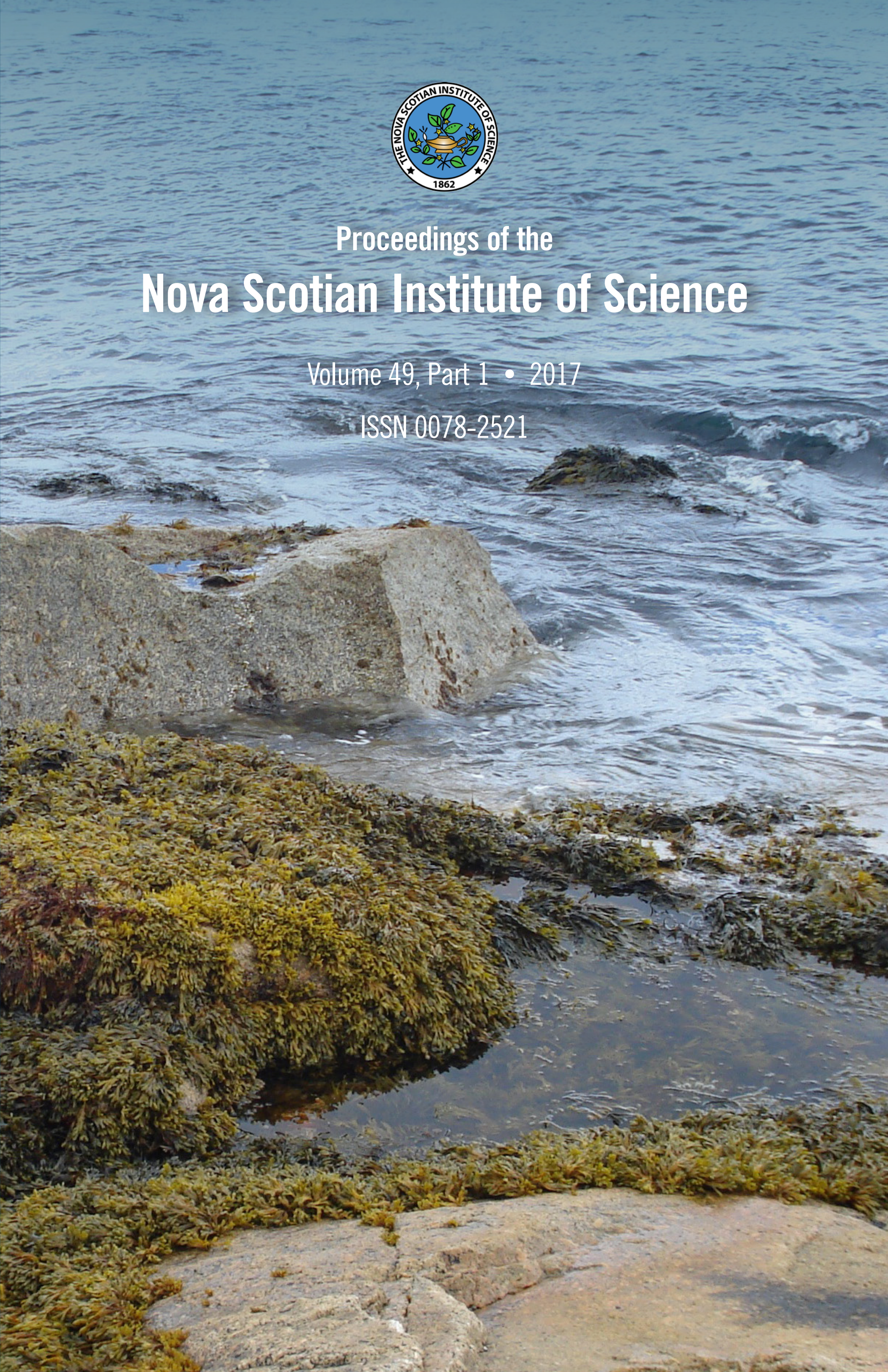

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Cover photo credit: Herb Vandermeulen, coastal seaweeds of Cape Breton Island.

Back cover inset photo credit: Tara Imlay - Adult Bank Swallow;
P.G. Wells - Snapping Turtle, Lupins, Dragon Fly.

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EDITORIAL

Nova Scotia Science – Accomplishments and Challenges

This PNSIS Issue and the ongoing series of monthly NSIS talks (2016-17) illustrate the range of science that is conducted in Nova Scotia and the region, and the amazing contributions that are celebrated continually across Canada and globally. The articles in this Issue cover topics that include the diversity of lichens and seaweeds found in Nova Scotia, the history of marine research, the importance of understanding changes in avian populations, advancements in management techniques in agriculture, insights into the process of discovery, and the requirement that scientific data be accessible to all potential users. Attention is drawn to two distinguished scientists, Arthur McDonald and Mary Ann White, noted for their special accomplishments and stellar careers. For the first time in recent issues of the Proceedings, reviews of two books prepared by local authors are included.

The various articles are just a thin slice of the many annual research contributions from the scientific and engineering communities in the province. Of special note recently is the award of the NSERC 2017 Gerhard Herzberg Canada, Gold Medal for Science and Engineering, to Dalhousie Physics Professor Jeff Dahn for his leading work in battery technology – the science of lithium-ion batteries. This is the third recent Herzberg award to a researcher in Atlantic Canada. Previous winners were W. Ford Doolittle (2013) and Axel Becke (2015), also of Dalhousie University. This is surely a home run in Maritime science!

Also noteworthy is the range of research conducted by young investigators, as shown by the contributions submitted each year to our student science writing competition, and the two excellent papers in this Issue by young investigators, Chen and Wilson, and by other young investigators in past years. This is so important – Nova Scotia must encourage and retain its highly educated young persons, as they will fuel the scientific breakthroughs, innovations, new products and a new and expanding economy for the region. Supporting all of this science requires political vision, leadership and investment for success. The Canadian federal government recognizes this fact, as well as the benefits of evidence-based/informed decision making, and to this end the government at various levels across Canada is reinvesting in science and science education.

That said, many scientific challenges are ahead of us as a society. For example, several environmental issues in Nova Scotia require new research and enhanced communication with the public and public officials. From my perspective as a marine scientist, these include: understanding the effectiveness of marine protected areas as they are established in our coastal waters; monitoring the potential environmental impacts of tidal power generation in the Bay of Fundy; and evaluating the potential risks of oil spills from tankers in the Bay of Fundy/Gulf of Maine and by offshore, deep water oil exploration and production. Other challenges include: interpreting recent Bay of Fundy fish and invertebrate kills, a localized and as yet unexplained mass mortality event; comprehensively addressing climate change and its threat to humanity (see Homer-Dixon's article); and finally, investigating the spread of micro-plastics and nano-particles in the ocean, and their potential effects on the marine ecosystem and human health.

Most of these problems require in-depth, longer term, fundamental and applied research, and an investment in people and institutions to ensure success. Every reader can certainly add numerous topics that require attention, some with similar urgency.

The annual NSIS lecture series presents a broad range of new science that is conducted in the region. This year, two talks on advancements in genomics were given – one by John Archibald on "molecular clocks: using DNA to infer evolution", and one by Graham Dellaire on "how to edit a genome". This research is changing the face of biology and medicine, and is just one example of the very active research conducted locally. Some of our invited speakers are also noted authors of popular science books. The reader is encouraged to pick up a copy of John Archibald's "One plus One equals One", a fascinating overview of symbiosis, endosymbiosis, and the evolution of complex life.

The NSIS continues to present a range of important topics in its annual lecture series. This is of increasing importance at this time of considerable political change and uncertainty in the western world. As Rush Holt, the CEO of the AAAS, has stated: "This is not the time to be timid or to keep our heads down. Evidence matters and decisions made with scientific input are far more likely to succeed. We all need to make sure this message is heard loud and clear".

In Canada, we recently survived what some called "the war on science" under our last federal government (see previous editorials in PNSIS). We now have a government that understands the role of evidence in decision and policy making. It is supporting communication on scientific matters by its agencies and employees. In an age of false news ("alternative facts" and "post-truth"), NSIS has a vital role to play supporting the widest possible discussion of scientific, fact-based topics, essential for an informed society. Our annual lecture series is a critical communication mechanism both with respect to topics of interest and the role of scientists in providing factual information, i.e., evidence, to society as a whole.

It is hoped that the NSIS membership will grow and that its members will become engaged in the choice of future lecture topics. Debates also need to take place about science and its vital role in public policy making, in Canada and beyond. There is a role for both professional and citizen scientists in these endeavours. One of NSIS's most valuable contributions in future years will be to form bridges between these two groups, and between them and the general public, in the interests of our society and its long term well-being. The PNSIS continues to be one voice-piece in this on-going quest.

Acknowledgements A great many thanks are due to the NSIS Council for their work on the lecture program, the student competition, and other initiatives, and to Dr. David H. S. Richardson (Associate Editor), our editorial board, our reviewers, and Gail LeBlanc (Production/Layout Editor) in producing this Issue of the Proceedings. David Richardson is also thanked for his comments on this article.

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WHERE HAVE ALL THE SWALLOWS GONE[1]?

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Over the past 40 years, Breeding Bird Surveys (BBS) have documented severe and widespread declines among species of aerial insectivores, i.e., birds that feed in flight on flying insects (Nebel *et al*. 2010, Michel *et al*. 2015, Smith *et al*. 2015). These declines are greater in northeastern North America, including the Maritimes, and for birds that migrate greater distance, i.e., over-wintering in South America (Nebel *et al*. 2010). Interestingly, BBS data also show a common negative change point in population trends that occurred in the mid-1980s; this suggests a large-scale environmental change that is impacting all aerial insectivores (Smith *et al*. 2015). The cause of declines in aerial insectivores is presently unknown. However, two likely drivers are changes in the availability of aerial insects during the breeding season, and/or changes in conditions on the wintering grounds and migration routes (Nebel *et al*. 2010, Shutler *et al*. 2012). To impact populations, these potential drivers must either result in lower reproductive success and/or reduced survival. My work focuses on understanding how these potential drivers are impacting populations of Bank (*Riparia riparia*), Barn (*Hirundo rustica*), Cliff (*Petrochelidon pyrrhonota*) and Tree (*Tachycineta bicolor*) Swallows that breed in the Maritimes (Fig 1).

First, I focused on the relationships between aerial insect abundance and swallow breeding success. Insect abundance when Cliff and Tree Swallows were raising young was higher for pairs that nested earlier in the spring than those that bred later. This raised the possibility that early breeding birds could capitalize on higher insect abundance by raising young that had a larger body mass or higher survival. However, no relationships between nestling body mass or survival and insect abundance was found. Although these results do not support insect abundance as a driver of population declines for

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[1] This article briefly introduces the upcoming talk to be given at the Annual General Meeting of the NSIS, May, 2017.

Fig 1 **1. Just hatched Tree Swallow nestlings. 2. Begging Barn Swallow nestlings. 3. Adult Cliff Swallow in-hand.**

swallows in the Maritimes, it is possible that historical, rather than current, levels of insect abundance have impacted their populations.

Using data largely from the volunteer Maritimes Nest Records Scheme, I then determined if there were changes in the timing of breeding or success of each of the four species since 1960. During this 57-year span, first egg dates for Barn, Cliff and Tree Swallows advanced by 8-10 days, whereas first egg dates for Bank Swallows remained the same. Changes in breeding success varied

Fig 1 (cont'd) 4. Adult Tree Swallow sitting on a nest box.

considerably by species. In recent years, Bank Swallows have lower success and Tree Swallows have slightly higher success. Success for Barn and Cliff Swallows was largely unchanged. These results suggest that insect abundance may be impacting Bank Swallow populations through lower reproductive success, but there is little support for insect abundance driving Barn, Cliff and Tree Swallows population declines in the Maritimes.

Next, I focused on wintering ground conditions as a potential driver of population declines. Wintering regions were identified through a stable isotope analysis from feather samples. I compared individual levels of corticosterone, a stress hormone, between wintering regions to determine if there was a 'hotspot' where swallows were experiencing greater stress. There was no relationship between wintering region and corticosterone levels. This result may be due to the coarse scale of wintering regions, i.e., birds within each region are unlikely to use the whole area. It is also possible that no single wintering region is driving population declines, and that birds wintering in different areas are all experiencing poor conditions. Future work on the potential impact of wintering ground conditions will examine relationships between wintering locations and telomere length (a region of repetitive nucleotide sequences at each end of a chromosome – another indicator of stress), and the survival and subsequent reproductive success of swallows that winter in different areas.

From this research, it appears that there are at least some species-specific drivers of population declines for swallows, and possibly for aerial insectivores in general. For example, of the four species of swallows examined, only Bank Swallows are experiencing reduced breeding success in recent years. Recovery efforts directed at halting population declines will be more challenging if different approaches are required for each species.

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HISTORY OF RESEARCH AT THE ST. ANDREWS BIOLOGICAL STATION – A PERSPECTIVE

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In 2008, it was my privilege to be a keynote speaker at the conference celebrating the one hundredth anniversary of the permanent biological station at St. Andrews, New Brunswick. The historical papers given by participating scientists and technical experts revealed the impressive breadth, diversity, importance and sheer relevance of studies undertaken at the St. Andrews Biological Station (herein called SABS) over its hundred years. The scope of investigations revealed how much has been missed by other experts who have analysed fisheries and aquatic science – notably historians of science, sociologists, and maritime legal scholars. Their focus has been on science relevant to the theory of fishing and the management of commercial populations. For example, at the 2016 Coastal Zone Canada Conference in Toronto, one speaker commented on the narrowness of fisheries biology as a field, and linked current sustainability problems to that supposedly narrow focus. However, the book inspired by the SABS centenary celebration – *A Century of Maritime Science,* Hubbard, Wildish and Stephenson (2016) – shows that a history focused only on the development and elaboration of the theory of fishing misses huge swathes of fisheries and coastal science. In fact, despite the breadth of science covered in the book, it does not showcase all of the important research streams at SABS! Fisheries and aquatic scientists have been doing a great deal more than most people realize.

Recent Canadian and international scholarship has highlighted that if we are to attain environmental sustainability, and in this context for the oceans, it is important that we encourage collaboration across disciplines - collaboration that draws together academics, scientists, sociologists, indigenous peoples, and experts of all kinds, including local fishers, fishing associations, and especially historians.

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A Century of Maritime Science shows that the rich and broad output of SABS was likewise only possible because scientists and technologists with many different kinds of expertise collaborated with each other in identifying problems and figuring out how to deal with them.

Many scientists tend to have quite narrow fields of specialization. The effectiveness of an organization like SABS, devoted to researching aquatic and marine species and their environment, relies in large part on having many different kinds of scientific specializations present in one establishment. At SABS, this has included vital contributions from ecotoxicology and pollution research, oyster and scallop and herring research, research programs on paralytic shellfish poisoning and other marine pathogens, physical oceanography, experimental flow studies and fish culture research. *A Century of Maritime Science* shows how a diverse group of SABS scientists and technologists have worked closely together to identify and understand problems, and mitigate or eliminate obstacles and problems wherever possible. Because of the close proximity of so many different experts, and the absence of isolated research silos, SABS has – even during times of diminished Federal support – remained able to respond flexibly to the increasing and shifting challenges faced by the marine environment, communities, fishers and fisheries. Its ongoing research has also offered insights into global issues such as climate change and the effects of persistent toxic chemicals. A *Century of Maritime Science* shows how, in order to sustain relevance and respond fluidly to local environmental challenges, researchers from many different backgrounds must be available to conduct a variety of research projects.

A Century of Maritime Science includes an introduction and two chapters written by historians of science, and ten chapters contributed by scientists who either worked at or had strong connections with the Biological Station. It was a real labour of love and patience on all our parts. The papers had to be substantially revised once we decided to publish through the University of Toronto Press. Getting the book through peer review, revisions, and copy and proof editing took many years longer than projected. I believe that the final result warrants the wait.

The first four chapters provide the historical context of the Atlantic Biological Station, now called SABS. The first chapter is by Eric Mills, one of the world's premier historians of oceanography. His chapter gives a brief history of Canadian science and the scientific organizations in the 19th century which preceded and in a sense enabled the creation of the Board of Management of the Biological Stations of Canada. Of particular interest is the role and limitations of the Hydrographic Survey of Canada, and the Canadian Tidal and Current Survey. These surveys later assisted and were assisted by scientists at SABS. Elsewhere, in his recent book, *The Fluid Envelope of Our Planet* (Mills, 2009), Mills tells the story of the Scandinavian origin and spread of dynamic oceanography. The Canadian Fisheries Expedition was manned by scientific volunteers from SABS who worked in collaboration with Norwegian oceanographer and fisheries biologist, Johan Hjort. This event provided the first chance for Hjort's Scandinavian assistant, the oceanographer Johan Sandstrom, to spread the new techniques employed in dynamic oceanography beyond Norway and Sweden. A *Century of Maritime Science* includes references to Mills's book and other sources that highlight the important international role of SABS.

Mary Needler Arai also provides a broad context, describing the role of and treatment of women who were marine biologists in marine biological institutions in British Columbia, Washington State, Atlantic Canada, and in university biology departments and American museums. Her analysis also includes several women scientists supported by the U.S. Fish Commission. Her chapter is of particular importance as it reflects the views and understanding of a third generation woman Ph.D. scientist, whose grandmother, Edith Berkeley, worked at the Pacific Biological Station, and whose mother, Alfreda Needler, worked at St. Andrews and Ellerslie sub-station in PEI. Alfreda Needler's research on the biology of oysters led to her making seminal contributions to the study of paralytic shellfish poisoning and identifying the causal microorganism.

My chapter on the emergence of Maximum Sustainable Yield (MSY), as a management goal for commercial fisheries, continues to situate the Biological Station and the contributions of its leading scientists within an international context. The Station gained federal funding because it fell within the British amateur-gentleman tradition of science for the public good, which had been copied by university and other gentlemen scientists in the Dominion of Canada. The goal of MSY emerged first in German scientific forestry, which also shared a view that enlightened science could help governments and societies develop natural renewable resources in a sustainable manner. The marriage between late Victorian and Progressive conservation ideals resulted in the goal of rational and efficient exploitation for maximum sustained yield for peak production. Leading German forester, Bernhard Fernow, introduced German scientific forestry to the United States; he later joined the University of Toronto where he introduced Atlantic Biological Station director, Archibald Gowanlock Huntsman, to these ideas. Huntsman was to introduce measures drawn from forestry science into post-war theories of fishing.

The final introductory chapter is by former station director, Robert L. Stephenson, who was responsible for convening the SABS centenary conference. He surveys the effects of shifting government science-management policies on the scientific programs and output of SABS from its origins up to its hundredth year. His admirably concise history describes the shift from volunteer to professional scientists hired through the Biological Board of Canada, and the Board's growth as the Fisheries Research Board of Canada after 1937. He also highlights the key role played by SABS as a kind of "nursery ground" for fisheries and aquatic scientists, since most Canadian marine scientists for many decades received their fundamental training through SABS. He underscores the effects of the uncertainty over the future of SABS from the time the station burned down in 1932 and was rebuilt by Huntsman without authorization, right up until substantial Federal reinvestment in the station took place in 2008. He also highlights the challenges faced when government line management replaced the earlier management model. Before this change, station directors administered and directed the different lines of research, overseen by a board formed of industry members, university academics within the Fisheries Research Board of Canada, and Department of Fisheries personnel. Funding for research also shifted to agencies such as NSERC, requiring scientists to spend less of their time actually doing research and more time applying for funding. The research output and service to public science by SABS scientists shown in this volume thereby appears all the more amazing, given these challenges.

The next eight chapters focus on individual research programs by scientists, technologists and scientific groups at SABS. Tim Foulkes leads the way, with a chapter on the contributions of technologists who supported the various research programmes at SABS with their expertise and ability to design and build specialized scientific equipment. I particularly like this chapter, as it fits in with a recent focus in the history of science: the role of the non-scientific experts without whom the scientists would have never accomplished their most important work. Foulkes's chapter also gives a hint of what daily life was like at the station, with the mention of data analyst and gourmet curry cook, A. Sreedharran. While he covers the technology challenges that SABS faced from its beginning, the main focus is on his work beginning in the early 1960s, assisting researchers who required specific tools, such as underwater towed vehicles equipped with cameras, for their stock assessments and other research. He describes the development of the various specialized underwater towed vehicles.

Fred Page and Blythe Chang survey the history of oceanography at St. Andrews, describing its hesitant and limited beginnings in the 1910s when lack of equipment restricted oceanographic work, and its flourishing after the station's hire of the first Canadian professional oceanographer, the self-trained Harry B. Hachey. Hachey was attracted from the University of New Brunswick (Fredericton) physics department to work at SABS, not only by the immediacy and urgency of research problems (such as the potential physical, climatic and fisheries effects of proposed hydroelectric dams around Passamaquoddy Bay), but also by the presence of numerous women scientists at the station. The work of Hachey and other oceanographers enabled SABS to survey the marine environment in Passamaquoddy Bay and the greater Bay of Fundy, as well as the Scotian Shelf, the Gulf of St. Lawrence, and as far afield as the waters around Newfoundland, Hudson Strait and Hudson Bay. The expertise built up before the Second World War allowed Hachey and newer oceanographers to offer important scientific assistance to the war effort, and ultimately led to the creation of the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. They also fulfilled their mandate to assist fisheries investigations through providing the environmental information required by fisheries researchers. The always-changing ocean environment, in response to global temperature changes, for example, means that oceanographic research in support of fisheries, environmental sustainability and other issues is as vital as ever.

David Wildish and Shawn Robinson have contributed a chapter on the development of experimental flow studies at SABS, beginning in the 1960s. They write about the assistance required from technologists to build their flow research flumes and respirometers, and highlight the ways in which their research in turn assisted the research programmes of other SABS scientists. Their experimental flow studies investigated the effectiveness of filter feeding bivalves in different current strengths, and the rates at which chemical pollutants and naturally produced toxins were cleared from the bodies of filter feeders, studies which aided investigations of paralytic shellfish poisoning. Their studies of how swimming fish responded to different current strengths were used to assist SABS researchers investigating the effects of pesticides (e.g., fenitrothion) on salmon and trout in Maritime streams. Their investigation of how currents can scatter juvenile scallops, and how older scallops prevent displacement by strong currents, assisted SABS scallop researchers such as John Caddy. Wildish and Robinson's chapter shows, moreover, how seemingly abstract, basic science has real-world applications when used in clearly applied research programs.

The history of scallop research at SABS by John Caddy shows the fundamental importance of scallop research to the development of effective and successful national and international policies to ensure the sustainability of scallop fisheries. He also writes about how licensed private companies have adopted responsibility for monitoring commercial scallop grounds. Caddy's chapter is unique as he also comments on current issues in fisheries management, advocating for the use of spatial models and spatial considerations in understanding the structure and role of scallop populations in different locations, with reference to bottom substrates and prevailing ocean currents.

A highly personal account of the history of wild salmon research at St. Andrews is offered by Richard Peterson. The research focused on monitoring and attempting to increase the salmon populations, as well as on the effects of industrial pollutants and pesticides on Maritime salmon. He offers insights on the programme's character and characters through his personal perspective and anecdotes. The end of this important stream of SABS research sadly came with the discovery of the primary Atlantic salmon feeding grounds off Greenland in the early 1970s. The subsequent international fishing frenzy virtually annihilated this species. While the progressively fewer returning salmon have continued to be monitored, a recovery has been ruled out by the obstinate refusal of Greenland to shut down the diminishing sea fishery for salmon.

Jennifer Martin's chapter deals with the history of paralytic shellfish poisoning (PSP) and other shellfish toxicity research at SABS. The station became a world leader in algal toxin research, in part because the link between PSP, caused by a dinoflagellate that was renamed *Alexandrium fundyense* in 1985, was first recognized at SABS by Alfreda Needler. As well, the phenomenon of "red tide" was first recognized in the Bay of Fundy and was first investigated by SABS scientists. Jennifer Martin mentions that many other SABS researchers have contributed to research on paralytic shellfish poisoning and other shellfish toxins. She shows the very important role played by dedicated PSP researchers, including Carl Medcof, a world leader in the field, and other women researchers, notably Alfreda Needler, Viola Davidson and Carrie Lewis. Important breakthroughs were made by such PSP researchers in SABS' first century.

The theme of human-caused contamination and pollution by toxic chemicals is taken up by Peter Wells in the chapter on the history of ecotoxicology and environmental science at SABS. Its aquatic chemistry and toxicology program, sadly, was terminated a few years after the centenary conference of 2008, despite its critical role in protecting aquatic resources. The chapter recounts how John Sprague, Don McLeese, Vlado Zitko, and other researchers at SABS, helped to develop and apply this newly emerging science from the late 1950s to the 1990s, in conjunction with other aquatic research programs around the world. This research was essential to determining factors that influence toxicity, identifying natural and human-generated toxic substances, the effects of pesticides, and determining the levels at which industrial effluent pollution harms the environment and specific organisms in lakes, streams, and the coastal and open ocean. This research is also vital to preserving or remediating local environments from the effects of dredging, industrial pollutants, pulp mills, fish farming and other activities, and supports researchers investigating issues in aquaculture and bivalve research, among others. Ecotoxicologists have collaborated with other SABS research programs, showing that ecotoxicology remains fundamental to understanding environmental stresses on commercial fisheries and farmed fish.

The final chapter is by former SABS director, Robert Cook. Cook describes the long history of research on aquaculture and fish hatcheries at SABS, beginning with the technical challenges of oyster and other bivalve culture, and investigations into the practices and shortcomings of provincial fish and lobster hatcheries. Many technical and political difficulties were encountered in the ultimately successful development of salmon farms. Of particular interest are Cook's descriptions of the network of federal, provincial and private agencies and organisations that came together to assist in the creation and success of the Atlantic salmon aquaculture industry. SABS researchers have been central to identifying and solving specific technical problems that have arisen and continue to occur in this industry, such as the problem of disease control using chemicals. Cook was a central figure in this story; his history provides valuable insights into how the Atlantic Canadian finfish aquaculture program emerged and grew in the latter part of the 20th century.

A Century of Maritime Science does not cover the history of all of the important research programmes and people at SABS. However, it does give local citizens at St. Andrews, federal and provincial policy makers, and scientists and other scholars here and elsewhere, an idea of the depth, breadth and importance of the work that has been done at SABS in the 20th century. This volume is unique in the history of marine science in its presentation of the history of diverse research programs, and its ability to allow readers to see how each strand, while appearing unique and sometimes esoteric, is profoundly connected with other research programs. It is also highly relevant to the general history of marine science, since many of the breakthroughs at St. Andrews are pertinent to global issues and have contributed to international developments in fisheries and coastal science. As a historian of science, I have been privileged to be involved in this book project and remain deeply impressed by the clear indications that the ideals of public service and dedication to solving economic and environmental problems are alive and well at SABS.

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Note: The author was both a contributor to and an Editor of the book discussed in this article. This issue of PNSIS also has an independent review of the book.

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NSIS AND ATLANTIC ECOSYSTEMS INITIATIVE TO MAKE DATA ACCESSIBLE – ONE DATASET AT A TIME

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There has been considerable discussion in recent years related to open science and improving the transparency and reproducibility of scientific research. Much of this discussion is centered on the need for open access to research data. Like other aspects of open access, some researchers have been slow to respond. This is due, in part, to a lack of digital tools and standards and possibly related to misconceptions around attribution and digital rights management. One bright spot though in the open data movement is in the vibrant community of biodiversity data producers.

Cornerstones of the biodiversity data community are the many natural history museums and scholars with a history of contributing observational data to build larger datasets of species occurrences. Within this community, most data producers are choosing to share data via a growing number of online repositories. The ROpenSci website (github.com/ropensci/spocc) lists ten major repositories including GBIF (Global Biodiversity Information Facility), Berkeley Ecoengine, iNaturalist, VertNet, BISON (Biodiversity Information Serving Our Nation), eBird, AntWeb, iDigBio, OBIS (Ocean Biogeographic Information System) and the Atlas of Living Australia.

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Collectively these repositories contain millions of records ready for digital access, discovery and computational processing.

The move to online repositories is also promoted by the many journals that now recommend or require authors to deposit their data in a recognized data repository. As an example, the Canadian Journal of Fisheries and Aquatic Sciences includes in its instructions to authors the following text:

> "For primary biodiversity data authors are strongly encouraged to place all species distribution records in a publicly accessible database such as the national Global Biodiversity Information Facility (GBIF) nodes (gbif.org) or data centres endorsed by GBIF, including BioFresh (www2.freshwaterbiodiversity.eu) for freshwater data and the Ocean Biogeographic Information System (OBIS, iobis.org/) for marine biodiversity data, which also holds supporting measurements taken alongside the species occurrence data." (nrcresearchpress.com/page/cjfas/authors)

Unfortunately, while current online journals promote deposit in purpose built repositories, older print journal articles and their more recent digital surrogates have trapped a lot of occurrence data in a very analog-like digital state. That is to say, the tables and text of these articles aren't really useful to researchers without significant manual intervention. The result is that we have a significant gap in the availability of historic species occurrence data that could support current and future research and analysis.

In Atlantic Canada, COINAtlantic (Coastal and Ocean Information Network Atlantic, (coinatlantic.ca) is in its second year of the Atlantic Ecosystems Initiative (AEI) project. The purpose is to improve the accessibility of marine species occurrence data including the 'rescue' of datasets and make them available to the public, other researchers and managers for reuse. For details, see Sherin *et al*. (2016).

As part of the AEI project, many articles published in the Proceedings of the Nova Scotian Institute of Science (NSIS) were identified as being of interest because they contain species distribution information that includes scientific name and location. The taxonomic and geographic scope of the AEI project covers any taxa observed or collected within the Atlantic region and datasets collected by Atlantic Canadian researchers in other locations.

The focus of the AEI data rescue activity thus far has been to extract content from published articles and create a set of standardized records that can then be shared with the larger biodiversity data community. These records must conform to the Darwin Core body of standards using controlled vocabularies and terms promoted by biological and oceanographic data managers. Like most descriptive metadata standards, Darwin core is intended to facilitate data sharing and discovery. The standard allows biodiversity data managers to move their species occurrence data into shared data repositories where it can be managed alongside similar datasets. Before Darwin Core existed, biodiversity data producers managed their data in silos where it remained largely undiscoverable and unusable by others. Darwin Core has been successful because it is both simple and flexible. Simplicity is achieved by having a limited number of available terms and flexibility is achieved by having no required terms. Wieczorek *et al*. (2012) provide an excellent background on the history and development of Darwin Core but the official terms documentation should be consulted for the most current set of terms (rs.tdwg.org/dwc/terms/).

The AEI rescued datasets are uploaded to the OBIS (Ocean Biogeographic Information System) Canada data repository (ipt.iobis.org/obiscanada/), where they are reviewed for compliance with the Darwin Core standard and then committed to the OBIS Canada repository. Once the data is approved in the OBIS Canada repository, it is made accessible to the public and can be harvested by larger biodiversity aggregators. OBIS Canada is a node in the larger OBIS network (OBIS, iobis.org/contact/). OBIS currently harvests data from the Canadian node once every four months but plans to provide more seamless access in the near future. This work represents a small but significant contribution to national and global initiatives. Not only are gaps in species distribution being filled through these activities but critical temporal coverage is being expanded through the mobilization of content previously published by the Nova Scotian Institute of Science.

The public may query the OBIS database and its collection of integrated datasets through search interfaces on their portal (iobis.org/). All datasets include complete EML metadata (Ecological Metadata Language) with references and links to original source publications. Individual datasets may also be downloaded directly from the IPT (Integrated Publishing Toolkit).

The history and mission of OBIS is very complementary to the work of the COINAtlantic, Atlantic Ecosystems Initiative. OBIS emanated from the Census of Marine Life (2000-2010 and was adopted as a project under IOC-UNESCO's International Oceanographic Data and Information Exchange (IODE) programme in 2009 (iobis.org/about/). One of the recommended strategies of the Census of Marine Life program (CoML, coml.org/) was to obtain data from museums, oceanographic institutions, universities and commercial companies (Paterson *et al.*, 2000).

Based on this strategy, it is quite possible that the Census of Marine Life (and later OBIS) envisioned the reclamation of data from regional journals such as the NSIS Proceedings. This journal was first published in 1863 and has remained current in both content and format ever since. A complete digital archive of the NSIS Proceedings is maintained in the Dalhousie University institutional repository, DalSpace (dalspace.library.dal.ca/handle/10222/11192). Current issues are available to NSIS members immediately (and to the general public with a six month embargo period) at the NSIS Proceedings website (nsis.chebucto.org/; ojs.library.dal.ca/nsis). In both the archive and on the members' site, a link is in place to make readers aware when there is supplementary species occurrence data available for the article or special publication.

The first NSIS publication identified during the AEI project was the Birds of Brier Island (dalspace.library.dal.ca/handle/10222/72244). This special publication was originally only available to the public in print for a modest fee and to NSIS members via the NSIS Proceedings website. As part of the data rescue project, a pdf version of this publication is now accessible online to everyone with links to the species occurrence data in the OBIS Canada repository. The first version of species occurrence data associated with this publication contains a small subset of the source material that is essentially a listing of taxa found on the island (ipt.iobis.org/obiscanada/resource?r=brierisland_birds). Observations of 355 bird species for the Brier Island area (www4.rncan.gc.ca/search-place-names/unique/CAFBS) were made accessible to OBIS and will fill gaps in species distribution. A second version of the dataset will include more detailed information such as temporal and spatial distributions enhancing the accessible content.

The ability to revise and refresh content shared with OBIS highlights the advantage of taking an iterative approach to data reclamation.

Depositing even a small amount of previously inaccessible data to a shared repository can have tangible benefits and serve to kick-start further initiatives that enrich data with even more detail. Making data accessible can be done in waves. Perhaps it is appropriate that as an example we chose a dataset from the Bay of Fundy area – this initiative and NSIS are part of a tidal wave of researchers who, in addition to communicating their research via traditional articles and publications, are now making their data accessible to fellow scholars to answer their own research questions. Afterall, this is the foundation of science research building upon the research that preceded it. The NSIS is keeping pace with other leaders in scholarly communication by embracing technology, open data and a general willingness to share but maintaining a strong connection to the traditional scholarly record.

Williams *et al*. (2011) stated that "biodiversity is essential for the health of the planet and for humans because it underpins ecosystem functions that provide a wide range of goods and services to human societies." The continued collection of data on the diversity, distribution, and abundance of life in the ocean by OBIS enables ongoing monitoring of decline and/or recovery of biodiversity and ecosystem function against the baseline that was originally established by the Census of Marine Life. Rescuing older species observation data from publications and museum collections expands the geographic, temporal and taxonomic coverage of this initial baseline.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2016) emphasized the significance of scenarios and models that forecast changes in ecosystem services. Such forecasts are relevant to public policy and play a vital role in creating more direct connections between ecosystem services and social, economic, and political systems. Rich biodiversity data is required to create and test these models.

The Organization for Economic Co-operation and Development (OECD) Declaration on Access to Research Data from Public Funding recognized that "... international exchange of data, information and knowledge contributes decisively to the advancement of scientific research and innovation; … that open access to, and unrestricted use of, data promotes scientific progress and facilitates the training of researchers; … that open access will maximize the value derived from public investments in data collection efforts;" and "... that the substantial increase in computing capacity enables vast quantities of digital research data from public funding to be put to use for multiple research purposes … thereby substantially increasing the scope and scale of research" (OECD, 2004). Implicit in the declaration is a recognition of the substantial benefits that science, the economy, and society at large could gain from the opportunities that expanded use of digital data resources like OBIS have to offer.

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THE CENTENARY OF THE CANADIAN FISHERIES EXPEDITION (1914/15): AN IMPORTANT MILESTONE IN THE HISTORY OF NORTH AMERICAN MARINE RESEARCH

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Jennifer Hubbard, a history professor at Ryerson University, provides an excellent synthesis of the Canadian Fisheries Expedition, including the influence of the Norwegian expedition leader (Johan Hjort) on the development within Canada and the United States of America of an ecological and oceanographic approach to fisheries issues (Hubbard, 2014). Vera Schwach (at the Nordic Institute for Studies in Innovation, Research and Education in Oslo, Norway), in the same volume, also provides a synthesis of Hjort's brilliance as a scientist and leader (Schwach 2014). The report on the expedition, which was published by the Department of the Naval Service, Ottawa, is still a great read (Hjort 1919). Due to the fortunate timing of this two year study a century ago, the approach to addressing the fisheries issues of the day could be considered revolutionary.

The expedition followed closely Hjort's synthesis (published in 1914) of the *Migration Committee* work carried out under the guidance of the International Council for the Exploration of the Sea (ICES). The mandate of the committee, which was established at the initiation of ICES in 1902, was to solve the reasons for the decadal scale fluctuations in the landings of the *Great Fisheries of Northern Europe,* in particular those for cod and herring. In the 18th and 19th century during the good years for fishing (with abundant landings), the economies of Northern Europe were robust, whereas during the poor years society at large suffered. The issue being addressed by ICES was high profile within several northern European countries adjacent to the North Sea and the North Atlantic waters, and thus the stakes for the continuation of ICES beyond the first few years of initial funding were high.

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The extant hypothesis, based on the *Polar Migration* concept developed in 1746 by Johann Anderson, the mayor of Hamburg at that time, interpreted that the local fluctuations were caused by variable migration patterns of relatively constant abundance levels of the diverse, commercially important groundfish and small pelagic species (Wegner 1993). In essence the fluctuations in any particular area were considered to be due to an edge effect caused by climate variability; the overall abundance levels of the species were considered to be invariable, whereas local abundance varied due to migration patterns of the species. The scale required to address the issue under "migration thinking" was large (i.e. the northeast Atlantic as a whole). The title of this inaugural ICES Committee (the *Migration Committee*) reflected the current hypothesis of the day, an elaboration of the ideas of the Hamburg mayor from the mid-18th century.

