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Cover photo credit: (Sierra Wehrell), Atlantic sturgeon, *Acipenser oxyrinchus* (Mitchell 1814), at an intertidal fishing weir in Minas Basin, near Walton, NS, July 2008.

Back cover inset photo credits: Top: Sea Raven, *Hemitripterus americanus* (Gmelin, 1789), collected at Cape Blomidon, Jan. 4, 1874 (M.J.Dadswell); Center Left: Plastics and discarded fishing rope, Gulliver's Cove, Bay of Fundy, June 2019. (P.G.Wells); Center Right: Double-crested Cormorants, *Phalacrocorax auritus*, on the Bird Islands, off Cape Breton Island, July 2019. (P.G.Wells); Bottom: Butterfish black, *Peprilus triacanthus*, found in an intertidal fishing weir, Bramber, NS, July, 2017. (M.J. Dadswell).

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EDITORIAL

Addressing the crisis in biodiversity – our role

Across the globe, academic publications and the news increasingly carry stories about the growing crisis in biodiversity, both in terrestrial and aquatic environments. Biodiversity, or *biological diversity*, is "the variety of life found in a place on Earth or, often, the total variety of life on Earth" (www.Britanica.com). Globally, since the RIO World Summit of 1992 and the signing of the Convention on Biological Diversity, the United Nations Environmental Programme (UNEP) has led on this issue and has worked with the Global Environment Facility (GEF) "to arrest the decline in biodiversity and conserve ecosystem services for the benefit of current and future generations" (www.unenvironment.org/resources/factsheet/biodiversity-factsheet). Lately, various UN committees in New York have addressed the impacts of overfishing in international waters (areas beyond national jurisdiction) and the impending effects of industrial deep sea mining on species and habitats little studied or as yet unknown. Importantly, UNEP's latest report, concerned about the rate of biodiversity loss, "emphasizes that countries need to bring biodiversity into the mainstream of decision making and factored into policies across all economic sectors" (www.unenvironment.org/resources/report/global-biodiversity-outlook-5-gbo-5). A good source of the latest information on global biodiversity is also found at the UN's Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (www.ipbes.net).

Other groups have been actively involved in addressing the status and decline of global biodiversity. The World Wildlife Fund has just released its latest Living Planet report (WWF 2020), describing the rapid decline in a number of species populations since 1970 and the global implications for the natural world, human health, and our economies. The IUCN (International Union for the Conservation of Nature) has documented the biodiversity decline over decades and in recent years; of late, almost one quarter of the assessed species are threatened with severe loss or extinction. This is attributed to human population pressure and the resulting demand for space and resources, pollution, and climate change. Most recently, the American Association for the Advancement of Science (AAAS) has highlighted the problem in an editorial, stating that "we are in danger of losing 80% or more of the world's species……..and have clearly entered the world's sixth major extinction event" (Raven and Miller 2020). Clearly, the problem is dire!

The IUCN recognized that "nature will recover if given half a chance", illustrated by some species being brought back from the edge of extinction (www.iucn.org/news/species/201912/species-recoveries-bring-hope-amidst-biodiversity-crisis-iucn-red-list). "W*hen governments, conservation organisations and local communities work together, we can reverse the trend of biodiversity loss"* (J. Smart, IUCN Biodiversity Conservation Group). In this spirit is the recent funding by Norway of mapping the worlds tropical forests, critical for assessing the Earth's species diversity and the role of forests in climate control (*BBC News*, 23-10-20); new insights about the recovery of marine ecosystems after conservation interventions (Duarte *et al.* 2020); and the role of social sciences and local communities in many aspects of coastal and ocean management (Manuel and MacDonald 2020, McKinley *et al.* 2020).

Bringing the biodiversity issue to public attention across the globe has been the role of many film makers, producing such television series as Nature and Nova seen on the US PBS channel. As with climate change, a large informed and concerned public will help convince politicians and policy makers to heed the importance of biodiversity and turn the situation around. Science has a key role here to provide reliable information and advice. Making this point has been the objective of the noted UK's David Attenborough, in his recent interviews, films and books.

Especially noteworthy and an engrossing read is his latest book, "*A Life on Our Planet*" (Attenborough and Hughes 2020). Attenborough provides a chronology of one person's observations of the dramatic changes to global ecosystems and species, and a template for how to arrest them over the next few decades. After a polemic on the problems, he describes a few actions that could be taken – switching to greener energy to arrest climate change and its broad effects on ecosystems, rewilding the oceans through establishing more protected areas and practising sustainable aquaculture, using land space within urban areas more efficiently, reducing deforestation, protecting more terrestrial wilderness, having so-called wildland farms (a mixture of agriculture and wild areas), introducing top predators into rural areas, and planning for the impact of 2-3 billion more people within the next few decades. These suggestions are general and may need to be modified for specific regions. The main message is that humans across the planet have to rethink their interactions with nature, reverse the course of habitat and species loss, and slow the increase in our population. This must be done within the next few decades.

In Canada, the many status reports that are on the Species at Risk Public Registry for 2020, prepared for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2019), attest to the fact that Canada is not doing well to protect its biodiversity, in spite of considerable effort. Action is needed on all fronts. This should include greater protection and conservation efforts in both marine and terrestrial ecosystems.

Thinking locally, what is the role of NSIS, its members, and the general public in Nova Scotia in the biodiversity issue? Nova Scotia has had a litany of biodiversity challenges for many decades. For example, the small population of mainland moose are of concern due to habitat alteration and loss, amongst other factors; they are considered endangered (Snaith and Beazley 2004, NSDNR n.d.). Freshwater turtles are often in the news too, due to concerns about the endangered Blanding turtles of SW NS; considerable conservation efforts continue for them, such as at Kejimkujik National Park. Other turtles (wood, snapping) may be at risk too. Sadly, our many roads continue to kill or injure countless small amphibians, reptiles and mammals.

However, it can be argued that the poster children of provincial biodiversity loss and needs are birds and whales. We need to think more about the fate of our songbirds and migratory shorebirds, many of which spend the winter thousands of km to the south and which continue to decline as a result of loss of their wintering habitat and the problems of migration in relation of more severe storms resulting from climate change (www.birdscanada.org; COSEWIC 2013a,b). Logging during the nesting season for newly arrived songbirds is a continued threat. For whales, the much diminished and endangered population of North Atlantic Right whales is in crisis with fewer than 366 individuals left and too few breeding females (Cooke 2020); in our waters, they formerly inhabited the outer Bay of Fundy in the summer months and now spend that period in the southern Gulf of

St. Lawrence (Gunn 2020), exposed to the pressures of ship strikes and entanglement with fishing gear.

The plight of the forest dwelling birds is connected to how we as citizens are looking after the land and the land-sea interface. The birds suffering the highest declines are the aerial feeders, such as swallows and swifts, and insect feeders such as flycatchers (Harding, G., pers. comm., Nebel *et al.* 2020). Large scale deforestation continues relentlessly around the clock in Nova Scotia, despite the 2-year old Lahey report on forest practices (Lahey 2018) and provincial government promises to redress the problem. The proportion of mature and old growth forest, where the greatest biological diversity occurs, continues to decline. To repeat, clear cutting occurs even during the spring nesting season for many songbirds, a huge concern due to its obvious impact and the blatant disregard for wildlife and the natural world shown by industry and government.

In contrast, on the positive side is the increasing effort and success of groups, such as the NS Nature Trust and the Nature Conservancy of Canada, amongst others, to conserve lands near Halifax, Cape Breton Island, south-west Nova Scotia and along the eastern shore, all of which offer habitat protection for wildlife and nature experiences for citizens. Our provincial biologists and ecologists work hard to document our fauna and flora and their population health. Many of our scientists, professional and amateur, contribute to the work of COSEWIC, documenting the status of species from lichens to mammals. That said, there needs to be more such recognition of the status and requirements of wildlife with which we share our province.

This Issue of PNSIS (51-1) features a research article by Dadswell and Rulifson (2021) on the fishes of Minas Basin in the upper Bay of Fundy, a highly diverse coastal ecosystem. Note the cover picture of the Atlantic sturgeon caught in a coastal weir; these magnificent ancient creatures still thrive, even under the pressures of fishing, river obstructions and general habitat deterioration (Bradford *et al.* 2016). In recent Issues, we also have had articles on species such as lichens (Cameron and Bayne 2020), endangered plants (Fancy *et al.* 2020), and biodiversity survey methods (Cameron 2019), to mention some of the scientific effort that contributes to provincial biodiversity conservation. The NSIS can initiate a number of actions to bring sustained attention to the need for biodiversity protection in our Province. These could include more lectures on the issue, focussed field trips to places where endangered species reside (e.g., Brier Island, Kejimkujik National Park, the Tobeatic Wilderness Area), and the encouragement of student projects and papers on wildlife and their needs. NSIS could also encourage and support more citizen science, by individuals and NGOs, to help monitor and document the status of critical habitats and species. NSIS could interact with other scientifically based groups on this issue and make concerns known to policy makers and legislators in the provincial government. Finally, the PNSIS always welcomes papers on any aspect of the biodiversity of provincial lands and waters, as shown by the above examples. Great conservation science will support great protection policies. It is hoped that NSIS members and our readers will pursue some of these activities to help protect and conserve the rich biodiversity of Nova Scotia.

Acknowledgements We thank Dr. Gareth Harding for his review of this article.

REFERENCES

Attenborough, D. & Hughes, J. (2020). A Life on Our Planet. My Witness Statement and a Vision for the Future. Grand Central Publishing, New York, Boston. 266 p.

Bradford, R.G., Bentzen, P., Ceapa, C., Cook, A.M., Curry, A., LeBlanc, P. & Stokesbury, M. (2016). Status of Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) in the Saint John River, New Brunswick. Canadian Science Advisory Secretariat (CSAS) Research Document 2016/072, Maritimes Region, Ecosystems and Oceans Science, Fisheries and Oceans Canada, August 2016. v + 55 p.

Cameron, R.P. (2019). Biodiversity survey method for detecting species of conservation concern in Nova Scotia protected wilderness areas and nature preserves. *Proceedings of the Nova Scotian Institute of Science* 50 (1): 165-180.

Cameron, R.P. & Bayne, D.M. (2020). Identifying lichen-rich areas in Nova Scotia. Proceedings of the Nova Scotian Institute of Science 50 (2): 227-231.

Cooke, J.G. (2020). "Eubalaena glacialis". IUCN Red List of Threatened Species. Version 2020-2. www.iucnredlist.org.

COSEWIC. (2013a). Assessment and Status Report on the Barn Swallow. wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/cosewic/sr_barn_swallow_0911_eng.pdf.

COSEWIC. (2013b).Assessment and Status Report on the Piping Plover. wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/cosewic/sr_Piping%20Plover_2013_e.pdf.

COSEWIC. (2019). Canadian Wildlife Species at Risk. wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/species/CanadianWildlifeSpeciesAtRisk-2019.pdf.

Dadswell, M.J. & Rulifson, R.A. (2021). A review of the fishes and fisheries of Minas Basin and Minas Passage, Nova Scotia, and their potential risk from tidal power development. *Proceedings of the Nova Scotian Institute of Science*, this issue.

Duarte, C.M., Agusti, S., Barbier, E., *et al.* (2020). Review. Rebuilding marine life. Nature 580: 39-51. April 2, 2020. doi.org/10.1038/s41586-020-2146-7.

Fancy, S., Lopez-Gutierrez, J.C., Walker, A.K., LaRue, D. & Browne, R. (2020). Evaluating out-planting success and mycorrhizal status of endangered Geum peckii Pursh (Rosaceae), the Eastern Mountain Avens, in Nova Scotia. *Proceedings of the Nova Scotian Institute of Science* 50 (2): 269-282.

Gunn, A. (2020). North Atlantic right whale now critically endangered. The Chronicle Herald, July 10, 2020. p.A5.

IUCN (International Union for the Conservation of Nature). (2019). The IUCN Red List of Threatened Species[T.] IUCN, Gland, Switzerland.

Lahey, W. (2018). An independent review of forest practices in Nova Scotia. Executive summary, conclusions and recommendations. University of King's College, Dalhousie University, Halifax, NS. 82 p.

Manuel, P. & MacDonald, B.H. (2020). Local governments and coastal communities are more than "Stakeholders" in marine spatial planning. *The Journal of Ocean Technology* 15(2): 136-137.

McKinley, E., Ascott, T. & Yates, K.L. (2020). Marine social sciences: Looking towards a sustainable future. *Environmental Science and Policy* 108: 85-92. doi.org/10.1016/j.envsci.2020.03.015.

Nebel, S., Casey, J., Cyr, M.-A. *et al.* (2020). Falling through the policy cracks: implementing a roadmap to conserve aerial insectivores in North America. *Avian Conservation and Ecology* 15(1): 23. doi.org/10.5751/ACE-01618-150123.

Nova Scotia Department of Natural Resources. (NSDNR). (n.d.). Eastern Moose. Alces alces americana (Mainland Population). Fact Sheet. 2 p. www.gov.ns.ca/natr/wildlife/ , www.cpawsns.org/moose/.

Raven, P.H. & Miller, S.E. (2020). Editorial. Here today, gone tomorrow. *Science* 370(6513): 149.

Snaith, T.V. & Beazley, K.F. (2004). The distribution, status and habitat associations of moose in mainland Nova Scotia. *Proceedings of the Nova Scotian Institute of Science* 42(2): 263-317.

