provenance Matters: Early development thermal reaction norms among populations of sockeye salmon. Conference Presentation, World Fisheries Congress. May 7-11, 2012. Edinburgh, Scotland.

10. Other contributions and deliverables

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

- January 2012 to present - We tracked >30 new media reports that have occurred pertaining to the testimony Miller gave at the ISAv hearings in December, including newspapers The Vancouver sun, The Globe and Mail, The Montreal Gazette, Toronto Sun, The Province, Toronto Star, and The National Post, CTV news, CTV Calgary, KPLU radio, CBC news, BBC news, and Nature Volume 483.
- March 10, 2012 – Australia Broadcasting Corporation's The Science Show interview on high temperatures, fisheries stressors, and spawning migrations of Pacific salmon (Interviews with M. Donaldson and K. Jeffries)
- July 2012 – R. Thomson interview published by Keven Drews, Canadian Press, in Times Colonist and Globe and Mail regarding the Thomson et al., Marine and Coastal Fisheries paper on the poor 2009 return for Fraser River Sockeye Salmon.

Invited or contributed open-to-public presentation/contribution.

- March 2012 - "Fishing for answers: Salmon facts & fiction"; Tony Farrell, invited speaker, TerreWEB, UBC, Vancouver, BC.
- March 31, 2012 - Miller gave an invited talk to the annual general meeting of the Qualicum Beach Streamkeepers that highlighted the innovative research combining acoustic and radio- tagging with genomics to a public audience of over 100.

Invited or contributed presentation/contribution at a workshop.

Cooke, S.J. Advancing surgical techniques for animal tagging. Great Lakes Acoustic Telemetry Observing System Workshop, Millersburg, Michigan. Feb 2012.

Donaldson, M.R. 2012. Understanding the consequences of fisheries capture on migrating Pacific salmon. Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. Feb. 9, 2012.

Drenner, S.M., T.D. Clark, C.K. Whitney, D.A. Patterson, S.G. Hinch. 2012. Ocean Tracking of Adult Fraser River Sockeye Salmon. Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. Feb. 9, 2012.

Eliason, E., T.D. Clark, S.G. Hinch, and A.P. Farrell. 2012. Among population differences in pre-smolt and adult sockeye salmon thermal tolerance. Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. Feb. 9, 2012.

Martins, E. G., Hinch, S. G., Cooke, S. J. and Patterson, D. A. Climate warming and temperature effects on survival of Fraser River sockeye: an overview. Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. February 9 2012.

Nguyen, V.M., M.A. Rudd, S.G. Hinch, S.J. Cooke. 2012. Information from social science: research relevant to salmon conservation and management. Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. Feb. 9, 2012.

Raby, G.D., S.G Hinch, D.A. Patterson, S.J. Cooke. 2012. The fate of coho salmon bycatch released from beach seines. Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. Feb. 9, 2012.

Rechisky, E.L., D.W. Welch, S. G. Hinch, T.D. Clark. 2012. Telemetry-based estimates of marine survival of Fraser and Columbia River Salmon, 2011. Presentation at the State of the Pacific Ocean 2012 Workshop. February 15-16, 2012, Nanaimo, B.C.

Robinson, K.A., S.G. Hinch, M.K. Gale, G.D. Raby, and S.J. Cooke. 2012. Facilitated recovery of sockeye salmon following capture. Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. February 9, 2012.

Sopinka, N.M., C.K. Whitney, A.G. Lotto, and S.G. Hinch. 2012. Intraspecific variation in embryonic thermal tolerance and fry swim performance . Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. Feb. 9, 2012.

Sopinka, N.M, and S.G. Hinch. 2012. Transgenerational effects of stress in sockeye salmon. Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. Feb. 9, 2012.

Wilson, S.M. S.G. Hinch, and S.J. Cooke. 2012. Energetics and behaviour of adult sockeye salmon during migration from coastal waters to inland natal spawning sites in British Columbia. Workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries, University of British Columbia, Vancouver, BC, Canada. Feb. 9, 2012.

Invited or contributed presentation/contribution at a seminar series.

Cooke, S.J. An interdisciplinary approach to quantifying and reducing post-release mortality in Pacific salmonids. Danish Technical University AQUA, Silkeborg, Denmark. Invited Presentation. Aug 2012.

Cooke, S.J. Fitness physiology of fish. University of Windsor, Department of Biology Seminar, Windsor, ON. Jan 2012.

Cooke, S.J. The art and science of recreational fisheries. University of Washington, Bevan Series on Sustainable Fisheries. Seattle, WA. Jan 2012.

Eliason, E. Can local adaptation save sockeye salmon from climate change? Departmental seminar, School of Biological Sciences, University of Sydney. Aug 3, 2012.

Hinch, S.G. Changing climate and changing behaviour: using physiological telemetry and experimental biology to examine a conservation crisis in migrating adult Pacific salmon. William Main Forestry Seminar Series, University of California, Berkeley CA , Jan. 2012.

Jeffries, K.M. Effects of water temperature on Pacific salmon gene expression. University of British Columbia Comparative Physiology Seminar Series, Vancouver, British Columbia, Canada. Mar. 2012.

Nguyen, V.M. Biological and Social Science Aspects of Pacific Salmon Fisheries Interactions in the Lower Fraser River**.** Carleton University Biology Departmental Seminar, Ottawa, Canada. Feb. 17, 2012.

Miller, K. Acoustic/radio tracking and genomics. University of Victoria Molecular Biology seminar series January 27, 2012.

Miller, K. New genomic microbe surveillance program and health assessments of wild salmon. Departmental seminar, Beaty Biodiversity Centre, University of British Columbia, February 15, 2012.

Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, Glider runs, and/or data deposition to an agency/database (e.g., MEDS, GenBank, OBIS, etc.), as well as a contribution to a larger piece of work in any of the former.

- Clark, TD, Riddell, B, Farrell, AP, Welch, DW and Hinch, SG. 2012. Assessing river and coastal ocean survival and movement rates of Chilko Lake sockeye salmon smolts using acoustic telemetry: A synthesis of findings from 2011. Submitted to Pacific Salmon Foundation, and Department of Fisheries and Oceans Canada.
- Rechisky, E.L., D.W. Welch, S. G. Hinch, T.D. Clark. 2010. Telemetry-based estimates of marine survival of Fraser and Columbia River Salmon, 2011. State of the Pacific Ocean: 2012 Workshop. February 15-16, 2012, Nanaimo, B.C. Published extended abstract.
- Numerous CTD casts taken while tagging sockeye off the coast of British Columbia (August 2011,2012).
- Microarray data associated with the paper "Consequences of high temperatures and premature mortality on the transcriptome and blood physiology of wild adult sockeye salmon (*Oncorhynchus nerka*)" have been deposited in the Gene Expression Omnibus (http://www.ncbi.nlm.nih.gov/geo/) with the accession number GSE33586. (March 2012).
- Martins, E. G., Gutwosky, L. F. G., Harrison, P. M., Patterson, D. A., Power, M. and Cooke, S. J. 2012. Entrainment vulnerability of sub-adult and adult bull trout and burbot at Mica Dam (Kinbasket Reservoir). Technical report prepared for BC Hydro, Burnaby, BC. 71pp.
- Martins, E. G., Harrison, P. M., Gutwosky, L. F. G., Cooke, S. J., Power, M. and Patterson, D. A. 2011. Entrainment vulnerability of sub-adult and adult bull trout and burbot at Mica Dam (Kinbasket Reservoir): Preliminary findings. Technical report prepared for BC Hydro, Burnaby, BC. 34pp.

Books

Cooke, S.J., S.G. Hinch, M.C. Lucas, and M. Lutcavage. In Press. Chapter 18 - Biotelemetry and biologging. in A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries Techniques, Third Edition. American Fisheries Society, Bethesda, Md.

Cooke S.J., G.T. Crossin, and Hinch S.G. 2012. Migration of Pacific Salmon – Closing the Loop. In: Farrell A.P., (ed.) Encyclopedia of Fish Physiology: From Genome to Environment, San Diego: Academic Press.

Binder T.R., Cooke S.J., and Hinch S.G. 2012. The Biology of Fish Migration. In: Farrell A.P., (ed.) Encyclopedia of Fish Physiology: From Genome to Environment, San Diego: Academic Press.

Thomson, R.E. 2012. Strait of Georgia: The Physical Ocean. *In*, The Strait of Georgia, Springer Publishing, edited by Richard Beamish and Sandy McFarlane (submitted).

Anything else that isn't a primary publication that has you communicating (specify) with others (specify).