The radical new interpretation by Hjort (1914) could be termed a paradigm shift, in the true sense of Kuhn (1962). Under this new thinking being developed within ICES, fish species were considered to be comprised of populations or in the language of the early 20th century, "races". Some species like herring and salmon are characterized by many populations, whereas other species such as mackerel and tuna have only a few. At the extreme end of the scale of richness one species, the European eel, was hypothesized to be panmictic, i.e., there is a single population for the species. Thus population richness (and their diverse spawning areas) was considered to be a species specific trait, which needed to be described and interpreted. Furthermore the abundance levels of the populations/"races" of the diverse species were concluded to be variable on decadal time scales due to year-class variability. The observed variability in year-classes was considered to be caused by oceanographic processes. In addition, the spatial scale of the problem of the fluctuations of landings under population thinking, in contrast to species thinking, shrunk to some degree for some commercial species. A detailed analysis of the shifts in perspective on research strategies with respect to fisheries issues at the time of the Canadian Fisheries Expedition was provided by Sinclair and Smith (2002) on the occasion of the centenary of the founding of ICES.

In essence the *Migration Committee*, during about a decade of international multi-disciplinary ecological and oceanographic studies, redefined the very nature of the societal issue of "*fluctuations in the* *great fisheries*" of northern Europe. Thus the timing of the Canadian Fisheries Expedition was very fortunate. The questions asked by Hjort and his colleagues were ecological and oceanographic, rather than being focused on the search for biogeographical laws in the tradition of Darwin and Wallace, and as carried out in the oceans in the *Challenger* (1872-1876) and *Michael Sars* (1910) expeditions, respectively. The Canadian Fisheries Expedition initiated modern oceanographic and marine ecological research in North America. We owe a great intellectual debt to ICES, and in particular to the Scandinavian scientific leaders who participated in the expedition a century ago.

In October, 2014, ICES organized a symposium in Bergen, Norway (the *Johan Hjort Symposium on Recruitment Dynamics and Stock Variability*) to celebrate the centenary of the publication of the classic paper by Hjort (1914). Canada was very well represented at the gathering, illustrating that the seeds of marine science planted by Johan Hjort and his team a century ago have born considerable fruit. Furthermore, in 2016, the *Canadian Journal for Fisheries and Aquatic Sciences* published a volume on the proceedings of the symposium (Can. J. Fish. Aquat. Sci., Volume 73). These past few years have been a time for Canadian marine scientists to celebrate the magnificent contribution by the mostly Scandinavian team of scientists, who a century ago initiated our field of research in support of management of ocean uses.

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ARTHUR B. McDONALD – A RECENT NOBEL LAUREATE

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Dr. Arthur B. McDonald

Arthur B. McDonald was born in 1943 in Sydney, Cape Breton Island. His parents, Bruce and Valerie, were from families of Scottish and French settlers. Art's father, who was a lieutenant in the Canadian Army, went to Europe not long after Art was born to participate in the liberation of Holland, where he was both wounded and decorated for bravery. Art's youth was spent in Sydney, where he attended the Sydney Academy and was an active member of the YMCA youth service club, the Hi-Y. It was through the Hi-Y that he met Janet, his wife of (so far) 50 years. At 17, Art left Cape Breton (but not Nova Scotia) to study physics at Dalhousie University in Halifax. He was an enthusiastic student and obtained both a B.Sc. and an M.Sc. from Dalhousie. For his Ph.D., Art decided to travel farther afield and in 1965, he travelled west to the California Institute of Technology, from which he graduated with his doctoral degree in 1969. After his doctoral work, he was employed at AECL's Chalk River laboratories in Northern Ontario for several years, after which he was appointed as faculty at Princeton University. It was while he was at Princeton

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[1] "Arthur B. McDonald - Biographical". Nobelprize.org. Nobel Media AB 2014. Web. 20 Dec 2016. <nobelprize.org/nobel_prizes/physics/laureates/2015/mcdonald-bio.html.

Photo Credit: Queen's University.

that he began work on the project that eventually became the Sudbury Neutrino Observatory (SNO). In 1989 he moved from Princeton to Queen's University in Kingston Ontario, where he remained for the rest of his career and is emeritus faculty.

Neutrinos are subatomic particles which interact only weakly with other matter. They are not electrically charged and they do not carry any of the quark's form of charge, colour. When neutrinos were first discovered, they were thought to be massless. No experiment provided any evidence that neutrinos had mass, and at the beginning there were no theories that included neutrino mass. There are known to be three different kinds ("flavours") of neutrinos: electron neutrinos, muon neutrinos, and tau neutrinos. One significant source of the neutrinos that we can observe on earth is our sun. They are a product of some of the nuclear reactions that are the sun's bread and butter. The neutrinos produced in the sun's reactions are one flavour: electron neutrinos.

The first experiments to measure the flux of neutrinos from the sun detected many fewer neutrinos than were expected. The sun's luminosity indicates how many nuclear reactions must be taking place there, and for some reason, the neutrinos produced in those reactions were not being observed here on earth. This became known as "the solar neutrino problem", which, ultimately, Art McDonald and his collaborators at (SNO) lab, with his co-Nobellists at the Super-Kamiokande lab in Japan, were able to resolve.

Because neutrinos only interact very weakly with matter, it takes a lot of looking to detect neutrinos. Neutrino detectors are generally very large volumes. The neutrino detector at SNO lab, 2 km below the surface of the earth in an INCO nickel mine, was an engineering feat. In an active, full-time operating mine, the laboratory was maintained at standards of cleanliness that are the envy of many above-ground laboratories. The detector itself consisted of an acrylic vessel several stories high, filled with heavy water and surrounded by 9500 tremendously sensitive light sensors. When there was a rare interaction between a neutrino and some of the water in the tank, the upshot would be a little flash of light in the deep underground darkness. The light sensors recorded the pattern of the flash, and from that the scientists in the SNO collaboration were able to deduce the presence of neutrinos from the sun.

The great brilliance of the SNO detector was to borrow 1000 tonnes of heavy water from Atomic Energy of Canada Limited (AECL). This one apparently simple adaptation allowed the SNO detector to be sensitive to the other kinds of neutrinos as well as electron neutrinos. Heavy water is chemically the same as water, but the hydrogen atoms have an extra nucleon; each hydrogen atom is twice its normal weight. Heavy water is rare (and expensive) but since CANDU reactors use it, AECL had a stockpile that the SNO project could use for a while. Filling their acrylic vessel with heavy water permitted the scientists at SNO to distinguish the light flash pattern that could only be caused by electron neutrinos and that which was caused by any of the three flavours.

Years of hard and clever work on the part of the SNO collaboration, with Dr. McDonald in the lead, permitted two measurements of the neutrino flux from the sun: One measurement was the electron neutrino flux only and the other was the sum of all (including the electron neutrinos). If neutrinos were massless, then the electron neutrinos created in the sun would be electron neutrinos when they reached the earth and no other flavours of neutrinos would be detected — the electron-neutrino-only flux would be equal to the all-flavours-of-neutrinos flux. However, the two were not equal. There were other flavours of neutrinos arriving at the SNO laboratory on earth that had originated in nuclear reactions in the sun.

The sun's nuclear reactions only produced electron neutrinos, so they were changing flavour during the journey between the sun and the earth. Such a remarkable thing, changing flavour, requires neutrinos to have mass. A massless neutrino simply cannot change flavour. So the work by the scientists at SNO, under Dr. McDonald's direction, revealed that the resolution to the solar neutrino problem was that neutrinos are massive particles.

It remains unknown what the mass of the neutrino is. It is known to be very small, and there are some details known about the relationships between the masses of the different flavours of neutrinos. The measurement of the mass of the neutrino will be another enormous scientific undertaking involving many collaborators and complicated and clever equipment. And perhaps the leader of that effort will also be a very pleasant Caper, a bright spark from Sydney making an invaluable contribution to science, so important that it merits recognition from the Nobel committee.

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MARY ANNE WHITE NAMED OFFICER OF THE ORDER OF CANADA

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Dr. Mary Anne White

On November 17, 2016, one of Nova Scotia's best known and most prolific scientists, Dalhousie Chemistry Professor Emerita, Mary Anne White, was invested as an Officer of the Order of Canada. The award citation captures the essence of Dr. White's career – her lifelong dedication to science as expressed through her research program and her public outreach:

> "Mary Anne White has made critical advances to materials chemistry and to science outreach in Canada. A professor of chemistry at Dalhousie University for over three decades, she is Canada's leading expert on how various materials physically react to heat. Notably, she contributed to the understanding of materials that change colour based on their temperature, a breakthrough that is now used in commercial products. Passionate about fostering a love of science in the next generation, she has played a leadership role in coordinating National Chemistry Week and in the creation of a science discovery centre in Halifax."[1]

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[1] *Order of Canada Investiture Ceremony.* gg.ca/document.aspx?id=16628&lan=eng, accessed 22/01/2017.

Photo Credit: Nick Pearce, Photography Services, Dalhousie University.

This latest honour caps off a stellar career, which began in her student days at the University of Western Ontario and McMaster University and continues today in her role as Professor Emerita at Dalhousie University. Following her doctoral studies, Dr. White spent two years as an NSERC Postdoctoral Fellow at Oxford University, U.K., before receiving a prestigious NSERC University Research Fellowship as she began her academic career at the University of Waterloo in 1981. Two years later, she moved to Dalhousie University where she has built a research program that has brought together chemists and physicists interested in how the properties of materials change with temperature.

In over three decades at Dalhousie University, Professor White published over 180 papers and a textbook, "*Physical Properties of Materials*", now in its second edition. At the same time, she has been a leader in science outreach, fostering public appreciation for science and promoting science literacy. She has been a strong role model to aspiring young scientists, in particular to young women. The driving force behind the creation of numerous resources for elementary school aged students, coordinator of National Chemistry Week, and leader in the creation of Halifax's Discovery Centre, Dr. White is often heard on CBC radio, including as a frequent contributor to "Quirks and Quarks."

Professor White has received numerous awards from Dalhousie for both her teaching and research. Since 1996, she has held Research Professorships including a Killam Research Professorship, University Research Professorship, and in 2015 was named the Harry Shirreff Professor of Chemical Research. She has twice received Honorary Degrees, from McMaster University in 2008 and from University of Western Ontario in 2011. She has been elected Fellow of the Chemical Institute of Canada (CIC; 1995), the International Union of Pure and Applied Chemistry (IUPAC; 2002), and the Royal Society of Canada (RSC; 2013). Her numerous national awards for her contributions to teaching and research include the Canadian Society for Chemistry Noranda Award for Research in Physical/Theoretical Chemistry (1996) and the CIC Union Carbide Chemical Education Award (2002) – one of only a handful of women to receive either award. Other prestigious awards include the Royal Society of Canada McNeil Medal for Public Awareness of Science and the American Chemical Society (ACS) Award for the Incorporation of Sustainability into Chemical Education. A full summary of awards and distinctions is listed on the Dalhousie website, Thermal Properties of Materials – mawhite.chem.dal.ca/Biography.htm

In 2016, after being a long-time member of the NSIS, Professor White was made an Honorary Member in recognition of her conspicuous service to the advancement of science in Nova Scotia, Canada, and indeed the world. Although "retired", she continues her work unabated, a true role model for women in science.

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THE LICHEN-FORMING FUNGI IN THE HALIFAX PUBLIC GARDENS, NOVA SCOTIA

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ABSTRACT

Fifty-three lichens species belonging to 28 genera were recorded from the Halifax Public Gardens in Nova Scotia. A brief history of the gardens and of lichen recording in the city is presented, along with a commentary on the lichens found in this study. The results of this lichen survey are of particular interest as the lichen flora has not been previously documented and it provides a baseline for monitoring future changing patterns of pollution and climate. In addition, the Halifax Public Gardens are celebrating in 2017 the 150th anniversary of the opening of the gardens.

INTRODUCTION

The Halifax Public gardens are Victorian in style and date back to the formation of the Nova Scotia Horticultural Society in 1836 which established a garden that was eventually joined with the adjacent Public Gardens and officially opened in 1867 (Anon. 2016). The gardens are a rectangular block, 235m wide by 275m long and the total area is 6.4 ha which includes a small lake and outflow stream. The gardens are now looked after by staff of the Halifax Regional Municipality. In addition to the trees and other plants, there are winding paths, statues of Roman goddesses, a band stand, the Queen Victoria Diamond Jubilee fountain and decorative bird baths. The Gardens are surrounded by a wrought iron fence and very decorative main gates (McIvor, 2009). Many of the trees in the gardens are large and some are over 100 years old despite the impact

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of Hurricane Juan in 2003 which blew down many of the garden's larger trees (Anon. 2003). The gardens have busy roads on all four sides, with buildings opposite in the case of the east side (Lord Nelson Hotel and a high rise development under construction) and on the south side (apartment buildings and Sacred Heart School). To the west of the gardens is the Camp Hill Cemetery. To the north is an athletics field and the city greenhouse complex that supplies plants for the gardens.

Studies on the lichen communities in Nova Scotia were initiated by A.W. Mackay, the Principal of Pictou Academy, who focused on his local area. However he listed seven lichens that he observed in Halifax. i.e. *Cladonia furcata, C. uncialis, Lecidea spilota, Leptogium tremelloides, Peltigera aphthosa, Pertusaria leioplaca*, and *Umbilicaria muhlenbergii* (Mackay, 1881). Some seventy years later Mackenzie Lamb (1954) published an account of the lichens of Cape Breton Island and his study was extended by Selva (1999). Detailed studies on the lichen communities of the rest of Nova Scotia really began when Wolfgang Maass, in the early 1980s, turned his attention from mosses to lichens. He published a series of pioneering papers (see Richardson and Cameron 2016 for the list). Further research by Seaward *et al*. (1997), Cameron *et al*. (2010), McMullin *et al*. (2008), McMullin (2012) and Anderson (2014) have extended Maass's work.

Two lichen studies have focused on the city of Halifax. One was completed in 1968 by high school student and prodigy Philip Ward. He was interested in lichens and Lepidoptera, subsequently becoming a professor of entomology at the University of California Davis. His distribution maps provide the best historical data on the lichens of the city of Halifax (Ward 1968). He collected the alien species *Lecanora conizaeoides* on 23rd February, 1968, from Camphill Cemetery (Field notebook record). The species was identified for him by Irwin Brodo. One year later, he recorded this species as growing on a large old *Ulmus americana* in the Public Gardens, but did not list any other species from this site. There was one other study carried out in 1976, which examined the diversity and abundance of seven lichen species along main roads in Halifax in relation to traffic volume (Brawn and Ogden 1977). One of the seven lichens was also *Lecanora conizaeoides*. This lichen has subsequently been reported from St John's NL, Saint John NB and Halifax NS in eastern Canada and from Vancouver BC and Victoria BC in the west as well from Boston Massachusetts, Seattle Washington, Portland Oregon and Illinois in the USA (LaGreca and Stutzman 2006). In Europe and particularly in the United Kingdom, *Lecanora conizaeoides* was widespread and extremely common on the trunks of trees in the 1960s. However, with the reduction of sulphur dioxide and levels of acid rain and the increase in nitrogen, ammonia, and dust, this lichen has become rare (Seaward, 1993) and replaced by members of the genus *Physcia* s.l, and *Xanthoria* s.l. Visually this has led to a change in colour of tree trunks from green-gray to silver and gold . Such a change may also take place in Halifax over the next few years because of a similar change in the lichen flora of trees. Lichens are particularly responsive to air pollution (Richardson 1992, McDermott 2016). Within the last decade there has been a drop in the levels of transboundary acid rain in Nova Scotia (CCME 2013), and there are more hybrid and fuel efficient vehicles in the city of Halifax as well as a change from oil to natural gas as the source of heating for many homes and commercial buildings. In addition, the Tufts Cove Generating Station is now able to operate on both coal and natural gas depending on fuel economics. Finally, new weather patterns and rising temperatures from climate change may also induce alterations in the lichen flora of the Halifax Public Gardens. The object of the present study was therefore to record the current lichen flora of the trees in the Halifax Public Gardens and to provide baseline data on the species and abundance of lichens in relation to the host trees. In addition, the results of this lichen survey are of particular interest as the Public Gardens celebrate the 150^{th} anniversary of the opening of the first public garden in Halifax (Anon. 2016).

METHODS

The authors of this paper visited the Halifax Public Gardens to survey the lichens in November, 2016. One hundred and thirty trees were carefully examined from ground level to 2 m from the ground using hand lenses. The observed species were recorded and specimens of all but the easily identified lichens were collected. A georeference was recorded at each tree using a Garmin GPS and the data transferred to a computer with the help of Greg Baker at Saint Mary’s University. The lichens were identified by morphoanatomical observation, microscopic examination of the lichen ascospores, chemical spot tests and response to ultraviolet light. The following were valuable for identifying the collected species (Brodo *et al*. 2001, Brodo 2016, Hinds and Hinds 2007 and Smith *et al*. 2009). The nomenclature generally follows Esslinger (2016). Samples of the more interesting lichen species collected will be deposited in the Nova Scotia Museum of Natural History. A copy of the GPS data and lichens recorded on each tree will be given to the Halifax Public Gardens to lodge in their archives.

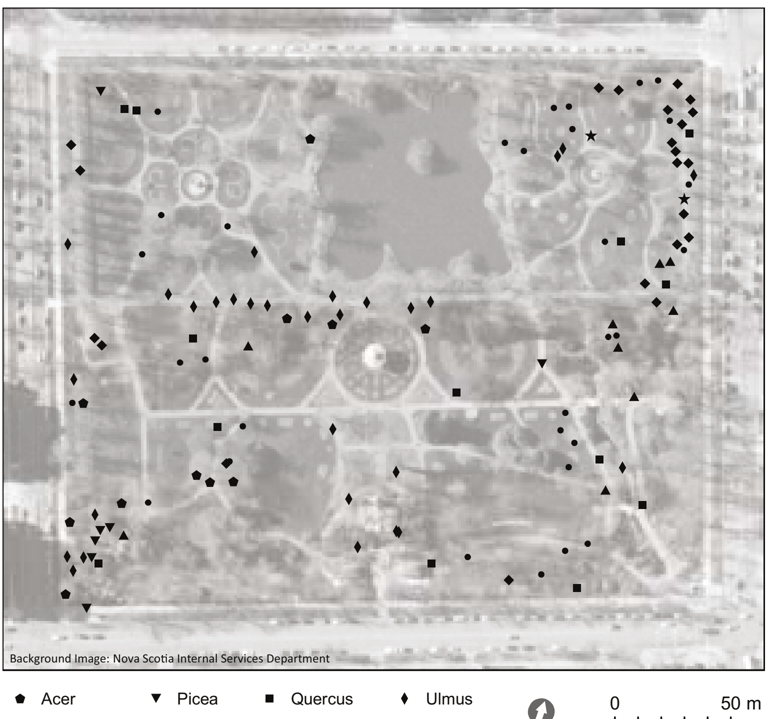

Fig 1 **Map of the Halifax Public Gardens, Nova Scotia, showing the distribution of the trees examined for their lichen flora (Map constructed by Greg Baker, Saint Mary's University).**

RESULTS AND DISCUSSION

Fifty three lichen species belonging to 28 genera were found growing on trunks of 26 different tree species in the Halifax Public Gardens (Table 1). The most frequently recorded genera were: *Cladonia* (6 species, 12% of the total number of species), *Lecanora* and *Physcia* (5 species, 10% of the total number of species respectively). Foliose lichens were the most common at 54%, while crustose and fruticose lichens made up 29% and 17% respectively. Thirty six percent of the species reproduce by ascospores and 64 % by vegetative propagules (isidia and soredia).

The distribution frequency of lichen species varies; *Parmelia squarrosa*, *P. sulcata*, *Physcia millegrana, Melanelixia subaurifera, Hypogymnia physodes* and *Usnea sp*. have high frequency and are widely distributed on deciduous and coniferous trees as shown in Table 2. Thus for example, *Candellaria* was found on six types of tree while *Parmelia sulcata* was found on nineteen different tree types.

In order to compare the lichen diversity between the different tree species, we calculated the Shannon–Wiener diversity index (Table 3). The number of lichen species and diversity differ between the tree species. *Ulmus, Quercus* and *Acer* had the highest diversity while coniferous genera such as *Pinus* had lower values. The low value for *Fraxinus* reflects the fact that only two trees in this genus were examined.

Lichens are a conspicuous component of the flora of Nova Scotia. They have intrigued at least a few people since Mackay (1882) gave his lecture to the Nova Scotian Institute of Science. He began with the words "Lichenology is the botanical field of romance, in it tales are told of beautiful blue and green algals under the tyrannous grasp and mastery of fungi which live upon them and cannot live without them". The fifty three species of lichens found in the historic Public Gardens of Halifax contrast with the lichen flora of roadside trees in the Halifax peninsula, which comprises the core of the city. In this core area, Norway Maple and Red Maples are commonly planted trees and their trunks are covered by a limited number of lichens especially *Hypgymnia physodes, Parmelia sulcata* and *Parmelia squarrosa* that frequently exhibit white or pale pinkish patches caused by the parasitic *Nectria parmeliae* (Lawrey 2000). Occasional thalli of *Melanelixia subaurifera* and a few small tufts of *Usnea subfloridana or Bryoria* are to be found with abundant *Physicia millegrana* and sometimes

Table 1 **The lichen species that were recorded and/or collected on each tree genus in the Halifax Public Gardens are shown by one or more crosses. The number of crosses reflects the abundance of a particular lichen on the surveyed tree. Three crosses +++ represent abundant large patches; ++ many small patches, + a few or rare patches. The nomenclature and authorities mainly follow Esslinger (2016).**

	Ulmus	*Acer*	*Quercus*	*Tilia*	*Fraxinus*	*Picea*	*Pinus*	*Others*
Number of trees in each genus of tree	29	11	13	22	2	7	9	32
Number of lichen species in each genus of tree	35	19	26	19	7	12	9	30
Amandinea punctate (Hoffm.) Coppins & Scheid.								+
Bryoria furcellata (Fr.) Brodo & D. Hawksw.			+					
Bryoria trichodes (Michaux) Brodo & D. Hawksw.			+					
Buellia disciformis (Fr.) Mudd	+		+					
Buellia stillingiana J. Steiner			+					
Candelariella efflorescens R.C. Harris & W.R. Buck	+	+	+	+				+
Candelaria concolor (Dick.) Stein	+							
Chrysothrix caesia (Flot.) Ertz & Tehler				+				
Cladonia chlorophea (Flörke ex Sommerf.) Spreng.	+	+						+
Cladonia coniocraea (Flörke) Spreng.	+		+					
Cladonia cristatella Tuck.						+		
Cladonia fimbriata (L.) Fr.	+							
Cladonia ochrochlora Flörke	++		++	+		+	+	++
Cladonia pyxidata (L.) Hoffm.								+
Evernia mesomorpha Nyl.	+	+	++	+		+		+
Flavoparmelia caperata (L.) Hale.	++	+	+	+				+
Flavopunctelia flaventior (Stirt.) Hale.								+
Hypogymnia physodes (L.) Nyl	+++	++	++	+	++	++	+++	++
Hypogymnia tubulosa (Schaer.) Hav.			+					
Lecanora cinereofusca H. Magn.			+					+
Lecanora conizaeoides Nyl. ex Crombie	+++	++	+	+		+++	+++	+
Lecanora hagenii (Ach.) Ach.	+					+		
Lecanora symmicta (Ach.) Ach.	++	++	+	+		+	+	++

Table 1 ***Cont'd***

	Ulmus	***Acer***	***Quercus***	***Tilia***	***Fraxinus***	***Picea***	***Pinus***	***Others***
Lecanora thysanophora R.C. Harris		+						+
Lecidea albofuscescens Nyl.	+							
Lepraria caesiella R.C. Harris	++	+	+	+		+		+
Loxospora pustulata (Brodo & W.L. Culb.) R.C. Harris								+
Melanelixia glabratula (Lamy) Sandler & Arup	+							
Melanelixia subaurifera (Nyl.) O. Blanco *et al.*	++	++	++	+++	+	+	+	+++
Melanohalea exasperate (De Not.) O. Blanco *et al.*								+
Mycoblastus caesius (Coppins & P. James) Tonsberg.	+							
Ochrolechia androgyna (Hoffm.) Arnold	+							
Ochrolechia arborea (Kreyer) Almb.	+			+				
*Parmelia squarrosa*_Hale.	+++	+++	++	+++	+		+	++
Parmelia sulcate Taylor	+++	+++	+++	++	+	+	++	+++
Phaeophyscia orbicularis (Neck.) Moberg	+							
Phaeophyscia pusilloides (Zahlbr.) Essl.	+	+		+				+
Phaeophyscia rubropulchra (Degel.) Essl.	++	+	+	+	+			+
Physcia adscendens (Fr.) H. Olivier	+++	+	+	++	+			++
Physcia aipolia (Ehrh. ex Humb.) Fürnr.								+
Physica millegrana Degel.	+++	++	++	+++	++	+	+	+++
Physcia stellaris (L.) Nyl.				+				
Physconia detersa (Nyl.) Poelt	+							+
Platismatia glauca (L.) W.L. Culb. & C.F. Culb.	+	+	++				+	+
Punctelia rudecta (Ach.) Krog	+		+					
Ramalina americana Hale.								+
Ramalina farinacea (L.) Ach.	+							
Ramalina roesleri (Hochst. ex Schaer.) Hue.	+		+					+
Scoliciosporum chlorococcum (Graewe ex Stenh.) Vezda		+						
Usnea subfloridana Stirt.	+++	+	++	+		+		+

Table 1 ***Cont'd***

	Ulmus	***Acer***	***Quercus***	***Tilia***	***Fraxinus***	***Picea***	***Pinus***	***Others***
Usnea dasopoga (Ach.) Nyl.	+							
Xanthoria parietina (L.) Th.Fr								+
Xanthoria polycarpa (Hoffm.) Rieber	+		+					

The number of trees surveyed in each species of a given tree genus were as follows: *Acer* (*Acer platanoides* (3), *Acer pseudoplatanus* (2), *Acer platanoides* "Crimson King" (4), *Acer saccharinum* (1), *Acer pseudoplatanus f.aureovarietatum* (1)), *Fraxinus* (*Fraxinus excelsior* (2)), *Picea* (*Picea rubens* (1), *Picea pungens* (5), *Picea glauca* (1)), *Pinus* (*Pinus nigra* (3), *Pinus cembra* (1), *Pinus siyvestris* (2), *Pinus strobus*" Pendula"(3)), *Quercus* (*Quercus robur* (8), *Quercus rubra* (5)), *Tilia* (*Tilea europaea* (18), *Tilia americana* (2)), *Ulmus* (*Ulmus americana* (2), *Ulmus americana* "Princeton" (2), *Ulmus parvifolia* (1),*Ulmus glabra* (3),*Ulmus procera* (1)).The other tree category includes: *Aesculus hippocastarum* (6), *Abies alba* (1), *Aralia elata* (1), *Betula alleghaniensis* (1), *Castanea dentate* (2), *Cerasus* (2), *Cercidiphyllum japonicum* (2), *Crataegus monogyna* (1), *Cupressus* (1), *Fagus sylvatica* (3), *Ginkgo biloba* (2), *Juglas cinerea* (1), *Larix laricina* (1), *Liriodendron tulpifera* (2), *Malus sp*. (2), *Magnolia soulangeana* (1), *Phellodendron amurense* (1), *Platanus* x *acerifolia* (1), *Pyrus calleryana* (1).

Table 2 **The number of different tree species on which each species of lichen was recorded in the Halifax Public Gardens.**

Lichen species name	Number of tree genera on which the lichen was found	Lichen species name	Number of tree genera on which the lichen was found
Amandinea punctate	1	*Melanelixia glabratula*	1
Bryoria furcellata	1	*Melanelixia subaurifera*	20
Bryoria trichodes	1	*Melanohalae exasperata*	1
Buellia disciformis	2	*Mycoblastus caesius*	1
Buellia stillingiana	2	*Ochrolechia androgyna*	1
Candelariella efflorescens	6	*Ochrolechia arborea*	2
Candelaria concolor	1	*Parmelia squarrosa*	16
Chtysothrix caesia	1	*Parmelia sulcata*	19
Cladonia chlorophae	4	*Phaeophyscia orbicularis*	1
Cladonia coniocraea	1	*Phaeophyscia pusilloides*	4
Cladonia cristatella	1	*Phaeophyscia rubropulchra*	9
Cladonia fimbriata	1	*Physcia adscendens*	13
Cladonia ochrochlora	14	*Physcia aipolia*	2
Cladonia pyxidata	1	*Physica millegrana*	20
Evernia mesomorpha	8	*Physcia stellaris*	1
Flavoparmelia caperata	9	*Platismatia glauca*	6
Flavopunctelia flaventior	1	*Physconia deters*	2
Hypogymnia physodes	18	*Punctelia rudecta*	1
Hypogymnia tubulosa	1	*Ramalina americana*	1
Lecanora cinereofusca	1	*Ramalina farinacea*	1
Lecanora conizaeoides	13	*Ramalina roesleri*	3
Lecanora hagenii	2	*Scoliciosporum sp.*	1
Lecanora symmicta	12	*Usnea dasopoga*	1
Lecanora thysanophora	2	*Usnea subfloridana*	12
Lecidea albofuscescens	1	*Xanthoria parietina*	1
Lepraria caesiella	11	*Xanthoria polycarpa*	2
Loxospora pustulata	1		

Table 3 **Lichen diversity assessment using the Shannon–Wiener diversity index in relation to the different tree types in the Halifax Public Gardens.**

Name of Tree	Number of lichen species	Percentage (%)	Diversity Index
Ulmus	35	66.04	3.100
Acer	19	35.85	2.662
Quercus	26	49.06	2.904
Tilia	19	35.85	2.559
Fraxinus	7	13.21	1.889
Picea	12	22.64	2.223
Pinus	9	16.98	1.890
Others	30	56.60	2.904

patches of *Lepraria* or *Cladonia* on the lower parts of the tree trunks. The gray-coloured lichens on the trees in the Public Gardens are more diverse and include *Physconia detersa* that was found on Elm (*Ulmus* sp.) and Horse Chestnut (*Aesculus hippocastanum*).

Many of the trees in the Halifax Public Gardens and trees in the grounds of the adjacent Sacred Heart School are colonized by the alien lichen, *Lecanora conizaeoides*. It too is affected by another lichen parasitic fungus, *Athelia arachnoidea,* which is found affecting the lichen in the United Kingdom and other parts of Europe where this lichen is native (Gilbert 1988). *Lecanora conizaeoides* requires or thrives where there is at least some sulphur dioxide in the surrounding air and colonizes trees that have more acidic bark. Thus, in the Public Gardens, this lichen is found on elm but is even more common on coniferous trees upon which it is one of only a few species. *Lecanora conizaeoides* is easily identified by its greenish thallus, its pale greenish brown apothecia and its spot test reaction of Pd+Red using Steiners reagent. Brawn and Ogden (1977) recorded this lichen at seven of their 31 sampling sites noting that the lichen was plentiful to numerous at three sites, but they did not specify the locations within Halifax.

Another group of foliose lichens are yellowish green. *Flavoparmelia caperata* is a common species that forms large circular patches on old deciduous trees and is commonly seen in rural areas of Nova Scotia where it is often referred to as the 40 mile per hour lichen, being conspicuous enough to identify from a moving vehicle. While not common in Halifax, it was found in the public gardens along with the very much rarer *Flavopunctelia flaventior* which was discovered on Japanese Cherry (*Prunus* sp.).

A conspicuous part of the lichen flora of Nova Scotia is provided by the lichens that are bright yellow to orange in colour. These include the genera *Candelaria* which is foliose and *Candelariella* which is crustose. Both are negative when spot tested with the KOH reagent. This reaction contrasts with the other common yellow-orange lichen, *Xanthoria,* which turns bright purple with this spot test. These lichens seem to thrive when there is an abundance of nutrient rich particulates. *Xanthoria* is generally associated with seashore rocks and eutrophicated habitats like farm buildings but the species *Xanthoria parietina* seems to be spreading throughout eastern North America based on observations and anecdotes (Allen 2016). It's not clear yet what impact this species will have on the existing lichen communities. This readily identifiable lichen was only recorded twice by Ward (1968) in his Halifax study, both fairly close to the Northwest Arm, but today it is more common in the city and was recorded in our study of the Public Gardens.

A considerable number of crustose lichens were recorded in the Halifax Public Gardens. *Lecanora*, *Lepraria* and *Buellia* were common but there were also unusual or often easily overlooked lichens such as *Chrysothrix caesia*, *Loxospora pustulata* and *Scoliciosporum chlorococcum*. None of the crustose lichens proved to be new records for Nova Scotia (I. Brodo, *pers. comm.*).

In conclusion, the Halifax Public Gardens have a surprisingly rich lichen flora for a site that is in the centre of a large city. The reasons likely include the diversity of trees and the fact that some are over 100 years old. Secondly, interesting or unusual tree species planted in the gardens may have been imported from Europe or other parts of Canada and in the first instance brought with them *Lecanora conizaeoides* and its parasite. Indeed, lichens can even be imported on timber (Alstrup 1977). Whatever the sources of the interesting lichen flora, it is hoped that the present study will provide a baseline that will be of value for monitoring changes in the lichen flora of Halifax resulting from new patterns of weather or alterations in the levels of pollutants such as acid rain, sulphur dioxide or nutrient rich particulates.

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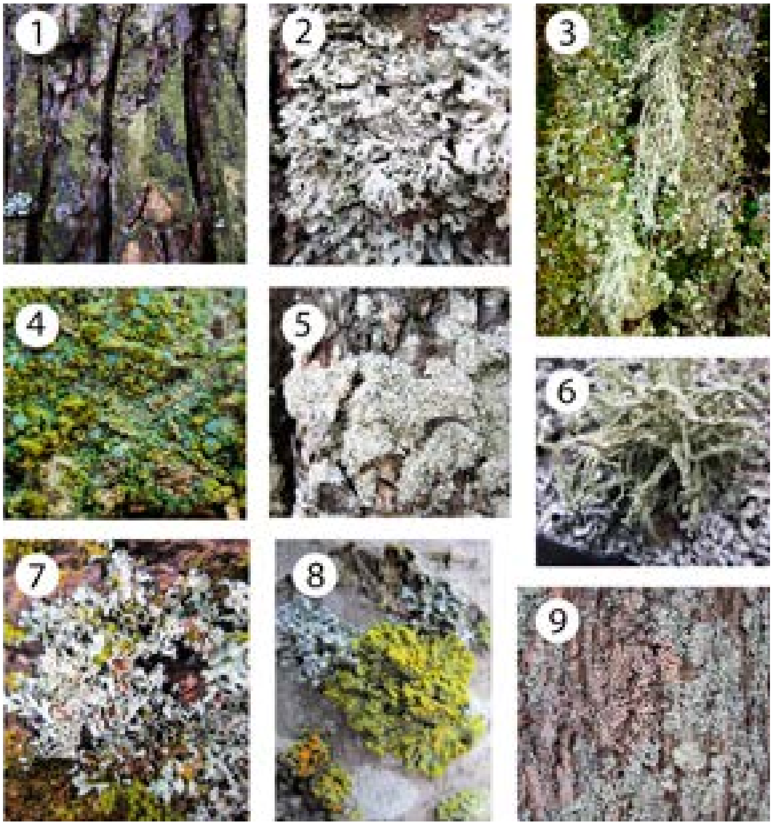

Some of the lichens in the Halifax Public Gardens:

1. *Lecanora conizaeoides* – Pollution Rim-lichen; 2. *Hypogymnia physodes* – Puffed Shield Lichen; 3. *Usnea sp*. – Beard Lichen and Cladonia chlorophaea – Mealy Pixie-cup; 4. *Chrysothrix caesi*a – Dust Lichen; 5. *Physcia millegrana* – Mealy Rosette Lichen; 6. *Evernia mesomorpha* – Boreal Oakmoss Lichen; 7. *Parmelia squarrosa* – Bottlebrush Shield Lichen; 8. *Xanthoria parietina* – Maritime Sunburst Lichen (centre) and Xanthoria polycarpa- Pincushion Sunburst Lichen (Lower left); 9. *Parmelia sulcata* – Hammered Shield Lichen infected by the fungus Nectria parmeliae (pinkish in centre).

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NATURAL HISTORY OF THE TERRESTRIAL GREEN ALGA, *PRASIOLA CRISPA* (TREBOUXIOPHYCEAE), AND ASSOCIATED HERRING GULLS ON BRIER ISLAND, NOVA SCOTIA

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ABSTRACT

The local distribution of *Prasiola crispa* is reported for the first time in Nova Scotia. It was common on emergent basalt outcrops in a coastal wetland on the Bay of Fundy shores of Brier Island. The alga was present on 19 of 102 basalt outcrops in one of the breeding colonies of the Herring Gull, *Larus argentatus*, and was only associated with basalt outcrops with gull feces. Patches of *P. crispa* were typically associated with the north facing slopes of the rock or were present in depressions or parts of the rock shaded by adjacent vegetation. At Western Light, the gulls are both facilitating the presence of *P. crispa* and acting as ecosystem engineers by nesting in the adjoining vegetation where their trampling and nutrient inputs are modifying the surrounding wetland ecosystem.

Key Words: Brier Island, ecological engineers, Herring gulls, *Prasiola crispa*

INTRODUCTION

The genus *Prasiola* comprises 35 specific and infraspecific taxa occurring in marine, freshwater and terrestrial communities (Guiry and Guiry 2016). The genus is cosmopolitan, occurring on all continents and from arctic to tropical habitats (Rindi 2007). Most species consist of monostromatic blades typically less than 1 cm, although

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some species may be 10 cm or longer, and some developmental forms may be uniseriate or ribbon-like.

Prasiola crispa (Lightfoot) Kützing is a Holarctic species and associated with arctic to temperate maritime conditions in both the Northern and Southern Hemispheres. The species is well known and extensively collected from Greenland and many coastal regions of western Europe through to the White Sea (e.g., Rindi 2007, Garbary and Tarakhoskaya 2013). However, the species has been poorly documented in eastern North America with Canadian historical records limited to Newfoundland and Quebec (Collins 1909, South 1973, Gauthier *et al*. 1980), and there is little information on its ecology. Recently Mathieson and Dawes (2017) included Nova Scotia as part of the distribution, without providing specific locales.