Species at Risk Public Registry. (2020). Latest Publications and News. www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html.

World Wildlife Fund (WWF). (2020). Living Planet Report 2020 - Bending the curve of biodiversity loss. Almond, R.E.A., Grooten M. & Petersen, T. (Eds). WWF, Gland, Switzerland.

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ERRATA

In PNSIS 50(2), 2020, there was an error in one author's name:

1) In the Table of Contents, E. Porter's name was misspelled – it should be E. Porter, not Potter.
2) Page 283, same error - the correct spelling is Erica Porter.

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REMEMBERING HUDSON-70

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ABSTRACT

Hudson-70 was the last big multidisciplinary global oceanographic expedition. Organized by the Bedford Institute of Oceanography (BIO), based in Nova Scotia, this epic eleven-month voyage lasted from November 1969 to October 1970, involved 128 scientists from five countries, and traversed five oceans. Enroute, the CSS *Hudson* steamed 56,000 nautical miles and became the first ship to circumnavigate the Americas. A huge amount of new oceanographic information in all disciplines was collected in environments ranging from tropical to polar. Major highlights are summarized. General overviews of the expedition were published in three books and the results of individual studies were reported in over 50 scientific publications. Hudson-70 was a major Canadian oceanographic accomplishment, truly worthy of celebrating fifty years later.

INTRODUCTION

In 1962, the Bedford Institute of Oceanography (BIO) opened on the shores of Bedford Basin in Dartmouth, NS. It soon grew into Canada's largest centre for ocean research. The following year marked the delivery of the CSS *Hudson*, a diesel-electric driven ship with a Lloyds Ice Class I hull to enable work in ice-infested waters, was built at Saint John Shipbuilding and Drydock in Saint John, NB. She was well equipped for multidisciplinary oceanographic research and could carry four hydrographic launches and a helicopter. Ninety meters in length, she had a displacement of 4793 tonnes, cruising speed of 13 knots, at-sea endurance of 50 days, and accommodation for 25 scientists. Well-designed for working in the North Atlantic and Eastern Arctic, she soon developed an international reputation as a superb platform for working under adverse weather conditions.

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She became the queen of the fleet and an icon for BIO. The many accomplishments over her long career have been summarized by Smith (2003). Without doubt, her most notable accomplishment was the Hudson-70 Expedition during which she became the first vessel of any kind to circumnavigate both North and South America.

ORIGIN OF HUDSON-70

In 1967, BIO wished to extend its area of operations beyond the North Atlantic and Eastern Arctic. It was suggested by Dr. Cedric Mann, a physical oceanographer, that it would be worthwhile to measure the flow of water through the Drake Passage, between the southern tip of South America and Antarctica, which had not yet been quantified. There was also interest in studying the fjords of Chile, recording the gravity and magnetic fields along a south-north transit of the Pacific for calibrating oceanographic satellites, conducting geophysical surveys off the Queen Charlotte Islands (Haida Gwaii), surveying the little known Beaufort Sea and navigating the Northwest Passage.

Under the lead of Dr. Cedric Mann (Fig 1) and Dr. William Ford, Director of BIO, these ideas were assembled into a proposal for a major eleven-month oceanographic expedition following the summer around the Americas and completing the first ever circumnavigation. This proposal was subsequently approved by the Honourable Joe Greene, the Minister of Energy, Mines and Resources, and detailed planning proceeded which included adding additional projects as time and space permitted.

Fig 1 Dr. Cedric Mann, lead scientist for Hudson-70.

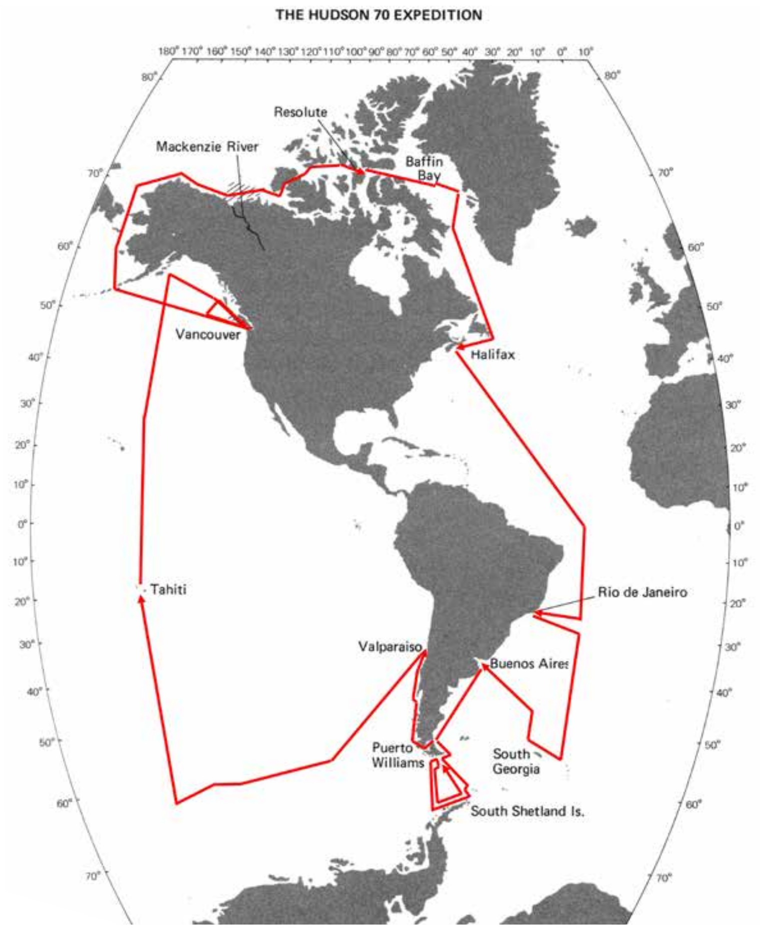

Fig 2 Cruise track of Hudson-70.

OVERVIEW

The Hudson-70 Expedition (Fig 2) took 330 days and was divided into nine legs. The total distance steamed in the North Atlantic, South Atlantic, South Pacific, North Pacific and Arctic oceans was 56,000 nautical miles. There were 128 participating staff from five countries (Canada, US, UK, Argentina and Chile), including scientists, technical support and graduate students. The majority came from BIO and Dalhousie University. A large number of agencies were involved: the Atlantic Oceanographic Laboratory (BIO), the

Marine Ecology Laboratory (BIO), the Canadian Wildlife Service (BIO), the Defense Research Establishment Atlantic (Dartmouth), the Marine Sciences Branch (Ottawa), the Geological Survey of Canada (Ottawa), the National Research Council (Ottawa), the National Museum of Natural Sciences (Ottawa), the Pacific Oceanographic Group (Nanaimo), the Institute of Oceanography (Dalhousie), the Institute of Oceanography (UBC), Queens University, University of Toronto, McGill University, Trent University, the Woods Hole Oceanographic Institution (US), the Scripps Institute of Oceanography (US), Oregon State University (US), University of Washington (US), the Royal Navy (UK), the Argentinian Navy and various Chilean universities. Research programs were carried out over a broad range of scientific disciplines including physical oceanography, chemical oceanography, biological oceanography, ornithology, marine geology, geophysics, geodesy, hydrography, and underwater acoustics.

Leg 1 – Halifax to Rio de Janeiro
19 November to 14 December 1969
Dr. C.R. Mann (BIO), Chief Scientist

After sendoff speeches, including the Honorable Joe Greene, the Minister of Energy, Mines and Resources, the freshly painted and fully provisioned *Hudson* departed BIO on 19 November 1969 for her eleven-month voyage around the Americas (Fig 3). She proceeded south in the North Atlantic conducting gravity, magnetic and bathymetric surveys and acoustic reverberation research.

Fig 3 *Hudson* departing BIO.

Upon reaching the Equator at 30°W, she began a line of oceanographic stations down the 30°W meridian in the South Atlantic. Water samples throughout the water column were collected for the determination of temperature, salinity, oxygen, nutrients and organic carbon. Other work included a deep scattering layer study using one-pound explosive charges, Isaacs-Kidd mid-water trawls and vertical plankton tows. Measurements of primary production were also carried out. On the passage between stations at night, a neuston net was deployed to catch surface fish and zooplankton. Whenever whales were spotted, the ship stopped to take acoustic recordings. Upon reaching 25°S, *Hudson* proceeded to Rio de Janeiro.

Leg 2 – Rio de Janeiro to Buenos Aires
20 December 1969 to 16 January 1970
Dr. C.R. Mann (BIO), Chief Scientist

Upon departing Rio, the *Hudson* resumed the line of stations southward along 30°W. The station routine was the same as Leg 1 with the exception that piston cores of seafloor sediment were collected at each station. Christmas Day was spent at 32.5°S and New Year's Eve occurred at 47.5°S with suitable celebrations. At the southern limit of the transect, 55°S, *Hudson* encountered icebergs, albatrosses, penguins, a full spectrum of other Antarctic birds as well as fin and pilot whales. Turning to the northwest, she investigated a gap in the Scotia Ridge which was thought to be a northward route for Antarctic Bottom Water and then sailed for Buenos Aires.

Leg 3 – Buenos Aires to Punta Arenas
22 January to 23 February 1970
Dr. C.R. Mann (BIO), Chief Scientist

From Buenos Aires, the *Hudson* sailed southward toward Cape Horn, making seabird observations on the way. She then entered Magellan Strait, made a call at Punta Arenas, Chile, and threaded through the Beagle Channel to make another port call in Puerto Williams, Chile, the southernmost settlement in the world. Here, some biologists left the ship for a month to study coastal and beach fauna using a survey launch. After conducting some bottom sled stations and plankton tows off the Wollaston Islands, *Hudson* then proceeded south. After passing Cape Horn in under unusually calm conditions, she entered the Drake Passage and sought out areas of level seabed suitable for deploying a line of current meter moorings, one of the original justifications for the expedition. Once suitable sites were located, four moorings were deployed. Each mooring consisted of a railway wheel at the bottom, a subsurface float at the top and Braincon current meters at depths of 150 m and 1,500 m, as well as 100 m above the bottom (Fig 4). Each current meter was fitted with a thermograph and a depth gauge. Standard oceanographic stations were carried out at each location.

Fig 4 Deploying a current meter mooring the Drake Passage.

Once the moorings were deployed, *Hudson* sailed further south and began a sampling program among the South Shetland Islands off the Antarctic Peninsula. This included plankton tows, rock dredge sampling, epibenthic sled tows and grab sampling. Shore parties explored several interesting sites. This program was interrupted when it became necessary to return to Puerto Williams to drop off a technician whose son had just died. While there, the biologists conducting inshore surveys in the launch were reprovisioned. *Hudson* then headed south again to pick up the current meter moorings and carry out a line of closely spaced oceanographic stations across the Drake Passage. All were relieved when the moorings were recovered in good order. *Hudson* then returned to the South Shetland Islands for some further sampling before returning to Puerto Williams to recover the launch party and steaming to Punta Arenas.

Leg 4 – Punta Arenas to Valparaiso
1 March to 7 April 1970
Dr. George Pickard (UBC), Chief Scientist

This leg was run by the Institute of Oceanography, University of British Columbia, and included a contingent of Chilean scientists. The purpose was to study the oceanography of the little known Chilean fjords. Seabird observations were also made. Heading northward, *Hudson* made her way through an intricate web of fjords and conducted surveys in 32 of them. Many were surveyed for the first time. *Hudson* then sailed westward into the open Pacific Ocean to visit Juan Fernandez Island and carry out a short transect of stations before steaming to Valparaiso.

Leg 5 – Valparaiso to Tahiti
15 April to 12 May 1970
Mr. R.C. Melanson (BIO), Chief Scientist

Departing Valparaiso, *Hudson* sailed southwest toward 65°S 150°W. On the way, she passed over a previously unknown underwater peak (seamount) and deep trough. These were subsequently named after *Hudson* and are now shown as such on international charts. Unfortunately, a high concentration of icebergs was encountered before reaching 65°S so the ship was forced to turn north at 63°S 150°W to begin the longest south-north transect of continuous oceanographic sampling ever completed. Gravity data were collected to allow the calibration of a radar altimeter about to be launched by satellite. Oceanographic stations were also made along the way and the sampling program was similar to that followed in the South Atlantic. At 16°30'S, sampling operations ceased and the ship headed to Tahiti (Fig 5).

Leg 6 – Tahiti to Vancouver
16 May to 12 June 1970
Dr. W.M. Cameron (MSB, Ottawa), Chief Scientist

Upon leaving Tahiti, *Hudson* returned to where sampling had ceased on the previous leg and resumed the sampling program of continuous gravity measurements and periodic oceanographic stations, while heading north along 150°W toward Alaska. At the oceanographic stations, data were collected on temperature, salinity, oxygen, nutrients and organic carbon throughout the water column.

Fig 5 ***Hudson* at anchor in Tahiti.**

A variety of plankton tows continued to be made. Planktonic foraminifera were collected at pre-programmed depths with a new sampler. In addition, detailed measurements were made on the size distribution of particles in surface water. Crossing the Equator marked the end of six months working in the Southern Hemisphere. The sampling program along 150°W was terminated over the Aleutian Trench at 57°30'N. This marked the end of an unprecedented 7,200 nautical mile south to north sampling transect in the Pacific Ocean. From here, the ship proceeded to Vancouver, the first Canadian port since departing Halifax eight months earlier. Upon arrival, *Hudson* was warmly welcomed and hosted an open house. The ship then moved to Esquimalt, just outside Victoria, for engine repairs that took almost a month to complete (Fig 6).