- Collins, A., and S.G. Hinch. 2012. Tracking sockeye salmon. Branchlines. Volume 23 (1): 7 http://www.forestry.ubc.ca/Publications/Branchlines.aspx
- Ken Jeffries gave a guest lecture in, 4th year course, Conservation 486: Fish Conservation and Management. 'Fish diseases (and parasites) and emerging Pacific salmon issues' University of British Columbia, Vancouver, British Columbia, Canada. March 2012.
- Collin Middleton. BSc Honour's Thesis. 2012. Transgenerational effects of stress in sockeye salmon (*Oncorhynchus nerka*) on offspring fertilization success and embryonic survival. University of British Columbia, Vancouver, BC. *won Faculty of Forestry Best Undergraduate Thesis, April 2012.
- Natalie Sopinka wins 1st place in the University of British Columbia Three Minute Thesis competition where contestants must creatively present objectives and significance of research to a non-specialist audience. Video link: http://www.youtube.com/watch?v=4B2KHFDH-ts ; January 2012.
- Natalie Sopinka and Charlotte Whitney give tour of sockeye salmon research laboratory to 20 high school students participating in the Greater Vancouver Regional Science Fair. University of British Columbia,Vancouver, BC. April 2012.
- Presentation by Natalie Sopinka and Charlotte Whitney to Annual Metro Vancouver Science tour for elementary children, 'Fry'n Eggs Insanity'. April 2012
- Sam Wilson, Let's Talk Science Volunteer: Presentation on Pacific Salmon life history to Gr 10 Applied Science Apr 25th, 2012.

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

We are aware of several grants and funding requests that are either submitted or in development that leverage the OTNC NSERC or CFI grants, or their current infrastructure, including:

- Using OTN (former POST) acoustic lines and HQP as leverage, Cooke and Hinch were awarded an NSERC Engage grant to work with Area B Seine Fishing Association in BC waters to address a coho bycatch problem (June to Dec 2012).

- A new collaborative research program centered on salmon health was developed by DFO (Miller), the Pacific Salmon Foundation, Genome BC, and the US Geological Survey Fish Health laboratory that will seek a greater understanding of the role of infectious disease in shifting productivity dynamics of wild salmon populations. Phase 1 of this four phase program has been approved for funding (Genome BC is providing 200K of the 937K phase 1 project). Phase 2, currently under development, will involve leveraging using OTN infrastructure and HQP; salmon acoustically tracked in Pacific OTN projects will be among those analyzed using the high throughput microbe surveillance technology being developed and applied in this program.
- Mark Shrimpton (UNBC) developed an NSERC Discovery grant that will rely on the OTNC as a platform for some smolt osmoregulatory work.
- Kristi Miller (DFO) and Hinch each submitted proposals to the Southern Endowment Fund of the Pacific Salmon Commission for smolt sampling and genomics work. OTNC infrastructure and data are key aspects of the leveraging.
- Timber Whitehouse (DFO) submitted a proposal to the Southern Endowment Fund of the Pacific Salmon Commission to capture and assess downstream migrating smolts. OTN tags and HQP will be used at their capture site.
- David Patterson (DFO) received funding from the Southern Endowment Fund of the Pacific Salmon Commission to improve models for predicting escapement adjustments. These incorporate OTNC based telemetry results on adult sockeye mortality estimates.
- Brian Riddell (Pacific Salmon Foundation) provided funds in 2012 to again help with OTNC tagging and tracking of sockeye smolt, he will again approach private donors this coming year to secure additional funds for continuation of the project.
- David Welch (Kintama Ltd) is developing a large research proposal to study impacts of fish farms on wild Pacific salmon migrations and survival (TEFFS) for consideration by DFO, industry and private foundations. OTNC infrastructure is a key component to the proposal.

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.

1. MSc student Samantha Wilson (and team) developed the first ever calibration of an acoustic accelerometer transmitter on fish using swim tunnel respirometry. The equations derived in the study will be widely used by salmon researchers and has been written up into a paper that is under review. In a related development, MSc student Nich Burnett assessed the utility of new inexpensive externally mounted accelerometer biologgers.
2. PIs Miller, Farrell and Hinch combined Biomarkers predictive of the 'Mortality-related Signature' (MRS) obtained from telemetered and tracked fish with quantitative assays for 17 salmon pathogens and run on the Fluidigm BioMark. They assessed the prevalence of the MRS across tissues, years and stocks and to begin to identify the pathogens carried by sockeye salmon. The pathogen research was a "proof of principle" for a future new project inspired by our finding of: multiple mortality signatures among co-migrating fish including the activity of various infectious agents, the identification in this program of a novel salmon parvovirus, the identification of short sequences from BC salmon that showed high homology to the Infectious Salmon Anemia virus (which is not known to be present in BC), and the clear lack of knowledge on the pathogens and

diseases that may be negatively impacting performance of wild BC salmon displayed by fish health researchers testifying at the Cohen Inquiry.

3. PhD student Graham Raby tested a new method for external attachment of VEMCO V8 acoustic transmitters for adult coho salmon migrating through marine areas. The method involves attaching the transmitters by threading the end-cap of the transmitter onto a spaghetti tag inserted through the dorsal musculature, just posterior to the dorsal fin.
4. An experiment was conducted at UBC using lab-raised smolt-sized juvenile sockeye which were surgically implanted with dummy V5 tags (some had small amounts of gill filaments removed; others were non tagged/non clipped controls). After 30 days, none of the tagged fish (with or without gill removal) had died and there were no discernible differences among treatments in fish growth indicating it was feasible to emulate this tagging/handling approach with wild smolts in the field.
5. The study above was conducted using VEMCO V5 sized tags - a tag type never used before in large scale studies.

A proof of concept in relation to any of the above

1. The acoustic accelerometry calibrations developed by Sam Wilson are being used to facilitate a field comparison of logger accelerometer versus transmitter accelerometer technologies for studying Pacific salmon migration energetics (Aug and Sept 2012), led by MSc student Nich Burnett.
2. We conducted a proof of concept analysis that combined microbe surveillance of the novel salmon parvovirus on tissue samples from adult salmon tracked through OTN, and identified a significant association in one Fraser River stock between presence and load of the virus and successful migration. This is an extension of the microarray approaches identifying host biomarkers associated with successful migration that will be expanded upon in the new salmon microbe program developed under a new Genome BC Strategic Initiative.
3. PhD student Graham Raby tested a new method for external attachment of VEMCO V8 acoustic transmitters for adult coho salmon migrating through marine areas. The method was tested and validated in the field using a 24-h holding study on board a commercial purse seine vessel, and 50 transmitters were deployed on coho that were released to resume their migration. The resulting telemetry data will be the first ever tracking data for coho salmon in the marine environment from any population.
4. Gill samples were taken from 200 outmigrating sockeye smolts that were tagged to assess pathogen status and related it to migratory fate. This is the first time the pathogen status of released and tagged smolts has been investigated, and we hope to relate these data to acoustic detection data in the river and early marine environments.
6. Approximately 200 smolts were implanted with the newly available VEMCO V5 tags which are detectable with 180 kHz VR2W receivers or VR4 receivers (none of these fish had gill samples removed). This was the first ever mass release of this new type of VEMCO tag.

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.

- In collaboration with the Fraser River Environmental Watch (DFO) program, Pacific OTN HQP collected over 1000 physiological samples from wild salmon. These data contribute to a long-term database on reference conditions of fish in the Fraser Watershed.

11. Collaborations with Industrial and Government 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 OTNC Canada Pacific research (e.g. Drs. K. Miller and R. Thomson and their lab groups; D. Patterson and the Fraser Environmental Watch Program). 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 (Mark Saunders; Dave Patterson) provided technical personnel to help in the field and lab, and have loaned equipment. DFO fisheries managers (e.g. Timber Whitehouse, Barry Rosenberger) 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 recent 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 Pacific Salmon Foundation (PSF) is a federally incorporated non-profit charitable organization committed to the conservation and restoration of wild Pacific salmon and their natural habitats in British Columbia and the Yukon. Brian Riddell (President) provided OTNC Canada Pacific investigators with funds for our smolt studies. The PSF has been instrumental in communication of OTNC results and findings to fisheries managers, the ENGO community, senior bureaucrats, politicians, and the public at large.

Environment Canada is a federal agency responsible for, among other things, water quality monitoring. The Water Quality Monitoring Program in the Pacific and Yukon Region consists of 49 long-term ambient water quality monitoring stations on rivers in British Columbia, and ten stations on rivers in the Yukon. These stations are primarily operated on rivers of federal interest (e.g. transboundary, national parks, major fisheries). Mark Sekela (Senior Environmental Quality Scientist) and Jennifer MacDonald from this group partnered with us and used their vessels to deploy OTNC acoustic receivers on hydrographic buoys in the lower Fraser River estuary transition area – they also deployed a new buoy for us. This enables us to obtain environmental data that are directly linked to fish passage.

Kintama Research Corporation is involved in telemetry array design, development, installation, and maintenance, design and analysis of telemetry data, and surgical tagging and tag programming. They have collaborated with OTNC Pacific investigators since 2006. They are involved with downloading and maintenance of POST acoustic arrays and thus in providing to POST data for the Pacific OTNC studies. Kintama owns a series of receivers situated in the mouth of the Fraser River which collected important data from our juvenile and adult salmon studies in 2011. They have provided these data to us and are assisting in their analysis (PDF Erin Rechisky). They have also been instrumental in helping to train

some of our students in surgical approaches and tagging, and in assisting in the design our juvenile salmon tagging project.