Prasiola crispa can be easily confused with the more marine species, *P. stipitata* Suhr ex Jessen, which is common along the Atlantic and Bay of Fundy shores of Nova Scotia and throughout much of northeastern North America (Taylor 1957, Sears 1998, Mathieson and Dawes 2017). *Prasiola stipitata* is common in the splash zone of exposed rocky shores where gulls deposit their droppings. On Digby Neck and associated islands (including Brier Island) and around the Bay of Fundy, the species is common (Edelstein *et al*. 1969, Wilson 1979, South *et al*. 1988, Kang *et al*. 2013), and in winter and spring may cover many square meters (Kang *et al*. 2013). During summer the populations are much smaller. One extensive population of *P. stipitata* was found near North Light on Brier Island in mid-August in the splash zone associated with bird droppings, crab remains, and the lichen *Xanthoria* sp. (Garbary, unpublished observations). There are other terrestrial species of *Prasiola* such as. *P. calophylla* (Carmichael ex Greville) Kützing, and *P. furfuracea* (Mertens ex Hornemann) Kützing, that occur in terrestrial coastal habitats around the North Atlantic and Arctic Oceans (e.g., Rindi 2007, Garbary and Tarakhovskaya 2013),

In the present paper, we report results of a survey on Brier Island for the occurrence of *Prasiola crispa*, a boreal/arctic species of this algal genus, where cold water upwelling of the Bay of Fundy creates boreal conditions (Brown and Gaskin 1988). *Prasiola crispa* was discovered in 2016 on basalt outcrops of the island in a nesting colony of the Herring Gull, *Larus argentatus* (Pontopiddan 1763).

MATERIALS AND METHODS

Study Area

Brier Island, Nova Scotia (44°15'N 66°22'W, Fig 1), has a boreal climate and vegetation largely comprised of scrub forest of *Picea mariana* (Mill) BSP (Black Spruce), with extensive wetlands of bogs and fens through to coastal heaths. The island is home to the rare flowering plant, *Geum peckii* Pursh (Paterson & Snyder 1999, Blaney 2010, Garbary and Hill 2014). The principal population of *G. peckii* is in Big Meadow Bog (44°15.17'N, 66°21.5'W), and it is threatened by an estimated 6000 Herring Gulls (Toms 2015), the second largest nesting colony east of the Great lakes (Cotter *et al*. 2012). A second breeding colony of Herring Gulls occurs at Western Light (44°14.7'N, 66° 23.5'W, Fig 2), and a third colony occurs on shoreline cliffs near the eastern tip of the island at Big Cove (44°15.8'N, 66°20.66'W). The small community of Westport (population ca. 400) thrives on diverse commercial fishing activities and tourism.

The area occupied by the gulls includes ca. 20% of a large wetland-heath system that has been partially drained by road development and ditching of the gravel road to the lighthouse. The Western Light area differs from the larger wetland of Big Meadow Bog in that the former has numerous outcrops of the basalt bedrock in an area ca. 130,000 m^2 where the birds nest and use the rock outcrops and clumps of Black spruce as perches. The gulls deposit considerable fecal matter on the rocks and throughout the wetland community. We initially investigated this site to collect regurgitated gull feeding pellets for comparison of feeding activity with the gulls in Big Meadow Bog (Hill and Garbary, unpublished data). As part of this survey, populations of an epilithic, green foliose alga were noted that were likely members of the genus *Prasiola*.

Field Methods and Observations

Numerous walks through Big Meadow Bog occurred from 2014 onward by both authors without observing any colonies of *Prasiola*. The very-large gull nesting colony in Big Meadow Bog had neither rock outcrops nor *Prasiola*. A single examination of the nesting colony near the eastern end of the island at Big Cove (Fig 1) had no apparent *Prasiola,* despite extensive basalt cliffs.

The area at Western Light where the gulls were nesting in the vegetation was studied during three random walks through the

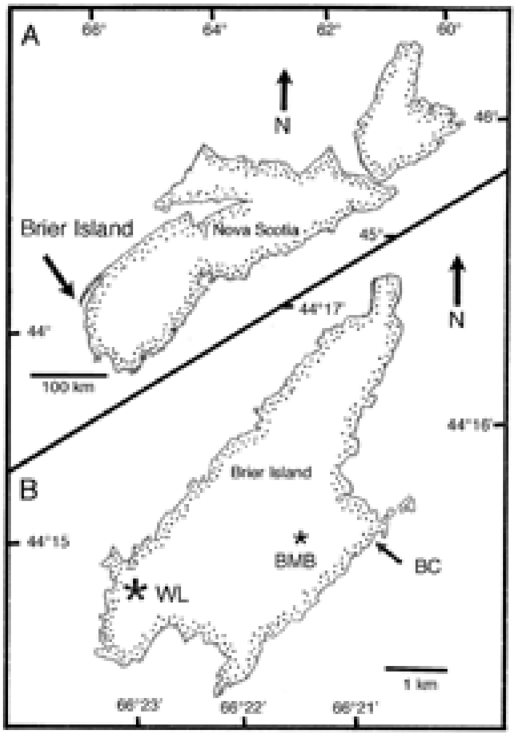

Fig 1 **Map of Nova Scotia (A) with insert of Brier Island (B) indicating breeding colonies of Herring Gulls in Big Meadow Bog (BMB), Big Cove (BC) and Western Light (WL), the latter where *Prasiola crispa* was found.**

habitat in early to mid-August 2016. The individual rock outcrops ranged from ca. 1 m^2 to about 100 m^2, and many had patches of lichens, mosses and heath plants. The position of each outcrop with evident gull feces was recorded as degrees, minutes and decimal minutes to three decimal places using a hand-held GPS unit (Garmin eTrex, Olathe, Kansas), along with the occurrence of populations of *Prasiola*. The position of each of these outcrops was later mapped onto Google Earth (Fig 2).

The microhabitat of the colonies on the outcrops (i.e., flat surface, crevices, slope and shade from surrounding vegetation) and aspect (i.e., general direction of the primary colonies) were also noted. On each outcrop where *Prasiola* occurred, a numbered sample from the largest one or two patches was scraped into separate plastic bags that were returned to the laboratory for microscopic evaluation.

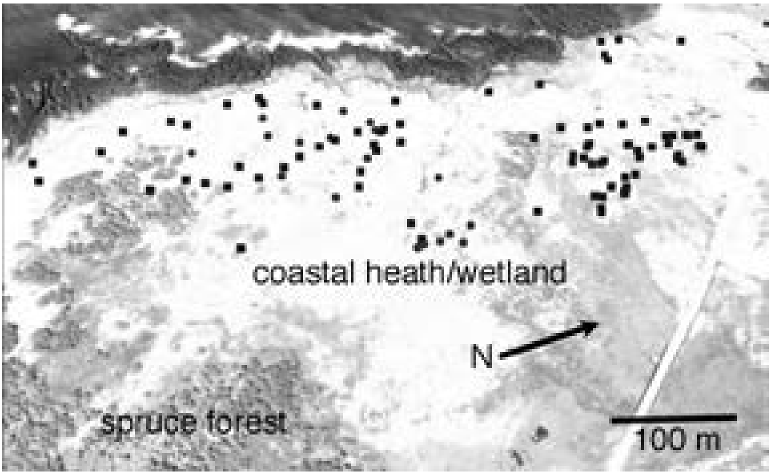

Fig 2 **Google Earth image of habitat at Western Light on Brier Island indicating distribution of rock outcrops with gull droppings, either with (circles) or without (squares) colonies of *Prasiola crispa*.**

Microscope slides were made from each collection, and identification was based on the key in Rindi (2007). Herbarium specimens were deposited in STFX, ACAD and MICH.

RESULTS

Microscopic examination of the collected samples from Western Light showed that only *Prasiola crispa was* present (Fig 3). Two additional collections from the splash zone at Northern Light were *P. stipitata*. *Prasiola crispa* is morphologically distinct from the other terrestrial species of the genus in lacking a conspicuous stipe. The colonies on each outcrop consisted of thousands of overlapping fronds no more than 3 mm high. The filamentous form of this species (Rindi 2007) was observed on slides made from thalli of several of the 19 outcrops. These short uniseriate filaments can develop into the multiseriate monostromatic blades typical of the species (Rindi 2007). Some fronds had masses of spore-like structures (akinetes) formed by the apparent dissolution of the parental fronds.

One hundred and two separate outcrops (Fig 2) with gull dropping were sampled on the three random walks. Several additional outcrops near the northern end of the Western Light colony at the road had

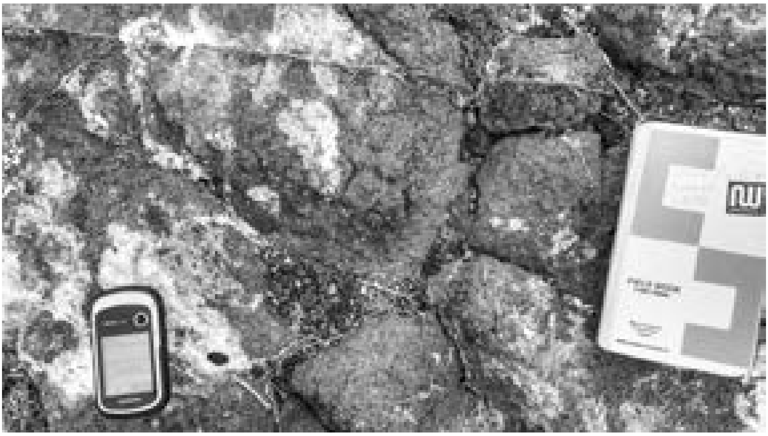

Fig 3 Portion of rock surface with typical patches of *Prasiola crispa* (green) and extensive gull droppings (white). Field book and GPS for scale.

neither droppings nor *P. crispa*. Of the 102 outcrops with gull droppings, *P. crispa* was present on 19 (18.6%). On some outcrops, there was a single well-defined patch from 10-50 cm^2, whereas on other outcrops, there were many small to large irregular-shaped patches (Fig 3). Colonies were rare on the flat upper surface of the rock, fully exposed to the sun. Most colonies were on the sloped sides of the outcrops and many were north facing. Some patches were in depressions in the rock or shaded by adjacent shrubs or boulders.

Prasiola crispa was not randomly dispersed. No apparent colonies were seen close to the road, and none on the cliff tops adjacent to the shore. Indeed, 20 m was the closest that *P. crispa* was found to the seashore cliff tops (ca. 5 m above high tide). The furthest from the shore that we found *P. crispa* was about 150 m. *Prasiola crispa* was most frequent in the central nesting area of Western Light where many outcrops stood out above the surrounding vegetation and allowed the birds vantage points and access to nest sites in the surrounding vegetation.

A search of other gull nesting sites on Brier Island was carried out. The Herring Gull nesting population on the cliff side in the eastern corner of the island (near Big Cove) with extensive basalt columns has a south facing exposure and the spruce forest comes to the top of the cliff, thereby restricting habitat for *Prasiola*. Exploration of this area revealed no *Prasiola*. Two populations of *P. stipitata* were confirmed near Northern Light in the splash zone, one of these being used for the physiological study by Kang *et al*. (2013). Nesting colonies of various seabirds are also present on Peters Island (Stewart *et al*. 2015) but access to survey for *Prasiola* was not possible.

DISCUSSION

This survey of *Prasiola crispa* on Brier Island provides an indication of its preferred habitat in Nova Scotia. The microhabitat distribution of *P. crispa* over the 102 sampled outcrops shows that it is primarily associated with shaded or north- facing rock surfaces, as well as depressions and crevices. The association with high nutrient loading was confirmed as rocks without droppings never had *P. crispa*. We did not attempt to quantify the abundance of fecal deposits in relation to the abundance of the *P. crispa*, but the general distribution of the alga in the area where the gulls, and their droppings, seemed most abundant, would suggest significant levels of droppings are required for the alga to thrive. However, the abundance of *P. crispa* may simply reflect gull activity, and possible gull dispersal, rather than amount of nutrients per se. The relationship with sea spray commented upon by most authors (e.g., Rindi 2007) was not observed; indeed *P. crispa* was not found at the top of the sea cliffs that lined the shore at Western Light, despite the abundance of gulls and their droppings.

The influx of Herring gulls to Brier Island began in the 1970s and led to the formation of the large nesting colony in Big Meadow Bog. The natural landscape near Western Light of rock outcrops in a wetland/coastal heath plant community, combined with human intervention, gave rise to a partially dried wetland that attracted a portion of the nesting Herring gull population that increased until at least 2006 (Eric Mills, personal communication). The outcrops on Brier Island provide perching vantage points, and the vegetation provides suitable nest building sites that are hidden from predators. As a result of breeding activity, the gulls have acted as ecological engineers from two perspectives: 1) the nutrient loading and trampling modified the plant community (Hill, unpublished observations), and 2) the gull droppings provided the habitat for *P. crispa*. Based on the 19% current colonization by *P. crispa* of the available rock outcrops, we suggest that *P. crispa* likely arrived following the increase in the Herring gull population on the island. Without long-term observation, experimental manipulation and molecular fingerprinting, it is difficult to know whether wind based or gull based dispersal of *P. crispa* occurs within the habitat or over larger geographic distances. However, adult and juvenile movement on and around the outcrops likely facilitates the transport of algal propagules; during parental feeding of the chicks via regurgitation pellets or the smashing of larger food items on the rocks (e.g. crabs, sea urchins, molluscs), spores or small frond may be dispersed.

Unlike other *Prasiola* species, the occurrence of *P. crispa* may be more closely associated with seabird areas (Broady, 1996). *P. crispa* has been identified in the nesting material and as gull-transported materials in Antarctica (Parnikoza *et al*., 2012). Wind may also be a dispersal agent of the microscopic spores and juvenile fronds as suggested for the supratidal *Prasiola* species by Garbary & Tarakhovskaya (2013) on the shores of the White Sea.

Herring Gull colonies are numerous along the Atlantic coast of Nova Scotia (Chardine 2015). Some gulls have been tracked from Kent Island to Brier Island (Shlepr 2017), both being boreal outposts in the Bay of Fundy. As several boreal plants occur on Brier Island (Hill and Garbary, unpublished) and two-thirds of the moss flora of Kent Island is boreal (Futamura and Wheelwright 2000), we predict that the epilithic boreal alga, *P. crispa*, could be more widely dispersed on seashore gull colonies around the Bay of Fundy where boreal conditions occur. Further surveys should be done, and *P. crispa* may be useful as a biomonitor to study the impact of the Gulf of Maine warming that has been recently documented (Pershing *et al*. 2015).

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A SURVEY OF THE SEAWEEDS OF LENNOX PASSAGE AND ST. PETERS BAY, CAPE BRETON ISLAND, NOVA SCOTIA

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ABSTRACT

A novel, bay-scale (i.e. tens of km) survey method was employed to examine algal populations on the southwestern shore of Cape Breton Island, Nova Scotia. Since traditional remote sensing methods were unlikely to be successful in these waters, underwater video and acoustic methods were applied. A transponder positioned towfish housing video camera and sidescan sonar was hauled along predetermined transects perpendicular to shore to provide information on bottom type and algal cover. The towfish data were used to ground truth echosounder data (bottom type and macrophyte canopy height) collected along 5, 10 and 20 m depth contour lines. The survey area was divided into six zones comprising a range of exposure, depth and bottom types. Destructive quadrat samples were collected at each depth, plus shore stations, to provide biomass estimates. Over thirty taxa were enumerated, indicating depths and zones of common occurrence. *Ascophyllum* was abundant at some of the shore stations. The genera *Chondrus, Cystoclonium, Desmarestia, Fucus, Phyllophora, Polysiphonia,* and *Saccharina* were common at 5 m. *Desmarestia* and *Saccharina* dominated at 10 m with wet weights sometimes over 1 kg·m^{-2}. *Agarum* dominated at 20 m. The towfish / echosounder grid sampling system was relatively coarse in order to cover the 140 km^2 survey area within 12 days. As a result, the survey did not produce spatially detailed information. However, adequate information was gathered to describe the general characteristics of bottom type and algal cover by zone and for focussing further exploration.

Keywords: acoustics · algal assemblages · Cape Breton · macroalgae · video
Abbreviations: VH = Visual Habitat™ software

INTRODUCTION

Over a decade has been spent developing methods to survey bottom type and macrophyte cover at bay-scales (i.e. tens of km) in nearshore

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marine environments on Canada's eastern sea-board (Vandermeulen 2007, 2011a, 2011b, 2013, 2014a, 2014b, 2016a, 2016b, 2017). Traditionally, nearshore surveys of benthic habitat (including algae) have been performed by intertidal or SCUBA based transects. For example, Parsons *et al.* (2004) utilized GPS positioned diver video transects to create a detailed bottom habitat map in a small bay in New Zealand. The classification included a variety of algal habitats. The area they surveyed was small, however (less than 1 km^2), and the level of effort required to sustain that intensity of survey at the bay-scale or larger would be prohibitive.

Remote sensing has often been used to assess and map algal biomass in the nearshore, and these methodologies can work very well in the intertidal zone or if the canopy reaches the sea surface, as is the case for some of the larger kelps (Stekoll *et al.* 2006). However, the utility of remote sensing in some of the more turbid, low tidal range waters of Atlantic Canada is debatable (Vandermeulen 2011a, 2014b). There remains a steady chorus of researchers either challenging the accuracy of satellite or air photo based remote sensing methods for detecting benthic habitat features at depth (e.g. Shao and Wu 2008) or suggesting that acoustic methods may be more appropriate for this purpose (Sabol *et al.* 2002, 2009, Komatsu *et al.* 2003, Hewitt *et al.* 2004, Parsons *et al.* 2004, Barrell and Grant 2013). In our experience, Chamberlain *et al.* (2009) quite correctly state that acoustic methods detect considerably more submerged aquatic vegetation than aerial photographic methods, and the biomass detection also occurs to a greater depth.

Although acoustic methods have most commonly been used to describe bottom characteristics such as hardness or rugosity, or habitat features associated with benthic invertebrates (e.g. Moore *et al.* 2009), there have also been ongoing efforts to map aquatic macrophytes. Earlier studies utilizing single beam echo sounders to determine the presence or cover or biomass of aquatic macrophytes used simple, visually-interpreted echosounder paper tracings to identify signals indicating macrophytes. Duarte (1987) used echosounder tracings to obtain biomass estimates of vascular macrophytes in lakes based upon canopy height. Spratt (1989) also used echosounder tracings to determine eelgrass distribution in Tomales Bay, California.

More recently, sidescan sonar has been successfully applied to survey seagrass beds (Mulhearn 2001, Stolt *et al.* 2011, Vandermeulen 2014b) and crustose coralline algal beds (Pereira-Filho *et al.* 2012).

Modern multibeam echo sounding has also found its place. McGonigle *et al*. (2011) utilized multibeam backscatter to specifically target the canopy volume of deep-water benthic macroalgae including *Laminaria* and *Agarum*. Abukawa *et al*. (2013) used multibeam echo sounding to assess the canopy height and biomass of aquatic vegetation in a lake to a depth of about 20 m. Komatsu *et al*. (2003) used multibeam to map *Zostera caulescens* Miki bed volumes in shallow waters (< 10 m) in Japan. Using slightly different methods, Che Hasan *et al*. (2014) created habitat classes that included mixed brown, red and green algae via multibeam echo sounding backscatter measures. They were working down to depths of 80 m in Discovery Bay, Australia.

Single beam echosounder technology, both hardware and software, has improved greatly since the days of paper tracings. Anderson *et al*. (2002) used an echosounder running QTC VIEW software to discern macroalgae on rock, primarily *Laminaria*, *Agarum* and *Chondrus,* in the coastal waters of Newfoundland. Jordan *et al*. (2005) used two different echosounders on different vessels to map inshore and offshore seabed habitats for potential MPA designation in south-east Australia. They were able to distinguish both seagrasses (*Halophila*, *Posidonia*, *and Zostera*) and dominant brown algae (*Phyllospora*, *Ecklonia*).

BioSonics Inc. is the only company that produces echosounder hardware and software specific for the detection of aquatic macrophytes. Their digital echosounders (mainly the DE and DT model series) and transducers (narrow beam, 6° or less; ~200, 420 or 430 kHz) have been used widely to assess rooted vascular macrophytes in marine and freshwaters. EcoSAV™ software is proprietary to the company, and provides an analysis of canopy height and cover from the echosounder data. BioSonics-based surveys have included both tropical and temperate seagrasses (Marbà *et al*. 2002, Sabol *et al*. 2002, Tegowski *et al*. 2003, Chamberlain *et al*. 2009, Stevens and Lacy 2012, Barrell and Grant 2013) and macrophytes in lakes (Thomas *et al*. 1990, Leisti *et al*. 2006, Winfield *et al*. 2007, Istvánovics *et al*. 2008, Sabol *et al*. 2009, Valley *et al*. 2010, Herbst *et al*. 2013).

All of the acoustic based examples mentioned above utilize some form of ground truthing to differentiate an acoustic macrophyte signature from an acoustic substrate signature. Typically, ground truthing is performed via rake or other destructive sampling, SCUBA observations, drop cameras, towed video or remotely operated vehicle.

With the above background information in mind, it was decided to perform a Cape Breton based survey utilizing a novel combination of equipment and new methods which avoided the inherent problems of aerial remote sensing. A towfish combining video and sidescan hardware was run along transects to ground truth BioSonics-based echosounder data collected along depth contour lines. The novelty of the method stems from the fact that our devices are nested in scale, from video to sidescan to echosounder, each device in that sequence providing ground truth data for the next – culminating in the echosounder tracks which covered the greatest possible geographic area. The complete survey was set to occur during the summer months to coincide with peak algal diversity and biomass.

MATERIALS AND METHODS

Study site The island of Cape Breton is the northeastern extension of the province of Nova Scotia, Canada. For reasons of access and infrastructure, the survey focus was the Lennox Passage region. Lennox Passage is found in the south of Cape Breton Island, between the Cape Breton shore to the north and Isle Madame to the south (Fig 1). The passage extends to the east towards St. Peters Bay, which has a canal entering into Bras d'Or Lake – a large estuary in the interior of Cape Breton Island.

The western end of Lennox Passage at Rabbit Island is a moderately exposed area opening out into Chedabucto Bay to the south. As one moves east from Rabbit Island through the passage the waters rapidly become calmer and more protected. From the midpoint of Lennox Passage and heading further east, the waters gradually become more exposed again, eventually opening up into a wide bay broadly exposed to deep ocean swells coming from the open Atlantic. The easternmost headland of the bay is Red Point. Our survey incorporated the area from Rabbit Island through to Red Point.

Although there are no long term data sets on water column temperature or salinity for the area (Adam Drozdowski, pers. comm.), there are nearshore surface sampling records for these parameters going back a number of years from 2015 (David MacArthur, pers. comm.). These surface samples are collected at a number of stations in western & eastern Lennox Passage, St. Peters Bay, and Little Harbour (Red Point area). Summer maximum surface temperatures

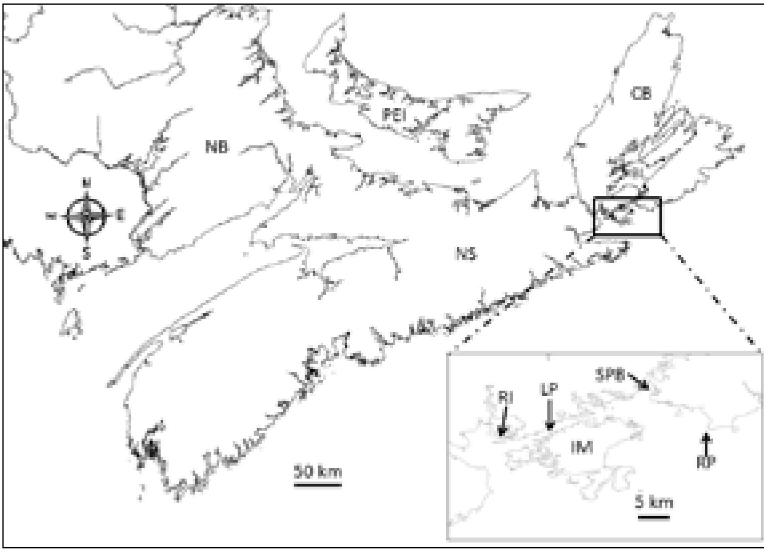

Fig 1 **The study area. The provinces of New Brunswick (NB), Prince Edward Island (PEI), and Nova Scotia (NS) with its Cape Breton Island region (CB) including Bras d'Or Lake (BL). Inset: Ilse Madame (IM), Rabbit Island (RI), Lennox Passage (LP), St. Peters Bay (SPB), and Red Point (RP).**

at these stations can reach 23°C, while salinity ranges from 0 to 37 ppt depending upon freshwater inputs (David MacArthur, pers. comm.). There is variable ice cover in Lennox Passage during the winter months.

Towfish survey A novel towfish was deployed as described in Vandermeulen (2011a, 2013, 2014b). Briefly, the towfish consisted of a video camera with 10 cm laser scale and a 330 kHz sidescan sonar set to a 30 m swath width. The video feed was used to ground truth the sidescan imagery in real time. The towfish was positioned to sub-meter precision via a transponder / transceiver system coupled to a high end dGPS with Canadian Coast Guard beacon correction. During the survey, the towfish was hauled behind the vessel from depth to the shallows on transects perpendicular to shore. Some transects were run from shore to an opposite shore. The vessel speed over ground during transect runs was approximately 1.5 knots. The towfish was held approximately 30 cm off the bottom at all times. In this position, the field of view of the camera was approximately 1 m.

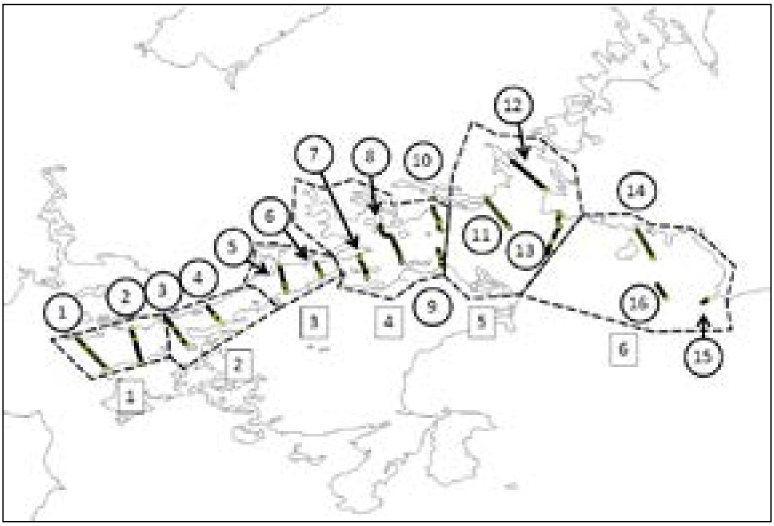

Fig 2 **The survey area divided into six zones (numbers in rectangles). The towfish transects are indicated by numbers in circles.**

The survey area was divided into six zones, with at least two transects per zone (Fig 2). The zones were chosen to reflect differences in depth and exposure within the survey area. Zone 1 was moderately exposed with depths to just over 10m with a water surface area of approximately 12 km^2; Zones 2 and 3 were much more protected and shallower (approximately 9 and 7 km^2, respectively); Zone 4 was a transition area where Lennox Passage widened and became deeper (>10m) and more exposed, with a surface area of 22 km^2; Zone 5 was a broad exposed area with depths >20m and a surface area of approximately 37 km^2; and Zone 6 was a large, deep open bay with extreme exposure (large swells from the open Atlantic). Its water surface area was approximately 52 km^2.

Post processing of towfish data was accomplished via the use of specialized commercial software (Vandermeulen 2011a). A MapInfo GIS project was created with a hydrographic chart background layer in which sidescan GeoTIFF images, towfish track positions (which were updated every 1.3 seconds) and AVI video clips were embedded. Each video clip was approximately 10 min long and embedded into its starting point on the associated GeoTIFF image. In this manner, each transect was assigned a number and then divided into sections defined by the associated video clips. For example, transect number

3 in the section covered by video clip number 5 would be coded as T3S5. By examining the sidescan imagery in a particular section of the transect and comparing it to the video clip for that section, it was possible to classify bottom types and macrophyte types associated with each towfish track position. The resulting towfish based classification was used to ground truth the echosounder survey that followed.

Echosounder survey Independently of the towfish transects, an echosounder system was deployed as described in Vandermeulen (2011b). The BioSonics Inc. (Seattle, WA 98107) system consisted of a DT-X digital echosounder surface unit, a 210 kHz single beam digital transducer with 6° cone angle, and a 430 kHz single beam digital transducer with 6° cone angle and built in heading / pitch / roll (HPR) sensor. The transducers were chosen for their ability to detect bottom type and macrophyte cover, respectively. Both transducers operated at the same time, with alternating ping cycles. The echosounder track was recorded to sub-meter precision via the same dGPS unit used for the towfish. During the survey, hydrographic chart contour lines were followed to get relatively uniform sized ping foot prints for better precision in later data analyses (Vandermeulen 2011b). The vessel speed over ground was approximately 4 knots, similar to Sabol *et al*. (2009). In order to maximize the ability to pick out different types of algal assemblages, 5, 10 and 20 m contour lines were chosen for this survey.

Data processing was accomplished via specialized software from BioSonics, Inc. (Vandermeulen 2011b). Visual Bottom Typer™ was applied to the 210 kHz dataset to sort and cluster acoustic bottom signatures into groups of bottom types (e.g. hard versus soft). EcoSAV™ was used on the 430 kHz dataset to create bins of macrophyte canopy heights. Later on, both datasets were revisited with Visual Habitat™ software, an update incorporating and enhancing the properties of the previous two software packages.

Quadrat survey Data from the towfish and echosounder surveys was extracted to determine sites for SCUBA based destructive sampling for standing stock data on dominant algal species. An effort was made to select representative algal communities at 5, 10 and 20 m depths along towfish transects based upon the video data. The survey design was not random; it was an attempt to discern areas with notable algal cover. The survey effort was divided into the three depths plus shore stations in order to maximize the ability to explore different types of algal communities.

One m^2 and 0.25 m^2 quadrats were constructed from aluminum angle, and paint scrapers were used to remove all algae within each quadrat at each sampling station. A slurp gun was used to remove delicate algal forms which could not easily be stuffed into a collection bag after scraping (Vandermeulen *et al*. 2011). Three quadrats of equal size were used at each sampling station. The quadrats were deliberately placed by the divers to obtain a representative sample of the attached algal flora in the immediate area. Material from each quadrat was placed into individually labelled sampling bags, repackaged in the dive boat and placed into coolers for transport. That same evening, the algal samples were spun in a mesh bag or in a salad spinner to remove surface moisture. Material from each quadrat was sorted by species and a wet weight per species was obtained. Rare species, where wet weight was less than 1 g, were ignored. The weight of epiphytes was also ignored; the epiphyte load was light in any case. In some instances, subsamples were preserved in formalin and taken back to the lab for later sorting and weighing or to confirm identification. Average weights were calculated from the three quadrats for each algal species at each station.

RESULTS

Species list

The algal and other macrophytic species found during this study are listed in Table 1. Unless multiple species were present in a genus, species are referred to by generic name alone.

Towfish survey

The survey ran from June 8-10, 2010. Sixteen transects were completed, covering a total distance of approximately 26 km and a total zonal surface area of approximately 140 km^2 (Fig 2). Fig 3 provides an example of bottom type results at the north end of transect 1 (T1), with the shoreline indicated in tan color at the top of the figure. The hydrographic chart background is useful for interpreting the towfish data. Note how our vessel was able to obtain sidescan and video data in waters <1m deep. In this example, the substrate transitions from a soft muddy bottom (low acoustic reflectivity, dark brown sidescan image) into a coarse gravel bottom (high acoustic reflectivity, light 'brassy' sidescan image) at a depth of about 10 m from Canadian Chart Datum (essentially a point below which the

Table 1 Species list of algal and other macrophytic species found during the seaweed survey.

Taxon
Agarum clathratum Dumortier
Ahnfeltia plicata (Hudson) Fries
Antithamnionella floccosa (O.F. Müller) Whittick
Ascophyllum nodosum (L.) Le Jolis
Bonnemaisonia hamifera Hariot
Callithamnion spp.
Callophyllis cristata (C. Agardh) Kützing
Ceramium virgatum Roth
Chondrus crispus Stackhouse
Chorda filum (L.) Stackhouse
Chordaria flagelliformis (O.F. Müller) C. Agardh
Corallina officinalis L.
Cystoclonium purpureum (Hudson) Batters
Desmarestia aculeata (L.) J.V. Lamouroux
Desmarestia viridis (O.F. Müller) J.V. Lamouroux
Dictyosiphon foeniculaceus (Hudson) Greville
Dilsea integra (Kjellman) Rosenvinge
Ectocarpus spp.
Fucus distichus L.
Fucus serratus L.
Fucus vesiculosus L.
Furcellaria lumbricalis (Hudson) J.V. Lamouroux
Gracilaria sp.
Halosiphon tomentosus (Lyngbye) Jaasund
Laminaria digitata (Hudson) J.V. Lamouroux
Neosiphonia harveyi (J.W. Bailey) M.-S. Kim, H.-G. Choi, M. Guiry & G.W. Saunders
Odonthalia dentata (L.) Lyngbye
Palmaria palmata (L.) Weber & Mohr
Phycodrys rubens (L.) Batters
Phyllophora spp.
Polysiphonia fucoides (Hudson) Greville
Ptilota serrata Kützing
Rhodomela confervoides (Hudson) P.C. Silva
Saccharina groenlandica (Rosenvinge) C.E. Lane, C. Mayes, L. Druehl & G.W. Saunders
Saccharina latissima (L.) C.E. Lane, C. Mayes, L. Druehl & G.W. Saunders
Sphacelaria spp.
Zostera marina L.

tide rarely falls). The sidescan imagery was ground truthed via the associated video clips to generate the bottom classification seen in the midline of the transect. The midline represents the actual position of the towfish during the haul, and each colored symbol is a towfish position data point generated by the towfish transponder / transceiver system. The macrophyte classification for this same portion of the bottom is shown in Fig 4. As would be expected, the deeper soft muddy bottom has no macrophytes while *Saccharina* grew on the coarse gravel bottom in its deeper portion with *Fucus* in the shallows.

Fig 3 **Typical results of towfish bottom type data embedded into the GIS. Sidescan image with bottom classification in mid-line (olive circles = soft sediment; blue stars = coarse gravel; the red chevron indicates the direction of the towfish haul and the position of the associated video clip). The width of the sidescan image is 30m. Transect T1.**

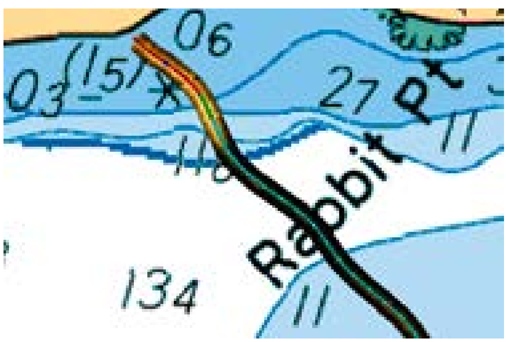

Fig 4 **The same towfish track as Fig 3 with the macrophyte classification (light blue circles = 100% bare substrate; green = *Saccharina* dominated; red = *Fucus* dominated; dark blue = *Zostera* dominated).**

A thin band of *Zostera* was also seen in the shallows on the gravel.

Different bottom types were recognizable with the sidescan imagery (Fig 5). A dark, featureless sidescan image indicates a soft bottom of low acoustic reflectivity (Fig 5a). The two bright bands on either side of the sidescan image are artifacts. Figure 5b demonstrates the much higher acoustic reflectivity of coarse sand, resulting in a much brighter image which is also relatively flat and featureless (there are a couple of larger boulders in the lower left of the image, note the long dark acoustic 'shadows' they create). A bright image with more 'texture' or features is seen in Fig 5c, constituting a gravel base with

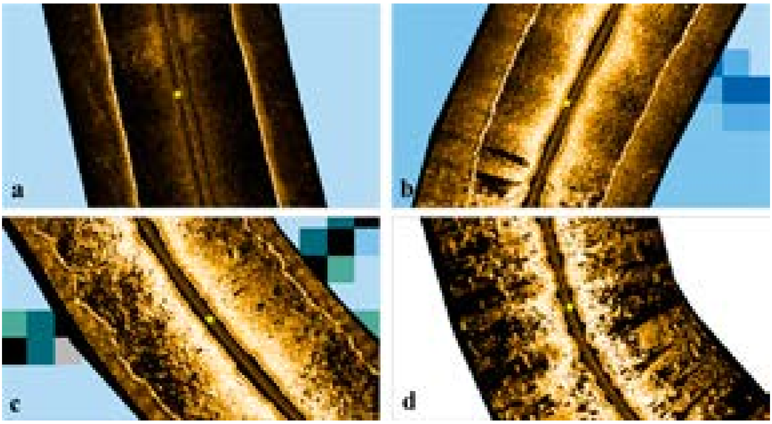

Fig 5 Sidescan imagery associated with different bottom types (each image is 30m wide). a) mud bottom (T8S7). b) coarse sand with pebble (T10bS1). c) gravel base with scattered cobble (T11S2). d) boulders and cobble on gravel (T16aS2).

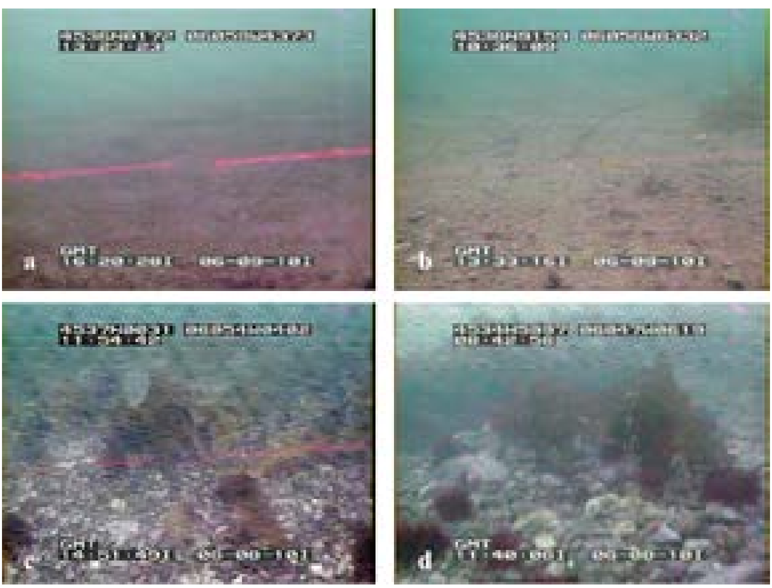

Fig 6 Bottom type screen shots from the towfish video (10 cm red scaling laser, latitude and longitude in degrees decimal minutes at top of each image, GMT time and date stamp on bottom). a) mud bottom (T8S7). b) coarse sand with pebble (T10bS1). c) gravel base with scattered cobble (T11S2). d) boulders and cobble on gravel (T16aS2).