Leg 7 – Victoria to Victoria
12 July to 5 August 1970
Dr. C.D. Maunsell (BIO), Chief Scientist

This leg was devoted to conducting geophysical surveys in the region west of the Queen Charlotte Islands (Haida Gwaii), the northern termination of the Juan de Fuca Ridge and the area surrounding the Explorer Trench. This area was of special interest to geophysicists studying plate tectonics for it marks the location where the American, Juan de Fuca, and Pacific plates meet at a 'triple junction'. The program, conducted with the assistance of the CNAV *Endeavour*, involved bathymetric, gravity and magnetic surveys as well as seismic reflection profiling.

Fig 6 ***Hudson*** **departing Vancouver.**

Leg 8 – Victoria to Resolute

13 August to 22 September 1970
Dr. B.R. Pelletier (BIO), Chief Scientist

Departing Victoria, *Hudson*, now equipped with a helicopter for ice reconnaissance, sailed westward toward the Aleutian Islands. She was now accompanied by the CCS *Baffin* which had sailed from BIO by way of the Panama Canal to assist with work in the Beaufort Sea and the transit through the Northwest Passage. In addition, the newly commissioned CSS *Parizeau* from Victoria accompanied them to participate in the Beaufort Sea program. At Unimak Island, *Hudson* entered the Bering Sea. Soon after, a generator exploded which decommissioned one of her four engines for the duration of the voyage. After crossing the Arctic Circle, heavy pack ice was first encountered off Point Barrow which necessitated some backing and ramming. However, after crossing US-Canada boundary, the pack ice was located much further offshore and this allowed the first intensive oceanographic study of the southern Beaufort Sea to be carried out as planned. The only previous oceanographic work in this part of the Beaufort Sea was a few stations done from the Royal Canadian Mounted Police schooner *St. Roch* during her transit of the Northwest Passage in 1940. Gathering oceanographic information from this region was high priority at the time for the

Canadian Government because of active hydrocarbon exploration by industry and a successful oil find at Atkinson Point in the Mackenzie Delta in 1969.

A survey grid of parallel lines was established running northward from the coast out to the edge of the pack ice, along which seismic profiling and echo sounder, gravity and magnetics measurements were made. In addition, a sidescan sonar fish was deployed to examine seabed features. *Hudson* stopped periodically for hydrocasts, sediment cores, and seabed photography. Extensive seabed scouring by ice was observed out to depths of 100 m. Numerous underwater pingos were discovered similar to those observed on land in the Mackenzie Delta. These ice-cored mounds, looking like small conical volcanoes, rise as much as 70 m from the seabed and can be a hazard to shipping. Fortunately, the oil tanker SS *Manhattan* did not encounter any while passing through this area on her controversial passage through the Northwest Passage the previous year.

At the end of the survey, scientific personnel were exchanged by helicopter at Tuktoyaktuk and *Hudson*, still accompanied by *Baffin*, set off to navigate the Northwest Passage along the northerly route through Prince of Wales Strait and Parry Channel.

Heavy pack ice was encountered part way through and the Department of Transport icebreaker CCGS *John A. Macdonald* had to be called from Resolute, on Cornwallis Island, to break a channel (Fig 7). Some hydrocasts and bottom grabs were made along the way as conditions allowed. Polar bears were frequently observed. Once completed, the successful passage through the Northwest Passage was duly celebrated. The final port of call was Resolute.

Leg 9 – Resolute to Halifax

30 September to 16 October 1970

Dr. D.I. Ross (BIO), Chief Scientist

Before leaving Resolute, a plaque commemorating Hudson-70, made by the bosun, was installed on a rock outcrop at nearby Cape Martyr (Fig 8). This plaque was revisited in 2002 and, except for a few bullet holes, was found in good condition.

The final leg of Hudson-70 was a geophysical survey of northern Baffin Bay involving two-ship seismic refraction work. *Hudson* served as the listening ship and the United States Coast Guard icebreaker USCGC *Edisto* served as the shooting ship. This survey

Fig 7 Traversing the Northwest Passage with *Baffin*.

demonstrated that underlying rocks in this region are oceanic rather than continental in origin. Once this survey was completed, the ship headed for home. At first it was planned to pass through the Straits of Belle Isle, inside Newfoundland, but then it was recognized that *Hudson* should pass outside Newfoundland over the Grand Banks so that it could be truly said that she circumnavigated the Americas.

On 16 October 1970, the *Hudson*, accompanied by *Baffin*, returned to BIO escorted by a fireboat and other water craft while coming up the harbour. It was a most fitting welcome home after an absence of almost a year. Many willing hands ashore were willing to catch her lines (Fig 9).

Fig 8 Bosun Joe Avery and Dr. Bernie Pelletier installing plaque outside Resolute.

Fig 9 Looking somewhat worse for wear, *Hudson* returns to BIO.

A large crowd had gathered on the quay. A podium had been constructed and after the lines were secure, there were welcoming speeches by Dr. William Ford, the Honourable Joe Greene and others (Fig 10). The Honourable Joe Greene also presented Captain David Butler with a commemorative plaque celebrating the successful completion of the expedition.

Fig 10 **Dr. William Ford, Director of BIO, presenting his welcome home speech. Sitting behind him on the podium are the Honourable Joe Greene, Minister of Energy, Mines and Resources, and Captain David Butler. The commemorative plaque is in front of the podium.**

SUMMARY

Hudson-70 was the last big multidisciplinary global oceanographic expedition, a tradition that began with the epic voyage of HMS *Challenger* in 1872. It established Canada's credentials in 'blue water' oceanographic research and was one of the most ambitious expeditions of its kind ever mounted by any nation. However, by 1970, the general features of the world ocean were relatively well known and future oceanographic cruises were more focused and regional in nature.

A huge amount of new oceanographic information was collected from five oceans in environments ranging from tropical to polar. Many regions traversed had not been studied before. Bathymetric, gravimetric and magnetic data were measured continuously while the ship was underway. While stopped on station, data on temperature, salinity, oxygen, nutrients and organic carbon were collected throughout the water column. Seabed sediments were also sampled. Sampling of plankton, benthos and fish, as well as seabird observations, provided new fundamental information on the distribution of species in the world ocean.

The current meter moorings in the Drake Passage were the first direct measurements of water transport through this important part of the global ocean circulation and stimulated further studies by other nations. The Chilean fjord survey was the first and still the most thorough oceanographic survey of these unique fjords. A new seamount and trench, now named after *Hudson*, were discovered in the South Pacific. The 7,200 nautical mile transect up 150°W from the Antarctic to the Aleutians was unprecedented and provided critical geophysical information for calibrating satellite altimeters. Detailed studies of the size distribution of organic particles in surface water laid the basis for the development of the biomass size spectrum theory for analyzing pelagic ecosystems. The geophysical surveys off Haida Gwaii provided new information on the plate structure of the North Pacific. The extensive multidisciplinary survey of the Beaufort Sea was the first of its kind and provided information of immense value to the developing hydrocarbon industry and the defense of Canadian sovereignty. The *Hudson* was only the sixth ship to transit the Northwest Passage. The concluding geophysical survey provided new information on the crustal structure of Baffin Bay.

Full details of Hudson-70 operations are recorded in the BIO cruise reports. The scientific results have been reported in over 50 scientific publications, including peer-reviewed scientific journals, technical reports and graduate student theses. Honorary degrees were presented to Capt. David Butler by Brock University (1971) and Dr. Cedric Mann by the Nova Scotia Technical College (1972), in recognition of the critical roles that they played in the success of the expedition.

Three books have been written on Hudson-70. The first is *Voyage to the End of the World* (Edmonds 1973). Alan Edmonds was a journalist who did not participate in the expedition but interviewed key participants soon after it was completed. It is a very readable account of events with considerable insight into happenings behind

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the scenes and interesting stories about the participants. The second is *The Great Ocean of Truth* (Wadhams 2009a). Peter Wadhams was a recent Cambridge University graduate who participated in the entire expedition as a technician looking after the geophysical equipment. As well as describing the general events, it also documents his personal memories and experiences, both at sea and onshore during port calls. The third book is *Getting Around the Americas: the Hudson-70 Expedition* (Schafer and Smith 2012). Both Charles Schafer and Roger Smith participated in certain legs of the expedition. It provides a thorough overview in words and pictures. In addition, two shorter overview articles have been written (Wadhams 2009b, 2014). As is certainly warranted, the Hudson-70 expedition has been very well documented for posterity.

Hudson-70 provided graduate students with marvellous training opportunities and formative experiences. In particular, Peter Wadhams was stimulated to pursue a PhD and is now the Head of Polar Ocean Physics Group at Cambridge. He became an expert on arctic ice and recently published a book on its gradual disappearance due to climate change (Wadhams 2017).

As testimony to her design and construction, *Hudson* is still afloat and in active use in 2020 at the advanced age of 57 years. This is quite remarkable for an oceanographic vessel. The only known research ship to surpass this number of years of service is the RV *Atlantis* which operated out of the Woods Hole Oceanographic Institution from 1930 to 1966 and then, renamed *El Austral*, carried out oceanographic research in Argentina up to 2006 for total of 76 years. *Hudson* will not surpass this record because a replacement vessel is planned and the keel is scheduled to be laid in the fall of 2020.

In 2009, BIO organized an event to celebrate the 40th anniversary of the departure of *Hudson* on Hudson-70. Over 50 of the original participants, including crew, attended and enjoyed presentations, receptions and a tour of the ship. Many old friendships were rekindled.

REFERENCES

Edmonds, A. (1973). Voyage to the Edge of the World. McClelland and Stewart, Toronto, ON. 254 p.

Schafer, C.T. & Smith, R.W. (2012). Getting Around the Americas: The *Hudson* 70 Expedition. Virtualbookworm Publishing, College Station, TX, USA. 69 p.

Smith, R. (2003). CCGS *Hudson* - A snap shot of historical firsts. Pages 44-47 *in* Bedford Institute of Oceanography 2002, in Review (D. Geddes, Ed.). Bedford Institute of Oceanography, Dartmouth, NS.

Wadhams, P. (2009a). The Great Ocean of Truth: Memories of “Hudson-70”, the first circumnavigation of the Americas. Melrose Books, Ely, Cambridgeshire, England. 378 p.

Wadhams, P. (2009b). Hudson-70: the first circumnavigation of the Americas. *Oceanography* 22: 226-235.

Wadhams, P. (2014). The Hudson-70 Voyage of Discovery: First Circumnavigation of the Americas. Pages 21-28 *in* Voyage of Discovery: fifty years of marine research at Canada’s Bedford Institute of Oceanography. (D.N. Nettleship, D.C. Gordon, C.F.M. Lewis, and M.P. Latremouille, Eds.). Bedford Institute of Oceanography – Oceans Association, Dartmouth, NS.

Wadhams, P. (2017). A Farewell to Ice; a Report from the Arctic. Oxford University Press, New York, NY, USA. 240 p.

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IAN ALEXANDER McLAREN (1931-2020) – A LIFE IN BIOLOGY

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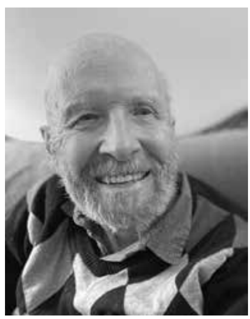

Fig 1 Ian Alexander McLaren (1931-2020), in Halifax in February, 2020 (Photo: Mary McLaren).

Marine biologist, Professor Emeritus, renowned birder, and long-time member of the Nova Scotian Institute of Science, Ian McLaren (Fig 1) is probably best known to most of us in Nova Scotia for his work on Sable Island, where for many years he made a small and rather inconspicuous bird, the Ipswich Sparrow (a localized sub-species of the widespread Savannah Sparrow), his special object of study. But there is a great deal more to be said about his highly varied and very productive life in science and society at large.

To summarize his career first. Born a naturalist, Ian McLaren spent a dozen summers researching Arctic animals before moving to Halifax to join Dalhousie University's Department of Biology in 1966. His numerous graduate students during four decades arrived from the world over, many working on the wildlife of Sable Island,

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on marine mammals, and on zooplankton biology. At the same time, he kept up a very active life as an expert field ornithologist. He was the first President of the Canadian Nature Federation (now Nature Canada), editor of the Nova Scotia Bird Society's quarterly publication *Nova Scotia Birds* for many years, and was instrumental in establishing the Sable Island Preservation Trust and Nova Scotia Nature Trust. He will also be remembered by many Nova Scotians for his regular appearances through the 1990s and early 2000s on CBC Radio answering listeners' bird identification questions. His was a life of astonishing variety and remarkable accomplishments. A lifelong advocate for birding, field ornithology, conservation, and biodiversity, with noteworthy research contributions also in marine biology and ecology, Ian was unfailingly generous with his time for people in all walks of life, and widely admired for his affability and good humour.

Ian McLaren was born on January 11, 1931 to Alexander Lithgow McLaren, a painter and commercial artist, and Christine (née Tabrett) McLaren, a schoolteacher, in Montréal. His love of wildlife and adventure began in his pre-teen years, with entire days spent exploring and birding in the then plentiful woods in and near Montréal. One summer during his high school years, he shipped out for a summer as a deckhand on an ore carrier between Montréal, Dingwall, Nova Scotia, and South America. Apparently the stay in Dingwall made a big impression. He told us that, while there, the crew went ashore and found a dance in progress, which he joined. But it was mainly adults, and he and a similar-aged young woman soon tired of it, and at her suggestion they joined a kitchen-party in one of her relative's houses. Ian was surprised to find a language being spoken that he had never heard before – it was Gaelic, which even his Lowland Scots ancestors might not have understood.