The Area B Seine Association is the organization that represents a commercial fishing industry user group in BC that uses seine nets to target Pacific salmon in coastal waters. The association has representatives sitting on DFO harvest management committees and they work with various ENGOs and other fisheries stakeholders to advise on harvest strategies.

Name of supporting organization: **DFO Pacific Region**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$64 900
2) Donation of equipment, software	$34 800
3) Donation of material	$8 000
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$107 700
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **Pacific Salmon Commission**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$28 750
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$28 750
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **Pacific Salmon Foundation**	**Year 3** 2012
Cash contributions to direct costs of research	$42 800
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$42 800
Is this new funding (acquired during this reporting period)?	Yes

Name of supporting organization: **Kintama Research Services**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$12 500
2) Donation of equipment, software	$13 500
3) Donation of material	
4) Field work logistics	$24 000
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$50 000
Is this new funding (acquired during this reporting period)?	Yes

Name of supporting organization: **Environment Canada**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$4 000
2) Donation of equipment, software	$4 000
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$8 000
Is this new funding (acquired during this reporting period)?	Yes

Name of supporting organization: Area B Seine Association	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
Salaries for scientific and technical staff	
4) Donation of equipment, software	
5) Donation of material	
6) Field work logistics	
7) Provision of services	
8) Other (specify): Boat Charter	$50 000
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$50 000
Is this new funding (acquired during this reporting period)?	Yes

12. Expenditures and Support

Year 3 (2012)

Budget Item	Year 3 (2012)				
	Proposed	**Actual Expenditures** 1 Jan - 30 Sep 2012	**Total Balance** 30 Sep 2012	**Projected Balance** 31 Dec 2012	**Deviation**
1) Salaries and Benefits					
a) Students	$47 000	$47 160	-$160	-$160	0%
b) Postdoctoral Fellows	$40 000	$10 769	$29 231	-$769	-2%
c) Technical/Professional	$41 000	$67 789	-$26 789	$3 211	8%
d) Other	$0	$0	$0	$0	
2) Equipment or Facility					
a) Purchase or Rental	$50 000	$50 004	-$4	-$4	0%
b) Operations/Maintenance	$0	$0	$0	$0	
c) User Fees	$10 000	$8 394	$1 606	$1 606	16%
3) Material and Supplies					
a) Materials and Supplies	$25 000	$30 523	-$5 523	-$5 523	-22%
4) Travel					
a) Conferences	$6 000	$6 753	-$753	-$753	-13%
b) Field Work	$30 000	$32 207	-$2 207	-$2 207	-7%
c) Collaboration/Consultation	$3 000	$3 246	-$246	-$246	-8%
5) Dissemination					
a) Publications	$1 000	$1 292	-$292	-$292	-29%
b) Other	$0	$0	$0	$0	
6) Other (specify)					
a) Other	$0	$0	$0	$0	
b) Other	$0	$0	$0	$0	
Totals					
Totals	$253 000	$258 137	-$5 137	-$5 137	

The above budget table is correct as of December 15, 2012.

Last winter Pacific OTNC requested and was granted permission to re-allocate salaries, specifically 30K was moved from postdoctoral fellows to technical assistants. Although that is not reflected in the 'proposed' budget line, it is reflected in total balance to date, and in the projected balance. When those changes are factored into the salary lines, there is only minor deviations in any of the salary categories.

Materials and supplies at present are only over-spent by 2% (we had a 22% deviation - this 2% amounts to about $500. We had some carry-over funds from last year in this category which we can apply to this minor amount. Although we are 9% over budget (29% deviation) in publication costs, this over expenditure amounts to about $300. The ~$1300 expense in this category was to pay for publication of one paper.

How the remaining Projected Balance of Year 3 on 31 Dec 2012 will be spent

There are no funds left at end of 2012 from the 2011 period, and we were overspent by 5.1K. However we are still carrying forward a surplus from previous years thus our current grand total surplus is 30K on Dec 31, 2012.

Whether year 2 (2011) actual expenses for October-December were on target with what was forecast in last year's report

Yes they were.

Conference travel budget justifications

The very small conference budget that the entire Pacific Arena had (6K) was very well spent. We sent several HQP to conferences, all of which presented research and in each case, students had to secure additional funds on their own in order to make the trip financially feasible (e.g. through conference and university travel awards). Each student only received a small amount of OTN funding to assist. In some cases, OTN funding was not used to assist. We also partially assisted students in their conference travel through other grants. Attendance added clear value to the network as students were presenting at very large international venues, in addition to smaller, regional ones. Our PIs and HQP presented at 26 conference, large workshop, or seminar venues. Listed below are presentations made by HQP at large conferences.

6th World Fisheries Congress. Edinburgh, Scotland,

Nguyen, V.M., E.G. Martins, G.D. Raby, M.R. Donaldson, A.G. Lotto, D.A. Patterson, D. Robichaud, K.K. English, A.P. Farrell, W.G. Willmore, S.G. Hinch, S.J. Cooke. (2012) The relative roles of stress, injury, and recovery on the migratory behaviour and success of sockeye salmon captured and released in the lower Fraser River. 6th World Fisheries Congress. Edinburgh, Scotland, UK. May 7-11, 2012

Nguyen, V.M., M.A. Rudd, S.G. Hinch, S.J. Cooke (2012) Adopting responsible fishing in a British Columbia recreational salmon fishery: a look at angler behaviour, communication preferences, perceived threats, and support for angler education programmes. 6th World Fisheries Congress. Edinburgh, Scotland, UK. May 7-11, 2012

Raby, G.D., M.W. Davis, M.R. Donaldson, V.M. Nguyen, S.G. Hinch, D.A. Patterson, A.P. Farrell, and S.J. Cooke. 2012. Using simple reflex actions to predict post-release mortality in Pacific salmon: a synopsis of 3 years of research. 6th World Fisheries Congress, Edinburgh, Scotland, UK, May 7-11, 2012.

Robinson, K.A., S.G. Hinch, M.K. Gale, and S.J. Cooke. Effect of facilitated recovery on post-release survival of sockeye salmon. World Fisheries Congress, Edinburgh International Conference Centre, Edinburgh, Scotland. May 11, 2012.

Whitney, C.K., S.G. Hinch, and D.A. Patterson. Provenance Matters: Early development thermal reaction norms among populations of sockeye salmon. Conference Presentation, World Fisheries Congress. May 7-11, 2012. Edinburgh, Scotland.

Canadian Conference for Fisheries Research

Donaldson, M.R., S.G. Hinch, S.J. Cooke, D.A. Patterson, K.M. Miller, G.D. Raby, V.M. Nyguyen, and A.P. Farrell. 2012. Understanding how Pacific salmon respond to fisheries-related stress in a changing climate. 65th Canadian Conference for Fisheries Research, Moncton, New Brunswick, January 2012.

Ecological and Evolutionary Ethology of Fishes

Sopinka, N.M., Middleton, C.T., Patterson, D.A. & Hinch, S.G. 2012. Stressed out salmon: effects of parental stress on sockeye salmon offspring. Ecological and Evolutionary Ethology of Fishes, Windsor, ON, Canada, June 17-21, 2012. *won R. Jan F. Smith Conservation Award for Best Application of Behaviour to Fish Conservation

Pacific Ecology and Evolution Conference

Sopinka, N.M., C.K. Whitney, A.G. Lotto, and S.G. Hinch. 2012. Does intraspecific variation in burst swim capacity reflect early life history in sockeye salmon? Pacific Ecology and Evolution Conference. Bamfield, Canada. March 3, 2012.

Whitney, C.K., S.G. Hinch, and D.A. Patterson. 2012. Provenance matters: Variable effects of climate change of juvenile sockeye salmon. Pacific Ecology and Evolution Conference. Bamfield, Canada. March 3, 2012.

Robinson, K.A., S.G. Hinch, M.K. Gale, and S.J. Cooke. 2012. Facilitated recovery of sockeye salmon following capture. Pacific Ecology and Evolution Conference, Bamfield Marine Science Centre, Bamfield, BC, Canada. March 2-4, 2012

Year 4 (2013)

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$55 250	$55 250		0%
b) Postdoctoral Fellows	$40 000	$40 000		0%
c) Technical/Professional	$41 000	$41 000		0%
d) Other	$0	$0		
2) Equipment or Facility				
a) Purchase or Rental	$50 000	$50 000		0%
b) Operations/Maintenance	$0	$0		
c) User Fees	$10 000	$10 000		0%
3) Material and Supplies				
a) Materials and Supplies	$29 000	$29 000		0%
4) Travel				
a) Conferences	$9 000	$9 000		0%
b) Field Work	$30 000	$30 000		0%
c) Collaboration/Consultation	$3 000	$3 000		0%
5) Dissemination				
a) Publications	$1 000	$1 000		0%
b) Other	$0	$0		
6) Other (specify)				
a) Other	$0	$0		
b) Other	$0	$0		
Totals				
Totals	**$268 250**	**$268 250**		

No changes recommended for year 4 budget.