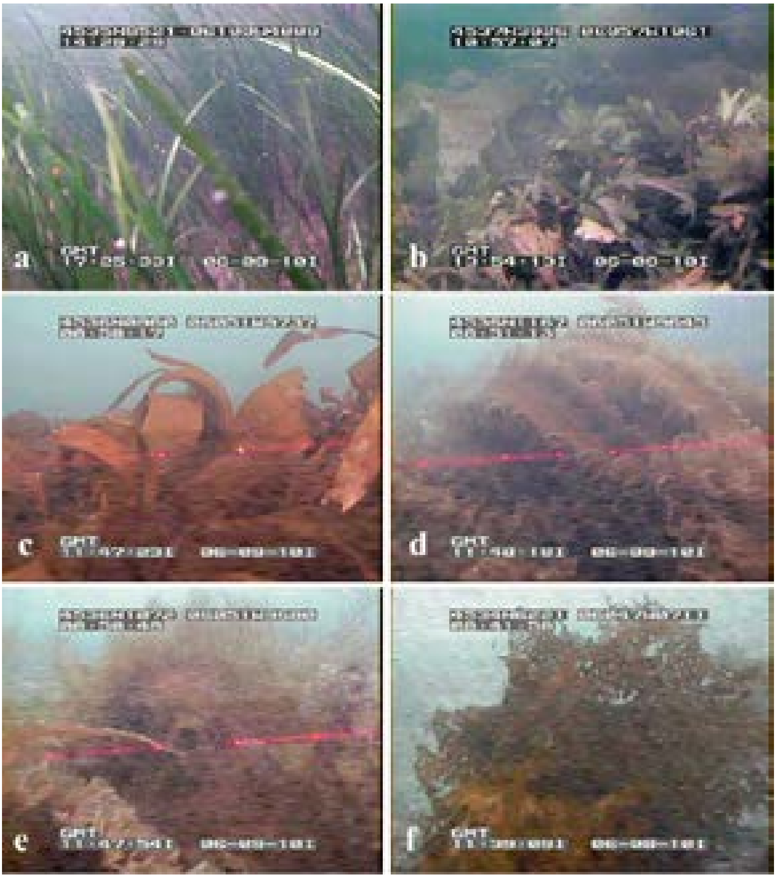

Fig 7 Macrophyte screen shots from the towfish video. a) eelgrass, *Z. marina* (T4S4). b) *F. serratus* (T10bS3). c) *L. digitata* (T13S2). d) *S. latissima* (T13S2). e) *Desmarestia* (T13S2). f) *Agarum* (T16aS2).

scattered mid-sized cobble (note the numerous small acoustic shadows). The greatest amount of texture is seen on boulder / cobble bottoms, with many long acoustic shadows covering the image (Fig 5d). All bottom types indicated by the sidescan imagery were confirmed by the associated video at the same location (Fig 6). It was also possible to identify different groups of macrophytes via the video feed (Fig 7).

The video and sidescan information from the towfish was used to create both a bottom classification (Table 2) and a macrophyte or canopy classification (Table 3). The canopy classification shown in Table 3 was driven by an attempt to find associations of algae where one species would dominate with a cover of ≥ 50%. In deeper areas

Table 2 Towfish bottom classification codes.

Code	Type
1	soft (mud / silt)
2	hard (sand / silt)
3	hard (coarse gravel with occasional cobble)
4	hard (cobble on sand base)
5	hard (boulder / reef)

Table 3 Towfish canopy classification codes.

Code	Type
1	*Fucus* dominant (cover ≥ 50%) – mostly *F. serratus*; may have some *Chorda / Halosiphon*, *Saccharina*, red algal turf or bare patches; *Zostera* cover can be up to 50% at some shallow locations
2	*Saccharina* dominant (cover ≥ 50%) – mostly crozier morph of *S. latissima* (T13 had *L. digitata* mixed in); may have some *Fucus*, *Agarum*, *Desmarestia*, red algal turf or bare patches
3	*Zostera* dominant (cover ≥ 50% as a 'meadow', more extensive than a collection of patches) – may have some *Fucus*, *Chorda / Halosiphon*, variety of other seaweeds, or bare patches
4	*Agarum* dominant (cover ≥ 40%) – usually in deeper areas with many bare patches, may have some *Saccharina*, *Desmarestia* or red algal turf (*Ptilota*)
5	70% bare – may have some algal turf (green, brown or red), *Zostera*, *Chorda / Halosiphon*, *Saccharina*, *Desmarestia*, *Agarum*, or drift material
6	100% bare – no consistent macrophyte cover; may have some algal mats, organic debris, or drift material
7	*Desmarestia* dominant (cover ≥ 50%) – may have some *Saccharina*, *Agarum*, bare patches or drift material
8	red algal coralline crust on boulders at depth (cover ≥ 50%) – may have some *Agarum*, *Desmarestia*, or sea urchins; upright coralline thalli rare

with many bare patches of substrate, *Agarum* would occasionally dominate as the main algal species but it's cover did not approach 50%. However, *Agarum* and its assemblage of species did constitute a valid canopy class and was given a canopy code of four (Table 3). The term 'crozier morph' has been associated with the taxon *Laminaria longicruris* Bachelot de la Pylaie in the past (Sears 2002). It refers here to thalli of *S. latissima* with elongated stipes of various degrees of inflation (Chapman 1973, 1974).

The towfish survey data were used to create 22,915 ground truth point records based upon latitude and longitude of the towfish at each 1.3 s time stamp with bottom type plus canopy codes at each of those towfish positions. The towfish ground truth point records were used to derive the proportion of bottom types recorded by towfish

Table 4 Towfish bottom type data by zone.

Zone	Count for bottom type #1 (%)	Count for bottom type #2 (%)	Count for bottom type #3 (%)	Count for bottom type #4 (%)	Count for bottom type #5 (%)	Total by zone
1	2910 (76.5)	38 (1.0)	750 (19.7)	106 (2.8)	0 (0.0)	3804
2	1921 (76.3)	0 (0.0)	596 (23.7)	0 (0.0)	0 (0.0)	2517
3	2205 (99.5)	0 (0.0)	11 (0.5)	0 (0.0)	0 (0.0)	2216
4	3715 (61.5)	236 (3.9)	2010 (33.3)	79 (1.3)	0 (0.0)	6040
5	1201 (21.6)	877 (15.8)	2213 (39.8)	0 (0.0)	1264 (22.8)	5555
6	0 (0.0)	943 (33.9)	1350 (48.5)	150 (5.4)	340 (12.2)	2783
Totals	11952	2094	6930	335	1604	22915

Table 5 Towfish canopy type data by zone.

Zone	Count canopy type #1 (%)	Count canopy type #2 (%)	Count canopy type #3 (%)	Count canopy type #4 (%)	Count canopy type #5 (%)	Count canopy type #6 (%)	Count canopy type #7 (%)	Count canopy type #8 (%)	Total zone
1	204 (5.4)	212 (5.6)	32 (0.8)	0 (0.0)	217 (5.7)	3139 (82.5)	0 (0.0)	0 (0.0)	3804
2	43 (1.7)	162 (6.4)	33 (1.3)	0 (0.0)	123 (4.9)	2156 (85.7)	0 (0.0)	0 (0.0)	2517
3	11 (0.5)	0 (0.0)	57 (2.6)	0 (0.0)	0 (0.0)	2148 (97.0)	0 (0.0)	0 (0.0)	2216
4	283 (4.7)	856 (14.2)	226 (3.7)	11 (0.2)	216 (3.6)	4263 (70.6)	185 (3.1)	0 (0.0)	6040
5	970 (17.5)	1666 (30.0)	257 (4.6)	38 (0.7)	116 (2.1)	2073 (37.3)	152 (2.7)	283 (5.1)	5555
6	0 (0.0)	34 (1.2)	0 (0.0)	976 (35.1)	562 (20.2)	1211 (43.5)	0 (0.0)	0 (0.0)	2783
Totals	1511	2930	605	1025	1234	14990	337	283	22915

survey zone, not binned by depth. The resulting summary (Table 4) provides a general overview of bottom types which are consistent with the hydrography of each zone. For example, zones 1 – 4 were the more sheltered zones of the survey and they were dominated by soft mud / silt (bottom type #1) with no hard boulder / reef areas (bottom type #5) and very little or no hard sand / silt areas (bottom type #2). Zone 5 was a transitional area depth and exposure wise, and it had a relatively even proportion of each of the bottom types (Table 4). Zone 6 had the greatest depth and exposure, and no soft bottoms were recorded by the towfish in that zone.

Table 5 is a summary of the proportion of canopy types in each towfish survey zone, also not binned by depth. Once again, the results are consistent with the hydrography of each zone. The zone with the most even proportions of all bottom types also had the most even proportions of all canopy types, Zone 5. It was also the only zone not missing any canopy types. Zones 1 – 3 were notable for their relative absence of macrophytes, having no consistent macrophyte cover over 80% of the time (canopy type #6). This is reasonable, considering that >76% of the surveyed bottom in these zones was soft mud or silt (Table 4). Zone 6 was the only zone missing *Zostera* (canopy type #3), consistent with the high degree of wave exposure in the zone. *Agarum* (canopy type #4) was the dominant macrophyte in Zone 6. There was also a considerable amount of completely or partially bare bottom, as would be expected for the overall greater depths found in Zone 6.

Echosounder survey

The survey was completed during June 21-24, 2010. The tracks of the echosounder data acquisition are indicated in Fig 8. A corrupted data file led to a gap in coverage on the 10m contour in the middle of Zone 4. A total of approximately 80 km of coastline was covered by the survey.

Both Visual Bottom Typer™ and EcoSAV™ software packages are loaded with echogram files, parameters are set for analysis, and data processing occurs in a batch mode. If the results from these packages seem odd or inconsistent with towfish ground truth data, the operator must reset the parameters based upon experience or other opinions as to what might improve the results. Although the results from Visual Bottom Typer™ and EcoSAV™ on the 210 and 430 kHz datasets were reasonably consistent with the towfish ground

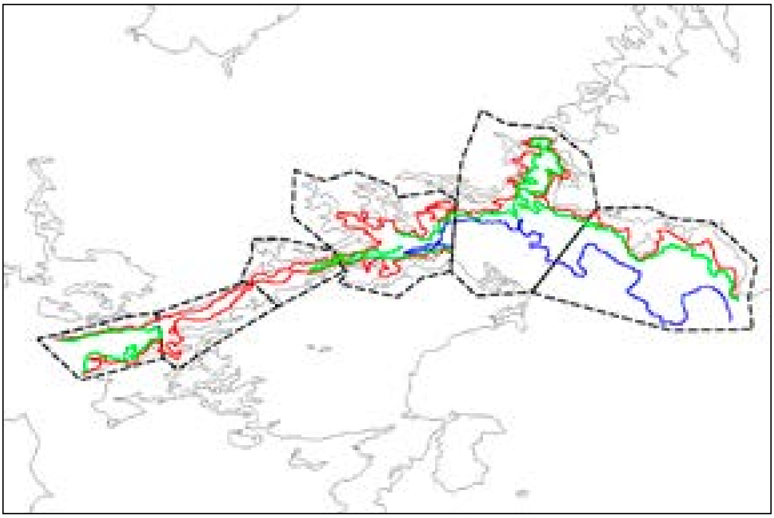

Fig 8 **The survey area indicating the tracks of the echosounder data acquisition. The tracks followed three different depth contour lines, 5m (red), 10m (green), and 20m (blue).**

truth data, a decision was made to revisit both datasets with more recent and updated Visual Habitat™ (VH) software.

The value of the VH software is the ability to edit echograms. The software selects bottom detection and macrophyte detection lines automatically, and these lines can be edited (Fig 9). Editing allows for the correction of errors in the creation of the original detection lines such as false positives for a macrophyte canopy. Softer bottoms occasionally generate these false positives and they are easily recognized in the echograms. After editing, VH can process the echograms to detect different types of acoustic signatures associated with different bottom types, or estimate the canopy height of macrophyte cover. In other words, VH includes the functions of both Visual Bottom Typer™ and EcoSAV™ in one software package.

After some experimentation with VH , it was determined that setting the software to search for six types / classes of acoustic signatures to associate with different bottom types provided quite robust results for comparison to towfish ground truth data. Similarly, binning the canopy height results into three different categories seemed most satisfactory.

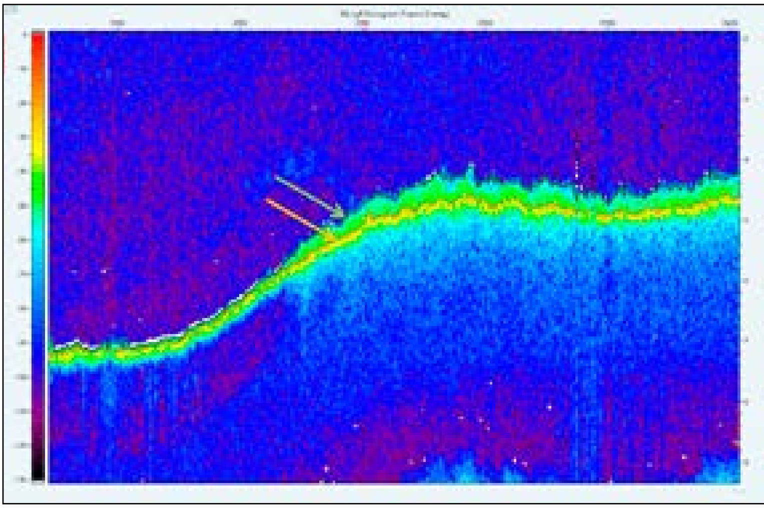

Fig 9 **Screen shot of VH bottom detection line (orange arrow) and macrophyte detection line (green arrow). The light green region between these two lines represents the macrophyte canopy.**

Echosounder ground truthing was obtained by examining cross points with towfish transects. Vandermeulen *et al*. (2017) explain this process and provide raw data tables of results. This can be illustrated by towfish transect T7 where it was crossed by a pass of the echosounder along the 10 m contour line (Figs 10 & 11). Essentially, this was an empirical process to check if the echosounder based VH classification matched the towfish classification at each cross point for both bottom type and macrophyte cover. The VH classifications were color coded in the GIS to match the towfish classifications as closely as possible. Table 6 provides the results for the VH bottom type classification.

The echosounder data and associated VH bottom classification analysis provided a mechanism to examine bottom types by zone and depth (Table 7). The proportion of unclassified (or clear) points in the GIS ranged from 10.5 to 56.3% – so an interpretation of this analysis is tentative at best. However, the general patterns of hard versus soft bottom identified by the analysis do seem logical. At the 5 m depth contour, Zone 6 had the highest proportion of hard versus soft bottom (proportion of blue versus red points in the GIS). This is consistent with the high degree of wave exposure in Zone 6. Zones 1 and 5 also had a relatively higher proportion of hard bottom at

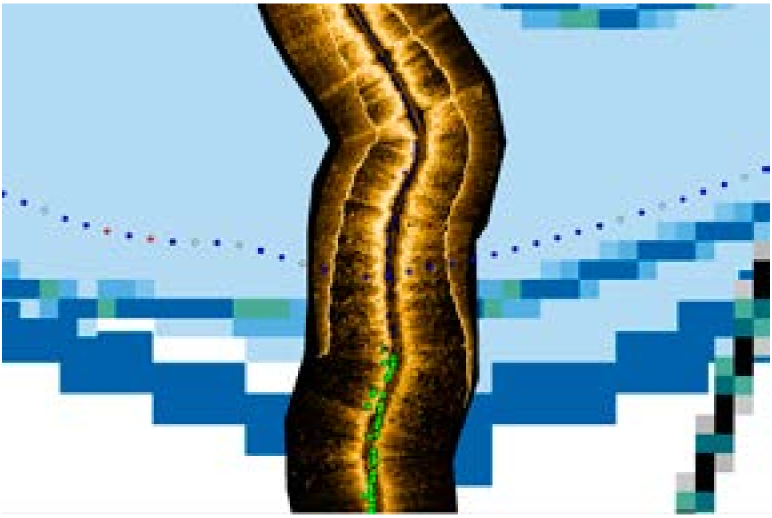

Fig 10 VH bottom classification crossing north end of towfish transect T7 near the 10m contour line. The towfish bottom classification (coarse gravel, blue stars) matches the VH classification (coarse gravel / sand or silt, blue circles) at the cross point.

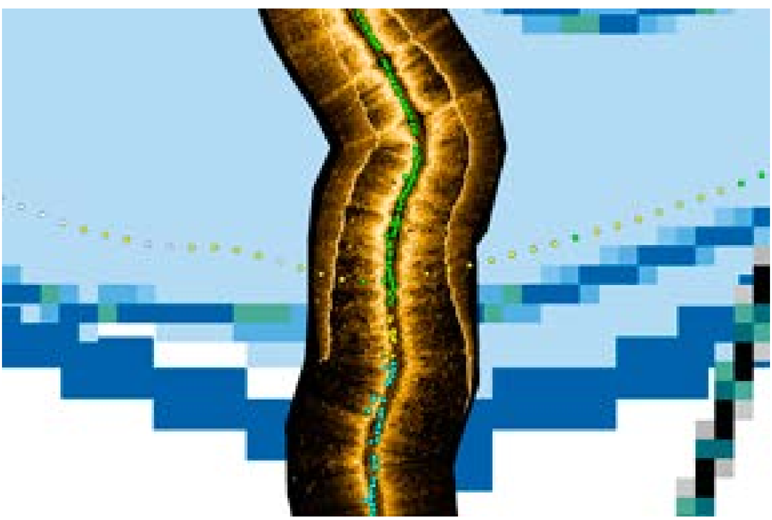

Fig 11 Ground truthing for VH macrophyte canopy classification. Same location as Fig 10. The towfish classification (*Saccharina*, green circles) is consistent with the VH canopy height classification of 0.5 to <1.6m at the cross point (green circles). Canopy height was slightly lower on either side of the cross point (yellow circles, 0.2 to <0.5m) but still consistent with a signal from a larger algal thallus.

Table 6 Color coded VH bottom classifications in GIS.

Depth (m)	Description	Color code
5	'soft'	red
5	'hard'	blue
5	undetermined	clear
10	'soft'	red
10	'hard'	blue
10	undetermined	clear
20	'flat' or featureless sediment of varying hardness	red
20	'hard or textured'	blue
20	undetermined	clear

the 5 m depth contour, matching their exposure regime relative to Zone 6. At the 10 m depth contour, Zone 6 continued to have a very high ratio of hard to soft bottom – a pattern followed by Zone 5. Although the data for the 20 m depth contour were limited (Vandermeulen *et al.* 2017), it was interesting to see that Zone 6 was dominated by a rugose or textured bottom (many blue colored dots in the GIS) consistent with the coarse gravel or boulders seen in that area.

Towfish data were also used to ground truth VH canopy analyses. Details are provided in Vandermeulen *et al.* (2017) and the summary results for all depth contours are seen in Table 8. A summary of canopy type classification by zone and depth is provided in Table 9. These results are consistent with the bottom type classification summarized in Table 7. For example, those zones and depths with greater than 80% of canopy in bin height <0.2 m (essentially no macrophyte cover) in Table 9 are also the zones and depths with a 'blue to red' ratio of <1 in Table 7. In other words, areas with little or no macrophyte cover are also dominated by softer sediments or relatively featureless bottoms with little relief. Conversely, those areas with over 50% of canopy in bin height >0.2 m (areas with a substantial amount of macrophyte cover) in Table 9 are also the zones and depths with a 'blue to red' ratio of >4 in Table 7. Areas with hard and textured bottoms had a greater macrophyte canopy.

Quadrat survey

The quadrat survey ran from July 10-14, 2010. Fig 12 provides the location of the various sampling stations. More detailed station descriptions are available in Vandermeulen *et al.* (2017). Station B – 2 was selected on the basis of echosounder information. The echogram at the 5 m contour in this area indicated large algae with lacunae,

Table 7 Summary VH bottom type classification by zone and depth (GIS points color coded clear, red and blue).

Zone	depth	clear	red	blue	total	% clear	% red	% blue	total %	Blue : red
1	5	966	522	2089	3577	27.00587	14.59323	58.40089	100	4.001916
2	5	1368	1755	1546	4669	29.29964	37.58835	33.11202	100	0.880912
3	5	780	1577	554	2911	26.79492	54.17382	19.03126	100	0.3513
4	5	2358	3016	3536	8910	26.46465	33.84961	39.68575	100	1.172414
5	5	1746	886	4280	6912	25.26042	12.81829	61.9213	100	4.8307
6	5	602	90	3291	3983	15.11424	2.259603	82.62616	100	36.56667
1	10	1681	853	451	2985	56.31491	28.57621	15.10888	100	0.528722
2	10	45	39	1	85	52.94118	45.88235	1.176471	100	0.025641
3	10	168	332	325	825	20.36364	40.24242	39.39394	100	0.978916
4	10	1007	1129	1338	3474	28.98676	32.49856	38.51468	100	1.18512
5	10	1803	320	3791	5914	30.48698	5.410889	64.10213	100	11.84688
6	10	477	30	2514	3021	15.78947	0.993049	83.21748	100	83.8
4	20	87	641	104	832	10.45673	77.04327	12.5	100	0.162246
5	20	210	428	670	1308	16.05505	32.72171	51.22324	100	1.565421
6	20	861	129	1406	2396	35.93489	5.383973	58.68114	100	10.89922

Table 8 VH canopy height bin classifications in GIS.

Depth (m)	Bin category	Bin limits (m)	associated macrophytes
5	detection limit	< 0.2	no macrophytes
5	mid-height	0.2 – < 0.5	*Fucus, Saccharina, Zostera*
5	tallest	0.5 – 3	*Saccharina*
10	detection limit	< 0.2	no macrophytes
10	mid-height	0.2 – < 0.5	*Saccharina*, *Agarum*[a]
10	tallest	0.5 – 1.6	*Saccharina*
20	detection limit	< 0.2	no macrophytes
20	mid-height	0.2 – < 0.5	*Agarum*
20	tallest	0.5 – 2.1	unknown[b]

[a] Sponge was found in this height bin at the T7 cross point.
[b] No algal data for this bin at cross points with towfish, most likely *Saccharina*.

most likely the crozier morph of *S. latissima* with an inflated stipe (Figs 13 & 14). Images of the shore stations are shown in Fig 15.

The shore stations were almost completely dominated by *Ascophyllum* and species of *Fucus,* particularly *F. vesiculosus* (Table 10). The only shore without accumulations of *Ascophyllum* was 8-S (Fig 15c). Sampling stations 10 – 5 – 2 and 10 – 5 – 3 were the only 5 m stations with *L. digitata*. These stations also comprised the most diverse and abundant algal flora of the 5 m stations (Table 10). The most cosmopolitan taxa at 5 m were *Ceramium, Phyllophora* and *S. latissima*. *Chondrus crispus* was found in moderate amounts at most of the 5 m stations. The only species of *Fucus* found at 5 m was *F. serratus* and its biomass rivaled that of the kelps, a pattern common for this taxon in the northern portions of Nova Scotia. As predicted by the echograms, station B – 2 had an extraordinarily high biomass of *S. latissima* at 14 $kg{\cdot}m^{-2}$ wet weight (Table 10). The thalli were very long (many over 2 m) with long inflated stipes and a crozier morph.

Table 11 provides biomass data for the 10 and 20 m stations. The 10 m stations contained a fairly diverse flora, although at biomass levels lower than that found at 5 m. *Saccharina latissima* was found at all 10 m stations but not at the 20 m depth contour. The two 20 m sampling stations displayed a sparse but distinctive algal flora. *Agarum clathratum* was predominant, while *Odonthalia dentata* and *Ptilota serrata* were only found at this depth and nowhere else.

Overall, the video collected near the sampling stations were quite consistent with the biomass data provided in Tables 10 and 11.

Table 9 Final VH canopy type classification by zone and depth.

Zone	Depth	<0.2m	≥0.2 and <0.5m	≥0.5m	Total points	Tallest thallus (m)	% <0.2m	% ≥0.2 and <0.5m	% ≥0.5m
1	5	1377	1722	508	3607	1.46	38	48	14
2	5	4034	548	88	4670	1.11	86	12	2
3	5	2434	433	45	2912	0.85	83	15	2
4	5	5158	2966	787	8911	1.87	57	33	9
5	5	3239	3356	317	6912	1.44	46	49	5
6	5	527	2201	1255	3983	2.54	13	55	32
1	10	2602	370	12	2984	0.81	87	12	0.4
2	10	82	4	0	86	0.26	95	5	0
3	10	733	88	4	825	1.24	89	11	0.5
4	10	2222	1105	146	3473	1.58	64	32	4
5	10	2706	2999	210	5915	1.24	46	51	4
6	10	600	1596	825	3021	1.57	20	53	27
4	20	704	126	2	832	0.7	85	15	0.2
5	20	851	413	44	1308	2.05	65	32	3
6	20	1067	1166	163	2396	1.63	45	49	7

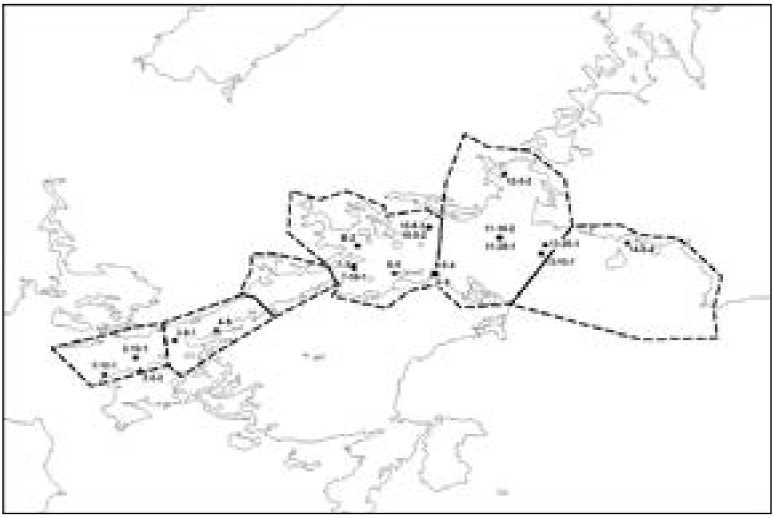

Fig 12 Sampling stations. The coding is transect number-depth-sample number.

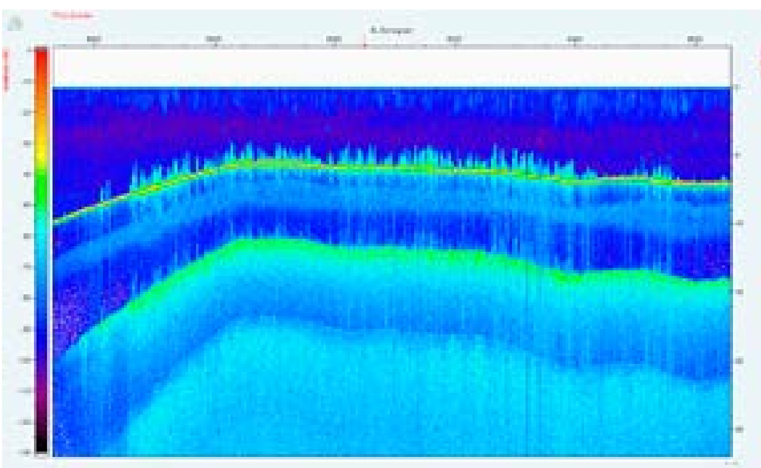

Fig 13 Echogram indicating large thalli of *S. latissima* with crozier morph at station B-2. The range scale on the right indicates that many of these thalli are close to 2m tall.

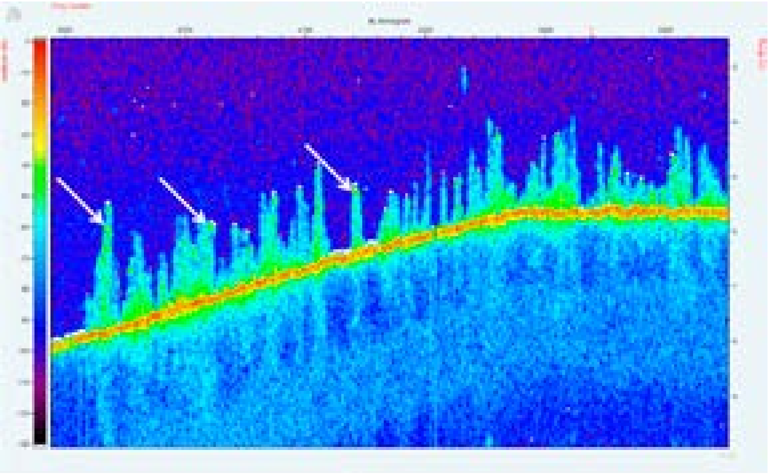

Fig 14 **Detail of echogram in Fig. 13. The more acoustically reflective areas near the top of many of the macrophyte echogram images (arrows) are consistent with the air filled stipe apex typical of the crozier morph of *S. latissima*. The large thallus takes the form of an inverted 'V' where the stipe floats upright from its holdfast and the fronds then hang downwards from the stipe apex.**

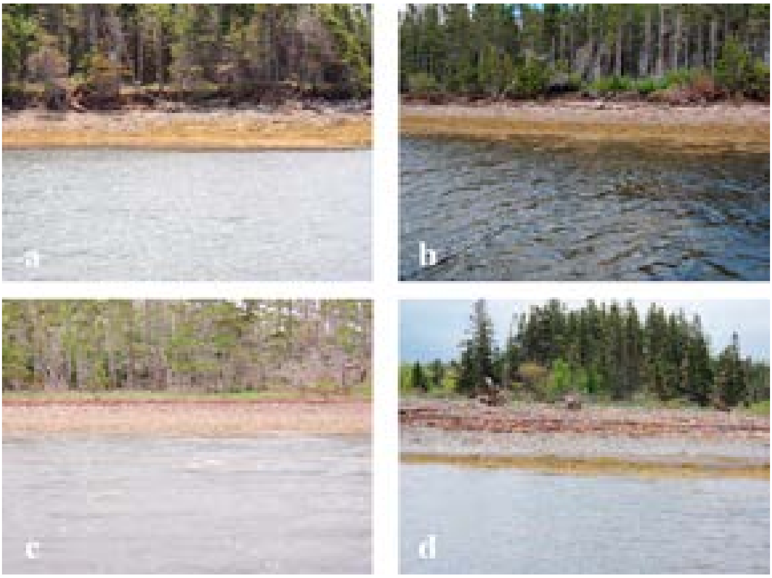

Fig 15 **Shore stations. a) 4-S (June 10, 2010). b) 7-S (June 9, 2010). c) 8-S (June 9, 2010). d) 9-S (June 9, 2010).**

Table 10 Biomass data (wet weight g·m^{-2}) for shore and 5 m sampling stations.

Taxon	Sampling Station ID#											
	4-S	7-S	8-S	9-S	2-5-2	3-5-1	B-2	9-5-4	10-5-2	10-5-3	12-5-2	14-5-4
Ahnfeltia										68		
A. nodosum	2200	14000		1900								
B. hamifera									200			
C. cristata									7.6	11		
Ceramium spp.[a]					31	26		23	390	2.7	6.4	43
C. crispus					44			56	11		130	87
Chordaria sp.								5.3				
Corallina sp.								73	9.3		95	
C. purpureum						5.8	25		21			80
Desmarestia spp.[b]			40							21		59
Dictyosiphon sp.					2.2							
D. integra										100		
Ectocarpus sp.					38							
F. distichus				200								
F. serratus	4200		360	200				3100		160	1800	2300
F. vesiculosus	670	3000	1600	4300								
F. lumbricalis					460	86		2.7	73	62	500	
L. digitata									2200	900		
P. palmata							27		270	6.7		5.3
P. rubens						20			22			
Phyllophora sp.					37	140	76	29	1100	410	100	92
Polysiphonia spp.[c]					42	14	160	630			110	4.0

Table 10 ***Cont'd***

Taxon	Sampling Station ID#											
	4-S	7-S	8-S	9-S	2-5-2	3-5-1	B-2	9-5-4	10-5-2	10-5-3	12-5-2	14-5-4
Rhodomela sp.[d]								5.3	6.3	28		29
S. latissima[e]					2300	6700	14000	2.7	73	1200	500	80
Sphacelaria sp.					5.6							

[a] Most commonly *C. virgatum*, occasionally tangled in with small amounts of *Polysiphonia* spp., *Callithamnion* sp. or *B. hamifera*.
[b] An almost equal mix of *D. aculeata* and *D. viridis*, plus samples not identifiable to species.
[c] An almost equal mix of *P. fucoides* and *N. harveyi*, plus a few samples not identifiable to species.
[d] Most samples not identifiable to species, but a couple seen as *R. confervoides*
[e] An almost equal mix of the short stipe morph with frilly blade and the long stipe morph. B-2 with large long stipe plants with crozier morph and hyper-inflated stipe. Many of the plants under this taxon may actually be *S. groenlandica* (Saunders pers. comm.).

Table 11 Biomass data (wet weight g·m-2) for 10 and 20 m sampling stations.

Taxon	Sampling Station ID#						
	1-10-1	**2-10-1**	**7-10-1**	**11-10-2**	**13-10-1**	**11-20-1**	**13-20-1**
A. clathratum						3500	89
Antithamnionella sp.				69			
C. cristata	2.4	5.0					
Ceramium spp.	39	6.7			17		
C. crispus	160			4.0			
Chordaria sp.	16						
Corallina sp.					130		
C. purpureum		4.0	6.7	190			
Desmarestia spp.				93	1600	110	
D. integra						9.3	
Ectocarpus sp.		23					
F. vesiculosus					61		
F. lumbricalis	180	100					
Gracilaria sp.				130			
O. dentata						11	4.0
P. palmata	11	6.7	11	12			
P. rubens						36	12
Phyllophora sp.	96	68	4.0			15	5.3
Polysiphonia spp.	54	190	60	530			74
P. serrata						8.0	11
Rhodomela sp.	5.7			16	40		
S. latissima	4100	3400	950	4400	2700		

Dominant algal taxa in the video tended to dominate biomass in the destructive quadrat samples.

DISCUSSION

Algal communities in the survey area

The abundance and diversity of algae observed in the study area was strongly related to the depth, diversity and abundance of bottom types in each zone. Zones 1 – 3 were relatively shallow and sheltered and were dominated by soft mud / silt (towfish data, Table 4). Towfish data also indicated over 80% of the bottom in these zones had no consistent macrophyte cover (Table 5). The echosounder data (Table 7) are consistent with the towfish data in this regard. The echosounder data were stratified by depth and indicated that of the three zones, only Zone 1 had moderate amounts of hard substrata and these only occurred in relative abundance at the 5 m depth contour. Zone 1 at 5 m depth was also the only location in these three zones with a relative abundance of taller canopy (Table 9), indicating kelps. Zone 4 was similar to the first three zones in terms of its shallow depths but it had slightly more hard substrate (Table 4). All four of these relatively shallow protected zones had limited algal or seagrass cover, usually less than 10% each of *Fucus*, *Saccharina* or *Zostera* dominated cover in the towfish transects (Table 5). Zone 4 also had small amounts of *Agarum* and *Desmarestia* (Table 5).

Zone 5 was a transitional area, deeper and with a greater variety of bottom types relative to the first four zones (towfish data, Table 4). Zone 5 also had the most even proportions of all canopy types and was the only zone not missing any canopy types (Table 5). This zone had the highest proportion of *Saccharina* dominated canopy at 30% (towfish data, Table 5). The echosounder data indicated that Zone 5 was also dominated by hard substrata at 5 m and 10 m depth (Table 7). Zone 5 also consistently had a detectable algal canopy of over 50% of classified VH data points at 5 and 10 m (Table 9). Of the first five zones, only Zone 1 at 5 m depth had similar algal cover (Table 9).

Zone 6 was the deepest and most exposed of all zones, with no soft bottoms recorded by the towfish (Table 4). Consistent with the greater depths of Zone 6, there was a considerable amount of completely or partially bare bottom and the dominant alga was *Agarum* (towfish data, Table 5). The echosounder data confirmed the very high proportion of hard bottom at all depths in Zone 6 (Table 7). Zone 6 had the highest proportion of detectable canopy in the VH analysis, with 80% or more of data points at 5 and 10 m indicating algal cover and over 50% algal cover even at 20 m (Table 9). A relatively high proportion of these data points at 5 and 10 m were for a canopy height of ≥ 0.5 m, indicating kelps.

Previous algal surveys in the study area

The study area was impacted by the "Arrow" Bunker C fuel oil spill of February 4, 1970 (Levy 1972). A survey of algae was made in the area approximately one month after the event, but no major effects were observed at the time (Craigie and McLachlan 1970). The observations were qualitative and limited but do match the species and distributions that we found. Thomas (1978) demonstrated that *A. nodosum*, *C. crispus* and *F. vesiculosus* could have significantly lower biomass at oiled locations in the area, at least over the short term. After approximately three years, much of the oiled shoreline had cleared naturally, but the upper intertidal zone of Rabbit Island was still covered in a stiff oil and sediment mixture six years later with spotty oiling still evident in portions of Lennox Passage (Keizer *et al*. 1978). In some sites, relatively unweathered oil deposits persisted even twenty years later (Vandermeulen and Singh 1994). Although we were not specifically looking for remnants of the oil spill in our survey, nothing obvious or untoward was observed.