Leaving the sea, at least temporarily, for academia, his studies at McGill University opened up the opportunity to spend summers in Eastern Arctic marine research under the supervision of Professor Max Dunbar, while he completed BSc and MSc degrees between 1952 and 1956.

Ian was an extensive Arctic traveler up to the mid-1960s, at first frequently aboard a storied research vessel, the Fisheries Research Board of Canada's small ketch *Calanus* (Fig 2). He told us that an important question Max Dunbar asked him before his first *Calanus*

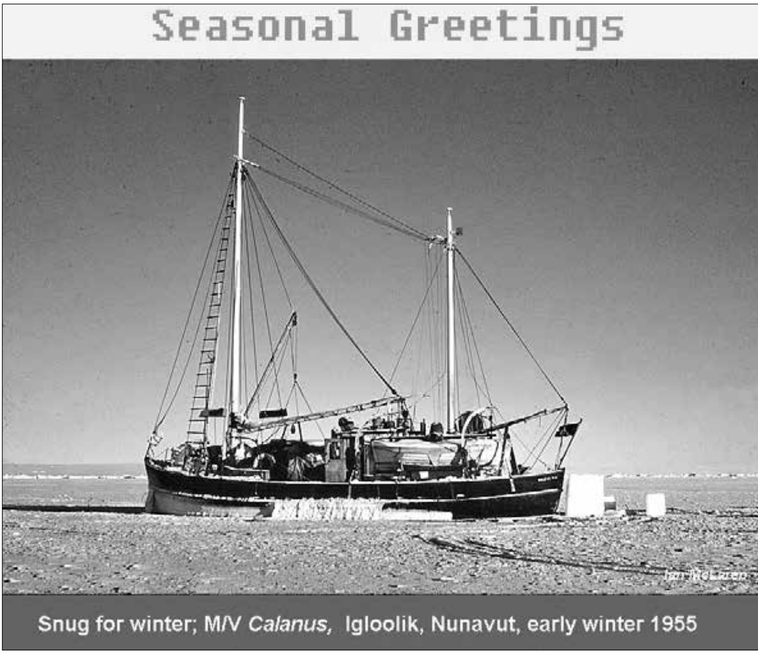

Fig 2 **The M.V. *Calanus* of the Fisheries Research Board of Canada in 1955, off Igloolik, Nunavut, in one of Ian McLaren's Christmas greetings (Photo: Ian McLaren).**

trip was how tall he was – because berths on the ship were very short. Even at that, as he told one of us, he sometimes slept on top of the engine, which he found more comfortable than a berth (presumably while the ship was not under power). Clearly, one way or another, he qualified for life on *Calanus*, spending three summers on the ship in the Eastern Arctic, 1951-1953. In 1954, in the course of his research on Ringed and Bearded Seals, he spent several months living with a group of Cape Dorset (Kinngait) seal hunters, carefully documenting his experiences in a vivid and memorable journal as well as carrying out his research. Ian especially enjoyed interacting with the Inuit people, whose rich lore and close-knit and vivacious culture left lasting impressions upon him. He met his wife Bernice (née Orchard) in Montréal between trips to the Arctic; they were married in her hometown of Miami, Manitoba, in October 1956. Bernice joined him as a research assistant (and diarist) when they spent the following summer of 1957 at Ogac Lake on Baffin Island (Qikiqtaaluk), studying its near landlocked Atlantic Cod and documenting the lake's plankton and other limnological features. During this period, 1955-1963, he was employed as a researcher with the Arctic Unit (later Arctic Laboratory) of the Fisheries Research Board in Montréal and Ste Anne de Bellevue. The McLarens moved to New Haven, CT, for a time, where, supervised by the noted ecologist G. Evelyn Hutchinson, Ian received a PhD at Yale University in 1961.

Ian taught at McGill University between 1963 and 1966. During this time, he brought to completion one of his most original works, on the adaptive value of vertical migration in zooplankton – in outline it suggested that zooplankton gained an advantage in growth by feeding in the warmer surface waters but metabolizing the food in cold deeper waters. This hypothesis stimulated a burst of activity on the phenomenon by many researchers. While at McGill, he found it convenient to do his field and laboratory work on zooplankton during summers at Dalhousie rather than in Montréal, and before long he was, in 1966, lured without difficulty to Halifax and Dalhousie University. He had recognized that Nova Scotia and Dalhousie had the potential to be a nexus of marine biology. Dalhousie in particular had a growing research faculty and proximity to many island ecosystems, in a far milder climate than the Arctic. It mattered, too, that the province was a birders' paradise and he soon took advantage of the opportunity to work on Sable Island (Fig 3), where he and his students studied bird biology, seal populations, and the resident horses.

At Dalhousie for 30 years, he led a full and at times frenetic life, publishing more than 100 peer-reviewed scientific articles and book chapters on marine mammals, zooplankton, ornithology, population biology, and ecological genetics, even well into his official retirement as George S. Campbell Professor of Biology Emeritus in 1996. He also served on the International Whaling Commission in 1982, leading to the first moratorium on whaling adopted by most nations that year, and on the Royal Commission on Seals and the Sealing Industry in Canada during the 1980s, as well as several other federal and provincial government panels.

Despite his many public and scientific advisory activities, Ian typically shied away from administrative positions, preferring to devote his efforts to graduate students and field research, while also teaching biology to thousands of undergraduate students, voluntarily

Fig 3 Ian McLaren in his preferred habitat, censusing Ipswich Sparrows in the Sable Island dunes, June, 1980 (Photo: Eric Mills).

taking on heavy teaching loads and serving on innumerable departmental and graduate-student committees. His educational and scientific impact was marked by his appointment to the George S. Campbell Professorship in Biology in 1984, and by several prestigious awards, including the Queen Elizabeth II Silver Jubilee and Diamond Jubilee medals, the American Birding Association's Ludlow Griscom Award for Outstanding Contributions in Regional Ornithology, and, most recently, Nature Canada's Douglas H. Pimlott Award for lifetime achievements in conservation. Through a generous private donation originating in his help to a student in distress, the Department of Biology at Dalhousie University established a graduate bursary in Ian's name in 2018.

Evaluating such a varied career and productive life, as family and colleague, is a challenging task. But considering his contributions as a biologist first, Ian McLaren was a world authority on seals, marine ecology, plankton and birds. His work, with several students and collaborators, on the biology and population ecology of marine copepods was world-class. His work, again always involving students, on Ipswich Sparrows on Sable Island, marked by major publications in the *Proceedings of the Nova Scotian Institute of Science*, moved an obscure and little-known sparrow to the forefront of population ecology and ornithology. He made the largest modern contribution since the great Robie Tufts to the ornithology of Nova Scotia, as shown in his editing and enlargement of the third edition of Tufts' *Birds of Nova Scotia*, the publication of the definitive *All the Birds of Nova Scotia* by Gaspereau Press, and many other writings on birds. As an environmentalist, by involving himself in the Canadian Nature Federation, the Sable Island Preservation Trust, and nearly every major environmental issue in the province during the past 50 years, he made an enormous contribution to the protection of Nova Scotia's natural environment. To us, he was a peerless parent, an academic's academic, a birder's birder, and a friend's friend. He is irreplaceable.

SELECTED BIBLIOGRAPHY OF THE CONTRIBUTIONS OF IAN McLAREN

(references in chronological order)

McLaren, I.A. (1958). The biology of the Ringed Seal (*Phoca hispida)* in the eastern Canadian arctic. *Bulletin of the Fisheries Research Board of Canada* 118, 97 pp.

McLaren, I.A. (1960). Are the Pinnipedia biphyletic? *Systematic Zoology* 9: 19-28.

McLaren, I.A. (1963). Effects of temperature on growth of zooplankton and the adaptive value of vertical migration. *Journal of the Fisheries Research Board of Canada* 20: 685-727.

McLaren, I.A. (1967). Introduction to biological studies of Ogac Lake, a landlocked fiord on Baffin Island. *Journal of the Fisheries Research Board of Canada* 24: 975-980.

McLaren, I.A. (editor). (1971). Natural regulation of animal numbers. New York: Atherton Press. 195 pp.

McLaren, I.A. (1974). Demographic strategy of vertical migration by a marine copepod. *American Naturalist* 108: 91-102.

Stobo, W.T & McLaren, I.A. (1975). The Ipswich Sparrow. *Proceedings of the Nova Scotian Institute of Science* 27, Supplement 2, 105 pp.

Corkett, C.J. & McLaren, I.A. (1978). The biology of *Pseudocalanus*. *Advances in Marine Biology* 15: 1-231.

Boulva, J. & McLaren, I.A. (1979). Biology of the Harbour Seal, *Phoca vitulina*, in eastern Canada. *Bulletin of the Fisheries Research Board of Canada* 200, 24 pp.

McLaren, I.A. (1981). The incidence of vagrant land birds on Nova Scotian islands. *Auk* 98: 243-257.

McLaren, I.A. (1981). The Birds of Sable Island, Nova Scotia. *Proceedings of the Nova Scotian Institute of Science* 31: 1-84.

McLaren, I.A. (1985-1986). Survey of 19th century ornithology in Nova Scotia, Parts I and II. Nova Scotia Birds 27 (2); 46-54; 27 (3): 65-71; and 28 (2): 71-79.

McLaren, I.A. (reviser, editor of **Tufts, R.W.** 1986). Birds of Nova Scotia. Third edition. Halifax, NS: Nimbus Publishing & Nova Scotia Museum, 478 pp.

McLaren, I.A., Sévigny, J.-M. & Frost, B.W. (1989). Evolutionary and ecological significance of variations in genome size among species of the copepod genus *Pseudocalanus*. *Canadian Journal of Zoology* 67: 565-569.

McLaren, I.A., Tremblay, M.J., Corkett, C.J. & Roff, J.C. (1989). Copepod production on the Scotian Shelf based on life-history analyses and laboratory rearings. *Canadian Journal of Fisheries and Aquatic Sciences* 46: 560-583.

McLaren, I.A. (1993). Growth in pinnipeds. *Biological Reviews* 68: 1-79.

McLaren, I.A. (1995-1997). Nova Scotia rarities in perspective, Parts 1-4. Nova Scotia Birds 37 (2): 23-28; 37 (3): 25-30; 38 (2): 37-41; 39 (2); 27-32.

McLaren, I.A., Maybank, B., Keddy, K. & Fitzerald, T. (2000). A notable autumn arrival of reverse migrants in southern Nova Scotia. *North American Birds* 54: 4-10.

McLaren, I.A. (chair of panel). (2001). Report of the Eminent Panel on Seal Management. Ottawa: Department of Fisheries and Oceans. 165 pp.

McLaren, I.A. & Horn, A.G. (2006). The Ipswich Sparrow: past, present, and future. *Birding* 38 (5): 52-59.

McLaren, I.A., Lees, A.C., Field, C. & Collins, K.J. (2006). Origins and characteristics of Nearctic land birds in Britain and Ireland in autumn: a statistical analysis. *Ibis* 148: 707-728.

McLaren, I.A. & McLaren, J.D. (2009). An analysis of unusual flights of Neotropical migrants to northeastern North America in April 2009. *North American Birds* 63: 384-388.

McLaren, I.A. (2012). All the Birds of Nova Scotia. Status and Critical Identification. Kentville, NS: Gaspereau Press. 247 pp.

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THE NSIS STUDENT SCIENCE WRITING COMPETITION

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ORIGINS AND CRITERIA

The annual Student Science Writing Competition (SSWC) started in 2003 as a vehicle for encouraging science and engineering students to practice and improve their writing skills. It has been open to any student registered at a Nova Scotian university or college.

As stated in the original announcements, the competition was designed to encourage and reward students for their skills in the communication of science. In 2003 prizes were awarded to undergraduates ($250) and postgraduates ($500), and three general categories were acknowledged:

- A concise discussion of original research.
- A review of current literature in a scientific field that provides a new analysis or perspective.
- An article directed to a non-specialist audience on some aspect of science and its impact on society.

At the same time a prize was awarded to students in programs such as journalism, history of science, or public relations for an article about the practice of science, or how it impacts on society.

In certain circumstances, a second prize or an Honourable Mention could also be awarded. Importantly, all winners are invited to submit their manuscripts to the PNSIS for consideration as a primary publication.

EVOLUTION OF THE COMPETITION

Over the years, as student submissions have accumulated, the SSWC has evolved in terms of emphasis. There is no longer a separate prize for students in journalism, etc., although such students,

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as undergraduates or postgraduates, are still eligible to submit manuscripts.

As well, the need for good communication of science to non-specialists has become more important for society as a whole. First, NSIS members come from a wide range of scientific disciplines or are members of the general public with an interest in science, and they appreciate articles outside their discipline that are interesting and comprehensible. Second, science needs to be more clearly communicated to the public at large and to decision-makers in academe, business, government and the military. When students become practitioners of science, they need to be able to impart their knowledge and results to non-specialists. As a result, judges now give more emphasis to this criterion when evaluating all submissions.

In recent years, the prizes have been increased to $500 (undergraduate winner) and $750 (postgraduate winner). Also, all students who submit a manuscript are now offered a free 1-year Student NSIS Membership.