Below is the budget justification for activities involving year 4 of the grant. This text is taken directly from the justification submitted in the original proposal. Portions of justification that involved years 1-3, and beyond year 4, have been removed where possible. The year 4 budget remains on track with the original submitted by the Pacific Arena.

Proposed Expenditures

Salaries and benefits

Students (total year 4 budget $55,250): One PhD student will be responsible for the multi-year oceanographic survey and modeling efforts conducted in the continental shelf and Salish Sea areas which spatially/temporally overlap with the migrations of returning adult salmon, and another PhD student will be responsible for the multi-year oceanographic survey and modeling efforts conducted in the coastal and estuarine areas which spatially/temporally overlap with the migrations of juvenile salmon - both running from years 1 to 4 (@ $19,000/yr for each – **year 4, $38,000**). One PhD student will be responsible for analyzing gene array results and identifying genomic / physiological associations between juvenile migration behaviour and fate (years 2 to 5; we will seek an individual holding a PGSD for years 2 and 3 and who would be a strong candidate for internal UBC fellowships in years 4 and 5). One PhD student will be responsible for the adult salmon physiological intervention telemetry study,

and another PhD student for the commercial fishery component and recovery evaluation of the capture-release telemetry study - for these two students we will seek individuals with NSERC PGSD support. An MSc student (year 2-4) will utilize juvenile salmon telemetry in the Salish Sea and link survival and fate to oceanographic conditions identified by the overlapping PhD studies discussed above and will draw on these results to design telemetry intervention experiments to test physiological hypotheses about the main survival factors identified by the first. We will seek students initially supported by NSERC PGSM so will only request funds for 6 months of year 4 (**year 4, $8,250**). We will take on a USRA (NSERC undergraduate award student) each summer over the seven year program. [Hinch/Cooke/Farrell have been awarded these through their departments in each of the last 6 years]. We only request top-up support (**year 4, $3,000**). We will also take on an additional undergraduate assistant (**year 4, $6,000**). Both students will assist with several of the projects.

Postdoctoral Fellows (total year 4 budget $40,000): We will support one postdoctoral fellow each year to conduct coastal transition zone biopsy telemetry on adult and juvenile salmon and link to oceanographic conditions (**year 4, $40,000**). In addition to conducting those specific studies, the PDFs will be responsible, each during their specific tenure, for helping the co-PIs and collaborators co-ordinate Pacific arena research, organize Pacific arena researcher meetings, assist with training of students, and writing grant proposals to seek funds for additional research projects that complement the OTN program.

Technicians (total year 4 budget $41,000): We will support 50% (**year 4, $35,000**) of the time of a technician (Andrew Lotto) who will be responsible for running and organizing all of the field sampling, experiment logistics and animal care including: fish capture, experimental apparatus set up and maintenance, lab water quality and temperature maintenance, lab on-site rearing of adults and juveniles, vehicle maintenance, safety training and planning, on-going animal care training of students. Mr. Lotto has worked in our group for the past 12 years, has a wealth of field and lab logistic and animal holding/experimentation experience. The remainder of his salary will be obtained through other on-going research programs. We will partially support another technician (**year 4, $6,000)** to assist with downloading data from oceanographic sensors, towed CTD units, receiver arrays, edit downloaded data, and provide to the graduate students and PDFs. The remainder of technician salaries will be obtained through other on-going research programs.

Equipment

Rental (total year 4 budget $50,000): We will charter a purse seine vessel to capture adult salmon for tagging and releasing ($5,000 / day, 9 days; **year 4, $45,000**). We will charter a small vessel to conduct CTD vertical profiles to characterize oceanographic features experienced by outmigrating juvenile salmon and to conduct some hand-tracking of outmigrating juveniles and returning adults (**year 4, $5,000**).

User Fees (total year 4 budget $10,000): There are charges to use tanks and space at the UBC aquatic research facility (which includes the time of an animal care technician) (**year 4, $10,000**).

***Materials and Supplies* (total year 4 budget $29,000)**

Stock ID: As we are interested in studying fish from specific stocks, as well as species, and because stocks often co-migrate, we need to be able to rapidly differentiate them. For example, there are over 150 stocks of Fraser sockeye salmon alone. DNA analysis (conducted at the DFO Pacific Biological Station lab) is needed to confirm stock ID on tagged fish. DNA analysis takes several weeks so it cannot be used for immediate ID but is necessary to ensure appropriate interpretation of telemetry

results. It costs approximately $20 per fish for the chemicals needed for DNA identification and the PSC will provide in-kind support of 50% per fish; we need support for the other 50% (**year 4, $5,000**).

Physiological assay supplies: DFO will pay for the consumable chemicals, bioassays and reagents needed for analyses of tissue lipids and protein, plasma ions, metabolites, and histological assays (see details below). We have budgeted for the bioassays and reagent costs for analysis of some of the stress hormones, indicators of oxidative stress and tissue damage, and all of the reproductive hormones which are the most expensive biochemical assays that we will run (**year 4, $5,000**).

Genomic supplies: We will conduct gene microarray analyses on subsets of juvenile telemetered fish. The consumable chemicals and slides needed for the gene microarray analyses cost $350 per sample. The gene microarrays are the most expensive physiological analyses that we will conduct but are still a good value because they offer cutting edge genomic technology for assessing physiological mechanisms at an integrated whole-animal level (~ 32,000 genes can be examined simultaneously), and can be used to identify novel genes and physiological pathways involved in migratory behaviour and fate. We will analyze 40 fish / year in years 2-5 (contrasting fish with different migratory routes or fates). We are gaining access to sophisticated equipment and technical assistance to run samples, all as in kind support from DFO (see details below - Molecular Genetics Centre, PBS, DFO Nanaimo, collaborator – K. Miller) who will also pay for 100% of the consumable costs in years 2 and 3 through BC Genome funds. We request funds for the consumable costs (**year 4, $14,000**).

Field supplies: batteries for three microwave energy meters, batteries for acoustic receivers, safety supplies, vials, coolers, dry ice, liquid nitrogen, rope, buoys and hardware, tools, tubing (**year 4, $5,000**).

Travel

Conferences (total year 4 budget, $9,000): We will partially support graduate students and PDFs to attend conferences @ $1,500 / conference but expect students to also find support through internal university funds and through specific conference and society funds. HQP numbers will peak in year 4. Our group will have 6 conference attendees in that year (**year 4, $9,000**).

Field work (total year 4 budget, $30,000): Lab and field sampling locations, in some cases, are considerable distances from each other and people, fish and samples need to be shuttled amongst them at different times of the year. Our adult salmon sampling locales are situated at two locales in the Salish Sea requiring a 2 hour drive and a 2 hour car ferry from UBC main campus. Our other adult sampling location in the Coastal Transition Zone near the Queen Charlotte Islands is 12 hour drive and 6 hour ferry from UBC main campus. The CAER is a 45 min drive from UBC main campus. Juvenile fish sampling locations are all within a 2 hour drive of CAER. Hinch's department owns and operates a 4X4 (Ford 350) pickup truck which can be used to transport fish in a large live box, and to move holding tanks. We also have access to a large Ford Econoline Van and small Mazda pickup truck. These vehicles will be largely available to us over the 7 year program for the transporting of fish from capture to the lab, and also to move people to the field capture sites. For years 2 – 7, we budgeted $15,000 per year for cost recovery of mileage on these vehicles and estimate to require $5,000/yr for gas costs (**year 4, $20,000**). Rental and gas estimates are in line with our experience with previous NSERC Strategic research involving adult and juvenile salmon telemetry. The capture of adult salmon requires living out of town for several weeks each year. We will rent hotel rooms or houses each year, depending on which is cheapest for our duration near a particular capture site (year 2 – 7, $5,000/yr; **year 4, $5,000**). We will pay for food of our students while living at field sites (year 2 – 7, $5,000/yr; **year 4, $5,000**).

Collaboration/Consultation (total year 4 budget, $3,000): We have budgeted for costs of students to train and be mentored in the labs of our DFO co-PIs (Dr. Kristi Miller - Pacific Biological Station; Nanaimo BC) and Dr. Rick Thomson (Institute of Ocean Sciences, Sydney BC). Specifically, they will live in Nanaimo and Sydney BC for several days each year training with DFO technical staff and conducting lab and oceanographic data analyses. Collaboration also includes our annual Pacific Arena 1 day workshop where all investigators, collaborators, partners, and students come together in Vancouver to discuss current results, transfer our results and knowledge to our partners and other interested user groups, and plan next years activities. Accommodation, food, airfare, ferries – **year 4, $3,000**).

Dissemination costs (**total year 4 budget, $1,000)** Many journals which we publish in now have no page charges and reprints can be obtained and distributed electronically at no cost. For journals with page charges, they typically run about $500 to $1000 per publication. Based on our previous NSERC Strategic research experience, we estimate generating at least 30 publications in the scientific literature and technical fisheries management bulletins during the duration of this grant but have only budgeted $1,000 / yr in years 3 – 7 with the assumption that nearly all of our scientific publishing will have few large costs associated with it (**year 4, $1,000**).