Moore *et al*. (1986) ran several SCUBA transects within our survey area. One was located just to the west of T1 at the west end of Rabbit Island. They recorded *Fucus* in the shallows, with a mix of *Saccharina* and *Chondrus* on boulders to a depth of approximately 10 m, and *Agarum* at 10 to 12 m with a softer bottom at 12 to 15 m. Their transect #36 in St. Peters Bay was located just to the north of T11. Here they found *Fucus* in the shallows again, with *Fucus*, *Saccharina* and *Laminaria* mixed on cobble and gravel to a depth of approximately 10 m. From 10 to 15 m, scattered boulders on gravel and mud began to predominate along with some filamentous algae. These observations are consistent with our survey, and indicate that the structure and zonation of the algal community had changed little in those two areas since 1984/85 – a span of 25 years. However, one of the Moore *et al*. (1986) transects, #37, (just east of T14) appears to be anomalous to our findings. They discovered *Fucus*, *Saccharina* and *Laminaria* on boulders in the shallows, and *Saccharina*, *Laminaria* and filamentous algae on boulders in gravel and sand at 8 m. In our survey, T14 was dominated by 70% bare or 100% bare bottom classes down to 10 m depth. This may have been due to the predominantly sandy bottom that we found below 5 m depth on T14, with perhaps a recent grazing or storm event removing algal cover in the shallows. T14 is situated in a very exposed small bay.

Novaczek and McLachlan (1989) provided a comprehensive assessment of different shore zones in Nova Scotia and associated algal floras. Our survey area falls within their Eastern Atlantic Sector designation and their detailed taxonomic list for this sector includes the more limited subset of genera which we observed. One of their sampling stations was located at the eastern end of Isle Madame in Rocky Bay, just outside of our survey area. The vertical distribution of algal taxa that they found at that station is consistent with our own general observations for the survey area.

The value of nested acoustic methods for assessing algal populations

One of the fundamental limitations of vessel based benthic habitat survey methods is equipment operating depths. Our vessel and hardware (both towfish and echosounder) can operate in < 1 m of water. This is very shallow for a sidescan, but consistent with other macrophyte based echosounder surveys (e.g. Duarte 1987, Leisti *et al.* 2006, Istvánovics *et al.* 2008, Herbst *et al.* 2013). Our depth maximum was 30 m, due to the pressure rating of the sidescan case. This operating range, essentially surface to 30 m, is adequate to capture algal populations in their normal depth ranges in Atlantic Canada.

There is a more specific limitation on the ability of an echosounder to detect a macrophyte canopy. After several decades of research on this topic, the general consensus is that narrow beam (≤ 6°) transducers running at ≥ 200 kHz appear to work best (e.g. Thomas *et al.* 1990) and most macrophyte studies now utilize transducers with similar specifications (Marbà *et al.* 2002, Sabol *et al.* 2002, Tegowski *et al.* 2003, Leisti *et al.* 2006, Winfield *et al.* 2007, Istvánovics *et al.* 2008, Chamberlain *et al.* 2009, Sabol *et al.* 2009, Valley *et al.* 2010, Stevens and Lacy 2012, Herbst *et al.* 2013). Our macrophyte transducer ran at 430 kHz with a 6° cone angle.

The detection limit, the point of rare false positive canopy identification by echosounder software, was 20 cm in our survey. A detection limit of approximately 10 – 20 cm is common in other macrophyte studies (Duarte 1987, Sabol *et al*. 2002, Chamberlain *et al*. 2009, Sabol *et al*. 2009, Abukawa *et al*. 2013).

Detection limits aside, it is still possible for echosounder software to incorrectly classify algal habitat as something else. Anderson *et al*. (2002) used an echosounder running QTC VIEW software to discern macroalgae on rock in the coastal waters of Newfoundland. There were issues with false positive QTC classifications of rock / macroalgae at depths >50 m, where the macrophytes were known not to occur. Post processing involving binning the results by depth and relief improved the accuracy of the classifications. Jordan *et al*. (2005) also binned echosounder data by depth strata from the surface to approximately 45 m to aid their macrophyte classifications. We tried to avoid misclassifications via our novel nested sampling technique, carefully ground truthing our data at each sampling scale and depth.

The towfish video with approximately 1 m width of view was used to ground-truth the sidescan imagery which operated at the next higher observational scale, the 30 m swath width. The towfish classifications of canopy and bottom types were then used to ground truth the highest survey scale, the echosounder data. To our knowledge, the only other survey to employ video, sidescan and echosounder to detect macrophytes was Hewitt *et al*. (2004), although with a different survey design and without transponder positioning. They used sidescan sonar to completely survey the relatively soft bottom of several 1 km^2 target areas at 10 – 20 m depth in Kawau Bay, New Zealand, and then ran discrete echosounder and towed video camera transects through a portion of each area. The echosounder data were analysed with QTC VIEW software. Seaweeds were not the major focus of their study, although they did record kelp and coralline algae in their video classifications with no further taxonomic specifications.

Our video and acoustic methods did provide algal information of interest for further investigation. It was possible to identify areas with bottom types conducive to the presence of algae, and to locate algal canopies within these areas. This was proven conclusively at sample site B-2, where echosounder imagery suggested very large thalli of *S. latissima* and subsequent destructive sampling at the site confirmed the presence of these thalli and their high biomass (14 $kg \cdot m^{-2}$ wet weight, Table 10).

The three field trips comprised a total of 12 days on the water, handled by a crew of three on one small vessel. The surface area covered by the survey was approximately 140 km^2 – about 12 km^2 per day. The survey was very cost effective in covering such a large area. However, the sampling 'grid', comprised of widely spaced towfish transects subsequently crossed by echosounder paths at 5, 10 and 20 m, was quite coarse. Ultimately, this led to a relatively high proportion of unclassified VH data points in the GIS (often > 20% and sometimes > 50%, Table 7) due to the relative paucity of echosounder ground truth crosses with the towfish transects. The addition of more towfish transects could have improved the accuracy of our spatial analysis, but with a greater field cost. The survey did not produce spatially detailed information; importantly, it did provide adequate information for focussing further exploration.

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SERENDIPITY IN THE SCIENCES – EXPLORING THE BOUNDARIES

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ABSTRACT

Serendipity in the sciences is an unexpected experience prompted by valuable interaction with ideas, information, objects, or phenomena. While serendipity is often associated with the "aha" and "eureka" moments that characterize well-known scientific discoveries such as the structure of DNA, serendipity may be more accurately described as a factor across the various stages of the scientific process. For example, serendipity in the sciences includes those unexpected encounters with prior research findings that are fostered by informal knowledge sharing within and among scientific communities. Serendipity's contribution to science is increasingly noted by scientists in formal scientific reports, by funding agencies which recognize the need to make room and provide support for serendipity in science, and is often credited with the development of fruitful scientific careers. This paper describes the process of serendipity—the pattern of the phenomenon—that will be familiar to many who have experienced it and noteworthy for those whose have not. Through examples of serendipity in the sciences, different perspectives on its role are explored and lessons drawn.

INTRODUCTION

The history of discovery is full of such arrivals at unexpected destinations, and arrivals at the right destination by the wrong boat.

~Arthur Koestler, 1964, p. 145

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Serendipity, a combination of "chance, sagacity and a valued outcome" (Copeland 2015, p. 17), is an integral part of the scientific process of discovery. In a scientometric study of 205 *Citation Classics*, commentaries by the authors of highly cited scientific papers, Campanario (1996) found 17 (8.3 per cent) of the commentaries reported chance or luck was involved in the research process, though just one to two percent of the citations actually use the term "serendipity" (McBirnie & Urquhart 2011). Campanario classified the appearance of serendipity in these commentaries, based on Van Andel's (1994) conceptualization of serendipity and reflective of journalist Arthur Koestler's (1964) musings on discovery and arrivals, quoted above:

1. The goal of a research project is reached accidentally;
2. In the course of an investigation, something is discovered that does not have to do with the original research (Campanario, 1996, p. 10).

The distinction between two "types" of serendipity is arbitrary, divided only by the nature of its perceived unexpectedness; regardless of whether a case falls roughly into the first or second category, a serendipitous experience must contain an element of accident, chance, or luck. For example, it may be that the intended research goal is reached by chance, in an unexpected or unplanned manner or, rather than reaching the intended goal, something else entirely is accomplished and ascribed to luck. The sagacity and valued outcome of serendipity that Copeland (2015) refers to in her definition is assumed in both types of serendipity. Luck on its own is never enough, as "chance favors only the prepared mind" (Louis Pasteur, as quoted in Liestman 1992, p. 530). Moreover, other factors, including characteristics of the environment, are key to serendipitous experiences (McCay-Peet, Toms, & Kelloway 2015).

Much of what is associated with serendipity in the sciences is closely coupled with discoveries that have global implications. Simonton (2004) lists a number of "episodes of serendipity" in science and technology dating from 1492 to 1948, including Fleming's discovery of penicillin, Röntgen's discovery of X Rays, and de Maestral's invention of Velcro. Gaugh (2010), in a beautifully illustrated book, describes such episodes up to 2005, when the Spirit Rover found evidence of liquid water on Mars, a monumental discovery for humankind. However, as Copeland (2015) notes in her exploration of serendipity in clinical research, “While serendipity is commonly associated with discoveries of greater-than-average value, this is not a necessary element of serendipity” (p. 5). Moreover, there are many examples of serendipity in science that are not about the “arrival” *per se* (i.e., the scientific discovery). In many cases, the serendipitous experiences speak to the scientific process, the incremental and unexpected steps taken that help scientists build knowledge and lead them in new directions in their research and profession. While “aha” or “eureka” moments are typically associated with the “discoveries of greater-than-average” in the sciences (e.g., Watson and Crick’s discovery of the structure of DNA [Watson & Crick 1953, Watson 1968]), many more serendipitous experiences have a wide variety of positive implications, though lack the same level of prestige.

In this paper, we first introduce the phenomenon of serendipity, its origin, definition, and evolving standing in the sciences. We describe the process of serendipity as it has been modelled as an information-centric phenomenon, reliant on triggers or cues (verbal, visual, or textual) that convey information which spark the experience. We in turn explain how this model of the serendipitous experience extends to the sciences. We then take a look at serendipity from a variety of perspectives relating to two of its less discussed potential triggers, namely verbal and textual triggers, as well as the notion of career serendipity as it relates to the professional lives of scientists. Throughout, we provide examples of serendipitous experiences, drawing out potential lessons to be learned by scientists in all fields and those who support their endeavors.

BACKGROUND

Horace Walpole, an English man of letters, coined the term *serendipity* in 1754 when he referenced a Persian fairy tale, *The Three Princes of Serendip*, in a letter to his friend, Horace Mann. Walpole explained, “as their Highnesses travelled, they were always making discoveries, by accidents and sagacity, of things which they were not in quest of” (Walpole 1754, as quoted in Merton and Barber 2004, p. 2). Because of its association with seeking, finding, and discovery, the term serendipity was particularly well suited to be picked up by both collectors and scientists when an edited volume of Walpole’s letters, including the one referenced above, was first published in

1833 (Merton & Barber 2004). However, while the use of the term serendipity became popular among bibliophiles and antiquarians in the Western World in the Victoria era, it was much slower to catch on among practising scientists. Though the Victorians were well aware of the role of accidents in scientific research and discovery, it was not until the 1940s or 1950s that scientists began to use the term serendipity (Merton & Barber 2004). Merton (1948), a sociologist, noted serendipity's relation to Charles Saunders Peirce's concept of abduction in science–the construction of creative explanations for observations or the notice of a "surprising fact" that leads to the development of a hypothesis. The abductive experience has been described as if being "jerked from our perceptual and conceptual slumber with a surprise" (Merrell 2005, p. 93).

One of the impediments to the term serendipity's adoption by the scientific community has been its negative connotation, attributable to its association with luck, accident, and error (Díaz de Chumaceiro 1997). In the nineteenth century, the Reverend William Whewell, an historian of science, demonstrated this reservation when he wrote:

> *No scientific discovery* can, with any justice, be considered *due to accident*….The common love of the marvelous and the vulgar desire to bring down the greatest achievements of genius to our own level, may lead men to ascribe such results to any casual circumstances which accompany them; but no one who fairly considers the real nature of great discoveries, and the intellectual processes which they involve, can seriously hold the opinion of there being the effect of accident….*Such accidents never happen to common men* (Whewell 1847, as quoted in Merton and Barber 2004, pp. 43-44).

Whewell could not reconcile serendipity's association with science because he equated scientific discovery with genius and serendipity with accident. The latter, Whewell maintained, diminishes the intellectual process involved in scientific discovery. An anonymous critic of Whewell at the time, however, argued that accidents have indisputably sparked scientific discovery (e.g., polarization by Huygen [Simonton 2004]), but while anyone may be able to make an observation, only those with "the most distinguished talents" (p. 43) could follow it through to make an advance in science (Merton & Barber 2004). These talents may be what Walpole had in mind when he first paired *accident* with *sagacity* in his description of serendipity in his letter to Horace Mann in the earliest mention of "serendipity."

Barber and Fox (1958) provide an example of this pairing—accident and sagacity—in their case study of the work of two scientists. Barber and Fox noted that the two scientists observed the same phenomenon: the injection of rabbits with a plant protease caused rabbit's ears to flop. However, only one of the scientists, Lewis Thomas, recognized the significance of the unexplained phenomenon and followed through, ultimately making a scientific discovery relating to rheumatic fever; "serendipity gained" for Thomas, "serendipity lost" for the other scientist, Aaron Kellner. Barber and Fox first learned of the serendipitous circumstances around the discovery relating to the floppy-eared rabbits in an article in the *Times*. No mention is made of serendipity in Thomas's (1956) report of the discovery in a prominent peer-reviewed journal although he does hint at it: "*For reasons not relevant to the present discussion* rabbits were injected intravenously with a solution of crude papain" (p. 245, emphasis added). Though history suggests a "scarce appreciation" of the role of serendipity in science (Campanario 1996), a review of recent biomedical research indicates that the tide may be turning; scientists commonly report serendipitous experiences in relation to their research (Allen, Erdelez, & Marinov 2013). Rather than simply noted by those with established careers and sound reputations in the scientific community (Díaz de Chumaceiro 1997), scientists now may be more comfortable attributing aspects of their research success to serendipity.

Despite the reluctance at times to attribute some scientific discoveries, at least in part, to serendipity, the phenomenon can undeniably have huge economic, medical, social, and political implications. Unsurprisingly, the motivation among scientists, institutions, and funding agencies to tip the scales toward "serendipity gained" is significant and how this can be achieved is both a topic of discussion in the media and the science community and, increasingly, a focus of research. The following section examines serendipity as a process influenced by a variety of factors. Individual differences, environment, work culture, research funding, technology, and other factors all play a potentially important role and, in many ways, provide a road map for facilitating serendipity in the sciences.

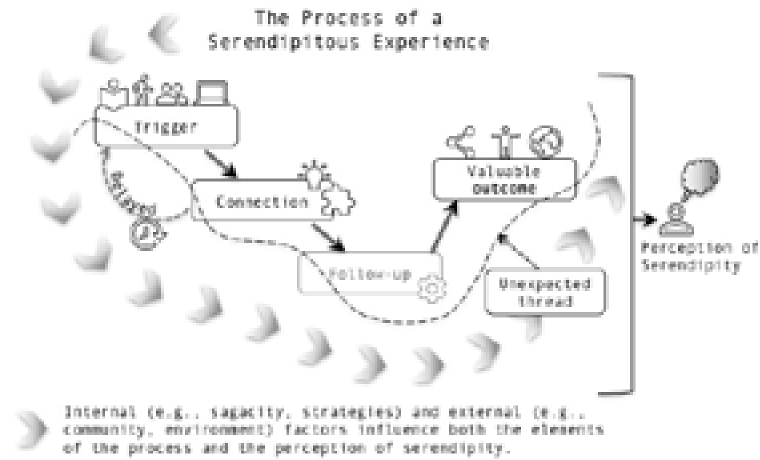

Fig 1 The Process of a Serendipitous Experience (adapted from McCay-Peet & Toms, 2015).

THE PROCESS OF A SERENDIPITOUS EXPERIENCE

McBirnie and Urquhart (2011) wrote: “Although sometimes described as a sudden moment of recognition, the clichéd flash of inspiration, serendipity is, upon closer inspection, both longitudinal and cumulative, the result of multiple events occurring over time” (n.p.). Due to serendipity’s information-centric quality and an increasing interest in the phenomenon, a number of models of the process of serendipity have been developed through information science research. Fig 1 illustrates the process of a serendipitous experience (adapted from McCay-Peet & Toms 2015) based on a study of a range of knowledge workers’ (e.g., journalist, historian, molecular biologist) experiences of serendipity and prior research and models of serendipity and related constructs (e.g., Cunha 2005, Erdelez 2005, Makri & Blandford 2012, McCay-Peet & Toms 2015, Rubin, Burkell, & Quan-Haase 2011, Sun, Sharples, & Makri 2011).

The model illustrates a serendipitous experience largely starting with a *trigger*. In a scientific context, a trigger, a verbal, visual, or textual cue, may be noticed, for example, while reading the literature, having a conversation with colleagues, conducting an experiment, while outside observing nature, or running a web search. A *connection* may be made immediately, or may be delayed, between the trigger and one's knowledge and experience. For example, in an interview with a molecular biologist who described a serendipitous experience, the biologist noted making a connection between her knowledge of insects which contain antifreeze proteins and the insects she saw x-ray in front of her, hopping in the snow, while she was out skiing during her leisure time (McCay-Peet & Toms 2015). Similarly, there was the connection made by Watson and Crick when they saw the x-ray crystallographic results of a sample of DNA in Rosalind Franklin's laboratory and deduced the alpha-helix nature of DNA, solving its structure and starting a revolution in the fields of biology and genetics (Watson 1968). *Follow-up* involves the work needed to make the most of the trigger-connection, to bring the serendipitous experience to fruition, to achieve that *valuable outcome* which may be felt at personal, organizational or community, and global levels. For example, Thomas followed up with experiments relating to the floppy eared rabbits, while Kellner did not (Barber & Fox 1958); the DNA example speaks for itself. The valuable outcome may be new and fruitful connections to scientists studying a similar phenomenon, a new career direction, or a scientific discovery (e.g., Thomas's discovery relating to rheumatic fever [Barber & Fox 1958]), or an important new area of research. An *unexpected thread* runs through one or more elements of this process with, for example, a surprising connection or unforeseen valuable outcome. The process of a serendipitous experience may be influenced by the interaction of both internal (e.g., sagacity, personality, personal strategies) and external factors (e.g., interaction with colleagues, design of a physical or digital space), reflecting "the concept of duality at [serendipity's] core" (McBirnie & Urquhart 2011, n.p.), a duality that research is just beginning to examine by exploring internal and external influences (Björneborn 2008, McCay-Peet, Toms, & Kelloway 2015).

Many have noted the importance of internal factors with respect to serendipity, as shown in the preceding discussion of sagacity and the prepared mind. *Super-encounterers*, for example, are people who are convinced of the importance of information encountering, "a memorable experience of an unexpected discovery of useful or interesting information" (Erdelez 1999, p. 25) and they frequently encounter information in this manner. Simonton (2004) pointed out that some scientists appear luckier than others, suggesting that some are, perhaps, more adept at exploiting their chance encounters, i.e., illustrating the sagacity component of the serendipitous experience as well as the value of developing strategies to increase opportunities for serendipity. Copeland (2016), however, underlines the importance of "community-based serendipity" in contrast to individualistic serendipity; that is, the involvement of a community of scientists in a serendipitous experience (e.g., communication among colleagues; colleagues' participation in experiments and peer review; further research; or the application of a discovery).

Bell Labs is touted as the United States' "gold standard for innovation" not only because of what was invented in its research and development laboratory (e.g., transistor, silicon solar cell, cellular telephone system) but because it was specifically designed to support serendipity (Corneliussen 2013). Jon Gertner, a former Bell Labs executive, credited the innovativeness of the Lab to its architecture; the buildings were interconnected, encouraging employees from different departments to interact with one another (Corneliussen 2013). Designing buildings to support serendipitous encounters and a dynamic work culture is one way to spur innovation and discovery (e.g., IBM, Canadian Institute for Advanced Research), but others (e.g., Jackson 2012) also note the importance of financial support for basic, curiosity-driven research such as that conducted at Bell Labs. Furthermore, in relation to environmental factors, technology has also come to the fore in discussions around serendipity in the past couple of decades. A growing body of research now examines how to develop digital information environments, such as digital libraries and social media, that support the serendipitous process to facilitate unexpected encounters with information that otherwise may not have been found (e.g., McCay-Peet, Toms & Kelloway 2015).

EXPLORING THE BOUNDARIES OF SERENDIPITY

While a common process is discernable across many different examples of serendipity (McCay-Peet & Toms 2015), there is still potential for variety within that process and many perspectives on serendipity have been offered that are relevant to today's active scientific community. While three triggers of a serendipitous experience have been noted (verbal, textual, visual) (McCay-Peet & Toms 2015), experiences triggered by visual cues, namely observations of unexpected phenomena by scientists, (e.g., alpha-helix nature of DNA [Watson 1968]), appear to resonate in practice and in the literature (e.g., Gaughan 2010, Roberts 1989, Simonton 2004) more so than those more closely associated with encountering information in an article or talking with a colleague.

To draw attention to the two triggers or catalysts of serendipitous experiences that are less evident in current discussions of serendipity in the sciences, but clearly significant, we focus now on serendipitous experiences marked by:

1) verbal or, more accurately, *social* triggers (e.g., a scientist's discussion with a colleague); and
2) *textual* triggers (e.g., a scientist's interaction with a passage in a digital or paper-based source).

Finally, we discuss career serendipity, unexpected and valuable experiences that have a profound influence on the direction and output of the careers of scientists. The two triggers of serendipitous experiences that we explore (social and textual) and career serendipity are not mutually exclusive, and others surely exist. We focus on these to explore a range of experiences within the boundaries of serendipity in the sciences and to draw lessons from them.

SOCIAL

As noted earlier, while serendipity is often associated with the lone scientist's "eureka" moment, the serendipitous process may be fostered by a community rather than solely by an individual. Copeland (2015, 2016) underlines the importance of scientific communities, or interactive networks of scientists, in serendipity and argues that some communities are more likely to experience serendipity than others due to their features, namely:

> encouraging members to take advantage of unexpected opportunities; enabling members to give and receive support for their insights while engaging in epistemic cooperation; and making new and accepted knowledge readily available to all members of the community. Further, community values and norms determine which unexpected observations will be taken up into processes of discovery (Copeland 2015, p. 177).

While social interaction is not necessarily required for serendipity to occur, an analysis of 50 randomly selected narratives drawn from the Citation Classics Database indicate that *collaboration* and *exchange*, involving an interaction between a scientist and other people (e.g., a colleague) were common motifs or recurring themes in serendipity-related narratives (McBirnie & Urquhart 2011). Exchange, in fact, was the most common motif of the four identified (exchange, solo, collaboration, chain), further underlining the importance of the social aspect of serendipity, as the exchange motif involved interaction between the scientist (the narrator) and another person. The exchange motif underscores the point made by Copeland (2016): individual contributions relative to serendipitous experiences are vital (e.g., observation, recognition of value, follow-up) but the scientific community provides the conditions necessary to support these serendipitous experiences (e.g., exchange of knowledge).

Barber and Fox (1958), for example, note that in the case of floppy eared rabbits, "As so often happens in science, an unsolved puzzle was kept in mind [by Thomas] for eventual solution through informal exchanges between scientists, rather than through the formal medium of published communications" (p. 132). Pepys (2007) recounted an experience of serendipity in which he was waiting to be granted entry to a chemical company when he struck up a conversation with a fellow visitor whom he did not know, Dr. Don Renn. In conversation, Pepys shared a scientific observation that had recently baffled him. Renn, as it turned out, was just the person he needed to talk to. Renn was an expert on the polygalactan polysaccharide, a complex carbohydrate produced by seaweed, and was able to provide both the information and materials that led Pepys and his team to make a breakthrough and led to "the original suggestion that this could be a novel therapeutic approach to systemic and local forms of amyloidosis [a rare disease]" (p. 568).

It seems that, to foster serendipity, scientists may need to "put themselves out there," to be social. A medical doctor noted, in McCay-Peet and Toms' (2015) study of serendipity among knowledge workers:

> Potentially if things are really on the boil, and you are really in a dynamic environment with people who have lots of views and lots of ideas and things are happening and they have big social networks etc., etc., then things [. . .] do often happen (p. 1471).

The willingness to give and attend seminars, and to share ideas and unexpected observations through informal exchanges with colleagues and people both inside and outside your field is a compellingly important condition for facilitating serendipity, generating new ideas and perspectives essential for novel approaches and discoveries in science. One of us (Wells) experienced this on numerous occasions while working as a young marine scientist at a large oceanographic institute in Halifax (Wells 2016).

Another example of the social side of serendipity comes from a description of scientific interactions at the famous Marine Biological Laboratory (MBL) of Woods Hole, Massachusetts. As described by Lewis Thomas in his book, *The Lives of a Cell* (Thomas 1974), the highly influential yet autonomous MBL was known for attracting "successive generations of people in bunches" (p. 69). Thomas describes one of the "governing mechanisms" of the MBL—interactions among the scientists, for example, at the Friday evening lecture in which international guest speakers presented and discussed their findings and at the local beach where biologists and even the occasional physicist would talk and draw diagrams in the sand. From such spontaneous sharing of information, many new ideas and approaches would often emerge in a very unpredictable and serendipitous manner: "Not many institutions can produce this spontaneous music at will, summer after summer, year after year" (Thomas 1974, p. 74). The publication record of scientists working at the MBL speaks for itself, especially through its main journal, The *Biological Bulletin*.

TEXTUAL

Although there are opportunities for exchange among scientists within their communities, it may be the scientist interacting with digital or paper-based sources of information that triggers serendipitous experiences. The *solo* and *chain* motifs identified by McBirnie and Urquhart (2011) through their analysis of the serendipity-related narratives in the Citation Classics Database highlight interactions between scientists and information or objects rather than among scientists as in the exchange and collaboration motifs. While finding something unexpected in the physical "stacks" in a traditional library is still very tightly coupled with humanities scholars (see for example, Martin & Quan-Haase 2013), stumbling upon digital information has become an important avenue of serendipity (Quan-Haase, Martin, & McCay-Peet 2015) and the same is true for scientists. As Workman *et al*. (2016) note, a walk among the library stacks or a search in PubMed may lead to encounters with information that address a prior though pressing information need. In a digital context, *serendipitous information retrieval* occurs when people are searching or browsing, "meandering from topic to topic while concurrently recognizing interesting and informative information en route" (Toms 2000, n.p.).

Due to very rapid advances in technology since the 1980s (e.g., personal computers, the web, social media, smartphones) and hyperlinking capabilities in general, digital environments provide a particularly fertile ground for *connections*, a vital part of the serendipitous process (see Fig 1) (McCay-Peet, Toms, & Kelloway 2015). Swanson (1986), an information scientist, first illustrated the value of what has become known as "linking" in the context of "literature-based discovery" when he found a connection between two independent bodies of literature on dietary fish oil and Raynaud's syndrome, the narrowing of arteries that supply blood to the skin. Swanson found, through a search of the Medline and Embase databases, that there was a logical connection between the two and thus posited that dietary fish oil could help treat Raynaud's syndrome (later supported by research). This has since spawned research on "undiscovered public knowledge" and the development of tools to support literature-based discovery and knowledge-based discovery in general. In this line, Workman *et al*. (2016), found that "serendipitous knowledge discovery" in online environments:

1) is an iterative process;
2) often involves reformulation;
3) is grounded in prior knowledge; and
4) is reliant on the way in which information is organized and presented.

Based on those principles, Workman *et al*. created a web-based tool called "Spark," designed to help scientists develop new hypotheses and discover connections within existing scientific information and knowledge. It remains to be seen, however, whether removing some of the chance by using such a tool has the potential to reduce the likelihood that any discoveries made through this approach would be perceived as serendipitous (McBirnie 2008, McCay-Peet & Toms 2015). McCay-Peet and Toms (2015) argue that in addition to being trigger-rich, highlighting triggers and enabling connections, an environment that supports serendipitous experiences must also be perceived to lead to the unexpected.

The technological challenge of support for serendipity, in the sciences and beyond, is the balance that needs to be struck between giving individuals content that matches their knowledge and experience, but also challenging them with content that perhaps may have the power to change their thinking from the norm. Perhaps this is particularly true for connections that are more difficult to make, connections that require a higher degree of intellectual capacity, knowledge, or experience on the part of the individual (McCay-Peet & Toms 2015). Famed novelist and philosopher Umberto Eco (1998) referred to people's knowledge and previous experience as our "background books." These background books are our "preconceived notions of the world, derived from our cultural tradition" (Eco 1998, p. 54) through which we interpret and explain what we encounter in the world. The interaction between our observations and our "background books" has an impact on the mental connections that we make. While our background books may help us to see beyond the information given (Bruner 1973), our background books may also prevent us from seeing, thinking about, or accepting something new.

The challenge with knowledge- and literature-based discovery is not only discovering what is there, but recognizing that not everything that is known is there to begin with. Many studies, especially ones with negative results, never make it to primary publication due to the difficulty of identifying possible "instructive failures" and the greater likelihood that successful research will be accepted for publication (Barber & Fox 1958, p. 131). Recall that Thomas kept the unsolved problem of the floppy eared rabbits in the back of his mind, ready for a possible solution to surface through informal communication with colleagues, not relying on formal scientific dissemination channels (Barber & Fox 1958). There is also a wealth of knowledge in the extensive grey literature (e.g., government technical reports), much of which until recently was not digitized and hence was difficult to access and explore comprehensively.

Because few failures or puzzling observations make it to publication, reducing the potential of text-based triggers of serendipitous experiences, talking with colleagues through informal exchanges is particularly important, as indicated in the preceding section of the social aspects of serendipity. Some also have pointed out the need to teach students the importance of sharing their observations, both informally and formally. Lenox (1985) stated that students of science are taught traditional scientific methods (e.g., ask questions, develop hypotheses, develop or adopt methods, collect data, test hypotheses) but omits "*how scientists arrive at the first step of the process*" (p. 282), which is posing important and testable questions. Lenox describes three methods by which scientists are drawn to particular problems:

1) the building-up method;
2) insight; and
3) chance or serendipitous discovery.

Lenox argues that, as serendipity is an important phenomenon in the sciences, undergraduate students should be informed about it so that they will be both open to chance observations and (possibly) recognize their potential significance. Lenox, for example, underlined the importance of *observing* over *seeing* and developing the habit of accurately recording both expected and unexpected observations. Moreover, he stressed the importance of teaching *students* to report the "actual process of discovery" (p. 284) to the scientific community, including incidents of chance that affects their work. Further, Nutefall and Ryder (2010) identify three strategies for preparing for serendipity that may benefit all students, science students among them: "the development of a rhetorical disposition towards sources, a sense of the rhetorical relationships among sources in a field, and strategies for accumulating background knowledge" (p. 232). As a result, scientists may be more apt to enable an opportunity for serendipitous discovery or insights with other scientists, by sharing personal observations more fully and make it more likely that they themselves will make connections between what they know and what they have found serendipitously through their readings and direct experiences. The example of the Marine Biological Laboratory, described earlier, should be kept in mind.

CAREER SERENDIPITY

Pepys (2007), Wells (2008) and more recently Estes (2016) have recounted how serendipitous experiences have shaped their careers, leading them to new areas of research, providing opportunities for career progression, and making important professional connections. As McCay-Peet and Toms (2015) note, in the case of career serendipity, the valuable outcomes associated with serendipitous experiences are largely personal in nature but can have a "cascading impact" on their organizations, fields of research, and beyond. Betsworth and Hansen (1996), in a study of 237 older adults associated with a university in the United States, found that 59 per cent of survey respondents believed their careers were influenced by serendipity. An analysis of reported incidents resulted in the development of 11 categories of serendipity-related career development events, including, for example: *professional or personal connections*; *unexpected advancement*; *right place/right time*; *encouragement of others*; *influence of previous work/volunteer experiences*; *obstacles in original career path*; and *unexpected exposure to interest area* (p. 95).

One of us, Wells (2008), as another example, described the impact of serendipity on his career, characterized by a combination of professional connections and encouragement from others. From an early tip about an available job; to being at sea and making unexpected observations of surface pollution, which piqued an interest in aquatic toxicology; to be working at a biological station that just happened to have an expert on the topic who was heading to a university and was recruiting graduate students; chance occurrences played a major role in the direction and early success of his career (Wells 2008). An important point, however, is that each unexpected opportunity requires a decision, involves a risk of failure, and seems open-ended at the time. But there is no doubt that the unexpected, the phenomenon of serendipity, plays a role in a person's career path if one is alert to opportunity and willing to cope with at least temporary uncertainty. Both characteristics (being opportunistic and confident) bode well for a person interested in conducting discovery science in a chosen field.

Exposure to a variety of chance events clearly can have a significant and positive impact on an individual's career (Bright, Pryor, & Harpham 2005). Because of the potentially numerous valuable outcomes that may arise in relation to career development, Bright *et al*. urge career counselors to encourage students to volunteer, join clubs, and generally increase the variety and extent of their interactions with others. Career serendipity is thus tightly coupled with the social aspect of the phenomenon of serendipity. However, this advice, which essentially encourages social behavior, could be equally valuable to those at various stages of a career. Career adaptability has become an important skill in an insecure work world, one which "waxes and wanes" regarding opportunities, and rewards those who face uncertainty with optimism and a desire to seize the moment when it appears, often unexpectedly. As Wells (2013) stated, "we cannot easily predict where and when the next major breakthrough [in science] will occur" (p. 208), and the same is true for associated careers.

CONCLUSION

The profound impact of some scientific discoveries aided by serendipity (e.g., penicillin, DNA, lasers, water on Mars) on society cannot be overstated, hence our general interest in the topic. This paper, however, explored the phenomenon of serendipity in the sciences, moving outside the traditional narrative of the serendipitous "discoveries of greater-than-average value" (Copeland, 2015, p. 5) to examine serendipity beyond this boundary, sharing examples which illustrate reliance on interactions with other people or the scientific literature and those that do not necessarily relate directly to discoveries at all (e.g., career serendipity). The importance of this phenomenon to both science and the progress of society in general has been recently highlighted by Nassim Nicholas Taleb (2010) in The Black Swan, which explores "the impact of the highly improbable" (the book's subtitle). That serendipity, as a process in discovery, is alive and well and highly influential is beyond doubt. Conditions and factors that contribute to the process of serendipitous experiences in the sciences include the exchange of information among established scientists, both formally and informally, and the education of early career scientists about serendipity. It is hoped that the latter group will be ready to fully exploit the phenomenon of serendipity in their research and careers, and expand our understanding of its boundaries and contributions to science.

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The Student Science Writing Competition of the Nova Scotian Institute of Science

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The Nova Scotian Institute of Science (NSIS) has sponsored the Student Science Writing Competition (SSWC) since 2003. Its objective is to encourage students to practice and improve their science writing skills, and to recognize high levels of writing achievement. The competition is open to any student registered at a university or college in Nova Scotia. Monetary awards are given to undergraduate and postgraduate students as an incentive to participate.

The SSWC has attracted increasing interest in recent years. The number of students expressing intent to enter and the number submitting manuscripts have approximately doubled since 2008-09.

The SSWC is an annual competition. In the Fall semester of each year, notices are sent to all deans and science departments in the province, asking faculty to encourage students to enter. At the same time, the competition is advertised on student-related social media. Students are directed to the NSIS website for further detailed information, and are asked to indicate their interest by the end of December. They are also requested to submit their manuscripts by a specified date in mid-February.

Students are advised that their papers should be directed at a general audience with an interest in science, and not at specialists in their particular field of study. The submissions are expected to conform to scientific research and writing standards. Papers generally fall into two categories – survey papers that describe a current aspect of science, or a description of some of the student's own original research. Students are expected to provide their insights and interpretations about the significance of the chosen topic.

A panel of judges reads and evaluates the submissions. Most judges are selected from the NSIS Council and represent a range of scientific disciplines. After considerable individual assessment and collective discussion, the judges select the undergraduate and

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postgraduate winners, and sometimes submissions that deserve Honorable Mentions. Awards are presented at the beginning of the NSIS monthly public lecture in April. Winners are invited to submit their papers for consideration as a publication in the Institute's journal, Proceedings of the Nova Scotian Institute of Science.

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ESTIMAGE: A MOBILE APPLICATION IN AGRICULTURE FOR IMAGE TO OBJECT COUNT ESTIMATION

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ABSTRACT

A major problem in the agricultural field is accurately estimating the yield of produce. Typically, farmers must wait to measure their crops after harvest using manual mechanical equipment. There is value in having better methods of yield estimation based on data that can be captured with inexpensive technology in the field, such as a smartphone. We develop a smartphone application for the Android platform with access to a cloud-based machine learning (ML) service that can estimate the amount of crop on a bush or tree from an image. The development of an image-to-object-count estimation system called Estimage is presented. The Estimage system consists of an Android client application for user interaction, a PHP server application for request handling, an Octave program for image normalization, and an open-source ML software package called ilastik that applies a predictive model to an image. The functionality of the mobile client application is tested and the system satisfies all of the functional requirements and most of the non-functional requirements. The system is tested on the images of coins on a table, logs stacked in a pile, and blueberries on the bush. We show that the system is capable of accurately estimating the count of objects in the images that have objects of the same (size, colour, and shape) as that used to train the model. The system is good at distinguishing object pixels from the image background pixels provided the background is consistent with that used to train the model.

Key Words/Definitions

Material Design: Material design is a popular interface design style that is recommended by Google [4]. It encourages good design with innovation and unified user experience across different platforms and device screen sizes.

Interface: In this thesis, interface is the user interface in an Android mobile application that is responsible for displaying contents to users.

Inflate: In Android application development, the action to create a user interface is called inflating an interface.

Desirable: A desirable requirement is an optional requirement that would be good for the system.

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Essential: An essential requirement must be satisfied by the system to provide key functions to users.

SQLite Database: The SQLite database is a popular light-weight open source database that is fully supported by the Android operating system. Users' data can be easily stored in and retrieved from the SQLite database without causing heavy burden on the memory or CPU of their hand-held device.

Image Record: Image record is an essential data structure in the Android application of the harvest-estimation system. It contains information about an image and its associated estimate. Instead of the original image, the image record keeps a thumbnail image version to reduce the memory requirement.