THE SSWC PROCESS

Originally, the process was conducted on paper and by telephone. Since computer tools and communications became more useful and widespread, the SSWC is conducted today almost entirely by digital means.

For the competition for a given year, the process starts in about late October of the previous year. An announcement is e-mailed out to all science and engineering deans and department chairs at all Nova Scotian universities and colleges, and to their administrative assistants, asking them to publicize the SSWC to their faculty and students. Announcements are also sent to the presidents of all science and engineering student societies. The SSWC is also posted on social media at some of the universities, and posters are placed in a number of strategic locations. Reminders are sent in early December to the above recipients. Paid advertisements are also put up on social media for several weeks in late December and early January.

The announcements ask the students to register by the end of January, and to submit their manuscripts to the Coordinator by the middle of February. Students who register are sent an “Information for Authors” document which describes the requirements and offers some advice for the preparation of manuscripts. Students who register are asked for a short paragraph describing their motivation for selecting the topic of their proposed paper (essay or article). Also, they are sent a reminder of the deadline in early February.

By the submission deadline, the Coordinator assembles a panel of five to eight judges. All are NSIS members, and many are drawn from current or former members of the NSIS Council. The judges are chosen to ensure coverage of a range of disciplines.

Once the papers have been submitted, the Coordinator sends copies of all of them to each of the judges, with students' names and academic affiliation removed. The judges return their individual evaluations to the Coordinator by mid-March, who compiles them and sends the compilation back to all the judges.

The judges meet in late March, discuss the papers, and arrive at the final decisions. There can be a Winner and/or an Honourable Mention in each of the undergraduate and the postgraduate categories, but this does not always occur. Sometimes, no prize is given in a category for the Winner or the Honourable Mention. In addition to the results, the judges discuss the constructive feedback that will be given by the Coordinator to each student who submitted a paper.

At the beginning of the April NSIS Public lecture, we give the prizes in person to those students who can attend. Otherwise, the cheques and certificates are mailed to the other Winners and to the Honourable Mentions.

COMMENTS AND OBSERVATIONS

Each year, the SSWC attracts a variable number of students who register their intent to participate, of which a fraction eventually submits manuscripts for consideration. Figure 1 shows these numbers for the past twelve years. The main reason for students dropping out of the competition is usually the pressure of other academic obligations.

The surge in numbers in 2014 is attributed to having a more thorough publicity of the SSWC across all university and college departments. The jump in 2016 coincided with the increased size of the cash prizes.

Over the years, virtually all Nova Scotian universities and colleges have provided competitors and most have provided one or

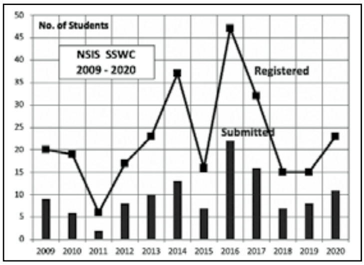

Fig 1 Numbers of interested students and submitted articles, 2009 to 2020.

more winners. Nevertheless, most of the competitors (about two-thirds) have been from Dalhousie University, it being the institution with the largest science and engineering components. The NSIS will keep trying to increase participation from the other universities and colleges in the province.

The papers that students submit cover a very wide range of disciplines and topics. There tends to be a focus on biological and ecological topics, but chemistry, geology, agriculture, ocean science, physics and engineering, and medicine are often represented. About half the papers are descriptions of some original research; the rest are reviews of scientific matters of current importance. The manuscripts are nearly always interesting, informative and well-written. Many are a true delight to read.

Each year, the judges consider and make recommendations for improvements in the SSWC. The result has been steady small changes in procedures, criteria, ways to publicize the competition, advice given to contestants, and the judging process itself.

We still struggle a little with making sure the students clearly understand that their submissions (essays or articles) should be accessible to non-specialists – people with an interest in science but without expertise in the particular topic or field of science. For example, the magazine "Scientific American" is a good role model. We still receive a few papers that are of refereed, journal-grade quality but which are opaque to all but an expert. However, these sometimes win the competition and are published in the PNSIS!

A personal comment – I have been the NSIS SSWC Coordinator since 2013 and have enjoyed the experience very much. The best part has been the pleasure of reading and assessing all of the submissions prepared by keen students covering diverse topics. For the upcoming 2021 SSWC, I am passing on the role to a pair of Co-Coordinators; I am confident that they will bring new ideas and improvements to the SSWC, a core part of the annual NSIS program.

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A REVIEW OF THE FISHES AND FISHERIES OF MINAS BASIN AND MINAS PASSAGE, NOVA SCOTIA, AND THEIR POTENTIAL RISK FROM TIDAL POWER DEVELOPMENT

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ABSTRACT

A total of 85 species of fish are known or suspected from Minas Basin and Minas Passage, Nova Scotia, Canada. This systematic review details their seasonal occurrence, habitat, abundance, migratory behavior, fisheries and potential impact from tidal power development. The fish assemblage is a mixture of species common to the Bay of Fundy and the Atlantic coast of Nova Scotia as well as numerous warm- and cold-water visitors seldom found elsewhere in Canada. Minas Basin fisheries exploit some species especially those that migrate through the Basin during summer. Fishes were captured or observed using angling, seines, benthic long lines, drift and fixed gill nets, intertidal fish weirs, bottom trawls and sightings while on vessels. Fishes are categorized with respect to their taxonomic diversity, seasonal occurrence, status, fisheries and the potential impact from tidal lagoons and propeller turbines resulting from development of tidal power in Minas Basin and Minas Passage.

Keywords: Bay of Fundy, habitat, species status, propeller turbines, taxonomic relationship, tidal lagoons.

INTRODUCTION

The objective of this review was to identify the diversity and seasonal occurrence of fishes in Minas Basin and Minas Passage for their habitat, abundance, migratory behavior, fisheries and their potential interaction with tidal power development projects. The annotated list and comments were compiled from published research sources available since the 1800's as well as the observations of local fishers and the personal observations of the authors

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based on their fisheries research in Minas Basin and Minas Passage since 1981. Additional sources include publications on the marine fishes of Atlantic Canada, those for different regions of the Bay of Fundy and its tributaries, as well as unpublished research works many of which are Honours, Masters and PhD theses completed at Acadia University, East Carolina University, Dalhousie University and the University of New Brunswick.

A need for this review exists because of the potential for open ocean tidal power development in Minas Basin and Minas Passage using tidal lagoons (Cornett *et al.* 2013) or open-stream hydrokinetic devices (Gill 2005, AECOM 2009, FORCE 2017). Minas Basin is a highly productive, summer warm marine embayment important to the biology of many fish species (Dadswell *et al.* 1984a, Rulifson and Dadswell 1995, Campana *et al.* 2008, Kendall *et al.* 2018) and Minas Passage is the conduit through which large numbers of fishes pass annually on their way into and out Minas Basin while migrating around the Bay of Fundy (Dadswell *et al.* 1984b, Stokesbury *et al.* 2016). The fishes apparently have little choice in this migration pattern since their migratory cue is the signal from the residual current structure of the Bay of Fundy which they follow along the coast (Dadswell *et al.* 1984b, Dadswell *et al.* 1987). Potential mortality from tidal power development in Minas Passage or Minas Basin may seriously impact designated species-at-risk (Amiro *et al.* 2003, Campana 2007), the diversity and abundance of fishes occurring in the region, and the productivity of local and distant fisheries (Dadswell *et al.* 1987, Rulifson *et al.* 2008, Dadswell *et al.* 2017, Dadswell *et al.* 2020, Rulifson and Dadswell, in press).

SOURCES OF DATA

Leim and Scott (1966) compiled approximately 60 years of observations on marine fishes of Atlantic Canada resulting from the fisheries work at the Biological Station, St. Andrews, NB. Their book includes considerable specific references to the populations of fishes found in the Bay of Fundy and Minas Basin and is often more complete than Scott and Scott (1988), which is lacking some of the local detail available in the earlier work. Scott and Scott (1988) is excellent with respect to the up-to-date taxonomy of Atlantic fishes, their biology and North Atlantic distribution. The systematic arrangement in our annotated work is based on www.fishbase.org.

Perley (1852) was the first to describe the fish and fisheries of the inner Bay of Fundy (iBoF). His observations form the baseline to which later works can be compared. Huntsman (1922) was the first modern work on the fishes of the inner Bay of Fundy and and Leim (1924) provided details on fishes captured in intertidal fish weirs in Minas Basin. Bousfield and Leim (1959) provided additional information on the fishes of Minas Basin and Bleakney and McAllister (1973) described the fishes that were stranded by extreme low tides at Kingsport in Minas Basin. Dadswell and co-workers (1984a, 1984b) detailed seven years of study on the iBoF including Cumberland Basin and Minas Basin and sampling using drift gill nets (6.0 cm–14.0 cm stretched mesh), drags (5.0 and 12.7 cm stretched mesh) and mid water trawls (5.0 cm stretched mesh), shore seines and intertidal weirs. Rulifson and co-workers (1987, 2008) studied the fishes captured in weirs along the north shore of Minas Basin. Wehrell (2005) surveyed fishes captured by a rock hopper trawl (a specialized 'Yankee 35' with 12.7 cm stretched mesh) from June to September in the southern Bight of Minas Basin and Scots Bay. Baker and co-workers (2014) detailed the fish captures in two weirs, one on the north side and one on the south side of Minas Basin during 2013. Dadswell *et al.* (2020) examined fish catches on every low tide during April-July 2017 from a weir at Bramber on the south shore of Minas Basin (Fig 1). Students at the Estuarine Centre of Acadia University have conducted numerous studies on fishes under the direction of G. Daborn, M. Stokesbury and A. Redden during 1973-2018. Dyer and co-workers (2005) and FORCE (2009, 2017) examined the fisheries from Minas Channel, Minas Passage and Minas Basin.

Fisheries and Oceans Canada (DFO) has or had annual stock assessment cruises and ichthyoplankton surveys in the Bay of Fundy since 1970 (Scott 1987, Scott 1988, Simon and Comeau 1994) using a 'Western' IIA bottom trawl of 12.7 cm stretched mesh with a 2.0 cm mesh cod-end liner and with 330 um 'bongo' plankton nets. There are approximately 22 stations occupied in the Bay of Fundy from Scots Bay to the Lurcher Shoal region. Unfortunately, the stations only go as far as Minas Channel and there are none in

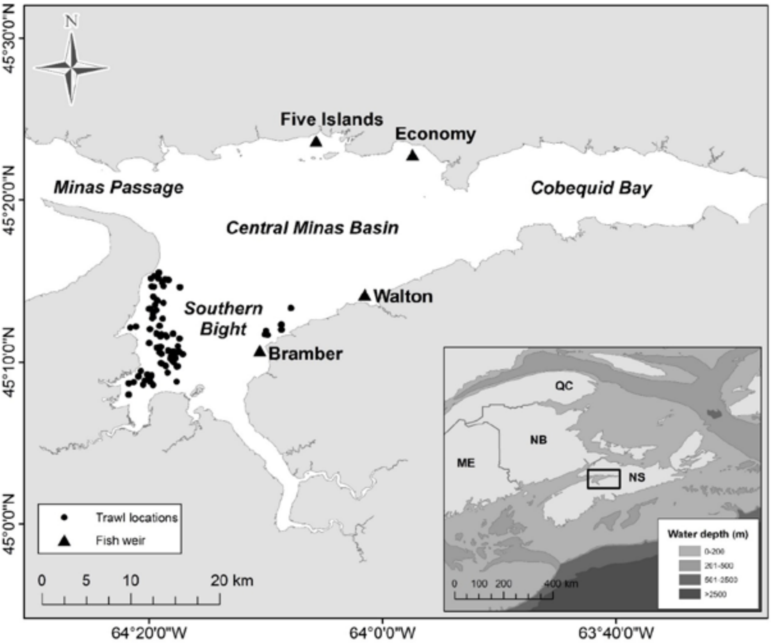

Fig 1 **Minas Basin and Minas Passage in the inner Bay of Fundy. Minas Basin consists of four regions: central Minas Basin proper, Cobequid Bay the eastern section inside Economy Point, the Southern Bight, and Minas Passage which connects Minas Basin to the Bay of Fundy. Triangles represent intertidal weirs where scientific studies have been carried out since 1982. Dots represent trawling locations using a Rock-Hopper trawl during sampling with commercial flounder fishers.**

Minas Passage or Minas Basin. All captured fishes are identified, enumerated, measured and weighed and physical oceanographic variables measured (temperature, salinity and substrate).