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

IV: OTN Networking and Ocean Governance Theme 5

1. Project Number: IV

2. Project Title: Integrating Research and Themes across Arenas and Implications for oceans governance (Tracking and Protecting Marine Species at Risk: Scientific Advances, Sea of Governance Challenges)

NOTE: the budgets for these two components (Networking and Ocean Governance) of the Network are combined both in the original Phase I proposal and in reporting. This report focuses on Theme 5 activities, as networking and integration are already described elsewhere throughout this report.

3. Project Leaders: Networking leader - S. Iverson (Dalhousie), Theme 5 leaders - D. VanderZwaag, R. Apostle (Dalhousie)

Collaborators: R. Branton, J. Hutchings, C. Taggart, B. Worm (Dalhousie), M. Castonguay, J. Ford (DFO), S Cooke (Carleton), J. Duff (SS, U Massachusetts, Boston), A. Fisk (Windsor), M. Litvak (Mount Allison), C. Norchi (SS, U Maine), J. Phyne (SS, St. Francis Xavier), M. Robinson-Dorn (SS, U California Irvine), P. Saunders (SS, Dalhousie), M. Stokesbury (Acadia), C. Tollefson (U Victoria), N. Young (SS, U Ottawa)

4. Public Summary of Report

In June 2011 a second two-day workshop (Protecting Marine Species at Risk: Towards Integrating Natural and Social Science Perspectives) was held at Dalhousie University, where an initial core of OTN natural and social science researchers shared views on their research interests and discussed possible ways forward in synergizing interdisciplinary collaborations under the OTN umbrella. One of the key workshop outcomes was a list of case studies to be conducted under OTN Canada. Among these case studies are American eel, Atlantic sturgeon, Pacific salmon, killer whale, and grey seal – cod interaction. These studies will explore tracking and scientific status of the marine species, the social and environmental threats to these species, as well as governance arrangements and challenges.

In June 2012 a third interdisciplinary two-day workshop was held, aimed at allowing the working teams of natural, social, and legal scholars, to develop a common research methodology, and to discuss preliminary findings in their respective fields of research. These case studies will be published in a special issue of the *Journal of International Wildlife Law & Policy* special issue during 2013.

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. In April 2012, D. VanderZwaag met with representatives from the Universities of Sydney, New South Wales, Tasmania, and Western Australia, as well as researchers from the Australian National University, the University of Technology at Sydney, the Australian Fisheries Management Authority, the Australian Institute of Marine Science, the Commonwealth Scientific and Industrial Research Organization (CSIRO), the Department of Sustainability, Environment, Water, Population, and Communities and the

Department of Fisheries, Government of Western Australia. As a follow up, a full project proposal is expected to be drafted under the lead of the social science team.

5. Training of Highly Qualified Personnel

Personnel	Title	% Time in project	% Support from SNG	Dates
Tsafirir Gazit	PDF	100%	0%	1 Jan 2012 – 30 Sep 2012
Cecilia Maria Engler-Palma	JSD (law)	75%	0%	1 Jan 2012 – 30 Sep 2012
Allison Reed	JD	25%		1 Jan 2012 – 30 Sep 2012
Emma Feltes	MA	5%	0%	1 Jan 2012 – 30 Sep 2012
Emma Feltes	MA	100%	100%	1 Sep 2012 – 30 Sep 2012

6. Progress towards Objectives/Milestones (1 Oct 2011 – 30 Sep 2012)

The interdisciplinary research teams started to work on the various case studies. Most of the fieldwork started towards the end of the year, soon after the theme 5 budget was approved.

A third interdisciplinary two-day workshop was held in June, aimed at allowing the working teams of natural, social, and legal scholars, to develop a common research methodology and discuss preliminary findings in their respective fields of research.

Interdisciplinary research teams have been formed. They are working on case studies to be published as special issue of the *Journal of International Wildlife Law & Policy*, expected to be published in early 2013.

Significant Deviations from the Original Objectives or Plans

The fieldwork start date was delayed due to the late budget approval (early May). Therefore, some delays and a budget rollover are expected.

Coordination and Integration

The purpose of the June 2012 Theme 5 meeting was to develop a common research methodology. Each interdisciplinary research team has coordinated its work independently.

Scientific and/or Engineering Significance of Results

At this time, we have only preliminary results.

7. Difficulties encountered

Due to the late budget approval in May, and the nature of the social science fieldwork, some work was delayed. We found it hard to coordinate and conduct necessary interviews during the summertime, especially out of town, where travel is involved.

8. Networking and outreach

Theme 5 presents a rather rare opportunity to look at things from different perspectives simultaneously; in this case, through the eyes of social, legal, and natural scientists. In that sense, the special issue being assembled is a very narrow window for each of OTN Canada species we are dealing with (as well as some non-OTN Canada species, but which are nevertheless linked). This special issue will serve as a collection of review papers for the various questions each case study raises and as a whole and some will be followed up with additional research. For instance, with the grey seal-cod case study, the following issues are being addressed:

- scientific uncertainty as a tool in the policy/decision making process;
- risk perceptions of the fishery communities, scientists, and the general public (this is THE basis for the social construction of the grey seal debate);
- the transition from commercial species to protected species to commercial threat (as some see it) (This paper compares the east and west Atlantic grey seal populations through history especially with the current developments in the UK.);
- science as a setback in environmental policy development process (This paper compares the marine and terrestrial environments.);
- protected species vs. protected areas from social and economical perspectives;
- public perceptions of the grey seal debate (surprisingly, there is not much on this);
- how knowledge (any knowledge: scientific, traditional, economical, etc.) is incorporated into the decision making process; and
- the roles of mass-media and social media in the social and political construction of the grey seal debate (very surprising findings).

The aim is to form links between these papers and examine how they can be used in the decision-making process. By doing this research many stakeholders have been engaged, including fishermen, NGOs, politicians, community leaders, industry, and scientists both in and out of academia. This resulted in members of our team being asked to organize a social science session in the upcoming Fishermen and Scientists Research Society (FSRS) conference for the first time. There are many ways to inform management, provide insight, and translate into relevant to policy. The ways to do this continue to be discussed in the broader forum of OTN.

Intra-Network Collaboration and Partner Meetings

The various social, legal, and natural scientists research teams have been working closely together on their respective case studies. This includes routine meetings and discussions, and in some cases, social scientists have accompanied natural scientists and HQPs into the field.

Interaction/Outreach to Broader Community

Interviews were conducted with various stakeholders. This includes OTN and non-OTN scientists and technians, ENGOs members, community leaders, industry, government officials, and others.

9. Dissemination of information and results

Conference Presentations (1 total) *– Contributed*

One paper will be presented at the Fourth International Conference on Science in Society to be held at University of California, Berkeley, USA from 15 to 17 November 2012:

- Deployment, Tracking and Data Management: Technology and Science for a Global Ocean Tracking Network By Tsafrir Gazit, Richard Apostle and Robert Branton.

10. Other contributions and deliverables

Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, Glider runs, and/or data deposition to an agency/database (e.g., MEDS, GenBank, OBIS, etc.), as well as a contribution to a larger piece of work in any of the former.

JA Hutchings, IM Cote, JJ Dodson,IA Fleming, S Jennings, NJ Mantua, RM Peterman, BE Riddell, AJ Weaver and DLVanderZwaag, The Royal Society of Canada Expert Panel Report on Sustaining Canada's Marine Biodiversity: Responding to the Challenges Posed by Climate Change, Fisheries, and Aquaculture (Ottawa: Royal Society of Canada, 2012) 315pp.

11. Collaborations with Industrial and Government Partners

Name of supporting organization: **SSHRC**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$38 547.36
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$44 247.36
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **Dalhousie University**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$51 000
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	$18 486
2) Salaries of managerial and administrative staff	
3) Other (specify): _____	
Total of all in-kind contributions	$69 486
Is this new funding (acquired during this reporting period)?	No

12. Expenditures and Support

In the original proposal submitted to NSERC, a budget for Network-wide annual meetings was submitted only for Years 2 and 4, and for Theme 5 workshops for Years 1 and 2. In response to the peer reviewers' comments on the proposal, it was the consensus of the OTN Canada proposal steering committee that we should make budgetary room for additional full annual meetings in every year if possible and for continued inclusion of Theme 5 activities and participation. This was "to ensure that integration and cross-Arena projects begin as soon as possible in the program and at the latest by the midway review". This was approved in the final grant awarded. Thus, S. Iverson has attempted (successfully) to save funds wherever possible under the larger OTN Canada program (primarily under both Networking and Administration budgets), so that this important part of OTN Canada could be continued every year.

From various cost-saving activities, a total of $88.7k carryover from 2011 ($55.6k from the original Networking budget and $33.1k from the remaining Administration budget) was available to apply to Networking and Theme 5 for 2012 (and beyond; i.e. to apply any residual funds for this purpose in future years). This is shown below.