Estimate: An estimation on an image produces the estimate of the number of objects in the image and a density map image.

Density Map Image: The density map image is one of the results from the estimation on an image. It recognizes the density of the objects in an image by marking the non-object pixels black and the object pixels white.

INTRODUCTION

Industries are in need of high-tech methods to aid in their work flows so as to maintain efficient operation. In the agricultural field, farmers rely on manual methods and mechanical equipment to measure harvest, and this can only be done after the crop is picked. It would be beneficial to have a system that can estimate the crop yield prior to harvest so that, for example, farmers can better plan the use of human and material resources on the farm.

Machine learning (ML), a sub-area of artificial intelligence, focuses on the study and construction of algorithms that learn from and make predictions from data (Kohavi and Provost 1998). One method of machine learning that could help with harvest measurement is called object classification. However, object classification is suitable for identifying separate objects and less so for estimating the number of overlapping objects (Fiaschi *et al*. 2012). A better approach is to estimate the density of pixels associated with the object integrated across the image. A machine learning method known as a random regression forest can be used to do this integration. A random regression forest can provide an accurate result if the proper learning parameters are used and sufficient training examples of the object are provided. This paper illustrates the development of an image-to-object-count estimation system called Estimage, which includes an application for the Android platform that calls cloud-based machine learning methods. We will evaluate how well the application functions to provide object count estimates to users based on the accuracy of count on different test objects.

DEFINITION OF THE PROBLEM

In agriculture, farmers have a difficult time accurately estimating the yield of their produce prior to harvest. They are unable to make a good estimate of the crop yields on the tree or on the bush until they harvest and measure all the crops with equipment that needs manual operation.

We wish to develop a smartphone application with access to a cloud-based machine learning service that can estimate the amount of crop on a bush or tree, such as the number of pints of berries on a blueberry bush. With this application, farmers would be able to predict their harvest volume and to take actions in advance to increase profit, such as making better marketing plans or planning use of available material and human resources on the farm.

PROJECT OBJECTIVES

The objective of this project is to design and develop the Estimage software system to help farmers evaluate crop yields in advance, and to assure the practicability of machine learning on a real life problem in the agricultural sector. The objective is achieved in two steps. First, a smartphone application is designed and implemented to allow farmers to upload images of crop fields to the server for estimation. Second, predictive models are built using existing machine learning software on the server to estimate the crop yields pictured in the uploaded images.

PROJECT SCOPE

The project presented herein is restricted in several ways to make it practical for an undergraduate honours research project. The smartphone application is developed for the Android platform, which is an operating system for hand-held devices. The Android platform provides a convenient way for users to perform operations in the field and it has a larger user group than any other hand-held operating system, such as iOS or Windows Phone (McCracken 2013).

We have initially trained the Estimage system to estimate (1) the number of coins laying on a table and (2) the number of berries on a bush. Theoretically, the system can be used to estimate the count of any object in an image, such as fish, apples, cans, and hats.

The goal of this project is not to create the best machine learning method for developing the estimation. Instead, predictive models are trained using existing machine learning and image processing software. The focus is on the development and testing of the Android application that must capture, format, and request execution of the ML models on the server and then receive and display the predicted results on the mobile platform. On-going research is intended to build upon the preliminary ML methods that are used in this paper.

BACKGROUND

Android Version

It is important to decide which version of Android we want our Estimage system to support. Many versions of the Android operating system have been developed, such as 4.0 (Ice Cream Sandwich), 4.4 (KitKat), 5.0 (Lollipop), and 6.0 (Marshmallow). In the Estimage system, the Android application supports all Android versions above 4.0 Ice Cream Sandwich, which accounts for 90% of the total Android user population.

Server

In this project, the server side programs for estimating objects in an image are running on a popular operating system called Ubuntu Linux. A server application was written in PHP to communicate with the Android client application over HTTP. The server application is able to call an Octave program to invoke ilastik to run a machine learning predictive model on an image to generate an estimate of object count. The estimation results are saved in a MySQL database. The following subsections introduce these server-side techniques that are utilized in the Estimage system.

Server application

A server application is a program that runs on a server computing system that is capable of handling requests from clients. A server application can be written in different programming languages such as C++, Java, PHP, or Ruby on Rails. While most of these programming languages take weeks or months for developers to learn, PHP is very easy to learn and developers can create a functioning server application within several days. There are many mature PHP frameworks for development and the performance of a PHP server application is sufficient to handle requests for most business applications. PHP nicely supports communication over HTTP and MySQL database access by default, which is one of the most popular server-side databases. For the above reasons, PHP is used in the Estimage system to develop a HTTP server application.

Machine Learning

As early as the 1950s, computer scientists studying artificial intelligence have been interested in enabling computers to mimic a human's way of learning from examples (Russell and Norvig 2003). However, the field of machine learning was not valued until the 1980s, when methods of developing more complex non-linear models were developed (Langley 2011). Since then, machine learning has flourished and is now one of the most promising fields of artificial intelligence.

Machine learning applications tackle the problem of how to develop predictive models directly from training examples. For example, marketing models are developed based on historical sales data. One of the most popular applications of machine learning is for recommending suitable products and services to customers who are surfing the web; examples of this are provided by companies such as Amazon and Yahoo!

Random Regression Forest Algorithm

One category of algorithms defined in machine learning is called supervised learning, which trains an algorithm to learn to produce approximate outputs for specific inputs (Mohri *et al.* 2012). The "random regression forest algorithm" belongs to this category. A random regression forest is an ensemble learning method that works by building multiple decision trees at training time and outputting the mean prediction (regression) of the trees (Ho 1995). A decision tree is a predictive model which maps input variables related to an item to the estimate or prediction of the item's target value (Quinlan 1986). In the tree structure, leaves serve as class tags and branches show unions of features that bring on those class tags. In random regression forest, decision trees are built with random selection of features.

The number of trees in a random forest and the maximum depth of each single tree are two key factors that affect the smoothness of the prediction and performance in the algorithm. In other words, few and shallow trees can create a model that is under-fitted to the data, while many and deep trees may create a model that is over-fitted to the data (Fiaschi *et al*. 2012). In the Estimage system, machine learning predictive models are built with 10 decision trees and 50 maximum depth.

ilastik

ilastik is an open-source image analysis tool that generates machine learning predictive models based on training images and parameters (Sommer *et al*. 2011). Various workflows are provided to automate the processes of image classification, segmentation and analysis.

One of the provided workflows, called density counting, satisfies our need to count overlapped objects of similar appearance in images such as blueberries or coins (Fiaschi *et al*. 2012). The process of density counting is as follows: (1) The objects to be estimated (shown in red) and their surroundings to be ignored (shown in green) are manually labelled in a set of training images using a marking tool. (2) ilastik uses image processing techniques to transform the marked pixels of labelled objects into image features. (3) The random regression forest algorithm introduced in Section is applied to train a predictive model based on the image features. (4) The model is used to predict the fraction of object per pixel.

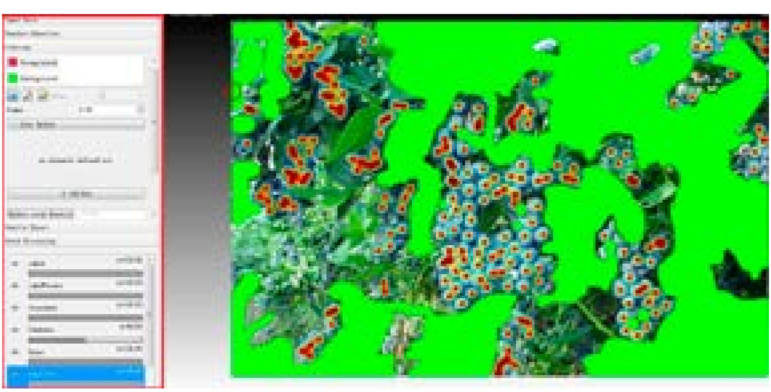


Fig 1 Using ilastik to train a machine learning model on an image.

(5) ilastik calculates the estimate of the number of objects in an image by adding all of the fractions of objects per pixel in the image.

Fig 1 depicts how a machine learning predictive model is trained using ilastik. The left hand side of Fig 1 is a functional menu detailed in Fig 2. The menu lists all the functions provided by the density counting workflow of ilastik. (1) Images can be imported to ilastik in the Input Data option. (2) The Feature Selection option provides features that the random regression forest algorithm can use for constructing predictive models. (3) The Counting option allows the user to mark selected pixels as being of the object class to count. The Update Total Density button starts running the random regression forest algorithm on an image to produce an estimate. (4) The Density Export and Batch Processing options are used for generating a density map image for each image to be estimated in a batch process. The density map image depicts the density of objects in an

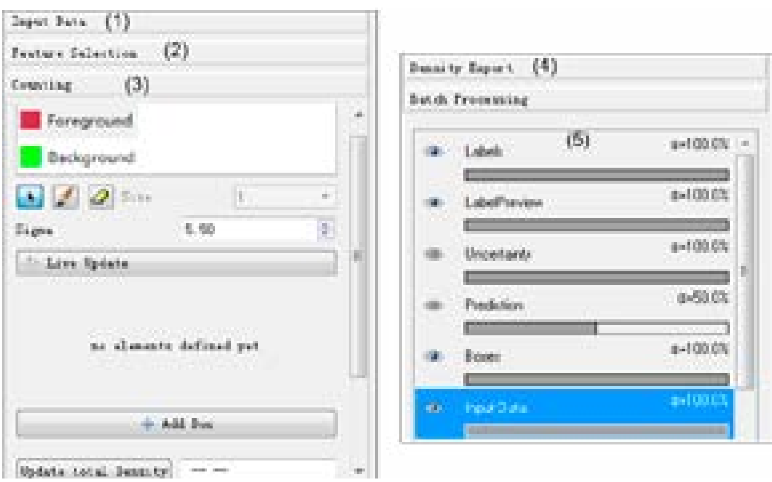


Fig 2 Object mark-up options and other menu options in ilastik.

image by marking the non-object pixels black and the object pixels white. (5) The visibility options below are used to show or hide the colour marks that were made before.

Using ilastik, we are able to train ML predictive models for different objects and store them on a server for access by a client application.

Octave

Octave is an open-source version of the popular MATLAB programmingenvironment. MATLAB was created to be a programming language to help people do numerical computations with computers on large sets of data (Eaton *et al*. 2015). It has become a common programming language for developing and executing machine learning algorithms.

In the Estimage system, an Octave program runs on the server and is responsible forreformattingtheselectedimageandcallingilastikto applyachosenMLpredictive model to estimate the number of objects in the image.

REQUIREMENT ANALYSIS

Refinement of Problem

The primary goal of this project is to create the Estimage system through which farmers are able to take a photo of a crop in the field and estimate its yield. The Estimage system has two components to be developed: an Android application and a server application. The Android application should provide an intuitive anduser-friendly user interface and allow farmers to easily upload images of crop in the field to the server for estimation. The server application should be able to estimate the cropyieldfromtheuploadedimagesusingmachine learning predictive models.

Context Diagram

This section presents how external actors (users) interact with the Estimage system. The following is a list of entities found within and external to the system described in the context diagram in Fig 3.

User: Users are the farmers in the field who can use the system to estimate their harvest. They interact with the Estimage client application found inside the Estimage system.

Estimage Client Application: As the core component in the system, the Estimage client application provides an interface for the Estimage system to communicate with the users. It helps users take a photo with a camera application or select an image with a gallery application. It is also responsible for posting requests to the Estimage server application and displaying returned results.

Estimage Server Application: The Estimage server application handles requests from the Estimage client application, and calls the

Octave program to invoke ilastik to run an estimation on an image. The Estimage server application then receives the estimation results from the Octave program and returns them back to the Estimage client application.

Octave Program: The Octave program is responsible for normalizing the images from the Estimage server application to proper format and calling ilastik to perform the estimation task on the normalized image. The estimation results from ilastik are returned to the Estimage server application.

ilastik: ilastik is an open-source machine learning software package that creates machine learning predictive models based on training images provided by the model developer. It is also responsible for running an estimation using a model from the model repository.

ModelDeveloper: Model developers are people who are responsible for preparing and selecting training images, developing ML predictive models using ilastik, and deploying the models in the model repository for use on the server.

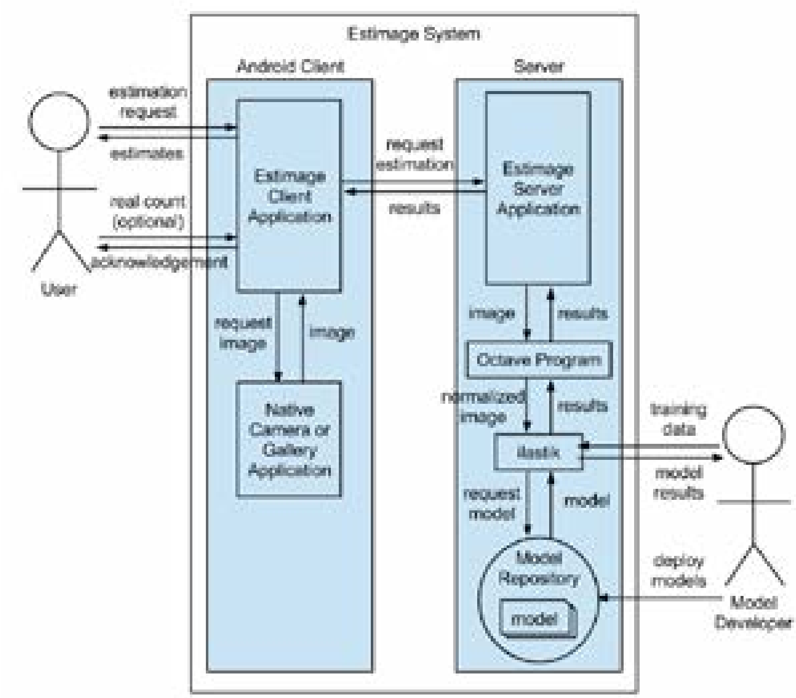


Fig 3 Context Diagram.

Model Repository: The model repository is a place to store the ML predictive models for different types of objects to be estimated. For the same object type, several models are also prepared for different sizes of objects in order to achieve the maximum accuracy. The model repository responds to requests from ilastik.

TESTING AND EVALUATION

This section focuses on the validation and verification of the Estimage client application and its server-side components. Although secondary to the mobile client application and cloud server development, the machine learning model performance of the system is evaluated in terms of the accuracy of the estimation functionality.

Non-functional Testing

Non-functional requirements were tested manually on a physical Nexus 4 Android smartphone and a Ubuntu server. The Nexus 4 Android smartphone has a Quadcore 1.5 GHz Krait CPU, a Adreno 320 GPU, 2 GB RAM, and 16 GB external storage. The Ubuntu server has a 2.40 GHz Intel@Xeon@Processor E5-2620 v3 and 8 GB RAM.

System Platform

1. [Essential] [*Satisfied*] The Estimage client application should be able to run on mobile devices with Android 4.0 Ice Cream Sandwich and above.
   The Estimage client application was installed and tested on the Android 4.0, 4.4, 5.0, and 5.1 operating system and all functions worked well.

System Performance — Time and Space

1. [Essential] [*Satisfied*] Little delay should be noticed when switching user interfaces in the Estimage client application.
   The maximum switching time between each pair of associated interfaces was tested to be less than 0.2 seconds, which is hardly noticed.
2. [Desirable] [*Satisfied*] The response time of each button click should be less than 0.2 seconds.
   The maximum response time of each button click was tested to be less than seconds.

3. [Essential] [*Satisfied*] The Estimage client application should spend less than ten seconds to display the whole list of image records (up to 50) on the screen.
   50 records were loaded in and displayed on screen in less than eight seconds.
4. [Desirable] [*Satisfied*] Each image record should occupy no more than two megabytes in the SQLite database on the Android device.
   The space used by each of 10 image records was tested and, on average, each image record occupied around one megabyte of external storage on the Android device.
5. [Essential] [*Satisfied*] The Estimage client application should take no more than three seconds to upload an image record to the server with a network speed of one megabyte per second.
   The maxium time it took to upload the image record and its image to the Estimage server application was less than two seconds.
6. [Desirable] [***Not Satisfied***] The Estimage server application should take less than five seconds to complete the estimation process of an image.
   During the testing process of the estimation performance mentioned in Section , the time cost of 10 estimation tasks were tested and, on average, each estimation task took around 13.4 seconds to complete. The maximum time of the 10 tests was less than 15 seconds.

ESTIMATION EVALUATION

The primary objective of this project is the development of the Android client application, not the ML models. However, it is important to provide an assessment of the full system using the predictive ML models developed on the server.

This section focuses on evaluating the image estimation functionality of the system. To test the estimation functionality, ML predictive models were created and trained for two types of objects: coins and blueberries. In this way, the estimation performance can be evaluated thoroughly by presenting results from a simple and ideal case to a complicated and realistic case that is the domain of harvest estimation.

The results from the following test cases are presented in three steps. (1) One of the test images is shown along with its density map image. (2) The actual count with an estimate of each estimation is presented. (3) The error rate of each estimation is calculated as follows:

$$error\ rate = \frac{|\ actual\ count - estimate\ |}{actual\ count}$$

Coin Estimation

The first test case is coin estimation. Since coins of the same value on the same background have the same appearance, most of the variability of the objects to be estimated is eliminated, and the complexity of counting the objects in an image is reduced.

Objective The objective of the coin estimation is to test the estimation performance of an ideal environment, where the appearances of the objects and the background colour are controlled.

Materials and Methods Images of 25-cent Canadian coins on a wooden table were provided for training the ML models as well as testing the models' performance. The shiny appearance of the 25-cent coin made it easily identifiable on the brown wooden background.

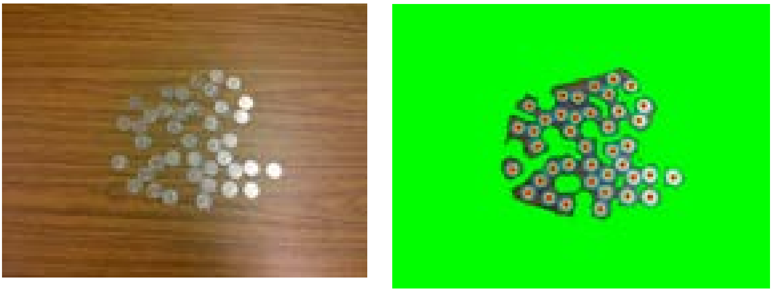
One image for training is depicted in Fig 4. Using ilastik, all the coins were labelled as one class of object to be recognized (shown in red) and examples of background pixels were marked as another class of object to be ignored (shown in green). The ilastik system generated features from the marked pixels and built a random regression forest ML model using these pixels of coins and background.

To test the performance of the coin estimation, the Estimage client application was used to take 11 images of coins with the number of coins varying from 0 to 40. These images were taken at the same height above the table to maintain the size of coins in each test image. This way, we could see how the estimates varied as the number of coins increased.

Results In Fig 5, all the coins were properly identified by the system.

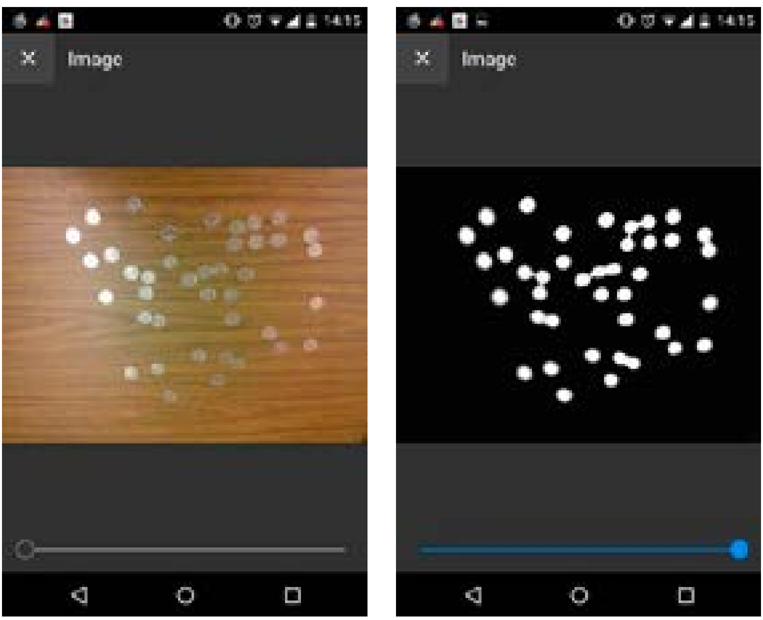
Fig 6 depicts the estimates of 11 test images. When no coins were in the image, the estimate was six. As the actual number of coins increased from 0 to 24, the estimate converged to the actual number of coins. When the actual number of coins increased from 24 to 40, the error of the estimate gradually increased in each estimation.

Fig 7 depicts the error rate as a function of the actual number of coins in the image. Since the error rate of the result from the image with no coins could not be calculated, it was not presented. As the



(a) Sample Image (b) Labelled Sample Image

Fig 4 Sample Image of Coins for Training.



(a) Original Image (b) Density Map Image

Fig 5 Sample Image of Coins for Testing.

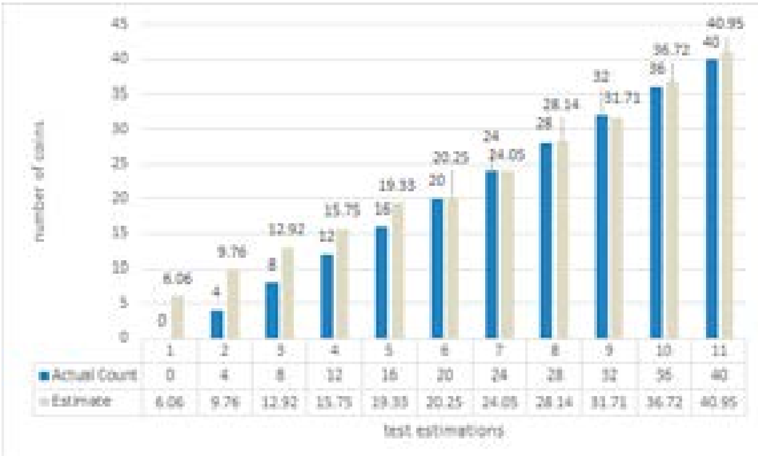


Fig 6 **Comparison between the actual counts and the estimates of coins.**

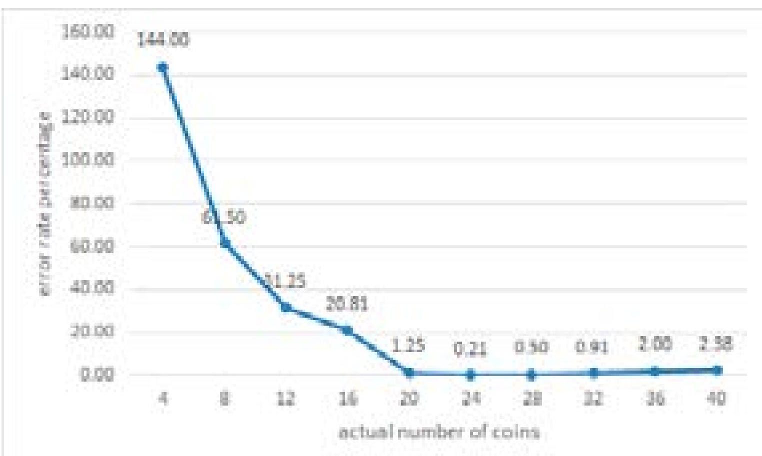


Fig 7 **Graph of the error rate percentage as a function of the actual number of coins.**

actual number of coins increased from 0 to 24, the error rate fell dramatically to 0.21%. When the number of coins increased from 24 to 40, the error rate gradually increased, such that at 40 coins the error rate was 2.38%.

Discussion Based on the results, the estimation of coins is quite accurate when the actual number is at least 20. However, when the actual number of coins is 16 or less, the error rate increases significantly. This is because there is a minimum value for each pixel to be set when an image is being estimated by the ML predictive model. All values of each pixel in the image including the background are added up to create the estimate. This means that even when there are no objects in an image, the count will be greater than zero. This explains why the estimate would be 6 coins when there are no coins in the estimated image.

There are two conclusions from the coin estimation. (1) The system works pretty well on estimating the number of coins on a wooden table when the actual number is at least 20. (2) The ML estimation approach currently being used needs to be improved for small numbers of objects.

Blueberry Estimation

The blueberry estimation needs to take into account the different appearances of blueberries as well as varying surroundings. On a blueberry bush, there are mature blueberries with blue colour and immature ones with light green colour. Blueberries have surroundings such as green leaves, brown soil, and light sky. All of these factors can greatly affect the estimation result.

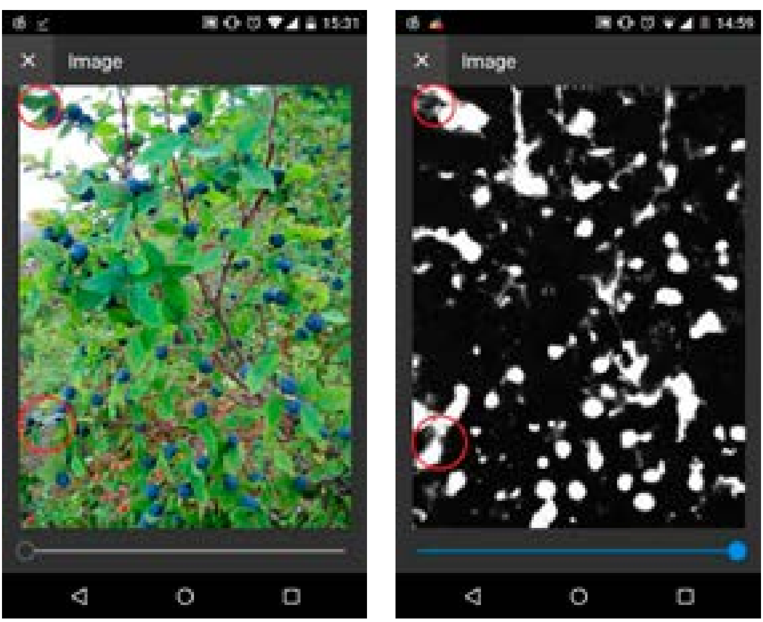
Objective The goal of the blueberry estimation is to verify the performance of the estimation in a realistic environment, where the color of the background can be different from or similar to the color of the objects to be estimated.

Materials and Methods Three images of a bush with mature blueberries were selected from the internet for training the ML predictive model. In Fig 8 one of the training images pictured the mature blueberries with surroundings that could be easily distinguished from the blueberries. Most of the mature blueberries were labelled as one class to be recognized (shown in red) while the small blueberries a short distance away were ignored. The immature blueberries and the background were marked as another class (shown in green) to indicate that they should be excluded.

In total eight images were selected from the internet for testing. The first four images had a background that was consistent with the images for training the ML model and could be well distinguished from blueberries. The other four images had a mixed background with mixture of colors that was similar to the blueberries in colour. To reduce the influence of blueberry size and focus on the influence of varying background, these eight test images were resized so that the number of pixels each blueberry occupied is similar to the blueberry size for training the ML model. Fig 9 depicts one of the images with a consistent background and Fig 10 depicts one of the images with a mixed background.

(a) Original Image (b) Labelled Image

Fig 8 Sample Image of Blueberries for Training.

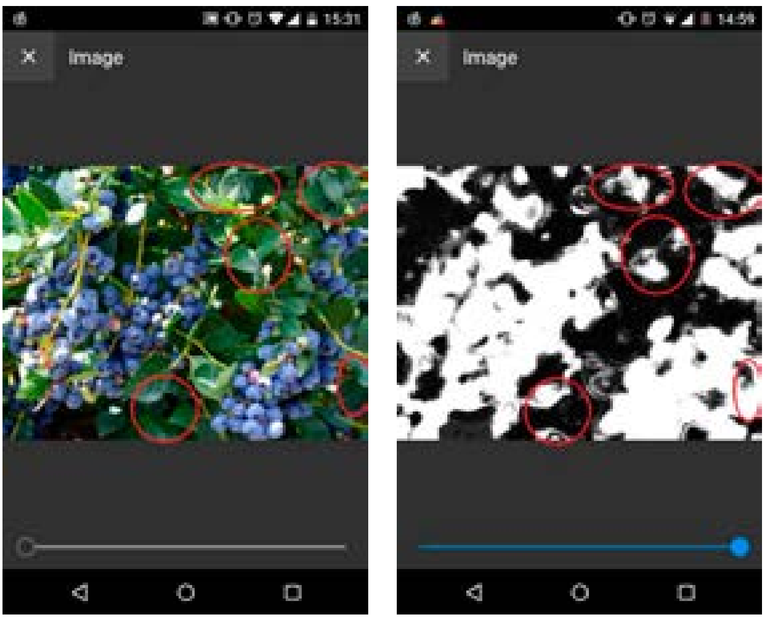


(a) Original Image (b) Density Map Image

Fig 9 Image of Blueberries with Consistent Background for Testing.

Results Fig 9 shows the test result for one of the test images with a consistent background: all blueberries were recognized. While most of the background was recognized to be separate from the blueberries, a small portion of the background was mistakenly viewed as blueberries, some of which is circled in Fig 9.

Fig 10 shows the test results for one of the test images with a mixed background. All the blueberries were recognized. However, a large portion of the background at the top-right and bottom-right corner was misrecognized as blueberries.



(a) Original Image (b) Density Map Image

Fig 10 Image of Blueberries with Mixed Background for Testing.

For a real application the model likely estimates the number of pints of berries; however, the number of berries is more practical for our current testing. Fig 11 presents the actual counts and the estimates for the eight test images. The estimate of the number of blueberries in an image with a consistent background was close to the actual number of blueberries. However, in each image with a mixed background, the estimate of the number of blueberries was a lot more than the actual number of blueberries. Fig 12 depicts the error rates of the results from the estimations. The estimation of each images with a consistent background had an error rate below 10%, while the estimation of each image with a mixed background had an error rate above 50%.

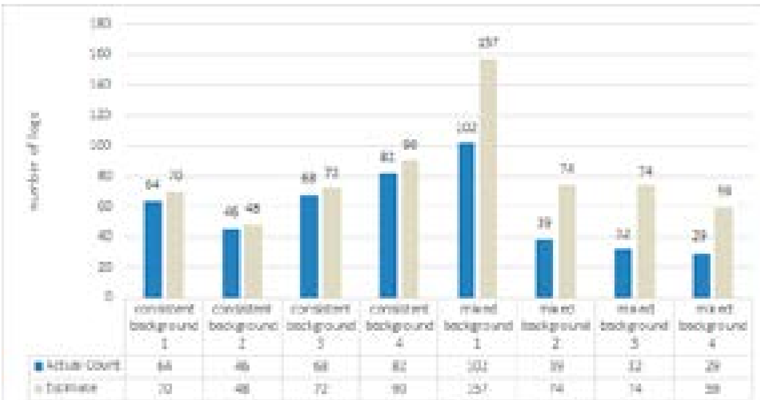


Fig 11 Comparison between the actual counts and the estimates of blueberries.

Fig 13 presents the error rates of test images with a consistent background. The mean of the error rates is 7.34% and the standard deviation is 2.65%. Fig 14 presents the error rates of test images with a mixed background. The mean of the error rates is 94.59% and the standard deviation is 32.14%.

Discussion The numbers of blueberries in all of the eight test images are overestimated because their backgrounds have parts recognized as blueberries. But a consistent background causes fewer errors in estimating the number of blueberries compared to a mixed background. Judging from the test results, the light sky, brown soil, and green leaves are all excluded in the first four test images with a consistent background because the ML model has been trained to ignore these background pixels. Therefore, the first four test images have accurate estimates. However, the other four test images have a mixed background that is similar to the blueberries in colour and the images tend to mislead the model to recognize some parts of their backgrounds as blueberries. This causes large errors in the estimates of the other four test images.

For the blueberry estimation, there are two conclusions. (1) The system can make an accurate estimate of blueberries provided

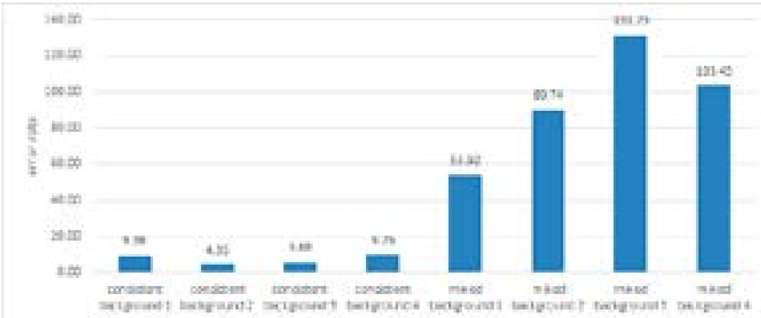


Fig 12 Depiction of the error rates in the blueberry estimation.

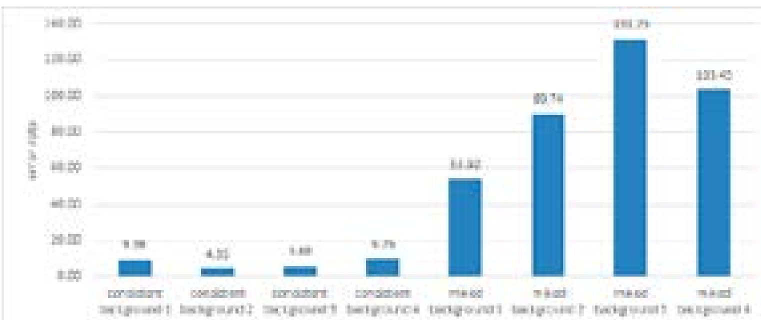


Fig 13 Error rates of test images with a consistent background.

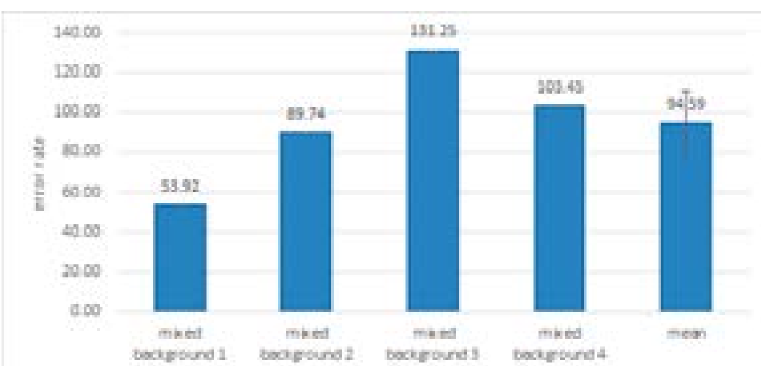


Fig 14 Error rates of test images with a mixed background.

the background is consistent to the one in the training images. (2) Improvements are needed in the ML approach being used to estimate the number of objects in an image with a mixed background.

Limitations

One important factor that is not taken into account in these two estimation experiments is the overlap between objects. The coin estimation experiment was set up to ensure that there was no overlap between any of the coins in each test image, and the estimation performance in an ideal environment could be tested. However, the blueberry estimation was set up to test the performance in a realistic environment, which inevitably involves the overlap between blueberries. Since the factor of overlap is hard to controlled, the two experiments above mainly focus on how estimation performance varies as the object appearance and image background change. Further experiments are needed to test the estimation performance in both ideal and realistic environments with control of overlap.

Conclusion

Factors that affect the estimation accuracy include the appearance of objects to be estimated and the image background. When the objects in an image can be distinguished easily from the background and have a similar size, colour, and shape, the estimation of the system is accurate. When the background is consistent with the training images of the ML model, the estimation also performs well. In order to get an accurate result, several steps should be followed when taking a photo for estimation.

(1) Select objects that have a similar appearance to the one used to train the ML predictive model. (2) Pick a background that is consistent with the training images. (3) Choose a distance and an angle so that the image pictures the objects with same size as the training images. (4) Cast enough light to the objects so that they are pictured in the same colour as the training images. (5) Take a photo in a way that the objects occupy at least half of the image.

SUMMARY AND CONCLUSION

This paper is concerned with the problem of providing farmers with a convenient software application for estimating crop yield in the field prior to harvest.

To solve the major problem, a software system called Estimage was created, which included an Android application for user interaction and a cloud-based machine learning service that could estimate the amount of crop pictured in an image. The Android application was analysed, designed, implemented and tested following the traditional system development process and was responsible for uploading images to the server for estimation. The Android application provided users with an intuitive and user-friendly interface to manage their image records and estimation tasks.

ML predictive models were built and trained using an existing machine learning software package called ilastik. A PHP server application was created to call an Octave program which in turn invokes ilastik to apply a machine learning predictive model to an image so as to estimate the number of objects in the image. With the Estimage system, users can conveniently take photos of the crops in the field and upload these photos to the server for estimation using their mobile device.

Three test cases were created to evaluate the estimation performance of the ML predictive models on different objects in order to find out the factors that affected the estimation accuracy. The first test case was an ideal case estimating the number of identical coins on a wooden table. The second test case was a transitional case estimating the number of logs stacked in a pile. The last test case was a realistic case estimating the number of blueberries on a bush. The test results showed that the system could accurately estimate the number of objects in a suitable image. Suitable images depicted objects of the same shape, size, and colour as the ones used to train the ML model and thus they had a more accurate estimate. Further, the more consistent the background, the more accurate results an estimation had. These factors could be controlled by adjusting the distance or the angle to the objects when taking a photo of them.

FUTURE WORK

Although the Estimage system has satisfied the goal of this project, there are still many aspects to be improved as below.

(1) The system should have a user account management system that allows users to register a new account and login. The users' information can be saved for other research purposes. (2) The system should have backup copies of users' image records on the server so that users can retrieve their image records to any Android mobile device using their accounts. (3) The system should help users to take a qualified image for better estimation of the number of objects. For example, the Android application could indicate how big an object should be in an image when users are taking a photo.

Currently, the prediction models are not very robust. There is need to process the image so as to better prepare the data prior to presentation to the machine learning model. For example, the images could be normalized in terms of object size.

There are other aspects of our system that could be explored. Theoretically, the system can be expanded to estimate the count of any object in an image, such as fish, apples, cans and hats. For any industry that has a problem of counting similar objects, the system provides a potential solution. For example, there is a need in biology to count the number of bacteria in a culture dish under a microscope. This counting process can be time-consuming and error-prone for human beings. The Estimage approach could be introduced as a solution to this task.