Based on the number of studies and the similarity of resulting fish captures, the fish occurring in the Bay of Fundy and Minas Basin are now well known. The fishes of Minas Basin and Minas Passage consist of marine and diadromous species. There are a high proportion of coastal migrant, warm water species from populations as far south as Florida (Fig 2, Dadswell *et al.* 1987, Rulifson *et al.* 2008, Dadswell *et al.* 2016) as well as species from the Gulf of Maine and the Scotian Shelf (MacDonald *et al.* 1984, Scott and Scott 1988) and the Gulf of Saint Lawrence (Saunders 1969). Unfortunately, there have been very few directed fish studies within Minas Passage itself except for surveys of herring larvae (Koeller 1979, Bradford and

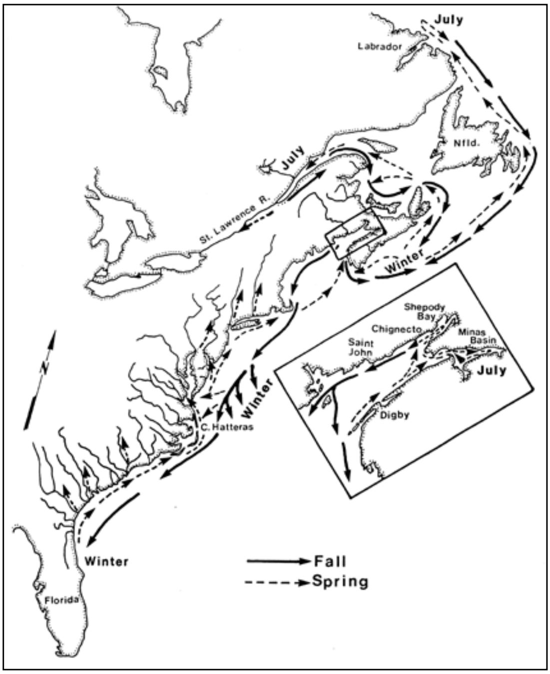

Fig 2 General migration pattern and terminus points for American shad on the Atlantic coast of North America based on 968 returns from 21,330 uniquely numbered spaghetti tags. Tags were deployed in Minas and Cumberland Basins in the inner Bay of Fundy during 1979-1984 and tag returns were received from 1980-1989.

Iles 1993), a brief pelagic trawl survey (FORCE 2010) and a series of studies on selected, acoustically tagged species in the area of the Fundy Ocean Research for Energy (FORCE) tidal turbine test site (Redden *et al.* 2014, Keyser *et al.* 2016) and the Ocean Tracking Network (OTN) acoustic receiver line deployed across the Passage (Stokesbury *et al.* 2016).

The exploitation of tidal power for hydroelectricity from Minas Passage has become possible since the development of instream hydro-kinetic devices consisting of a wide range of potential designs (Gill 2005, Karsten *et al.* 2008). Some designs are axial flow, hydraulic-lift propeller turbines similar in operation to those found in rivers and estuaries. These turbines have moving blades that can cause mechanical damage to fishes passing through the turbine draft tube (Von Raben 1957, Dadswell and Rulifson 1994, Hammer *et al.* 2015, Dadswell *et al.* 2018). Inside the turbine draft tube there are also changes to the pressure and velocity of the water passing over the turbine blades that can cause fish mortalities from shear, pressure flux or cavitation (Dadswell and Rulifson 1994, Deng *et al.* 2005, Buckland *et al.* 2013, Zangiabadi *et al.* 2016). In 2018 Cape Sharp Tidal Power Venture installed a 10 blade, 16 m diameter propeller tidal turbine in Minas Passage that was proposed to develop 2 MW of power (Cape Sharp Tidal 2018). Unfortunately, the turbine broke down soon after deployment. Other devices in use or in planning stages function like wind turbines or eggbeaters (FORCE 2017). Their impact on fishes has been little studied but may be less than from propeller turbines (Viehman and Zydlewski 2015). Still others have no moving parts in the water and produce electricity through the force of the tide on a large, floating kinetic keel (Big Moon Power 2018). This device appears to have no potential danger to fishes.

Development of tidal lagoon power is a distinct possibility in Minas Basin or at other sites in the inner Bay of Fundy (Cornett *et al.* 2013). There has already been one application with a proposal for Scots Bay just outside Minas Basin. The project would have involved a 10 km long barrage across Scots Bay containing 304 bulb turbines generating 1100 MW (Towse 2014). Because the bulb turbines were small, they would have had a generation speed of 90 RPM and low water discharges. These characteristics of the turbines would create a short water length in the draft tube (1.5 m) resulting in high fish mortality during passage (Van Raben 1957). A similar 254 MW tidal power project was developed in Korea using the same bulb turbines that is considered very successful (Won 1980, Sandru 2011) but it has caused mortalities to fishes and marine mammals (Towse 2014).

THE ENVIRONMENT

Minas Basin (45° 19'N, 64° 00'W) is a mega-tidal, cul-de sac marine embayment on the southeastern side of the inner Bay of Fundy and is semi-enclosed by the Province of Nova Scotia (Bousfield and Leim 1959). The triangular basin is 80 km long and 29 km wide at the base and ~2000 km^2 in area. It consists of the central Minas Basin proper, Cobequid Bay the eastern extremity inside Economy Point, and the Southern Bight (Fig 1). Maximum depth in the Basin is 17 m at low tide. Minas Basin has the largest recorded tides in the world (mean 11 m, maximum 17 m; Garrett

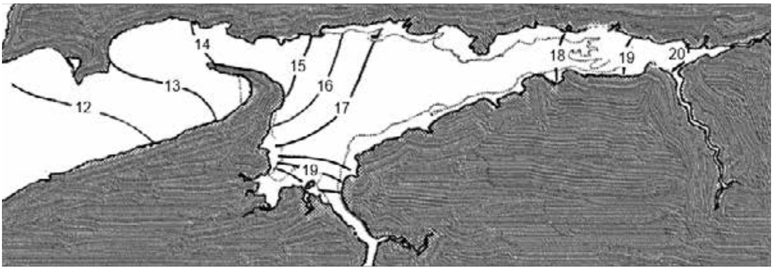

Fig 3 Isopleths of maximum summer, sea surface temperatures in Minas Basin, Minas Passage and Minas Channel, inner Bay of Fundy (after Bousfield and Leim 1959).

1972) and at low tide about one third of the Basin area (670 km^2) is exposed as tide flat (Parker *et al.* 2007). The tidal regime is semi-diurnal and an estimated 3 x 10^9 m^3 of water flows in and out of the Basin with each tide (Parker *et al.* 2007). Owing to strong tidal forcing over shallow bathymetry, water exchange ratios vary from 0.39-0.60 a tidal cycle (Ketchum and Keen 1953). Because of the extreme tides the water column is homogeneous for temperature and salinity. Sea surface temperature (SST) ranges from a peak of 16-22 C^o in summer (Fig 3, August-September; Bousfield and Leim 1959, Wehrell 2005, Dadswell *et al.* 2020) to -1.5-0.0 C^o in winter (February, Bleakney and McAllister 1973). Winter is characterized by drifting ice pans up to 5 m thick which in some years cover most of the Basin from January to March and severely scour the substrate of the intertidal zone (Desplanque and Mossman 1998, Sanderson and Redden 2015). During some years ice blocks can be the size of a house (Fig 4).

Numerous rivers and streams are tributary to Minas Basin. The largest are the Salmon and Shubenacadie Rivers entering Cobequid Bay and the Avon, Gaspereau and Cornwallis entering the Southern Bight. Inflow of freshwater to Minas Basin from its catchment averages approximately 239 m^3.s^{-1} annually but during July through September decreases to about 99 m^3.s^{-1} (Bousfield and Leim 1959). Salinities range from 22 at the inner ends of Cobequid Bay and the Southern Bight to 30 in the central Basin (Fig 5, Bousfield and Leim 1959, Sanderson and Redden 2015).

Because of the extreme tides much of the subtidal, benthic substrate in Minas Basin is sand, gravel or rock (Amos 1984, McLean *et al.* 2013) with extensive intertidal zones (1-5 km wide) of sand,

Fig 4 **An ice block grounded on the upper intertidal zone near Bramber, Nova Scotia, March 2016. For scale the woman in front of the ice block is 1.5 m in height (photograph courtesy D. Porter, Avondale, NS).**

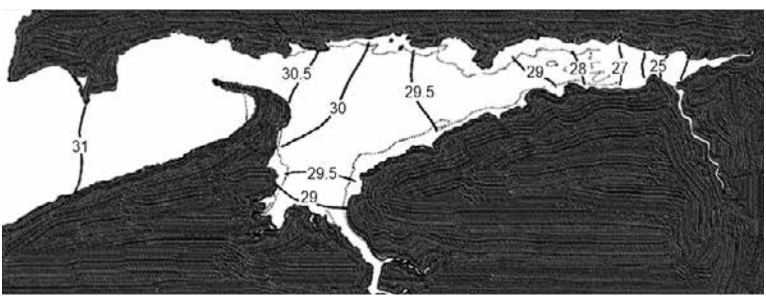

Fig 5 **Surface salinity isopleths during summer in Minas Basin, Minas Passage and Minas Channel, inner Bay of Fundy (after Bousfield and Leim 1959).**

silt and mud (Bleakney and McAllister 1973, Parker *et al.* 2007). Minas Basin has low to high turbidity depending on tidal amplitude, site and time of year (Amos 1984). Turbidity caused by the extreme tides is lowest during neap tides and in summer, highest during spring tides and in winter (Dadswell *et al.* 1983). Turbidity is highest in Cobequid Bay, the Southern Bight and the Avon estuary (Fig 6, Greenburg and Amos 1981). Suspended sediment and detrital levels in the macrotidal regions of the iBoF dramatically reduces light penetration. Detrital suspended particulate matter (SPM) can reach

Fig 6 Turbidity in Minas Basin and Minas Passage, inner Bay of Fundy. High turbidity levels occur where the water is brown in Cobequid Bay, the Avon River estuary and the Southern Bight, www.googleearth.

240 mg.L^{-1} (Crammen 1984) and secchi disk visibility decreases to 10-20 cm at tidal amplitudes over 8 m while light intensity declines to <4.6 x 10^{-3} µw.cm^{-2} at 3 m (Dadswell *et al.* 1983).

The movement of water in Minas Basin is driven by the residual element of tidal flow. This is the net flow created by the back and forth motion of tidal action and the bulk flow of water through the Basin. The residual flow results in a figure eight current pattern in the Basin (Fig 7, Greenberg 1984). Residual inflow enters along the north side of Minas Passage after being deflected northward by Cape Split. Flow continues along the north side of Minas Basin and then is deflected to the south side of Cobequid Bay by Economy Point. The residual current continues around Cobequid Bay on its north side and is again deflected to the south side of Minas Basin by Economy Point. A gyre exists in the central portion of Minas Basin and flow continues along the southern shore of the Basin through the Southern Bight exiting the Basin past Blomidon via the south side of Minas Passage.

Minas Passage is the body of water connecting the inner Bay of Fundy with Minas Basin (Fig 1). It is 15 km long and ~5 km wide with low tide depths of 35-115 m. Minas Passage has SST's of 14-16°C from June to October (Fig 3, Bradford 1987) and because of powerful currents the water column is isothermal from bottom to surface (Tee 1975, AECOM 2009). Because of the extensive

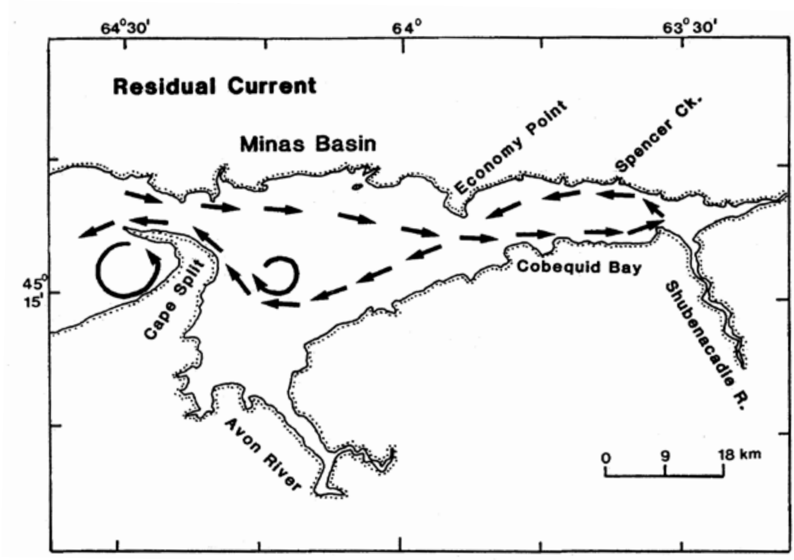

Fig 7 Residual currents in Minas Basin (adapted from Greenberg 1984).

upwelling caused by the currents Minas Passage is warmer in winter than Minas Basin. Winter temperatures range from 6.0° C in December to 1.0° C in March (Keyser *et al.* 2016). Salinity in the Passage ranges from 30-32 (Bousfield and Leim 1959, Sanderson and Redden 2015). Minas Passage also has clearer water compared to Minas Basin (Fig 6) seldom experiencing turbidity except during spring tides in winter.

Minas Passage is a region of complex and powerful currents caused by the extreme tides and shape of the shoreline. Approximately 14 billion metric tons *(t)* of water flow into and out of the Passage during each phase of the tide cycle, a volume greater than all the rivers on earth (Karsten *et al.* 2013). Tidal velocities from 3-6 $m.s^{-1}$ occur in Minas Passage during falling and rising tides and large gyres have been identified around Cape Split and Cape Blomidon (Fig 7, 8, Tee 1975, Greenberg 1984). Residual currents were calculated with speeds up to 0.75 $m.s^{-1}$ (Tee 1975). The strong tidal velocities have scoured most of the substrate of Minas Passage to bedrock (AECOM 2009).