Year 3 (2012)

Budget Item	Year 3 (2012)				
	Proposed	**Actual Expenditures** 1 Jan - 30 Sep 2012*	**Total Balance** 30 Sep 2012*	**Projected Balance** 31 Dec 2012**	**Deviation**
1) Salaries and Benefits					
a) Students	$7200	$600	$6600	$6600	92%
b) Postdoctoral Fellows	$0	$0	$0	$0	
c) Technical/Professional	$0	$0	$0	$0	
d) Other	$0	$0	0	$0	
2) Equipment or Facility					
a) Purchase or Rental	$0	$0	$0	$0	
b) Operations/Maintenance	$0	$0	$0	$0	
c) User Fees	$0	$0	$0	$0	
3) Material and Supplies					
a) Materials and Supplies	$0	$0	$0	$0	
4) Travel					
a) Conferences	$64373	$50438	$13935	$13935	22%
b) Field Work	$17124	$2461	$14663	$12971	76%
c) Collaboration/Consultation	$0	$0	$0	$0	
5) Dissemination					
a) Publications	$0	$0	$0	$0	
b) Other	$0	$0	$0	$0	
6) Other (specify)					
a) Other	$0	$0	$0	$0	
b) Other	$0	$0	$0	$0	
Totals					
Totals	**$88 696**	**$53 499**	**$35 197**	**$33506**	

Year 3 conference expenses were as outlined in the budget and included those for several small networking workshops and primarily the Annual OTN Canada Symposium, which brought together all students, PDFs, and eligible PIs to present projects and results, and discuss research tools and programs within and across Arenas. This Symposium also hosted the social science workshops to continue work being done on case studies for a dedicated journal issue of the *Journal of International Wildlife Law & Policy* to be published in 2013. The Symposium was also used to begin preparing for the Midterm Report and Proposal writing for Phase II of the NSERC Network.

As part of this overall Networking and Theme 5 budget, a sub-budget totaling $24.3K was approved by the SAC in 2012 to fund field work needed to complete the social science component of the OTN case studies in Phase I. Of this total, $3.1k was spent to date on field work activities (American eel and grey seal case study work) with the rest to be spent in the remainder of this year and in 2013 to complete Phase I work.

Other carry over here and in the Administration budget will be carried forward to Year 4 to ensure the funding of the Annual Symposium, and again, any carryover after Year 4 will be applied to the Networking and Theme 5 activities in Phase II.

Year 4 (2013)

Networking *(Iverson)*

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$0	$0	$0	
b) Postdoctoral Fellows	$0	$0	$0	
c) Technical/Professional	$0	$0	$0	
d) Other	$0	$0	$0	
2) Equipment or Facility				
a) Purchase or Rental	$0	$0	$0	
b) Operations/Maintenance	$0	$0	$0	
c) User Fees	$0	$0	$0	
3) Material and Supplies				
a) Materials and Supplies	$0	$0	$0	
4) Travel				
a) Conferences	$60 000	$60 000	$13 935	0%
b) Field Work	$0	$0	$0	
c) Collaboration/Consultation	$0	$0	$0	
5) Dissemination				
a) Publications	$0	$0	$0	
b) Other	$0	$0	$0	
6) Other (specify)				
a) Other	$0	$0	$0	
b) Other	$0	$0	$0	
Totals				
Totals	**$60 000**	**$60 000**	**$13 935**	

Theme 5 *(Vanderzwaag, Apostle)*

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$0	$0	$6 600	
b) Postdoctoral Fellows	$0	$0	$0	
c) Technical/Professional	$0	$0	$0	
d) Other	$0	$0	$0	
2) Equipment or Facility				
a) Purchase or Rental	$0	$0	$0	
b) Operations/Maintenance	$0	$0	$0	
c) User Fees	$0	$0	$0	
3) Material and Supplies				
a) Materials and Supplies	$0	$0	$0	
4) Travel				
a) Conferences	$0	$0	$0	
b) Field Work	$0	$0	$12 971	
c) Collaboration/Consultation	$0	$0	$0	
5) Dissemination				
a) Publications	$0	$0	$0	
b) Other	$0	$0	$0	
6) Other (specify)				
a) Other	$0	$0	$0	
b) Other	$0	$0	$0	
Totals				
Totals	**$0**	**$0**	**$19 571**	

As stated in the original budget justification: "Year 4 funds are requested for [a] complete OTN Canada workshop ($60k), which would bring in all students and the eligible PIs to the extent possible. DFO and industry would fund travel for their researchers. Issues concerning ocean governance will be a focus in terms of designing the year 6 workshop."

There is no deviation requested in this budget from that originally proposed. (Note: any carry over in expenditures that might occur in Year 4 will be applied to Phase II Networking.)

Ocean Tracking Network Canada OTNC **NSERC**
Progress Report Year 3 Review: 1 October 2011 – 30 September 2012

V. Ocean Tracking Network Canada Secretariat

1. Project Number: V

2. Project Title: OTN Canada Secretariat

3. Project Leaders: S. Iverson (Scientific Director), K. McKenzie (Network Manager), N. Beauchamp (Communications and Public Relations/AA) (Dalhousie)

4. Staff

Personnel	Title	% Time in project	% Support from SNG	Dates
Sara Iverson	Scientific Director	75	0	1 Oct 2011 – 30 Sep 2012
Daniela Turk	Network Manager	100	100	1 Oct 2011 – 31 Jan 2012
Glenn Crossin	Network Manager	100	100	1 Feb 2012 – 30 Jun 2012
Kyle McKenzie	Network Manager	100	100	25 Jun 2012 – 30 Sep 2012
Shauna Baillie	Administrative Asst. (AA)	100	100	1 Oct 2011 – 30 Jun 2012
Nikki Beauchamp	Public Relations Intern	100	100	20 Apr 2012 – 30 Jun 2012
Nikki Beauchamp	Communications and Public Relations/AA	100	100	1 Jul 2012 – 30 Sep 2012
Tracy Rounds	Administrative Asst.	33	0	1 Jun 2012 – 30 Sep 2012

5. Progress towards Objectives/Milestones (1 Oct 2011 – 30 Sept 2012)

The main objectives of the Secretariat in Year 3 are listed below:

i) Office Operation and HR

- Participate in regular 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 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) Meetings/Symposium/Workshops and Outreach

- Organize and host 2nd OTN Canada Symposium
- Organize Annual SAC and Arena Leaders meetings/conference calls.

- Promote understanding of role in Network and facilitate lateral communication among HQP
- Perform general outreach, communication, and promotion of the Network

iv) Reports and Proposals

- Produce consolidated annual progress report for projects active in 2011-2012
- Produce consolidated mid-term progress report for projects active in 2010-2012
- Produce proposal for Phase II (Years 5-7) of OTN Canada for NSERC

v) Website and Newsletter

- Populate the OTN Canada website
- Produce a Newsletter to be distributed to OTN, sponsors, and related international community

vi) Data Management

- Meet 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 Global management to coordinate efforts

The Secretariat has followed up on all the main objectives and made good progress to meeting the milestones for the third year, as further described below.

Office operation and HR:

Note: In July 2012, revisions were made to the OTN Management structure as a whole and as a result, the Secretariat of OTN Canada and OTN Global function as a fully integrated team. Although funded through separate agencies (NSERC and CFI) the activities of both have become very interlinked and coordinated. The following describes most roles in this transition phase.

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. S. Iverson is now also the Scientific Director of OTN as a whole ('Global') 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, she serves on the following 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 Management Committee, which meets 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 submits a monthly written report to this committee updating on progress and issues within the OTN Canada Network;
- the new International Scientific Advisory Committee (ISAC) which will meet once yearly in person (and other times as necessary by teleconference or by email) and will advise and report and

help guide the planning and coordination among all scientific projects undertaken that are supported by the OTN;
- the OTN Council, which meets twice yearly, and is the stewardship body for all of OTN (Global and Canada) on behalf of Dalhousie University and other stakeholders; the Council provides direction to the scientific and management affairs of the OTN that will ensure its development and enhance the value of its research leadership and assure its financial and scientific management;
- the Global 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 Status Committee, the committee of all members of the OTN secretariat, the OTN data team, and the OTN technical support, which meets weekly to review status and operations of OTN.

Kyle McKenzie is currently the Network Manager. He replaced Glenn Crossin (now a Collaborator on several OTN projects), who was Network Manager for the first half of the year and took over for D. Turk who left for another position. The Network Manager assists the Scientific Director in overseeing the administrative management of the Network. 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 Canada SAC;
- the OTN Management Committee; and
- the OTN Status Committee.

Shauna Baillie served as the Administrative Assistant until June 30, 2012. She worked closely with the Scientific Director and Network Manager on budget issues, meeting organization, annual report assembly, and network communication.

Nikki Beauchamp interned with OTN (April-June 2012) to complete her Public Relations program at the Nova Scotia Community College. She was subsequently hired in the Administrative Assistant position to perform Communications and Public Relations duties for OTN. She works closely with the Dalhousie/OTN Global communication officers on joint efforts with communications/dissemination of research results and produces web site and Twitter content, newsletters, and annual reports for public consumption. She also assists with meeting organization, annual report assembly, and network communication.