APPENDIX A. TEST LOG

Table A.1 10 Tests on Estimage Client Application Performance.

Time (secs)	Displaying Record List	Interface Switching	Button Click
	7.779	0.117	0.005
	7.820	0.334	0.003
	7.742	0.267	0.006
	7.759	0.069	0.004
	7.704	0.291	0.003
	7.750	0.240	0.001
	7.633	0.042	0.001
	7.712	0.050	0.003
	7.725	0.279	0.001
	7.734	0.246	0.003
average	7.736	0.196	0.003
min	7.633	0.042	0.001
max	7.820	0.334	0.006

Table A.2 10 Tests on Size of Data Created on User's Device.

Size (MB)	Image Record	Image	Density Map Image	Total
	0.100	0.654	0.016	0.770
	0.122	0.849	0.159	1.130
	0.109	0.765	0.113	0.987
	0.121	0.868	0.097	1.086
	0.104	0.719	0.023	0.846
	0.079	0.577	0.153	0.809
	0.119	0.675	0.162	0.956
	0.141	0.942	0.224	1.307
	0.154	1.067	0.075	1.296
	0.171	1.253	0.200	1.624
average	0.122	0.837	0.122	1.081
min	0.079	0.577	0.016	0.770
max	0.171	1.253	0.224	1.624

Table A.3 10 Tests on Estimation Time Performance.

Time (secs)	Android App	Data Comm	PHP	Octave	ilastik	Total
	0.111	1.672	0.748	3.6164	6.7896	12.937
	0.135	1.349	1.338	4.2544	7.2176	14.294
	0.084	0.683	0.869	5.1037	8.1723	14.912
	0.096	1.136	1.43	3.644	6.704	13.010
	0.113	1.799	1.222	3.6023	6.6677	13.404
	0.132	1.371	1.536	3.6382	6.8218	13.499
	0.122	1.587	1.118	3.6256	6.7574	13.210
	0.115	1.108	0.821	3.6227	6.7083	12.375
	0.133	0.665	1.516	3.6519	6.6771	12.643
	0.127	1.837	1.568	3.6196	6.8434	13.995
average	0.1168	1.321	1.2166	3.83788	6.93592	13.428
min	0.084	0.665	0.748	3.6023	6.6677	12.375
max	0.135	1.837	1.568	5.1037	8.1723	14.912

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A REVIEW OF THE MONITORING AND MANAGEMENT OF SPOTTED-WING DROSOPHILA (*DROSOPHILA SUZUKII*) IN LOWBUSH BLUEBERRIES

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ABSTRACT

The recent arrival of spotted-wing drosophilia (*Drosophila suzukii)* to eastern Canada is a major threat to the million dollar lowbush blueberry industry. The highly fecund female fly lays her eggs in ripe soft-skinned fruit. The maturing larvae consume the fruit interior, ultimately resulting in fruit collapse and decreased yield. Effective monitoring and management of this pest is essential for reducing the risk of export market closure and economic losses. In this literature review, an integrated pest management plan is developed that outlines current monitoring and management practices for the pest and considers preventative physical, chemical and biological controls.

INTRODUCTION

Spotted-wing drosophilia (*Drosophila suzukii*) or SWD has recently colonized and rapidly dispersed across North America and Europe, complicating the production of lowbush blueberries (*Vaccinium angustifolium*) and other susceptible fruit crops. To lay eggs, the female inserts her sharp, serrated ovipositor into ripe berries and fruit. The developing larvae consume the fruit interior, resulting in fruit collapse and yield loss for producers. Crop loss is intensified by the high fecundity and short generation time of *D. suzukii* and infection must be treated quickly and effectively to minimize damage and spread. Due to the near-immediate dissemination of SWD across the globe, researchers and producers are scrambling to comprehend the biology and ecology of this invasive and noxious pest. With the threat of export market closure and million dollar yield

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losses, wild blueberry producers are relying on researchers to find effective monitoring techniques and control measures for *D. suzukii*.

Biology and Ecology of *Drosophila suzukii*

Originally described in Japan, *Drosophilia suzukii* was first identified in the United States in 1980, in Hawaii (Kaneshiro 1983). By August 2008, SWD had colonized and infested strawberries and caneberries in mainland California (Lee *et al.* 2011b). In subsequent years, the fly spread northward and eastward, reaching Atlantic Canada in 2010 (Hauser 2011). At the same time, spotted-wing drosophila rapidly dispersed across Europe from Spain and Italy to France, Switzerland and Germany by 2011 (Calabria *et al.* 2012). Although drosophilids are not well-adapted for long distance flight, *D. suzukii* is easily dispersed by regional wind currents and is passively transported by global trade (Kimura 1992; Calabria *et al.* 2012). High dispersal rates of *D. suzukii* presents a significant challenge for controlling the species.

Drosophila suzukii are small drosophilids (2 to 3 mm) with distinguishing dark spots on the leading top edge of wings of male

Fig 1 A magnified photograph of a male *Drosophila suzukii*. Image distinctly shows two dark markings on the tarsal segments of the forelegs and the black spots on the wings. Photo courtesy of G. Arakelian and the University of California, Center for Invasive Species Research.

individuals, Fig 1. The females lack spots, but have a distinctly serrated or "saw-like" ovipositor on the abdomen (Cini *et al*. 2012). Both sexes of the species have red eyes, a brown-yellow thorax and continuous black stripes on the abdomen (Walsh *et al*. 2010). Although *D. suzukii* are generally dissimilar from other drosophilids, phenotypic characteristics are not static (males lacking spotted wings have been observed) and the only fully reliable identification tool is DNA barcoding (Cini *et al*. 2012).

A female lays her eggs in thin-skinned fruit by forming a slit in which she inserts 1 to 3 eggs (Lee *et al*. 2011a; Cini *et al*. 2012). Susceptible host fruits include a plethora of horticulturally significant crops: blackberries, blueberries, cherries, peaches, raspberries, strawberries, grapes (Lee *et al*. 2011a). Eggs hatch within 72 hours and the maturing larvae consume the fruit interior (Walsh *et al*. 2010). Within two weeks, the larvae pupate. Shortly after emergence (1 to 5 days), *Drosophila suzukii* adults are able to produce viable progeny and over her lifetime, each female SWD oviposits an average of 380 eggs (Mitsui *et al*. 2006). At ideal temperatures (between 20 and 25°C), populations of *D. suzukii* can repeat their entire developmental cycle in as little as 8 days (Walsh *et al*. 2010), causing exponential increases in the population and risk to the fruit industry.

Fruit damage caused by *D. suzukii* is the result of oviposition. Larval feeding of fruit interior compromises fruit integrity and reduces quality of pulp. After infection, fruit can pre-maturely drop from the stem or stored fruit may collapse post-harvest, ultimately reducing yield. In addition, the slit torn by the females' serrated ovipositor serves as an entry point for secondary bacterial or fungal infection, increasing the rate of fruit deterioration (Calabria *et al*. 2012). Spotted-wing drosophila has the potential to cause wide-spread damage to fruit crops across the Northern Hemisphere due to:

1. Wide host range for oviposition (Lee *et al*. 2011a, Walsh *et al*. 2010).
2. Rapid generation time.
3. Extreme fecundity (Walsh *et al*. 2010).
4. High dispersal potential via post-harvest fruit transportation and wind movements (Walsh *et al*. 2010).
5. Infection of ripe, pre-harvest fruit (Basoalto *et al*. 2013).

Eastern Canadian Lowbush Blueberry Production

Lowbush or wild blueberries are woody perennials managed commercially to produce high yields of sweet, blue-colored fruit. *Vaccinium angustifolium*, low sweet, and *Vaccinium myrtilloides*, sourtop, are two species that naturally occur in eastern Canada and are well-adapted to the temperate climate (Kinsman 1993). When appropriate management practices are implemented, blueberry rhizomes can spread and plants densely cover acidic, abandoned woodland. Management of naturally occurring stands in eastern Canada and Maine led to commercial production of wild blueberries in the 1940s and 1950s. Since the 1950s, wild blueberries have been introduced to over 20 countries throughout the world (Barker *et al*. 1964, Kinsman 1993). Blueberries are highly marketable because they have high antioxidant levels and other health benefits – an important attribute in a progressively health-conscious consumer market (Kalt and Dufour 1997).

Wild blueberries are the major fruit export crop in Canada. Millions of tonnes of frozen berries are distributed to the United States, Japan, Germany and the Netherlands annually (Anonymous 2010). Production is limited to eastern Canada, with the majority occurring in Nova Scotia and New Brunswick. In these two provinces, there are over 1100 wild blueberry farms harvesting a combined marketed value of $42 million in 2010 (Anonymous 2010). As markets continue to grow, Canadian producers are aiming to maximize crop yields and increase production acreage to feed increasing demand.

Commercial production of wild blueberries in eastern Canada is threatened by *D. suzukii*. Economic losses associated with the pest include reduced yield, and increased labor and chemical inputs costs for monitoring and management. Post-harvest fruit selection processes may be implemented, further increasing economic costs (Lee *et al*. 2011b). Also, there is the potential for closures of export markets if/when importing countries impose thresholds of zero larvae in imported fruit and berries (Bruck *et al*. 2011). This would be a significant setback for Canadian lowbush blueberry producers, as over 75% of harvest is exported (Anonymous 2010).

The potential for economic damage as a result of SWD infection has been realized in several regions across the globe. Economic losses in Europe resulting from SWD infection include significant losses in Italy, 30-40% loss in highbush blueberries, and France, 80% loss in strawberries (Lee *et al*. 2011b). Estimated yield losses in the US blueberry industry, based on 2008 production values, would result in $56.7 million (US) in losses (Bolda *et al*. 2010). The economic impact of SWD is well shown: how can Nova Scotia wild blueberry producers minimize inevitable damage and loss?

MONITORING AND MANAGEMENT OF SWD: AN INTEGRATED APPROACH

Trapping and monitoring populations of SWD enables producers and researchers to quantify the severity of infection and evaluate the success of a control measure. Information obtained through pest monitoring can be compiled to map the distribution and spread of the species, as well as predict regions of future colonization (Burrack *et al*. 2012). Researchers are currently optimizing trap design to actively and selectivity capture SWD adults (Basoalto *et al*. 2013, Walsh *et al*. 2010). Post-harvest monitoring protocols for larval identification have also been developed, but have limited utility in a field setting and are used primarily in research.

D. suzukii adults are more frequently captured in colored traps with numerous entry holes baited with volatile fermented sugars.

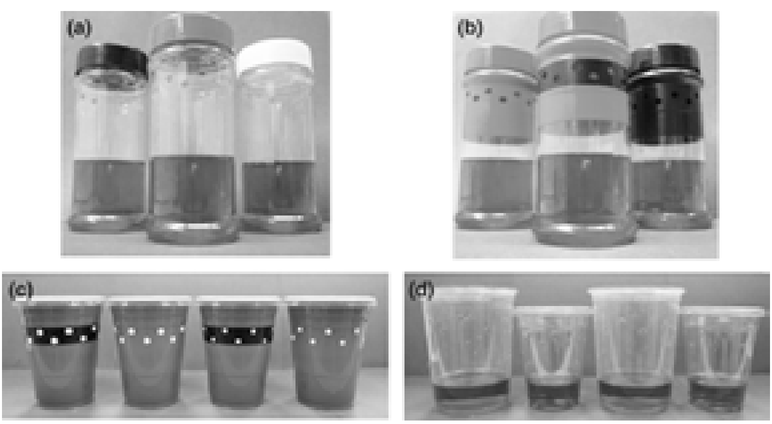

Fig 2 Cup-trap designs tested by Basoalto *et al.* (2013) and baited with apple cider vinegar to capture *Drosophila suzukii* adults: "(a) spice jars with black, red or white caps and ten 0.48-cm holes, (b) all-red, all-black and 'Zorro' traps with ten 0.48-cm holes, (c) 473-ml red cups with or without a horizontal 1.5-cm black stripe and ten either 0.48- or 0.63-cm holes and (d) 473- and 946-ml clear cups with 10 either 0.48- or 0.63-cm holes," (Basoalto *et al.* 2013).

Basoalto *et al*. (2013) identified promising and commercially viable jar/cup-style designs after testing the attractiveness of several different trap designs to SWD, Fig 2 (2013). More flies were captured in red/black striped traps with a greater number of entry areas (Basoalto *et al*. 2013, Lee *et al*. 2012). In SWD trapping studies, entry holes ranged in size from 0.32 cm to 0.63 cm; smaller sized holes increased selectivity for drosophilids and decreased the number of non-target captures (Basoalto *et al*. 2013). Traps were typically placed above the crop canopy in shaded areas. Although females are responsible for the damage to fruit, they are difficult to distinguish from their drosophilid cousins. The distinguishing dark spot on the wings of males allow for easy identification of the species. It can be assumed that if males are present, females are too!

Apple cider vinegar replaced weekly is recommended for baiting, although a mixture of yeast-sugar-water has shown to be more effective (Walsh *et al*. 2010). Overall, liquid baits are non-selective and difficult to handle in the field. The identification of selective chemical lures for SWD is an area of active research and some promising results using wine and vinegar volatiles have been observed by Cha *et al*. (2013). Researchers continue to design and evaluate trapping techniques for SWD in an effort to create a trapping protocol that is effective but affordable for producers.

Cultural Control/Prevention

Preventing infestation is the first step towards eradication of SWD. To reduce the exposure of fruit to *D. suzukii*, growers are encouraged to harvest ripe crops as early as possible. This strategy aims to disrupt crop-insect synchrony and eliminate niche accessibility. In addition, scrupulous sanitation of equipment and site can reduce habitat availability for flies as any fruit remaining in the field can provide a site for oviposition and feeding (Cini *et al*. 2012). After harvest, rejected fruit should be treated or destroyed to kill any SWD life stages present (Walsh *et al*. 2010). Site sanitation is a major concern for lowbush blueberry producers. Depending on the field topography and the type of harvest equipment, upwards of 10% of fruit may remain in crop fields post-harvest. However, by properly adjusting and operating harvester equipment, fruit loss can be significantly reduced (Sibley 1993).

Physical Controls and Trapping

Physical controls, such as netting or trapping, can be used to impede insect colonization. Netting (0.98 mm mesh) has successfully controlled SWD in highbush blueberry production (Lee *et al.* 2011b), but is impractical for application in lowbush blueberries which are often developed on rough terrain with patchy field coverage. Use of mass-trapping to control SWD has been successful in China (Wu *et al.* 2007). However, current bait is non-selective and applying this control to farms with large-acreage is costly and labour-intensive. After identifying SWD-specific pheromones and visual/auditory cues associating with courtship, researchers hope to develop synthetic compounds and trapping protocols that disrupt mating and oviposition (Cini *et al.* 2012).

Chemical Controls

Currently, chemical application is the most common method of SWD control applied by producers (Cini *et al.* 2012). Use of insecticides is advantageous because it provides rapid and residual treatment of the invasive insect. In a recent American study, Bruck *et al.* (2011) demonstrated that synthetic pyrethroids, organophosphates and spinosyns provided 5-14 days of residual control of *D. suzukii* in lab and field replicates (2011). These insecticides have short pre-harvest intervals (less than 7 days), an important attribute of a pesticide applied to ripe fruit within days of harvest. Within these chemical groups there are several insecticides and formulations currently registered for emergency use in Canada and the United States. Chemical control thresholds for SWD are stringent and control application should be implemented after finding one SWD individual in a given field. SWD is an extremely noxious and invasive pest and without treatment, populations proliferate and cause significant economic damage.

Insecticide treatment is extremely lethal to SWD adults. However, there are several limitations to chemical control. As with most pesticides, frequent insecticide application increases selection pressures and the likelihood of insecticide resistance developing in pest populations. Using broad spectrum insecticides also kills beneficial species. Pesticide application can reduce populations of natural pollinators which are extremely important for the production of lowbush blueberries. Several other issues were observed by researchers studying chemical control of SWD:

- Although specific insecticides may be registered for use in a given area, they may be restricted by international markets and government regulation. Compliance with maximum residue limits can significantly reduce control options. This is especially significant for fruit crops that rely on export markets, such as wild blueberries (Bruck *et al*. 2011).
- When populations of SWD were high, alternating use of insecticides had no significant effect on populations at harvest (Grassi and Pallaoro 2012).
- When studying pesticide efficacy, van Timmeren and Isaacs (2013) observed a significant decrease in insecticide efficiency when rain events occurred within days of application. This has significant implications for the lowbush blueberry industry, as Eastern Canada has a temperate climate.

Biological Controls

To find alternatives to chemical control, research is urgently needed to investigate viral pests, parasites and predators of SWD. Studies have identified parasites of *D. suzukii* in Japan, Europe and North America in field and laboratory conditions. One promising pupal ecto-parasite is *Pachycrepoideus vindemmiae*, studied in Oregon and British Colombia (Brown *et al*. 2011, Stacconi *et al*. 2013). When exposed to *P. vindemmiae*, only 11% of *D. suzukii* adults emerged from pupae, compared to an 85% emergence rate in uninfected control. In Summerland, British Columbia, the parasite was able to survive for 6 generations and led to the collapse of a colony of *D. suzukii* (Brown *et al*. 2011, Chabert *et al*. 2012). However, more research must be done to understand how/if these parasites are viable control measures in commercial fields.

After implementing a control, it is important to re-evaluate and continue to monitor pest populations to determine if further control measures are necessary. Integrated Pest Management programs are never static but rather they are in constant flux as superior control strategies are introduced and pest pressures fluctuate.

CONCLUSION

In conclusion, *Drosophila suzukii* is a noxious and invasive pest with the tenacity to damage the lowbush blueberry industry and production of other fruits in Canada. However, with proper monitoring and implementation of properly timed control measures, populations of this pest can be reduced and controlled. As researchers continue to study the biology and ecology of *Drosophila suzukii*, it is hopeful that new control measures and trapping strategies will be introduced in effort to save crops from this new threat.

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APPENDIX

Summative fact sheet for blueberry producers:

Monitor and Manage Spotted-Wing Drosophilia in Lowbush Blueberries

Why?

Spotted-wing drosophila, SWD or *Drosophila suzukii*, is a vinegar fly that lays its eggs in ripe fruit and berries. Infection results in collapse of fruit, reducing harvestability and crop yield. SWD has the potential to cause million dollars in losses to the Canadian lowbush blueberry industry.

How to Identify

Adult flies are small, 2-3 mm in length, with red eyes. Male SWD have a distinct black spot (B) on the upper corner of each wing and two dark bands on their forelegs (C). The spot is absent in females who have a "saw-like" ovipositor for egg laying (D).

In the field, traps are examined for male individuals. Although females are present, they are more difficult to distinguish from non-SWD vinegar flies without a microscope.

How to Monitor

TRAP: Strip a piece of black tape around a 12 or 16 oz. covered red cup (Solo Co.) or spice jar. Punch 8-10 holes in the cup through the tape (~0.30 cm).

Place traps in crop fields by the end of July (or earlier if advised). To set a trap, screw an adjustable ring clamp to a wooden stake. Position the clamp so that trap (held in the clamp) is about 20 cm above the crop canopy. Place as many traps per hectare as economically feasible, with a large proportion of traps placed near wooded areas and the field exterior.

Bait: Place 150 ml of bait in the cup and replace/check weekly. Use either apple cider vinegar (easier to use, less effective) or yeast-sugar-water mixture (more labor-intensive, more effective).

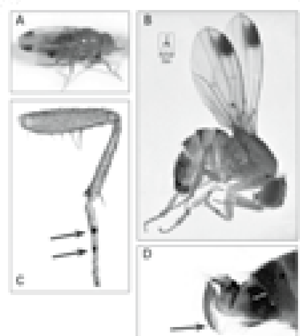
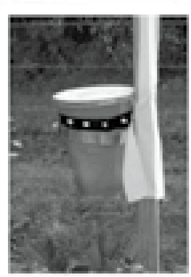


Photo above: Identification of spotted wing drosophila adult flies. A: adult flies, B: male adult with distinctive spotted wings, C: dark bands of male tarsi, D: serrate ovipositor of female SWD. Photos from Michigan State University Extension.

Photo below: Trap for SWD in lowbush blueberries, UMaine.



Thresholds

SWD is an extremely noxious and invasive pest with high dispersal potential. Currently, it is recommended to implement control measures after the first male is identified in a trap.

How to Control

Preventing Infection

Removing habitats for over-wintering adults and reducing egg-laying sites can reduce risk of SWD infection and re-infection. Some tips:

- Properly adjust and operate mechanical harvesters to minimize the number of berries that fall to the ground during harvest.
- Remove used/rejected blueberry boxes from field site.
- Harvest ripe blueberries as early and as quickly as possible.

Chemical Control Options

Chemical should be applied as soon as one male adult is trapped or one female adult is identified microscopically. Comply with processor and export market pesticide restrictions and maximum residue limits. Be aware of issues with insecticide use including the development of insecticide resistance and possible damaging effect on natural populations, including beneficial species and pollinators.

Other Control Options

Researchers are currently developing and improving control protocols. Keep up to date with findings and new products available on the market.

Evaluation

After application, continue monitoring for SWD. Re-implement controls as necessary.

SWD pupation on the surface of blueberries. British Columbia Ministry of Agriculture.

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BOOK REVIEW

***A Century of Maritime Science: The St. Andrews Biological Station*. J.M. Hubbard, D.J. Wildish & R.L. Stephenson. Eds. 2016. University of Toronto Press, Toronto, Buffalo, London, 488 pp.**

This volume provides a comprehensive review of the historical and contemporary scientific investigations conducted at the St. Andrews Biological Station (SABS) over its first 100 years. The twelve chapters are replete with detailed descriptions of a wide range of studies and the extensive bibliography and footnotes reflect the depth to which authors have gone to ensure that the legacy of the Biological Station will continue. The book's publication comes close on the heels of the Federal Government decision to close the Station's library along with most other Fisheries and Oceans research libraries, including that of the Pacific Biological Station, SABS' sibling. Hopefully researchers will find this volume a useful link to the significant accomplishments of SABS scientists.

The Biological Station was influenced by and served the research needs of many notable scientists and the volume is a veritable whos-who of marine science in Canada. Many of these scientists have research vessels named after them, *E.E. Prince*, (W.B.) *Dawson, Alfred Needler, J.L. Hart*. E.E. Prince was named the Dominion Commissioner of Fisheries in 1892 and was the main motivator for establishing the Station. W. Bell Dawson was the head of the Tidal and Current Survey and the first physical oceanographer associated with the Station. A.W.H. Needler conducted oyster research on P.E.I. in the 1920s where he was director of the Ellerslie substation. He was Station director from 1941-1954 during which time Station scientists' role in advising fisheries management grew considerably. He was part of the Canadian delegation that drew up the convention leading to the establishment of the International Commission for the Northwest Atlantic Fisheries (ICNAF). J.L. Hart was the Station director from 1954-1967 and placed more emphasis on human impacts on the marine and freshwater environment by starting a section on water pollution research. But, the most cited scientist in this book is A.G. Huntsman, an educator, leader, and advocate for women in science. In addition to fisheries research, he studied oceanography and fish processing. He curated and directed the Station from 1911-1934.

He is commemorated on a Canadian stamp, by the A.G. Huntsman Award of Excellence in the Marine Sciences, and through the Huntsman Marine Science Centre.

The context under which publically funded marine research developed in Canada is described by Eric Mills (Chapter 1). During the late 19th century, marine science was in its infancy and had to compete with agriculture, mining, forestry, and northern exploration for political attention and funding. Early marine research was driven by utilitarian needs and focused on species inventories, fishery development, and marine safety. The first marine station was built on a barge in 1899 and spent two years each in St. Andrews, Canso, Malpeque Bay, and Gaspé. After the floating station was damaged and abandoned enroute to the north shore of the Gulf of St. Lawrence in 1907, the first permanent marine research station was constructed in St. Andrews in 1908, taking advantage of "local fisheries, the richness of the marine biota, water quality, the availability of land, access to supplies, social factors and ease of access from central Canada." These same factors make St. Andrews a popular summer destination for tourists, scientists, and students alike.

As a publicly funded marine research institute, the focus of research at SABS changed with the times. Rob Stephenson (Chapter 4) describes this evolution where the Stations mandate changed from mainly supporting fisheries development in its early days to a greater emphasis on anthropogenic effects on the marine environment. Human pressures on fishery resources led to a greater emphasis on monitoring stock sizes and synoptic bottom trawl surveys were instituted in the early 1970s that covered the Scotian Shelf and Gulf of St. Lawrence. The impacts of mining, forestry and insect control on marine and freshwater ecosystems was a concern and the Station responded by developing related research programs. Atlantic Salmon aquaculture development created new demands for research in the 1970s and again the Station responded. The associated accomplishments are described by Robert Cook in Chapter 12. When the Canada *Species at Risk Act* and *Oceans Act* came into force, the Station had to take on new responsibilities related to conservation biology and ecosystem based research. This came at a time of severe funding pressure and demanded a creative approach.

The obstacles that faced women who were interested in marine science in the 1900s were many. Women were generally not permitted on research vessels in Canada until the 1970s, making field work on ships difficult to impossible. Work along the shore in the early 1990s was hindered by Victorian dress restrictions. Married women were not allowed to work in the same laboratory as their husbands. After marriage, several female scientists continued their research and published from home. Many worked on specimens collected by others. Mary Arai (Chapter 2), who followed her grandmother Edith Berkeley and mother Alfreda Needler as a marine scientist, describes both the challenges and accomplishments of female marine scientists in Canada. Their collective contributions were considerable despite the difficulties they faced. The individual stories are well worth reading.

The high level of collaboration within SABS is made clear by the cross referencing of individual programs throughout the book. The work by the technical staff in the workshops described by Tim Foulkes (Chapter 5) was integrated with a wide variety of research. The technicians developed an array of instruments to measure fishing gear performance, leading to several improvements. Many specialized experimental tanks were constructed. One was a very large hydraulic flume tank (volume 186,200 l) to test underwater instruments for fishing gear development. When that program ended, the tank was converted into an artificial stream used to study habitat selection by freshwater fish under various feeding and flow rates. One of my summer jobs at SABS was to record observations through the acrylic viewing window for my supervisor, Phil Symons. This work is described in Chapter 7, p. 234. A number of specialized flow simulators were developed to investigate fish and bivalve behaviour, physiology, ecology, aquaculture, and response to various toxic chemicals. The associated research is described in chapters by Wildish and Robinson (Chapter 7), Peterson (Chapter 9), Wells (Chapter 11), and Cook (Chapter 12). The workshops also developed towed underwater vehicle technology for camera and diver observations of marine organisms in their natural environments. The use of this technology in scallop research is described by Caddy (Chapter 8). After the workshops closed in 1993, technology development was transferred to the Bedford Institute of Oceanography. Collaborations continued with SABS scientists in the development of more advanced vehicles equipped with digital cameras and GPS. These instruments were used for mapping coastal benthic habitat.

Physical oceanographic data were collected by SABS scientists from the beginning. Initially it was the visiting volunteer biologists who undertook the work and thus observations were mainly made in summer in the vicinity of the Station. However, before long SABS scientists were collecting data from all over Atlantic Canada including the Canadian Fisheries Expedition in 1914-1915 and Hudson Strait and Hudson Bay in 1927-1929. Blythe Chang and Fred Page (Chapter 6) describe the many physical oceanographic projects at SAS and here are a few examples. SABS oceanographers worked with fisheries scientists in two impact assessments of proposed tidal poser projects in Passamaquoddy Bay in the 1930s and 1950s. In both cases, the predicted negative impact on herring fisheries in the area led to the abandonment of the projects. These are early examples of environmental impact assessment, a process now conducted in a much more formalized manner. The Atlantic Oceanographic Group was established at SABS in 1944 and remained active under a couple of names until 1960. Originally it was a joint undertaking of the Royal Canadian Navy, the Fisheries Research Board of Canada, and the National Research Council and part of its mandate had to do with the detection of submarines. Eventually the mandate was dominated by fisheries-related issues. The oceanography program was transferred to Halifax in 1960. After a hiatus, the oceanography program was rejuvenated with the hiring of a fisheries oceanographer and additional technical staff in 1984. This led to a number of national and international collaborations that currently cover fisheries, shipping safety, aquaculture (Cook, Chapter 12), tidal power generation (again), Marine Protected Areas, harmful marine phytoplankton (Martin, Chapter 10), and invasive species.

The multifaceted and interdisciplinary nature of the environmental science and ecotoxicology research at SABS is very impressive as shown by Peter Wells' contribution (Chapter 11). He presents early examples of this type of research, but things really got underway with the establishment of the Water Pollution Section in the late 1950s. The effects of industrial pollution on Atlantic Salmon was an important driver. Forest spraying with DDT to control spruce budworm was of great concern as was the exposure of Salmon in the Miramichi and Saint John rivers to mining and pulp mill effluent, as well as eutrophication caused by food processing plants discharge. In this context, a large number of new scientists were hired to begin applied research in environmental chemistry, aquatic ecology, and toxicology. Wells provides extensive documentation of the contributions of John Sprague and Vladimir Zitko, among many others. Field observations of Atlantic Salmon such as described by Dick Peterson (Chapter 9) coupled with laboratory experiments using specialized tanks and flumes built in the SABS workshops (Foulkes, Chapter 5, Wildish and Robinson, Chapter 7) and an impressive chemistry program produced world recognized results. Noteworthy is the citation of SABS DDT research by Rachel Carson in her very influential book, *Silent Spring*. Salmon were also being exposed to zinc and copper from mining. Lobster were being exposed to cadmium from smelting. The toxicity and behavioural effects of these metals were studied at SABS. But the list goes on. SABS responded to the oil spill created when the *Arrow* sank in Chedabucto Bay NS in 1970, to study the effects on lobster and the benthos. The effects of acid rain on aquatic organisms were studied in the 1970s. SABS personnel were instrumental in identifying domoic acid as the toxin responsible for the mussel crisis in PEI in 1987 (Martin, Chapter 10). Recent work has involved "assessing environmental impacts, identifying hazards, and assessing risks of chemical wastes" produced by the salmon aquaculture industry.

As pointed out by Jennifer Hubbard in the introduction to this impressive volume "there are many stories and research programs undertaken at the St. Andrews Biological Station that do not get the attention they deserve." One such program is Marine Fish Stock Assessment and Research. As noted earlier, Alfred Needler was a participant in establishing ICNAF (International Commission for the Northwest Atlantic Fisheries). The Canadian stock assessments for Scotian Shelf and Gulf of St. Lawrence finfish were conducted by SABS personnel as was the basic research into species distribution and demography that informed these assessments. The same personnel were involved in making the case to the Law of the Sea Convention which gave Canada exclusive jurisdiction over our 200-mile limit. By establishing the aforementioned synoptic groundfish trawl survey, monitoring the associated commercial fisheries and conducting supporting research, Canada demonstrated its capability to exercise this jurisdiction. The same data formed a significant part of the Canadian case for defining the international boundary between the US and Canada in the Gulf of Maine and on Georges Bank.

An additional chapter on this story, perhaps in the form of an article in the NSIS Proceedings, would be a significant addition to the SABS 100^{th} anniversary.

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BOOK REVIEW

Science, Information, and Policy Interface for Effective Coastal and Ocean Management. **B.H. MacDonald, S.S. Soomai, E.M. De Santo, & P.G. Wells. Eds. CRC Press, Boca Raton, FL, 474 pp.**

Any book entitled "Science, Information, and Policy Interface for Effective Coastal and Ocean Management" is guaranteed to attract the attention of a wide, and curious, audience. Integrated Coastal and Oceans Management (ICOM) is a highly topical international issue. All governments (international, federal, provincial, municipal), economic sectors, and communities, are constantly pressurized by a multitude of interacting issues concerning policy, legislation, and operations on the use of resources in coastal and ocean areas. Accordingly, it is important for all of these entities to organize themselves (both individually and collectively) to produce, receive and act on information of common interest. In Atlantic Canada we have seen many provincial, federal, academic, and community programs and plans aimed at contributing to the process of integrating and coordinating policy on coastal and marine issues. Some examples include: Coastal 2000 (Nova Scotia Land Use Committee, 1994), Gulf of Maine Council on the Marine Environment, Eastern Scotian Shelf Integrated Management Plan (DFO 2007; McCuaig and Herbert 2013), Atlantic Coastal Zone Information Steering Committee (ACZISC), and the Bay of Fundy Ecosystem Partnership). Science and information flow for decision-making has formed a prominent part in all of these programs. The oceans surrounding Nova Scotia (The Gulf of Maine, Northumberland Strait, Bay of Fundy, and the Scotian Shelf) rank amongst some of the best studied and monitored marine areas in the world. The region has many well-known commercial, research, academic, educational, government and non-government organizations involved in the generation and use of information for management of ocean and coastal resources. Despite this, the ICOM process, with its much-anticipated outcomes (IOC 2006), does not seem to have made much progress in Canada (DFO 2012 – dfo-mpo.gc.ca/ae-ve/evaluations/11-12/IOM-eng.htm). This might be explained by the diverse information requirements, and the characteristics of the numerous ICOM policy interfaces that are presented in this book.

That said, let's look at the book and see what it is about. Comprising a collection of 19 review-style articles, it is a product of the Environmental Information: Use and Influence Research Program operating out of Dalhousie University, Halifax. It originated in part from a session on information and evidenced-based policy that was convened at the 2014 Coastal Zone Canada Conference in Halifax, Nova Scotia. The editors and contributors to the book represent a diverse group, consisting of active researchers as well as individuals who have had many years of experience at the highest levels of international and national government policy development. The book presents a mix of international, and Canadian, insights with the authors coming from almost all corners of the globe (USA, UK, Canada, Holland, Italy, New Zealand, Australia and Morocco).

The book is presented as four separate parts. The first section by the editors gives an introductory discussion of the meaning of ICOM which centers around the International Oceanographic Commission (2006) definition of "a dynamic multidisciplinary, iterative and participatory process to promote sustainable management of coastal and ocean areas balancing environmental, economic, social, cultural and recreational objectives over the long term". The editors state that the purpose of the book is to deal explicitly with the role of scientific information in the policy making process critical to ICOM. To this end they present schematic models (Fig 1.1 and 1.2) that outline the basic characteristics of a science-policy interface and the players who are involved in the production, transfer and use of information.

The second section consists of 9 somewhat unconnected papers that present perspectives on theory and practice with topics that include: the role of science; global ocean governance; risk; fisheries, shipping and tourism; stakeholder searches; network analysis; research design; science and public policy; and measuring awareness, use and influence of information. Although presented as being conceptual, several of them also present useful case study examples to demonstrate the application. The chapter by Coffey and O'Toole (Chapter 3) presents a thought-provoking review of models relating research with different policy approaches. Rice, in Chapter 4, shares his thoughts and experiences from participating as an advisor in the development of UN international ocean governance. The closing chapter of this section (Chapter 11) by Soomai *et al.* contains a description of qualitative and quantitative methods for measuring information retrieval and application. It is interesting to note that they conclude that no single scientometric method will give a complete understanding of how information is used at the science-policy interface.

The third section contains a collection of seven case study reviews covering a mixed bag of topics including: Canada's State of the Scotian Shelf report; effects of ocean shipping; health knowledge; ACZISC; a career-based perspective of a Canadian government official; the United Nations FAO; and Ecology Action Centre activities. Of these, a highlight is the paper of Wells (Chapter 16) that presents a career-based perspective of some 40 years' experience in the Canadian Department of Environment, and demonstrates that science has indeed played a key role in defining policy in many aspects of ICOM. The papers on ACZISC (Chapter 15) and the Ecology Action Center (Chapter 18) accentuate the enormous service that these non-governmental organizations play in Nova Scotia towards ensuring awareness and flow of information that might be useful in the setting of policy. The paper on health knowledge is somewhat out of place given the subject of this book, but does indicate that there is common ground with other fields.

The final section attempts to make use of the material in the book to give a rationale for a way forward, particularly on information and communication approaches. The editors call for a need to better understand how to use existing information for decision-making in ICOM. I have worked for 40 years in science as a student, researcher, academic lecturer, research program administrator, and consultant. This has included work for governments (UN, federal, provincial and local) in South Africa, UK, Australia, Denmark, Canada, and many countries on the African continent. I have published many peer-reviewed articles and endless evidence-based gray reports on a multitude of policy-related topics (lake ecosystems, eutrophication, watershed management, indigenous plant use, mass algal culture, wetlands, hazardous waste, coastal and oceans management, species at risk, ocean noise, program evaluation, and climate change). It is sad to report that few, if any, of these have yet borne fruit and I cannot claim to have had any major influence on policy or practice, despite the issues being real. Upon reflection I have concluded that the governmental custodians of the resource, who supposedly should be acting as impartial organizers of the policy interfaces, have for a variety of reasons often or always played a biased role in the flow and use of the information provided. Most governmental decision-makers are highly skilled and experienced in the use of information, and are supported by a resilient culture of departmental screening. In my opinion, it's not just about learning how to use information, but rather about ensuring that the information is made available to all parties involved in ICOM. The control of information flow within, between, and from government departments, is a core potential ICOM barrier that needs research and attention.

Does this book merit the attention that the title promises? I feel that it has a considerable amount of useful concepts, perspectives, and case studies that most marine scientists and decision-makers will benefit from. However, as with most books that are made up of a collection of review-style conference and invited papers, it does not provide a complete picture of ICOM. There is a predominance of offshore ocean-related aspects with minimal content on the coastal situation where marine-land interactions make policy interfacing even more complex. It is a pity that the book has not been able to accommodate reviews of some key topics such as ICOM indicators, government structures, and formal evaluation approaches. The book does not make easy reading with many long detailed chapter introductions and paragraphs with considerable overlap and repetition. Nonetheless, most chapters can be viewed as stand-alone and thus the reader can be selective in coverage. It is not a cover to cover book for the time-constrained politician or decision maker who is looking for a quick recipe or silver bullet for solving any specific policy issue or approach. ICOM policy connoisseurs will find a wealth of perspectives, material and useful references; the book will be extremely useful in academia for undergraduate and postgraduate research students.