Currents through Minas Passage are strongly influenced by Cape Split (Fig 8). During flood tide flow is deflected northward by the Cape and the strongest currents (5-6 $m.s^{-1}$) occur along the north

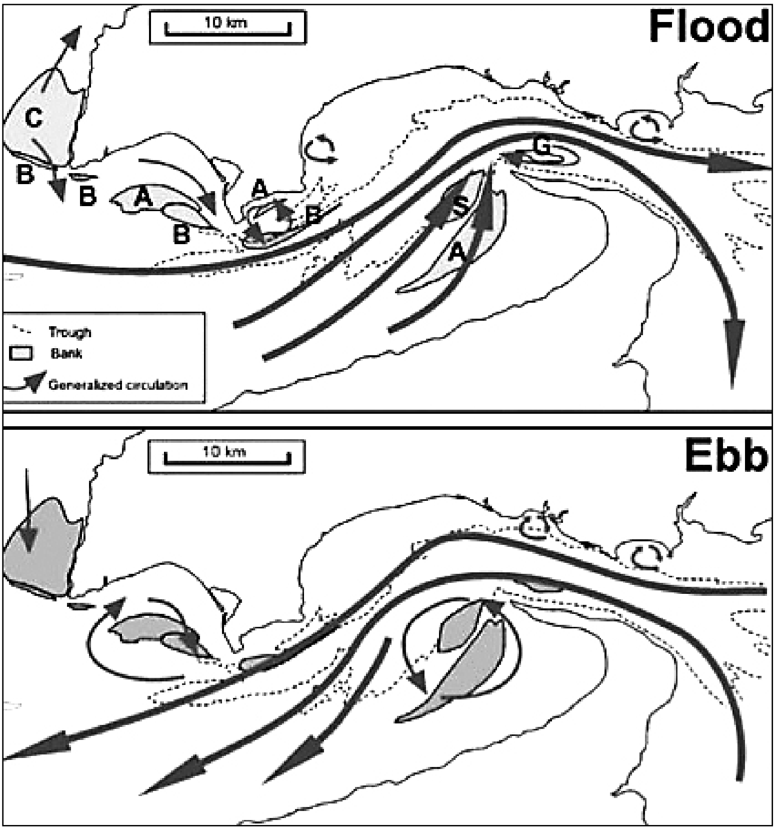

Fig 8 **Flood tide and ebb tide flow directions in Minas Channel and Minas Passage. Arrows indicate generalized direction of flow. Dotted line indicates the 30 m high tide depth contour (adapted from Towse 2014).**

shore of the Passage (AECOM 2009, Walters *et al.* 2013). During ebb tide currents across the Passage are similar (3 $m.s^{-1}$, Tee 1975, Walters *et al.* 2013) but the outflow past Cape Split creates a large gyre on the north side of Scot's Bay (Fig 8, G. Travis, commercial fisher, pers. comm.).

MIGRATION OF FISHES IN THE BAY OF FUNDY AND MINAS BASIN

Numerous studies on the fishes of the Bay of Fundy indicate most species migrate through the Bay of Fundy following the tidal, residual flow pattern. Residual flow in the Bay describes counterclockwise pattern entering the Bay on the south-east along the coast of Nova Scotia and exiting on the north-west side of the Bay along the New Brunswick shore (Fig 9, Lauzier 1967). The annual migration pattern of large sharks (Dadswell *et al.* 1984a), Atlantic sturgeon (Dadswell *et al.* 2016), Atlantic salmon (Saunders 1969, Meister 1984), coho salmon (Martin and Dadswell 1983), American shad (Dadswell *et al.* 1987), Atlantic herring (McKenzie and Tibbo 1961), haddock (McCracken 1965) and winter flounder (McCracken 1963) all display the same overall counterclockwise migratory pathway around the Bay of Fundy.

The American shad migratory pattern is well known and demonstrates how these fish closely follow the residual currents both in the Bay of Fundy and Minas Basin (Fig 10, Dadswell *et al.* 1987). American shad enter the Bay each year during April-May along the Nova Scotia shore, arrive in Minas Basin during June-July and exit along the New Brunswick shore in September-October. Migratory speeds are about 3.5 km.d^{-1} (Dadswell *et al.* 1987) which is slightly faster than the speed of the residual current (3.0 km.d^{-1}, Lauzier 1967). Inside Minas Basin shad follow the residual current closely, their migration taking a figure eight pattern like the current (Fig 10, Dadswell *et al.* 1984b).

Currents and gyres would be expected to hinder the progress of smaller species and life stages through Minas Passage because of the

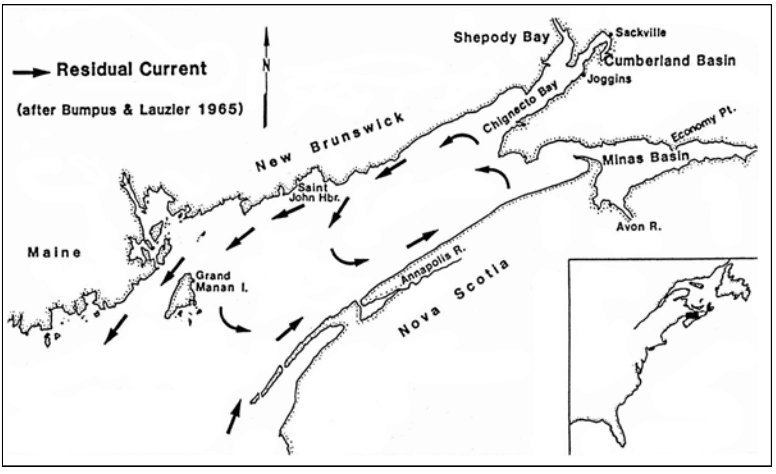

Fig 9 Residual currents in the Bay of Fundy (adapted from Lauzier 1967).

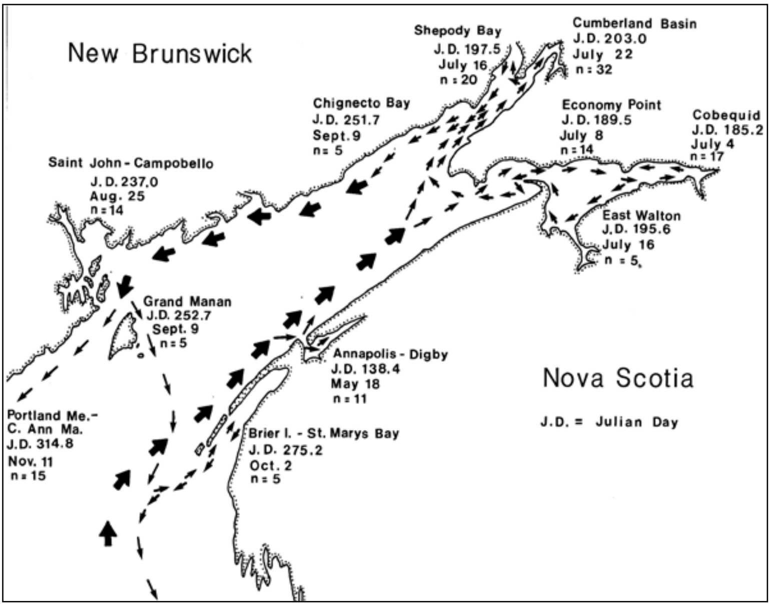

Fig 10 Migration pathway, seasonal time (mean date, Julien day) and number of tag returns of American shad from each locality in the Bay of Fundy during 1979-1985.

extreme tidal and residual velocities (Tee 1975, Walters *et al.* 2013) but may help to speed the progress of larger species and life stages. In general, fishes make about 2 body lengths/s ($bl.s^{-1}$) at cruising speed (Moyle and Cech 1996) and fishes smaller than about 20 cm in length, like Atlantic salmon smolts, can be held up in Minas Passage for longer periods than their average migration rates especially if caught up in the gyres (Lacroix *et al.* 2005).

Most large species entering Minas Basin apparently hold in the large gyre in Scots Bay during ebb tide and move into Minas Basin on the flood tide (Fig 8, G. Travis, commercial fisher, pers. obs.). This behavior can lead to extremely large bottom trawl catches at this site (Fig 11). Additionally, fishes follow the main current flow into and out of Minas Passage. American shad and Atlantic sturgeon enter Minas Basin predominately along the northern shore (Dadswell *et al.* 1987, Dadswell *et al.* 2016). Atlantic sturgeon departing Minas Basin during autumn predominately move along the southern shore of Minas Passage (Stokesbury *et al.* 2016).

THE FISHERIES OF MINAS BASIN AND MINAS PASSAGE

The fisheries of the inner Bay of Fundy began with the native Mi'kmaq. They used intertidal weirs and spears to capture fish for sustenance and trade (Gordon 1993). They captured Atlantic sturgeon, Atlantic herring, gaspereau, American shad, Atlantic salmon, Atlantic cod, tomcod and smelt.

When European settlers arrived during the 1600's the Mi'kmaq taught them how to use weirs to catch fish for their survival. Intertidal weirs are constructed during spring of spruce stakes with interwoven brush or netting in a V-shape with the V pointed offshore (Fig 12, Gordon 1993). At high tide the weir is underwater. As the tide ebbs fishes are guided into the weir pond that is then fished at low water. Before 1900 catches of 100,000 shad a tide occurred (Perley 1852, Prince 1912). Horse-drawn wagons were used to land the catch. Some weirs in Minas Basin were serviced with horses until the 1980's (Dadswell *et al.* 1984a) but are fished now with trucks or all-terrain vehicles (Fig 12).

Intertidal fish weirs have remained one of the main methods for fisheries in Minas Basin to the present day. During the 1800's hundreds of fish weirs lined the shores of Minas Basin and the American shad captured were so important to the economy of Nova Scotia that a Special Act of the Nova Scotia Legislature was passed in 1840 for its regulation, one of the first in Canada (Perley 1852). Today the main catch is gaspereau or river herring a mixture of the two species *Alosa pseudoharengus* and *A. aestivalis* that are very difficult to tell apart and which are used mainly as bait for the lobster fishery (Baker *et al.* 2014, Dadswell *et al.* 2020). Other commercial species captured now or in the past are Atlantic sturgeon, Atlantic salmon, Atlantic herring, American shad, striped bass, butterfish, winter flounder, tomcod, American smelt and Atlantic mackerel.

A drift, gill net fishery began in Minas Basin during the 1800's and has continued until the present (Huntsman 1958, Dadswell *et al.* 1984b). Species targeted were Atlantic salmon, gaspereau and American shad. Linen nets were used until the 1970's when the nets were changed to multifilament nylon. Nets were usually 6 m deep and 30 m long and were fished in gangs up to 1.5 km in length (Dadswell *et al.* 1984b). Cape Island vessels of 10-15 m in length were most often used (Fig 13). The fishery for Atlantic salmon

Fig 11 Spiny dogfish shark captured during a one-half hour tow with a 'Rock-Hopper' trawl in Scots Bay off the western side of Cape Split, July 2004 (photograph courtesy S. Wehrell, Acadia University).

Fig 12 The Bramber weir at low tide in Minas Basin that was used for the 2017 weir study (Dadswell *et al.* 2020). The v-shaped wings direct fish into the trap at the bottom of the photograph. Fisher's trucks are clustered around the trap. The channel leading from the trap and heart shaped structure (pond) is where fishes prohibited from take (sturgeon, striped bass, salmon) are released alive to await the return of the tide (photograph courtesy D. Porter, Avondale, NS).

Fig 13 **Cape Islander fishing vessel of the type used in the drift gill net fishery in the inner Bay of Fundy. The fisher hauling the net has an Atlantic salmon close to his hand; the deck hand has an American shad in his hand. The picture was taken during 1982 when the salmon fishery was still permitted (photograph MJD).**

was closed in 1984 but drift netting for gaspereau and American shad remains active. There used to be a large, hand line and drift net fishery for pollock in Minas Passage (Perley 1852). Pollock are still taken there commercially and recreationally but since the pollock stock collapsed after 1970 only hand lines are used (Dyer *et al.* 2005).

A trawler fishery began in Minas Basin during the 1950's and is still pursued annually. The season is from June 1 to October 31 (Wehrell 2005). The main species targeted are winter flounder and dogfish shark with a bycatch of cod and striped bass. Fishers use a 24 m wide, Yankee 33, box trawl with 14.0 cm stretched mesh in the trawl body and cod end and towed with 200 kg Bison doors (Wehrell 2005). A set usually lasts from 1-2 hours in length. There are 4-5 trawlers that work out of Delhaven and Parrsboro using vessels <14 m. All-bay, >18 m vessels from Yarmouth and Metegan also fish Minas Basin using similar trawls.

There is a small fishery for spring herring in the intertidal zone using 3.6 cm stretched mesh fixed gill nets. Fishers are restricted to 30 m of net.

Since 1990 a large angling fishery for striped bass has developed in Minas Basin (Broome *et al.* 2009). Fishers are allowed only one bass a day with a minimum total length of 68.5 cm. Anglers also fish for flounders and dogfish shark.

COMPILATION OF THE FISHES

Details are provided on a total of 85 fish species that have either been recorded in Minas Basin, Minas Passage and/or Minas Channel or can reasonably be expected to occur in the region. Systematic and taxonomic names (www.fishbase.org) are provided as a narrative for easy access to species information and scientific references. Where information is available seasonal migratory timing, water column distribution, known or expected abundance and past and present fisheries are provided. Maximum length is either fork (L_F) or total (L_T) length. It is very likely that more fish species occur in Minas Passage than are listed and their abundance could be greater than anticipated. These details will be determined as fish studies in the Passage progress.