Tracy Rounds is the OTN Global (CFI) Administrative Assistant. 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 now provides administrative services for OTN Canada, including helping to assemble documents, organizing of meetings, and taking of minutes at all administrative, SAC, and Arena Leaders meetings.

Office Setup: The OTN Canada Secretariat is currently located at Dalhousie University in the Life Sciences Centre. Scientific Director, S. Iverson has an office, as a professor within the Department of Biology. K. McKenzie, the Network Manager, currently shares office space with OTN Global Secretariat personnel. N. Beauchamp currently resides in the office of the OTN Global Data Management Group, also in the Life Sciences Centre. Dalhousie University is constructing a new Oceans Excellence Centre, which will provide space for the Secretariat office (K. McKenzie and N. Beauchamp), as well as all OTN Global personnel upon completion. Expected occupancy is April 2013.

Finances and Budget re-allocation

Reprofiling. This Sub-committee comprises a core of three members (currently A. Fisk (chair), J. Cullen, 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 would be called to meet only as issues and needs arise. The committee will review requests, make recommendations, and report to S. Iverson, the OTN Canada Scientific Director, who will then report to the SAC and NSERC. In this manner due process should be carried out in fairly making any such decisions.
Other Financial Matters. Currently the SNG is held as one account at Dalhousie, with an agreement to subdivide this into three accounts: one for administration, one for all of Dalhousie oceanography (I.1) projects (three separate projects), and one for everything else, including all institutional transfers, all other research projects held at Dalhousie, all networking budget items, and all Theme 5 budget items. However, Dalhousie is producing a single Form 300 for submission to NSERC at the time of the annual report. This continues to make budget keeping extremely complicated.

Committees, Meetings, Symposia, Workshops, and Outreach

The following describes meetings and workshops mostly within OTN Canada, those extending beyond the Network and other outreach and promotion of the Network are described in section **7**.

The Secretariat organized the 2nd OTN Canada Symposium and associated workshops, two SAC meetings (one in Halifax and one by teleconference), several Arena Leaders conference calls, an Atlantic PI meeting in Halifax, and assisted in organization of Arena meetings. 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.

Second Annual OTN Canada Symposium in Halifax

As described in the Overview, on June 4-6, 2012, we held the Second Annual OTN Canada-wide Symposium in Halifax, NS. The purpose of this symposium was to bring together all students, PDFs, and PIs to present projects and results, discuss research strategies, and focus on integration of the OTN Canada Network and sharing of research tools and programs within and across Arenas. Plenary sessions of topics of broad importance punctuated concurrent sessions aimed at the two major subsets of participants: HQP and PIs. HQP sessions focused on individual research projects, needs from the Network, and data tools. PI sessions focused on progress of the network toward its goals, integration of natural science projects with the social science component, and strategies for writing of the Phase II proposal. A lot of excitement and momentum was generated as a result. Full details are provided in Section 2.1 at the beginning of this document.

SAC meetings

The 2012 annual face-to-face SAC Meeting is scheduled for 19-20 November in Halifax (also in association with the OTN Global ISAC Meeting). The main objectives of this meeting are to review research progress of the Network, to approve Year 3 reports and budgets and review and approve proposed budgets for Year 4 to ensure that milestones are on target, to discuss aspects of the Phase II proposal, as well as to discuss any current or arising issues and planning for the Network.

Atlantic PI meeting

Principal Investigators from the Atlantic Arena met at Dalhousie University in Halifax, NS on April 10, 2012. Presentations on the status of projects in the morning were followed by a discussion of progress so

far and ideas for Phase II in the afternoon. Co-leaders from the Arctic and Pacific arenas joined the afternoon discussion by teleconference. This discussion broke a lot of ground for the Phase II proposal writing session at the June symposium.

Modellers and Observers Meeting, November 2012, Halifax, NS

F. Whoriskey chaired a half day meeting at Dalhousie University for modellers and observers based at Dalhousie University and involved with OTN. PIs and HQP from each group presented on their research and the whole group discussed matters on common interest, including data collection, availability, uptake, and use. Future meeting of this nature will likely include taggers and discussion of their needs.

Arena Leader Meetings

Several Arena Leaders meetings were held via teleconference throughout Jan-Jun 2012 to strategize about all the reports due this year and the Phase II Proposal and to plan the June Symposium.

Reports

Annual progress report templates (both written and financial) were updated and distributed to PIs to be completed by late September. This deadline was earlier than in previous years because of the need complete a mid-term report as well. The Secretariat made extensive efforts to consolidate and format the reports submitted, seek corrections and additional information where insufficient, produce network summaries, and to correct and assemble complete budget reports. These are being submitted to the SAC for final approval at the November meeting. NSERC Form 300s from all institutions are being provided by Dalhousie Financial Services.

A mid-term progress report is also being produced. The Secretariat provided all PIs with templates similar to those for the annual report and asked for their return by mid-October. This report is currently being compiled and will be submitted to NSERC by the end of the year.

At the same time as these reports are due to NSERC in late 2012, so also is a new OTN Strategic Plan, Management Plan, and Science Plan due to CFI. Thus, the amount of work required for assembling all these documents, creating and holding meetings with an entirely new OTN Council and ISAC, has greatly taxed the Secretariat. Some delays have been an outcome.

Website and Newsletter

The bi-annual OTN newsletter shares news and events from Canadian and Global perspectives, including updates on deployments, tracking initiatives, research outcomes, and data warehousing activities. The third edition was distributed at the 2012 OTN Canada Symposium and mailed electronically, as well as hosted on both the OTN Canada and Global websites. The newsletters have become regular items included in information packages to new members and potential collaborators due to their value in reflecting significant Network achievements and progress. In May 2012, OTN Canada began distributing a quarterly news bulletin featuring items relevant to the OTN Canada member community— specifically, HQP and PIs, as well as NSERC. These two- to three-page bulletins are a step towards greater intranetwork communication and collaboration through member profiles, calls to action, and status reports.

Both the OTN Canada and Global websites continue to be updated and expanded with information for OTN Canada researchers and the Global community. Noteworthy expansions include a research section attached to HQP profiles on the OTN Canada site. The sections, which are private among HQP, identify collaborative interests and opportunities, seasonal itinerary, and information on current research topics.

Data Management

K. McKenzie met several times with the OTN Global Data management team (Bob Branton and Lenore Bajona) to discuss data flow. Discovery Metadata are now available on a web portal that is currently under review by the PIs. The OTN Canada metadata can be found online at http://members.oceantrack.org/data/discovery/new2/OTNCanada.htm. These metadata allow data to be discoverable via the internet and provides users with a contact point to learn more about the data. The metadata will also be used in applications such as GoogleEarth. Further information on OTN Data Policy is available online (http://www.marinebiodiversity.ca/OTN/policies/otn-data-policy-ver-11-oct-30).

K. McKenzie and K. Morton (OTN Global Senior Project Manager) met with the OTN Global Data management team to discuss ways to use the data infrastructure to facilitate Network administration tasks such as keeping track of and communicating with PIs and HQP. Further meetings are required to determine if this effort will be productive.

Communication with OTN Global and Funding Partners

The Secretariat has been communicating regularly with OTN Global personnel on joint efforts including data management, web pages, organization of meetings, establishing a plan of projects, technician requirements, etc. S. Iverson and K. McKenzie attend and contribute to monthly OTN Global Management Committee Meetings and S. Iverson presents the update on OTN Canada. She also attends OTN Council and Global Coordination meetings. S. Iverson has continued to be in contact with NSERC in terms of Network issues and deadlines, and with DFO in terms of partnering of funding.

Significant Deviations from the Original Objectives or Plans

Change of SAC Composition:

Keith Thompson (Dalhousie) began sabbatical in July 2012 and resigned as SAC chair. He is replaced by Steve Cooke (Carleton). The current composition of SAC includes two members from each Arena representing six institutions: Atlantic: Ian Fleming (Memorial U) and Katja Fennel (Dalhousie U), Arctic: Aaron Fisk (U Windsor) and Svein Vagle (DFO-IOS, UVIC), Pacific: Scott Hinch (UBC) and Steve Cooke (Carleton U).

Coordination and Integration

See overall network report.

Intra-Network Collaboration and Partner Meetings

See overall network report.

Scientific and/or Engineering Significance of Results

N/A

6. Difficulties Encountered

The three major NSERC tasks, undertaken in the second half of 2012, place considerable burden on the

Secretariat and PIs, as the latter two were beyond the normal scope of administrative duties for all involved with OTN Canada compared to other years. A degree of 'reporting burnout' was witnessed among many of the PIs toward the end of the report collection process and resulted in late submissions, which in turn added pressure to the Secretariat in its efforts to complete all tasks on time. As this is a one-time occurrence in the life of the Network, no corrective action is needed for the future.

7. Networking and outreach

Interaction/Outreach to Broader Community

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.