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NSIS COUNCIL

Reports from the Annual General Meeting, May 2016

AGENDA

155TH ANNUAL GENERAL MEETING

5 pm - 2 May 2016

The Great Hall, University Club
Dalhousie University, Halifax, NS

1. Minutes of 154th AGM, 2015
2. President's Annual Report. 2015-2016 (Pat Ryall)
3. Treasurer's Annual Report. March 31, 2016 (Angelica Silva)
4. Editor's Annual Report (Peter Wells and David Richardson)
5. Librarian's Annual Report, 2015-2016 (Michelle Paon)
6. Public Lecture Report, Lecture Program for 2016-2017 (Sherry Niven)
7. Student Science Writing Competition 2016 (Hank Bird)
8. Proposed new By-law 6 Pertaining to Honorary Membership (Sherry Niven, Hank Bird)
9. Webmaster's Report (Suzuette Soomai)
10. Nominating Committee for 2016-2017 (Pat Ryall)
11. Any Other Business
12. Adjournment

NOVA SCOTIAN INSTITUTE OF SCIENCE

MINUTES OF THE 154TH ANNUAL GENERAL MEETING

4 May, 2015
Dalhousie University Faculty Club

Council Members present: Patrick Ryall (President), Michelle Paon (Librarian), Angelica Silva (Treasurer), Ron MacKay (Acting Secretary), Zoe Kirste (Student Representative, Dalhousie University), Richard Singer, John Young

Members present: Robert Cook, Chris Corkett, Ann Mills, Eric Mills, Carol Morrison, Sherry Niven, David Richardson, David Richey, Matthew Richey

Others present: Laura Bennett (Observer, Nova Scotia Museum), Victoria Turpin

Regrets (Council Members): Jason Clyburne (Vice President), Kelly Abbott (Secretary), Hank Bird (Coordinator of the Student Science Writing Competition), Suzette Soomai (Webmaster), Peter Wells (Editor of the *Proceedings*)

The President welcomed members and called the 154th Annual General Meeting (AGM) to order. It was noted that the reports, excluding the minutes from last year's AGM, would be passed as a unit at the end of the presentations.

1. **Approval of the Minutes of the 153rd Annual General Meeting of 5 May, 2014**
   Motion to accept the minutes of the 153rd AGM:
   Moved: Michelle Paon
   Seconded: Ron MacKay
   All in favour: Carried

2. **President's Annual Report (Patrick Ryall)**
   The President referred to the attached report.

   The President thanked Council members for their contributions in 2014-2015.

The President described a successful series of Public Lectures in 2014-2015. The theme for this series was interactions between humanity and the Earth. Eight lectures were delivered and generally well-attended. In keeping with the philosophy that the NSIS should promote science throughout the province, two lectures were at venues other than the Nova Scotia Museum of Natural History, Halifax. On 3rd November at Acadia University, Wolfville, Dr. John Shaw (Geological Survey of Canada) spoke on post-glacial changes in sea level in Atlantic Canada. This talk attracted a large audience (>100) and its success encouraged Council to plan a lecture for Wolfville in 2015-2016. Unfortunately, a lecture by Dr. Shannon Sterling (Dalhousie University) on the global water cycle, scheduled for 2 February, 2015, had to be cancelled. To make up this loss in the schedule, we asked Dr. Gordon Fader (Geological Survey of Canada) to speak on *The Shipwrecks of Halifax Harbour and Approaches*. A large audience (~90) attended Dr. Fader's talk in the Helen Creighton Room of the Alderney Gate Public Library, Dartmouth, on 16 March 2015. Some interested persons had to be turned away. The President thanked the members of the committee that organized the 2014-2015 Public Lecture series: Carol Morrison, Ron MacKay, Michelle Paon, Tom Rand and John Young. Patrick chaired this committee.

The NSIS supported three conferences in 2014-2015: the *Maury Conference on the History of Oceanography*, 14-15 June 2014, Kings College, Halifax; the *Coastal Zone Canada 2014 Conference* and the BOFEP *Bay of Fundy Science Workshop*, 15-19 June 2014, World Trade and Convention Centre, Halifax; and the *Sable Island Conference 2015 – The Science and History of Sable Island*, 1-2 May 2015, Kings College, Halifax. Financial support was provided for all three conferences and members of Council participated in the organization of the *Maury* and *Sable Island* conferences.

In 2014-2015, the NSIS donated a prize of $150 to each of ten science fairs in Nova Scotia.

In 2014-2015, a committee (Hank Bird, Zoe Kirste, Michelle Paon, Pat Ryall, Peter Wells) was established to plan scientific/cultural excursions for NSIS members in summer 2015.

Former member of Council and past editor of the *Proceedings* Dr. Alan Taylor bequeathed $15,000 to the NSIS for support of the NSIS library. We have obtained permission from Dr. Taylor's estate to use these funds to augment the holdings of scientific books in provincial libraries. Two-thirds ($10,000) of the bequest has been placed in a short-term investment. Laura Bennett (NS Museum) is negotiating a donation of $5,000 (as funds or purchases) with the Nova Scotia Provincial Library.

The President concluded with remarks on finances and the future of the NSIS. The NSIS is financially secure but we need new members, particularly young members, to fulfil our mission to support science in Nova Scotia. We are fortunate to have Zoe Kirste (Dalhousie University) and Nicole LeBlanc (Mount Saint Vincent University) as new Council members and Publicity Officers for 2015-2016. We anticipate that Zoe and Nicole will bring the NSIS to the attention of the many young scientists and other persons interested in science, nature, engineering and technology that reside in our province. However, an active drive is needed to increase the membership rolls and, at present, we have no Membership Officer, despite the provisions of our by-laws.

The President called on members of Council to present their reports.

3. Treasurer's Annual Report (Angelica Silva)
The Treasurer referred to the attached report.

The NSIS has 104 members: 74 regular, 9 life, 4 student and 17 institutional. Dues received in 2014-2015 totalled $3,310.

As of 31 March 2015, the net worth of the NSIS was $70,196.23: $8,586.91 in cash and $61,609.32 in investments maturing as late as 1 February 2018. Details on investments are provided in the Treasurer's report.

In 2014-2015, expenses were greater than revenue in the amount $160.71. Total revenue for 2014-2015 was $7,878.93. After dues, the largest revenue items were fees for the 2014 AGM dinner ($1,440), sales of publications ($1,316.50) and a grant from the Nova Scotia Department of Communities, Culture and

Heritage ($1,000). Total expenses for this period were $8,039.74. The largest expenditures were for the support of lectures, conferences, science fairs and the writing competition ($3,750), the AGM dinner ($1,874.44) and for mailing of the *Proceedings* ($1,326.82).

Michelle Paon suggested an error in the expenses reported for printing and advertisement. The Treasurer agreed to investigate and respond to Council at the next meeting.

4. Editor's Annual Report (Peter Wells)
On behalf of the Editor, The President referred to the attached report.

Volume 48 (1) of the *Proceedings of the Nova Scotia Institute of Science* was published in March 2015. This volume included a history of the NSIS by Dr. Suzanne Zeller as presented in a talk (co-sponsored by the NSIS and the Royal Nova Scotia Historical Society) at Kings College, Halifax, 21 November 2012.

The NSIS intends a special volume of the *Proceedings* for papers presented at the *Sable Island Conference 2015* that was held at Kings College, Halifax, 1-2 May 2015. Peter Wells and Dr. Martin Williston (Dalhousie University) will be co-editors of this volume.

Members of the NSIS and scientists in the region are encouraged to submit to articles of original research, reviews of Maritime scientific accomplishments and viewpoints on current scientific issues to the Editor.

5. Librarian's Annual Report (Michelle Paon)
The Librarian referred to the attached report.

Michelle Paon (Dalhousie University), oversees the receipt of journals from exchange partners around the world and works with her colleagues at the Killam Library to deposit these journals, manage printed issues and facilitate access to the online version of the *Proceedings of the NSIS*.

Open Journal Systems software is now being used by Dalhousie as the online publication platform for new issues of the *Proceedings*. *Volume 48 (1)* was published in this way in April 2015. Members have exclusive access to new issues for six months after publication.

The NSIS has 85 exchange partners (two less than in 2014), only seventeen of which have submitted IP-addresses for the receipt of access to the online version of the *Proceedings of the NSIS*.

In 2014-2015, sales of special issues of the *Proceedings* (18 copies of each of the *Birds of Brier Island* and the *Flora of Nova Scotia*) yielded $1,080. Copies of the *Birds of Brier Island* have been placed on consignment at two stores in Halifax.

The NSIS received $642.37 from *Access Copyright* as the 2014 repertoire payment to publishers.

The Librarian noted that NSIS Council has approved the discard of aged and fragile journals received from exchange partners for which online versions are available without charge. This project is ongoing at Dalhousie. New printed issues of exchange journals continue to arrive (114 were received from May 2014 to March 2015). Michelle thanked Carol Richardson and staff at the Killam Library for their work in processing these journals.

6. **Lecture Program for 2015-2016 – report of the organizing committee (Jason Clyburne)**
   As Vice President Clyburne was unable attend the AGM, the program of Public Lectures for 2015-2016 was not discussed.

7. **Proposed Excursions for 2015-2016 (Hank Bird)**
   As the coordinator of excursions for 2015-2016 was unable to attend the AGM, this item was not discussed.

8. **Student Science Writing Competition (Hank Bird)**
   As the coordinator of the science writing competition was unable to attend the AGM, this item was not discussed.

9. **Change to NSIS by-law 11 Regarding Membership Fees**
   The President referred to the attached document regarding NSIS *by-Law 11*. This document proposes the complete replacement of the current *by-law 11* with a new text that (11a) defines the annual period of membership as 1st September to 31st August, (11b) establishes that the membership fees include payment for publications, (11c) requires notice of changes in membership fees be given 14 days before the Annual General Meeting, (11d) establishes due

dates for fees, (11e) directs that invoices and receipts for individual membership fees be issued by e-mail unless a member requests postal service, and (11f) establishes that membership cards be issued with receipts for membership fees.

These changes to *by-Law 11* were prepared by Hank Bird and approved by Council in 2014-2015.

Motion to accept the proposal to change NSIS by-law 11:
Moved: Michelle Paon
Seconded: Ron MacKay
All in favour: Carried

10. NSIS Sponsorship of Local Scientific Events

The President referred to the attached document regarding *Guidelines for Responding to Requests for NSIS Support*. This document confirms that support for science-related activities organized by other parties or in collaboration with the NSIS is consistent with established principles and practices of the NSIS. Furthermore, Council should be guided by the following: (1) that the NSIS should budget for the support of ten Nova Scotian science fairs per year in the amount of $200 per fair; (2) that prizes for the annual Student Science Writing Competition be $500 and $750 for the undergraduate and graduate prizes, respectively; (3) that the annual Sable Island Report be supported in the amount $250; and (4) that support for *ad hoc* requests be limited to $500 per request and $3,000 in total per year. These guidelines include a list of activities (including specific examples) which have received support from the NSIS. *Ad hoc* requests made from September to April are to be considered immediately following meetings of Council; requests made from May to August are to be circulated by the President to Council by e-mail with final decisions by the President.

These guidelines were prepared by Hank Bird and approved by Council in 2014-2015.

Motion to accept the proposed guidelines for NSIS sponsorship:
Moved: Zoe Kirste
Seconded: Richard Singer
All in favour: Carried

11. Report of the Nominating Committee for the 2015-2016 Council (Pat Ryall)

The President (as Chair of the Nominating Committee) referred to the attached report.

The Nominating Committee is asking the AGM to elect the following to NSIS Council for 2015-2016:

President	Patrick Ryall
Vice President	Sherry Niven
Secretary	Kelly Abbott
Treasurer	Angelica Silva
Publicity Officers	Zoe Kirste and Nicole LeBlanc
Librarian	Michelle Paon
Editor	Peter Wells
Webmaster	Suzette Soomai
Councillor	Hank Bird
Councillor	Victoria Turpin
Councillor	Ron MacKay
Councillor	Donald Stoltz
Councillor	Rick Singer
Councillor	John Young

Thomas Rand (**President** 2014-2015) has kindly agreed to serve as **Past President** in 2015-2016.

The Nominating Committee was unable to nominate a **Membership Officer**.

Motion to elect to Council 2015-2016 the persons nominated:
Moved: Patrick Ryall
Seconded: John Young
All in favour: Carried

12. Any Other Business

The President recommended the acceptance of the reports submitted at this AGM excepting the Treasurer's Annual Report.

Moved: Patrick Ryall
Seconded: Angelica Silva
All in favour: Carried

A member of the audience asked whether we were turning away attendees at the Public Lectures. Have we exceeded the capacity of the auditorium at the Museum of Natural History? The President responded that while some lectures in 2014-2015 were very popular, we have not had to turn away potential attendees at the Museum of Natural History.

David Richardson invited members to pick-up copies of the new issue of the *Proceedings* at the conclusion of the AGM.

The President invited all present to enjoy the Public Lecture after the AGM on *Crop Responses to Multiple Components of Climate Change* by Dr. Mirwais Qaderi (Mount Saint Vincent University).

13. Adjournment

The 154th Annual General Meeting of the NSIS adjourned at 7:00 PM.

Respectfully submitted
Linda Marks
Secretary

REPORTS FROM THE NSIS COUNCIL NOVA SCOTIAN INSTITUTE OF SCIENCE

PRESIDENT'S REPORT 2015-2016

I would like to take this opportunity to thank Council members for their helpful collaboration during the past year – you've been a great group to work with, and thank you for putting up with me.

Public Lectures

This year's lecture series covered a wide range of topics from the study of offshore Nova Scotia, which has revealed features ranging from the imprint of ice sheets to an asteroid impact crater, to the interactions between people and the air, soil and water we depend on. For the second year we had our November talk at the Irving Centre at Acadia University in Wolfville. This was well attended with extensive questioning by the audience, which was not a surprise given that the topic was fracking.

Thanks to the organizing committee that put this series together (Jason Clyburn, Carol Morrison, Ron MacKay, Michelle Paon, Tom Rand, John Young and myself).

Also, we were involved in organizing the public talk of Nobel Prize winning Dr. Arthur McDonald.

Sponsorships

NSIS provided support for various activities since our last AGM:

Fishermen and Scientists Research Society Conference

NSIS provided sponsorship through a donation for the prize for the best student poster at the Conference.

Nova Scotia Regional Science fairs

NSIS continues to support 10 Regional Science fairs by giving a $150 prize for each fair.

Student Science Writing Competition

I'd like to thank Hank Bird for continuing to organize this competition – I'll leave it up to him to talk about the results.

Excursions

As a result of our survey we decided to go ahead with an excursion to Joggins and the Fundy geological Museum and an excursion to McNab's Island. However the person who was going to lead the trip around Joggins had committed to running a trip around Wasson Bluff with the Dalhousie Science Alumni so we combined with them and added a meal at the Ottawa House for NSIS participants. Similarly, we took part in a tour of McNabs Island run by the Friends of McNabs Island.

Dr. Alan Taylor's bequest

Dr. Alan Taylor left a bequest of $15,000 for the NSIS library. Council has had extensive discussions on what to spend this money on and over what period of time. We considered using this money to get popular scientific books into public libraries in the province and we did get approval from Dr. Taylor's estate. We have decided to donate $5,000 per year to the regional libraries throughout the province. The books purchased for the public libraries will have a bookplate recognizing NSIS and Dr. Taylor's contribution. The cheques and bookplates were mailed out on April 22nd.

Honorary Memberships

This year two people came to our notice for their achievements: Dr. Arthur McDonald, who was born and educated in Nova Scotia, who won the Nobel Prize in Physics, and Dr. Mary Anne White, a long time NSIS member and former President, who was appointed an Officer of the Order of Canada. Using our current By-Laws we have made Mary Anne an Honorary Member – she is the only one. I met with her and gave her a letter informing her she was now an Honorary Member. She was very pleased and has sent me a letter expressing her sincere thanks to the NSIS Council and giving NSIS best wishes for continued success in representing and presenting science to Nova Scotians.

We are proposing changes to the By-Laws so that it would be possible to award an Honorary Membership to Dr. McDonald, and perhaps to others in, or from, Nova Scotia, who have made outstanding scientific contributions.

The Future

The NSIS continues to be financially secure, but we are in a time when much is changing. We have a greying membership and need to reach out and get more young people involved. Last year we revised

Membership By-law in order to clarify the time of membership and provide a membership card which will allow us to develop exchange programs with other organizations. I'm pleased to say we had two young women, Zoe Kirste and Nicole LeBlanc, who worked together as Publicity Officers to reach out through the evolving social media to a broader audience. Unfortunately Zoe has had to step down due to other responsibilities, but I am pleased to say Nicole will continue her excellent work. We are also fortunate to have Ilya Kovalko as Membership Officer, our first one in many years. I would like to take this opportunity to thank Michelle Paon who, while officially being our Librarian, has worked above and beyond the call of duty. I also thank Ron MacKay who has filled in as Secretary on several occasions when Linda was not able to be at our meetings.

Finally, thanks again to all Council members. It has been a pleasure working with you and I look forward to continuing our work in the future as we seek to expand NSIS's outreach.

Respectfully submitted
Patrick Ryall, President

TREASURER'S REPORT

NOVA SCOTIAN INSTITUTE OF SCIENCE

March 31, 2016

ASSETS:	
Bank Account BMO (as of March 31, 2016)	6,588.15
Investments (value on February 29**, 2016)	62,777.09
TOTAL ASSETS:	**$69,365.24****
LIABILITIES AND NET WORTH	
Accounts Payable	
NET WORTH	
TOTAL LIABILITIES AND NET WORTH	**$69,365.24****
INVESTMENTS (as of March 31, 2016)	
Renaissance High Interest Savings Account (February 29, 2016) @1.0%	16,777.09
Manulife Bank Investment Certificate @2.45% due February 1, 2018	21,000.00
Equitable Trust Company GTD investment @2.15% due May 16, 2017	5,000.00
CIBC Full Service GTD @1.5% due February 02, 2017	10,000.00
HomeTrust CO GTD investment @2.1% due July 15, 2016	10,000.00
TOTAL INVESTMENTS (as of February 29, 2016)	**$62,777.09****

NOVA SCOTIAN INSTITUTE OF SCIENCE
REVENUES AND EXPENDITURES 2014-2015

REVENUE as of March 31, 2016	
Membership Dues	
Regular, students LIFE and institutions	$2,660.00
AGM dinner (May 2015)	1,035.00
Sales NSIS Proceedings, Birds of Brier Island, Flora NS	890.91
Nova Scotia Grant	0
Donations	0
Income/Royalties Access copyright Royalty	476.15
BMO Bank Interest	0
TOTAL REVENUE	**$5,002.06**
EXPENSES	
Proceedings PNSIS, print brochures, lecture posters)	$3,109.46
Mail PNSIS cost	257.05
AGM (2015) (dinner, lecturer accomod)	1,307.21
Lecture Sponsorship, NSIS Writing, Science Fairs	2,000.00
Rent MNHNS and Chebucto Net website	247.00
Supplies office, postage (membership, CRA)	74.90
Bank cost of printing History	5.20
TOTAL EXPENSES	**$7,000.82**

Finances

The net worth of NSIS is $69,365.24 as of March 31, 2016, though it would be slightly higher as an update on investments has not been received from CIBC Gundy yet.

For this 2015-2016 period, NSIS had a total income of $5,002.06 that resulted from Membership dues $2,660 [regular (68), students (5), LIFE Membership (12), Institutional memberships (16)]; Sales of NSIS Proceedings, Flora of Nova Scotia and Birds of Brier Island publications $830.91; Copyright Royalties $476.15; and AGM dinner registrations for $1,035.

Total expenditures of $7,000.82 were the result of: Printing Proceedings of Nova Scotian Institute of Science and Annual NSIS Lecture Brochures $2,060.38; Postage for PNSIS mail out $257.05; Printing of monthly Lecture Posters and Word on the Street participation $ 505.66; AGM dinner costs $1,307.21; contribution to Sable Island Round Table $750; contribution to ten Regional Science Fairs $1,250 (not all cashed yet). Other expenditures did include Museum (MNHNS) rental $177; Website with Chebucto Net $70; office supplies $74.9 and BMO charges $5.20.

Membership and Projected Budget

NSIS had 85 individual members (68 regular; 5 Students and 12 Life Members), and 16 institutional memberships.

A projected Budget for 2016/2017 shows a projected income of Revenue of $13,094.40 and includes transference from investments of ($6,788.40) to cover $5000 contributions to regional Libraries as per Dr. Taylor bequest to NSIS.

Projected expenses of $15,138.75 will be higher than in recent years as NSIS Student writing competition did result on 2 awards, an Undergraduate Student – YongHong (Peter) Chen for $500 and to a Graduate Student Carolyn Wilson for $750, that are paid after 2015-2016 financial year. Funding to Regional Libraries from Dr Taylor's bequest have been sent to Regional libraries at Annapolis Valley ($538); Cape Breton ($567); Colchester East Hants ($398); Cumberland County ($164); Eastern Counties ($180); Halifax Regional ($2,198); Pictou Antigonish ($346); South Shore ($309) and Western Counties ($299) and is included in projected budget. Updates to website are projected at $1200. Continuation of funding to School Science Fairs, lectures and student posters competitions will continue.

To cover extra costs this upcoming year, NSIS Council could consider re-investing $7,000 from a $10,000 GTD investment that matures on July 16, 2016 and to transfer $3,000 to the Bank account to cover update of website, printing of proceedings, annual brochures, and monthly posters.

Respectfully submitted to NSIS AGM 2015-2016 on May 2nd, 2016.

Angelica Silva, NSIS Treasurer
Angelica.silva@dal.ca
Halifax, Nova Scotia May 2nd, 2016

EDITOR'S REPORT

NSIS ANNUAL GENERAL MEETING
May 2nd, 2016

PNSIS Volume 48 (2) 2016 was published in April and has two parts. As usual, there is an editorial, a number of contributed scientific papers, and in this issue, two very interesting historical papers on the lives of two distinguished scientists, Leo Vining and Bill Ford, who were past NSIS members. As well, there is a commentary piece on data transparency and openness, introducing the need to have access to the data behind the scientific papers published in the Proceedings.

This Issue is distinguished with a special section on Sable Island, based on the Sable Island Conference that was held in Halifax on May 1-2nd, 2015. NSIS was a co-sponsor of the Conference with the Friends of Sable Island and the School of Resource and Environmental Studies, Dalhousie University. The papers were solicited by the Conference Chair, Dr. Martin Willison (Dalhousie Univ.), from the conference speakers and went through the usual PNSIS review process. Martin is thanked for his special efforts preparing this special section and writing the introduction to it, along with April Hennigar, Chair of the Friends of Sable Island. Zoe Lucas of Sable Island and the Green Horse Society assisted with the selection of photos for the Issue. The Friends of Sable Island have purchased copies for their membership and are thanked for their support of the printing. It was a pleasure and privilege working together on the conference and this Issue and hope we can collaborate again in the near future.

The printed copy of the new Issue is available for NSIS members and is available for sale. The Issue will be on the website for members and will be open access after six months. All of the Editorial Board are thanked for their work on this Issue, as well as Gail LeBlanc (long standing Copy-Editor of PNSIS), and staff of the Killam Library and Suzuette Soomai (Webmaster) for assistance with electronic storage through DalSpace and on the website. Lastly, we thank all of the authors for their contributions and their patience with the publication process.

As stated in past reports to the AGM, members of NSIS and scientists across the region are encouraged to submit papers based on their original research or expert knowledge of Maritime science.

Review papers and commentaries are also welcome. Additional papers or extended abstracts are being solicited from the speakers at our monthly meetings. We always need more papers, long or short, on these talks as they represent an excellent cross-section of regional science.

Respectfully submitted by:
Peter G. Wells, Dalhousie University, Editor
David H. S. Richardson, Saint Mary's University, Associate Editor
May 2nd, 2016

LIBRARIAN'S REPORT 2015-2016

Prepared for AGM May 2, 2016

It has been a pleasure to serve as the NSIS Librarian during the past year. In this role, I oversee the receipt of journals from NSIS exchange partners around the world. I also work with Killam Library staff members who prepare these journals for the shelves and facilitate access to the online *Proceedings of the Nova Scotian Institute of Science*.

Proceedings of the Nova Scotian Institute of Science

Sales

During 2015/2016, sales of the *Proceedings* generated $916.46 in revenue. Please see Appendix A (attached) for details. Of note, fifteen copies of the *Flora of Nova Scotia* were sold, and sixteen copies of the *Birds of Brier Island* were sold. Among the latter were a number of copies sold on consignment at retail outlets – two at Bookmark bookstore on Spring Garden Road and five at Atlantic News on Morris St. (At the store manager's request, the consignment at Atlantic News has come to an end.)

Institutional Members and Exchange Partners

Renewal notices were sent to institutional members in January 2016. There are currently 16 institutional members (one less than last year). There are currently 85 NSIS exchange partners (same number as last year).

Access Copyright

The NSIS Librarian submitted the required forms to Access Copyright for the 2015 repertoire payment to publishers. NSIS subsequently received a payment of $476.15. On September 8th, Editor Peter Wells signed a new and updated Access Copyright agreement, which ensures that royalties from the copyright collective will continue to be sent to NSIS for use of the *Proceedings*. The language of the agreement now reflects the changing online information environment.

Abstracting Services

The NSIS Librarian responded to a request from Zoological Record (abstracting service) to provide print copies of the Proceedings for indexing purposes. The Librarian also contacted Biological Abstracts, GeoRef and CAB Abstracts to confirm that these abstracting services have received all issues of the Proceedings. NSIS has informed the services that all issues of the Proceedings are now available online, and offered them the opportunity to provide their IP addresses to receive immediate access to new issues.

External Links to the Online *Proceedings*

NSIS members may be interested to know that part of the Nova Scotia Archives website now links to the online *Proceedings of the NSIS*. The Archives have created an online exhibit entitled “Harry Piers: Museum Maker” (novascotia.ca/archives/Piers/default.asp) to commemorate one of the early curators of the Nova Scotia Museum. Harry Piers was also a former president of the Nova Scotian Institute of Science (1934-1936) and a long-time member of the Institute. He authored more than twenty articles published in the *Proceedings*. The NSIS Librarian asked that a link be placed on the exhibit webpage to lead viewers to the Piers articles that are digitized and located in DalSpace. On November 17th, Provincial Archivist Lois Yorke confirmed that the link to the articles had been added to the following webpage: novascotia.ca/archives/Piers/harrypiers.asp.

NSIS Exchange Journal Collection

NSIS receives journal issues from exchange partners around the world. As an example, from May 2015 to March 2016, 118 journal issues and society publications were delivered to the Killam Library from the Institute’s exchange partners. These items have been processed and added to the NSIS collection in the Killam Library. On behalf of NSIS, I would like to thank Carol Richardson and the Serials Department staff in the Killam Library who process the exchange journals and make them shelf-ready.

Respectfully submitted by:
Michelle Paon
NSIS Librarian
May 2, 2016

Appendix A: Sales of Proceedings, May 2015 – April 2016

Date	Volume/Issue of Proceedings of the Nova Scotian Institute of Science	# Sold	Price	Amount Received ($)
May 2015	Birds of Brier Island	1	$10.00	$10.00
May 2015	Proceedings (v.47, pt. 1, 2012)	1	$10.00	$10.00
May 2015	Birds of Brier Island	1	$25.00	$35.00*
May 2015	Birds of Brier Island	1	$25.00	$53.96**
July 2015	Birds of Brier Island	1	$35.00	$35.00
July 2015	Flora of Nova Scotia	4	$35.00	$140.00
July 2015	Birds of Brier Island	2	$15.00	$30.00
July 2015	Flora of Nova Scotia	10	$35.00	$350.00
September 2015	Birds of Brier Island	2	$25.00	$50.00
November 2015	Birds of Brier Island	5	$17.50	$87.50
November 2015	Birds of Brier Island	2	$25.00	$50.00
January 2016	Birds of Brier Island	1	$25.00	$30.00*
April 2016	Flora of Nova Scotia	1	$35.00	$35.00
Total		32	---------	$916.46

* Amount paid/received includes shipping and handling fees.
** Purchaser sent cheque in the amount of $45.00 in US funds, including shipping and handling. [Currency exchange rate on May 15, 2015: US $1.00 = CDN $1.1992]

NSIS 2016-2017 PUBLIC LECTURES

The lecture series committee confirms the following line-up for the 2016-17 series. Titles and abstracts will be available by mid-May. (Editor: The final titles follow the ones proposed at the time of accepting to give a lecture.)

October 3, 2016 – **Jock Murray**, Dalhousie University, on Multiple Sclerosis (**Changing knowledge about Multiple Sclerosis over two centuries: From leeches to the human genome**).

November 14, 2016 – **Stephanie MacQuarrie**, Cape Breton University, on use of biochar by farmers as a more sustainable model for energy production (**Reaping Unsown Rewards from Biochar**).

December 5, 2016 – **John Archibald**, Dalhousie University on Molecular clocks: using DNA to infer evolution (**Molecular clocks: Using DNA to infer evolution**).

January 9, 2017 – **Hilary Moors-Murphy**, Bedford Institute of Oceanography, on whale communication (**Listening in on the deep: the story that whale sounds can tell**).

February 6, 2017 – **Graham Dellaire**, Dalhousie University, on how to edit a genome (**How to edit a genome**).

March 6, 2017 – **Danielle Cox**, Mount Saint Vincent University, on Math in the everyday world (**That's Math**).

April 3, 2017 – **Shashi Gujar**, Dalhousie University, on oncolytic viruses (**Oncolytic viruses**).

May 1, 2017 – AGM Lecture – **Tara Imlay**, Dalhousie University, on declining bird populations (**Where have all the swallows gone?**).

Sherry Niven
Chair of 2016-17 NSIS Lecture Committee,
and Vice President, NSIS

STUDENT SCIENCE WRITING COMPETITION 2016

May 2016 Report for the AGM

A record total of 47 students expressed intent to submit manuscripts, and in the end a record 22 students submitted papers – 14 undergraduates and 8 graduates (see Figures).

The 10 Judges (Stuart Grossert, Ilya Kovalko, Tom Rand, John Rutherford, Pat Ryall, Rick Singer, Don Stoltz, John Young, and I) each read between 8 and 22 manuscripts. We then met and reached our decisions, which were:

Winner (Undergraduate)
Yonghong (Peter) Chen of Acadia University, for his paper
"Estimage: A Mobile Application for Image to Object Count Estimation"

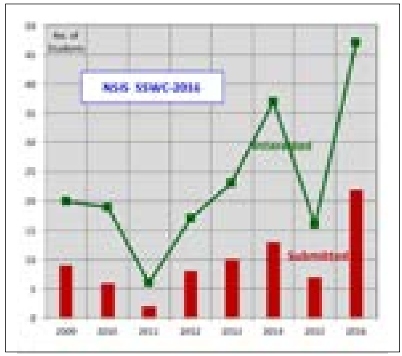
Honourable Mention (Undergraduate)
Rylee Oosterhuis of Acadia University, for her paper
Collateral Effects of Volatiles Introduced Into Honey Bee Colonies for Varroa Destructor Mite Management"

Winner (Graduate Student)
Carolyn Wilson of Dalhousie Univesity (Agriculture), for her paper
*"'The New Kid on the Block': Monitoring and Managing Spottedwing Drosophila (*Drosophila Suzukii*), an Invasive Pest of Nova Scotia Lowbush Blueberries"*

Cheques ($500 for the undergrad. winner and $750 for the grad. winner) and certificates have been distributed to these students.

The judges are working on a number of improvements in the Information for Authors, and in the judging process. Thanks again to all the judges for their work and wisdom.

Univ.	Interest	Submitted
Acadia	5	3
CBU	1	0
Dalhousie	32	16
MSVU	1	0
SFX	2	0
SMU	6	3
Total =	47	22



Hank Bird
SSWC Coordinator

PROPOSED NEW BY-LAW 6
PERTAINING TO HONORARY MEMBERSHIP

The President proposed to Council that By-Law 6 be revised to allow for election of nonmembers to honorary membership in the NSIS.

The current ByLaw 6:
Any member distinguished in some branch of science or who has rendered conspicuous service to the advancement of science in Nova Scotia, or to the affairs of the Institute, is eligible for nomination and election as an honorary member. Nominations must be submitted to the Council in writing, be signed by three (3) members in good standing, and be accompanied by a document presenting the reasons for awarding the honour. Election of candidates shall require the support of a majority of Council members.

The proposed revision of ByLaw 6:
Any Nova Scotian distinguished in some branch of science or who has rendered conspicuous service to the advancement of science, or to the affairs of the Institute, is eligible for nomination and election as an honorary member. For the purposes of this bylaw, a Nova Scotian is defined as someone who was either born in Nova Scotia or who conducted a substantial part of the work for which the honour is being conferred while resident in Nova Scotia. Nominations must be submitted to the Council in writing, be signed by three (3) members in good standing, and be accompanied by a document presenting the reasons for awarding the honour. Election of candidates shall require the support of a majority of Council members.

Motion to accept the proposed revision of By-Law 6
Moved: Sherry Niven
Seconded: Hank Bird
All in favour: Carried

WEBMASTER'S REPORT

AGM Meeting, May 2016

1. General Maintenance of the Website

The current NSIS website was designed in 2013. Re-designing the website using the latest WordPress software will update the look and functions of the site and enhance the security of the site. The new website will facilitate and complement the promotional work of the NSIS, e.g., social media and membership payments.

Mr. Lee Wilson, Dalhousie University, will be redesigning the website over the period July-August 2016.

Action Needed: Council is being asked to approve an honorarium of $1,200 to Lee Wilson for redesigning the NSIS website.

2. Maintenance

General maintenance and updates to the website were completed over the year October 2015-April 2016.

Submitted by
Suzuette Soomai, Webmaster

THE NOMINATING COMMITTEE REPORT

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Authors are encouraged to submit illustrations and line drawings in colour. Colour version will be in the e-copy, while black and white in print version.

Please refer to more recent issues of the Journal for general layout of papers. Pages of the electronic submission should be numbered. Authors may also include line numbers.

Please indicate running head of paper.

The title should be followed by names, addresses with e-mails of all authors. A footnote with an asterisk and worded: * Authors to whom correspondence should be addressed with the appropriate email address should be placed at the bottom of the first page of the manuscript.

An abstract of up to 200 words should follow. As appropriate, sections devoted to introduction, methods, results, discussion, conclusions and references should be included. Canadian spelling and SI units should be used wherever possible.

Latin or *scientific* names should be in italics as well as abbreviations like *et al*.

There should be a list of not more than five keywords after the abstract.

All tables, figures, photographs and illustrations should have a title and a self-explanatory legend, sent in separate files at 300 dpi or higher. Not to be embedded in the working document but the authors may indicate where each might be placed in the manuscript.

References are to be in alphabetical order – name first, initials after, with no space between initials. Give full title of the journal and issue numbers where appropriate, thus:

Nielsen, K.J., & France, D.F. (1995). The influence of adult conspecifics and shore level on recruitment of the ribbed mussel *Geukensia demissa* (Dillwyn). *Journal of Experimental Marine Biology and Ecology* 188 (1):89-98.

Cushing, D. & Walsh, J. (1976). The Ecology of the Seas. W. B. Saunders Company, Toronto.

Lee, G.F. (1975). Role of hydrous metal oxides in the transport of heavy metals in the environment. In: Krenkel, P.A. (ed.), Heavy Metals in the Aquatic Environment. Pergamon Press, Oxford, pp. 137-147.

References cited in the text should be separated by commas. See present issues for examples.

Personal Communication: Smith A.J. (2001, pers. comm.) in text.

Website Citation: Author (year) title, URL and date accessed.

Authors are responsible for correcting and electronically returning proofs promptly. Authors will be provided with a PDF of their paper, free of charge. NSIS members are able to access the Proceedings as soon as published as part of their annual membership. All new issues become open access after a six months embargo. A limited number of each issue will continue to be printed for members and other interested parties. Copies of any Special Issues of the NSIS proceedings published in hard copy may also be purchased from NSIS at a charge established by the NSIS. See the NSIS website nsis.chebucto.org/ for details.

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Les auteurs peuvent soumettre leur manuscrit en anglais ou en français et doivent l'envoyer sous forme numérique avec un fichier provenant de Word au rédacteur en chef (nsis@dal.ca et oceans2@ns.sympatico.ca). La soumission d'un manuscrit indiquera que les recherches décrites sont tout à fait originaux, c.-à-d. c'est le travail de l'auteur et n'a pas été publié avant, et n'est pas envisagé par une autre revue. Tous les auteurs d'un manuscrit doivent donner leur approbation avant de le soumettre. Pour les articles de synthèse, les auteurs qui désirent inclure des figures, des tableaux, ou des parties de texte déjà publiées ailleurs doivent obtenir la permission du (des) titulaire(s) de ces droits d'auteur, avant que le manuscrit soit soumis.

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Le titre du manuscrit doit être suivi des noms de tous les auteurs, leurs adresses respectives et leurs adresses de courriel. Une note infrapaginale précédée d'un astérisque (*Auteurs correspondants:) doit figurer au bas de la première page du manuscrit et doit etre suivie des adresses de courriel des auteurs correspondants.

Un résumé doit suivre qui comptera au plus 200 mots. Si approprié, il doit y avoir des sections tel que l'introduction, les méthodes, les résultats, la discussion, les conclusions et les références bibliographiques. Il est recommandé de se servir de l'orthographe canadienne-française et du Système international d'unités.

Les noms *latins* ou les noms *scientifiques*, ainsi que les abréviations (par exemple: *et al.*) doivent être écrits en italique.

Une liste de mots clés (contenant pas plus de cinq) doit suivre le résumé.

Chaque tableau, figure, photographie ou illustration doit porter un titre et une légende *auto-explicative* et doit être envoyé par fichier électronique de 300 ppp ou plus. Par explication hors du texte, les auteurs peuvent indiquer où chacune des images doit être située dans la mise en page.

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Cushing, D. & Walsh, J. (1976) The Ecology of the Seas. W. B. Saunders Company, Toronto.

Lee, G.F. (1975) Role of hydrous metal oxides in the transport of heavy metals in the environment. In: Krenkel, P.A. (ed.), Heavy Metals in the Aquatic Environment. Pergamon Press, Oxford, pp. 137-147.

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