Intra-Network Collaboration and Partner Meetings

K. McKenzie and N. Beauchamp began development of a Networking and Engagement Strategy during the second half of 2012. This strategy is aimed at HQP (students in particular) and is intended to address a number of concerns that have arisen in 2012:

- lack of uptake of solutions provided in response to HQP session at the June Symposium;
- lack of awareness of data sharing policies of OTN;
- minimal response to the Secretariat from HQP to requests for content for communication products;
- inconsistent messaging from PIs to HQP about the structure of the Network and role of the Secretariat; and
- ever changing HQP complement and the inability to reach them all once a year at the Annual Symposium.

The initial version of the strategy included a PowerPoint presentation addressing the following issues:

- response to HQP from the Secretariat as to how their concerns from the HQP session at the June Symposium are being addressed;
- communication to HQP of their role in the Ocean Tracking Network and their obligations to the Network;
- description of data products and tools available from OTN;
- explanation of need for continual anecdotal content from HQP to PIs and the Secretariat to assist with communication products and reporting, in lieu of formal publications; and
- discussion of the value of lateral communication among all HQP across the entire network and how best to achieve that.

It was felt that to have maximum impact, this presentation should be delivered to groups of HQP at their home institutions. To test the strategy, K. McKenzie delivered the presentation to HQP of the Pacific Arena projects at UBC on October 2, 2012. PI S. Hinch organized a meeting in the Faculty of Forestry and attended the session along with approximately 20 HQP and several DFO colleagues. Surprisingly, less than five HQP had attended the June Symposium and many found much of the content of the

presentation to be new information to them. HQP were well engaged in the presentation and a productive discussion followed. OTN-branded gifts (hats and pens) were offered to and readily accepted by the HQP present. It is hoped that these items will provide a lasting physical reminder of the presentation and foster a sense of belonging to an organization larger than just their immediate research projects.

In the weeks following the UBC presentation N. Beauchamp noticed a significant increase in communication from UBC HQP. The Secretariat will revisit the Networking and Engagement Strategy in early 2013 and consider its future course.

Interaction/Outreach to Broader Community

As Scientific Director of OTN S. Iverson participates in numerous meetings, presentations, and workshops related to OTN. Many of these are described in detail elsewhere in this report. Since January 2011 S. Iverson has:

- worked extensively with VEMCO and Dalhousie to secure support for two new faculty members who will work with OTN Canada;
- met with new Arctic collaborators in the US and Canada to establish a new research project on the effects of hydrokinetic energy on beluga populations;
- represented OTN at the annual GLATOS meetings in Rogers City, Michigan (Feb);
- co-sponsored and presented a talk at a special session on OTN at the 2012 Ocean Sciences Conference in Salt Lake City, Utah (Feb);
- presented testimony from OTN Canada bioprobe studies to the Senate Committee on Fisheries;
- presented a public lecture focusing on OTN studies at 'Blowhard Presents', a community entertainment program in Halifax (Jun);
- interview with CBC radio on OTN studies (Jul);
- represented OTN for the visit by German Chancellor Angela Merkel and participated in a round table discussion on ocean sciences and future collaborations (Aug); and
- gave the invited Dalhousie Annual Alumni Homecoming Lecture on OTN (Sep).

See overall network report for additional information.

8. Dissemination of information and results

Refereed Journal Articles (2 total) - *Accepted/Published*

Cooke, S.J., Iverson, S.J., Stokesbury, M.J.W, Hinch, S.G., Fisk, A.T., VanderZwaag, D.L., Apostle, R. and Whoriskey, F. (in press) Ocean Tracking Network Canada: A network approach to addressing critical issues in fisheries and resource management with implications for ocean governance. Fisheries.

9. Other contributions and deliverables

See the OTN Canada Network Overview for further details.

10. Collaborations with Industrial and Government 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.

Name of supporting organization: **CFI**	**Year 3** 2012
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	**
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	**
6) Other (specify): _____	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other: see below	
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

1) Provision of services through use of data management team and website assistance

Name of supporting organization: **Dalhousie University**	**Year 3** 2012
Cash contributions to direct costs of research	$12 000
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	$1 311
5) Salaries of managerial and administrative staff	
6) Other: see below	$30 103
Total of all in-kind contributions	$43 414
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 (K. McKenzie and N. Beauchamp), 250 square feet at $9.50sq/ft $2375;

2 and 3) 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).

12. Expenditures and Support

Year 3 (2012)

Budget Item	Year 3 (2012)				
	Proposed	**Actual Expenditures** 1 Jan - 30 Sep 2012	**Total Balance** 30 Sep 2012	**Projected Balance** 31 Dec 2012	**Deviation**
1) Salaries and Benefits					
a) Students	$0	$0	$0	$0	0%
b) Postdoctoral Fellows	$0	$0	$0	$0	0%
c) Technical/Professional	$0	$0	$0	$0	0%
d) Other	$135 838	$91 995	$43 843	$15 706	12%
2) Equipment or Facility					
a) Purchase or Rental	$0	$0	$0	$0	0%
b) Operations/Maintenance	$0	$0	$0	$0	0%
c) User Fees	$0	$0	$0	$0	0%
3) Material and Supplies					
a) Materials and Supplies	$10 609	$2 663	$7 946	$3 000	28%
4) Travel					
a) Conferences	$15 914	$9 262	$6 652	-$2 848	-18%
b) Field Work	$0	$0	$0	$0	0%
c) Collaboration/Consultation	$5 305	$3 000	$2 305	$1 000	19%
5) Dissemination					
a) Publications	$3 000	$1 786	$1 214	$500	17%
b) Other	$0	$0	$0	$0	0%
6) Other (specify)					
a) Other	$0	$0	$0	$0	0%
b) Other	$0	$0	$0	$0	0%
Totals					
Totals	**$170 666**	**$108 706**	**$61 960**	**$17 358**	

The original budget for Year 3 for Administration included

- staff salaries (Network Manager and Administrative Assistant);
- materials and supplies for running the office, SAC and other meetings, office supplies, postage, courier charges, long distance telephone charges, printing, and teleconference costs;
- travel costs to cover a) the annual SAC meetings and b) collaboration/consultation by the Secretariat; and
- publications/dissemination to cover production and distribution of financial and progress reports, OTN-Canada program posters, 1-2 page brochures, media releases, newsletters, cost of the implementation of public information efforts, and web page maintenance.

Specifics and any Deviations:

Staff positions: no deviations other than savings. Due to change-over of personnel, gaps in hiring, and some reduction in originally expected benefits costs, the total salary for the two positions will come

under that originally projected for 2013.

Materials and Supplies: no deviations other than savings. Budget was spent accordingly and is on target, again with some cost saving activities to be used for future Networking.

Travel: no deviations. At reporting time $9.2k was spent on SAC and admin meetings (mostly from the delay in travel claim reimbursements from the Nov 2011 SAC meeting) and for travel advances for the 2012 SAC meeting. There will be further charges this fall (and likely 2013) for the 2012 Nov SAC meeting. Collaboration/consultation travel was for partial funding for S. Iverson to represent OTN Canada at the annual GLATOS (Great Lakes Acoustic Telemetry Observation System) in Michigan and to co-host the OTN special session at the 2012 Ocean Sciences Meeting in Salt Lake City. S. Iverson supplemented costs for both travel items through other grant sources.

Publications/dissemination costs: no deviations.

Any carry over in final expenditures will be applied to continuing Networking budget.

Year 4 (2013)

Budget Item	Year 4 (2013)			
	Original	Revised	Carry Over	Deviation
1) Salaries and Benefits				
a) Students	$0	$0		
b) Postdoctoral Fellows	$0	$0		
c) Technical/Professional	$0	$0		
d) Other	$139 913	$127 666	$12 247	9%
2) Equipment or Facility				
a) Purchase or Rental	$10 000	$10 000		0%
b) Operations/Maintenance	$0	$0		
c) User Fees	$0	$0		
3) Material and Supplies				
a) Materials and Supplies	$10 927	$10 927		0%
4) Travel				
a) Conferences	$16 391	$16 391		0%
b) Field Work	$0	$0		
c) Collaboration/Consultation	$5 464	$5 464		0%
5) Dissemination				
a) Publications	$4 000	$4 000		0%
b) Other	$0	$0		
6) Other (specify)				
a) Other	$0	$0		
b) Other	$0	$0		
Totals				
Totals	**$186 695**	**$174 448**	**$12 247**	

The original budget for Year 4 for Administration included:

- staff salaries (Network Manager and Administrative Assistant);

- materials and supplies for running the office, SAC and other meetings, office supplies, postage, courier charges, long distance telephone charges, printing, and teleconference costs;
- travel costs to cover a) the annual SAC meetings and b) collaboration/consultation by the Secretariat; and
- publications/dissemination to cover production and distribution of financial and progress reports, OTN-Canada program posters, 1-2 page brochures, media releases, newsletters, cost of the implementation of public information efforts, and web page maintenance.

No deviations other than expected reduced overall salary totals for staff positions (despite annual raises) mainly due to reduced expected benefits costs. If this should change, there is still sufficient room to cover necessary salaries and benefits.