The fishes are also categorized with regard to their potential risk of interaction with tidal lagoons (Cornett *et al.* 2013) or proposed instream, axial-flow, hydraulic lift propeller turbines, the only type of hydrokinetic device that has been deployed on Minas Passage to date (AECOM 2009, FORCE 2017). The extreme impact category includes fishes that have a high probability of interaction with a propeller turbine and/or potential for significant harm to their population. The medium category contains fishes with some probability of interaction and a moderate risk of harm, and the low category, fishes with a low probability of interaction or harm. Degree of potential harm (Table 1) is determined by fish size and susceptibility to propeller turbine passage impact (strike, pressure effects, shear and cavitation; Dadswell and Rulifson 1994), their habitat (pelagic or benthic), their importance to fisheries and the size of their population (abundant, rare, endangered). A total of 13 fishes are suggested for the extreme category, 10 in the medium category and 62 in the low category.

A number of fishes which are known to occur in either Minas Basin or Minas Passage have been assessed as at-risk by the Committee on Endangered Wildlife in Canada (COSEWIC) and/or are listed under the Canadian Species at Risk Act (SARA). Inner Bay of Fundy Atlantic salmon (SARA, endangered, Schedule 1), great white shark (SARA, endangered, Schedule 1), shortnose sturgeon (SARA, special concern, Schedule 1) Atlantic wolffish (SARA, special concern, Schedule 1) are protected to one degree or another and require

Table 1 Summary of important Minas Basin/Passage fishes and their level of potential impact from propeller tidal turbines deployed in Minas Passage. The extreme category contains fishes that are likely to have population level impacts. The moderate category could expect some instances of high mortality and fisheries declines but unlikely with overall population effects.

Species	Lmax[a]	Habitat[b]	Population Size	Status[c]	Fishery Impact[d]
EXTREME RISK					
Basking shark	10.0	P	1-10	SC	na
Great white shark	5.0	P	10-20	E	na
Porbeagle	3.0	P	100	nl	na
Dogfish shark	1.1	B-P	2000K+	SC	na
Atlantic sturgeon	3.0	B-P*	10K	T	H
Atlantic salmon	1.0	P	1000?	E	H
American shad	0.6	P	3000K+	nl	H
Atlantic herring	0.5	P	10000K+	nl	H
Blueback herring	0.5	P	5000K+	nl	M
Alewife	0.5	P	5000K+	nl	M
Striped bass	1.5	P	100K	T	H
Pollack	1.0	P	?	nl	M
Atlantic halibut	3.0	B-P	100?	nl	H
MODERATE RISK					
Sea lamprey	0.8	P	10K	nl	na
Sand tiger shark	3.3	B	10	nl	na
Shortnose sturgeon	1.4	B	10	SC	na
American eel	1.0	P	100K+	T	M
Rainbow smelt	0.3	P	50000K+	nl	L
Atlantic cod	1.5	B-P	1000	E	L
Mackerel	0.6	P	100K+	nl	L
Lumpfish	0.8	P-B	?	T	na
Wolffish	1.5	B	?	SC	L
Winter Flounder	0.6	B	100K+	nl	L

[a]Lmax Maximum length in meters
[b]Pelagic (P), Pelagic-Benthic (P-B) or Benthic (B).
[c]Listed by COSEWIC or SARA as endangered (E), threatened (T), special concern (SC) or not listed (nl)
[d]High (H), Moderate (M), Low (L) or not applicable since no fishery (na)
[e]K = 1,000.
*Atlantic sturgeon traverse Minas Passage pelagically (Stokesbury *et al.* 2016).

an 'assessment of harm' for any potential environmental impact. COSEWIC has assessed Shortfin mako, porbeagle and Atlantic cod as 'endangered', Atlantic sturgeon, American eel, lumpfish, striped bass and white hake as 'threatened' and spiny dogfish, thorny and smooth skate and basking shark as 'special concern'.

SUPERCLASS: AGNATHA 'JAWLESS FISHES'

Order: Myxiniformes 'hagfish'

1. Atlantic hagfish *Myxine glutinosa* Linnaeus, 1758. Marine, benthic**.** Hagfish are abundant in the outer Bay of Fundy over mud bottoms (Scott and Scott 1988). They are benthic scavengers that usually burrow into the substrate during daytime. They are mostly associated with deep, cold water habitats and are especially abundant in the deep ocean around 'whale falls' (Moyle and Cech 1996).

Hagfish attack dead and dying fishes and will feed on shrimp. Sampling with baited traps can capture up to 500 hagfish during a 12 h set in Passamaquoddy Bay (Scott and Scott 1988). Hagfish have never been observed in the inner Bay of Fundy but possibly occur in Minas Basin and Passage especially during winter where there are subtidal mud substrates. They would accumulate around turbines if there were dead fish to feed on. Their risk for turbine interaction is low.

There is a world-wide fishery for hagfish. Hagfish skin is made into 'fish leather' and Koreans appreciate them as food (Knapp *et al.* 2011). There is a hagfish fishery in the Bay of Fundy (Ellis *et al.* 2015).

Order: Petromyzontiformes 'lampreys'

2. Sea lamprey *Petromyzon marinus* Linnaeus, 1758. Anadromous, benthic, pelagic. Larval lampreys or 'ammocetes' are benthic in fresh water where they burrow into mud and silt of stream shorelines**.** Juveniles and adults are pelagic in marine situations and are blood predators of fishes (Halliday 1991)**.**

Sea lampreys are semelparous and spawn in freshwater streams during April-July after which the adults die. After hatching ammocetes remain burrowed into sand-silt bottoms of streams for up to seven years before they metamorphose into juveniles during spring and then migrate to sea (Scott and Scott 1988).

Juvenile and adult lampreys attach to their prey with an anterior sucker equipped with multiple teeth used to bore through the skin and into the muscle (Scott and Scott 1988). They then inject an anticoagulant and pump out the fish blood. Their feeding often kills their prey. They begin preying on fishes for blood as juveniles during estuarine emigration. Maritime populations migrate to sea and live offshore on the Scotian Shelf or further seaward for an indeterminate period (Scott and Scott 1988, Halliday 1991). Lampreys are difficult to capture when in mid-water, marine situations because of their eel like form which allows them to escape from most sampling gear (Halliday 1991). Juveniles and adults prefer to feed on soft bodied fishes such as salmon and shad.

Lamprey are known from the Shubenacadie, Gaspereau and Kennetcook Rivers in Minas Basin (Leim and Scott 1966), but probably also occur in all other Minas Basin streams with anadromous fish populations. Ammocetes are common in shallow, silt covered sites along stream shorelines. Juveniles migrating offshore are abundant in Minas Basin during spring (April-June) attached to adult and juvenile gaspereau, shad and salmon. Adults migrating inshore to spawn are found in the pelagic zone of Minas Basin and Passage during April-June. Adults do not feed when migrating to spawn. Adult abundance during inward migration through Minas Passage would probably be in the range of 1000-10,000 y^{-1}.

There is no fishery for lampreys in Canada. In Europe they are captured in weirs and pickled. King John of Robin Hood fame died after overindulging on pickled lampreys, his favorite food.

Adult sea lampreys will be susceptible to turbine strike because of their body size, pelagic habitat and attachment to other fishes. Adults may be up to 80 cm L_T. They have been judged to be at low risk during interaction with axial-flow turbines (Gibson and Myers 2002).

SUPERCLASS: CHONDRICHTHYES ‘CARTILAGINOUS FISHES’ CLASS: ELASMOBRANCHII ‘SHARKS’

Many of the sharks have large body size (1-10 m L_T) which increases their chance of blade strike during propeller turbine passage. Also, sharks are mostly predators and scavengers (Moyle and Cech 1996) and although most are never common or abundant in Minas Basin or Passage there is a good probability they will be attracted to the Minas Passage turbine sites if there are dead or wounded fish present. Such behavior will further increase their chances of propeller turbine impact.

Order: Carchariniformes

3. Sand tiger shark *Carcharius taurus* Rafinesque, 1810. Marine, benthic**.** Sand tiger, a southern species is a rare shark in Canada.

Two specimens have been observed in the outer Bay of Fundy (Scott and Scott 1988). Two were captured by drift gill net in Minas Basin during August 1985 (Dadswell and Rulifson 1994) and one, ~2 m on length, was taken in a weir at Economy in Minas Basin during August 2017 (Fig 1, W. Linkletter, pers. comm.). Sand tiger may be more common in Minas Basin than observations suggest since the sandy bottom habitat they prefer is widely available in the Basin and summer water temperatures often exceed 20 C^{o} (Bousfield and Leim 1959, Wehrell 2005).

Records indicate this species would be occasional in Minas Basin and Passage and would only be encountered incidentally during summer. Abundance expected would probably be in the range of 1-10 y^{-1}.

Since body length of sand tigers can be up to 3.3 m L_F they are at moderate risk in axial-flow, hydraulic lift propeller turbines. Specimens captured in Minas Basin to date were 0.79-2.0 m L_F.

Order: Lamniformes

4. Thresher shark *Alopias vulpinus* **(**Bonneterre, 1788)**.** Marine, pelagic. There are three records of thresher shark captured in the Bay of Fundy (Scott and Scott 1988) and it may occur in the inner Bay. Specimens captured in the outer Bay of Fundy were large (3-5 m L_T, Scott and Scott 1988) and large individuals have been taken off Yarmouth in shark derbies during recent years (Dadswell, pers. obs.). Large sharks that were tagged have been documented to travel long distances rapidly (up to 5000 km, Casey and Kohler 1990) and virtually any species of large shark could be expected in the inner Bay of Fundy during summer.

Threshers feed on herring, alsoids and squid, all of which are abundant forage items in Minas Basin during summer (Dadswell *et al.* 1984a, Bradford and Iles 1992, Dadswell *et al.* 2020). Threshers could be expected in Minas during June to September but only in small numbers (1-10 y^{-1}). They would be attracted to turbine sites because of blood and vibrations created by wounded fishes. They would be in extreme danger of mechanical strike in axial-flow propeller turbines because of their large size. There is no fishery in the Bay of Fundy.

5. Great white shark *Carcharodon carcharias* (Linnaeus, 1758). Marine, pelagic. Piers (1934), Templeman (1963) and Scott and Scott (1988) have documented nine white sharks from the outer

Bay of Fundy which were caught from July to November. Case (1968) documented a 5.2 m L_T specimen caught in a drift gill net off Burntcoat Head in Minas Basin on August 15, 1966. A photograph of this specimen is in his publication. In August 2011, a juvenile great white (3.0 m L_T) was captured in a weir at Economy across the Basin from Burntcoat Head (W. Linkletter, pers. comm.). During 2013 three great whites tagged with acoustic tags off Massachusetts were detected in the OTN acoustic receiver line in Minas Passage (M. Stokesbury, pers, comm.). A dead, 3.0 m male great white beached in West Bay in Minas Passage during July 2015 (W. Joyce, DFO, pers. comm., Rees 2016) and during June-August 2017, a 2.7 m L_T female great white, tagged acoustically off Massachusetts, was detected by receivers in the Southern Bight (D. Porter, pers. comm.). Similarly, on July 22, 2018 a great white took a striped bass off an angler's hook near Economy (*CTV News* July 23, 2018) and the great white that was in the Basin during 2017 was again acoustically detected in the Southern Bight during 2018 (D. Porter, commercial fisher, pers. comm.). Great white shark now appear to be common in Minas Basin during summer!

Large great white sharks captured in the Bay of Fundy had fed on harbour porpoise and harbour seals (Scott and Scott 1988). Great white stomachs are often filled with whale blubber thought to be from dead whales, but they are also known to attack living whales in packs (Carey *et al.* 1982). Since porpoise, seals and whales are abundant in all parts of the Bay of Fundy during the entire year (Gaskin *et al.* 1985, Tollit *et al.* 2011) great whites should be expected in Minas Basin and Passage especially during June-August. Abundance may be low, probably not more than 5-10 y^{-1}. There is no fishery for great white shark in Canada and they are listed by SARA as endangered. Because of their large size great white sharks are at extreme risk for blade strike in propeller tidal turbines. Their endangered status dictates there should be 'no take'.

6. Basking shark *Cetorhinus maximus* (Gunnerus, 1765). Marine, pelagic. Basking sharks are common in the Bay of Fundy during summer. Perley (1852), Templeman (1963) and Scott and Scott (1988) report 12 documented occurrences from the outer Bay. Specimens often wash ashore off Saint John Harbour on either side of the Bay after being struck by ships. One, living, basking shark was observed by a wind surfer inside Minas Basin off Evangeline Beach during September 1987 and a dead specimen was found off Alma in Chignecto Bay during early October 2008 (Dadswell, pers. comm.).

Basking sharks are one of the largest fishes in the ocean and attain lengths of over 10 m L_T (Scott and Scott 1988). They filter feed on planktonic organisms, especially shrimp and they are known to dive to depths of 300 m at night to feed (Tobey 1977). These sharks then rise to the surface during daylight to 'bask' on the surface where they are struck and often killed by ships. They should be expected at depth or at the surface in Minas Passage during July to October. They will probably occur annually in Minas Basin and the Passage but numbers will be low (1-10 y^{-1}). They are at extreme risk from propeller turbine strike (Table 1).

7. Shortfin mako shark *Isurus oxyrinchus* Rafinesque, 1810. Marine, pelagic. Apparently common in the outer Bay of Fundy during summer but has never been reported in the inner Bay (Scott and Scott 1988). Numerous specimens have been captured recently during shark fishing derbies and landed in Yarmouth (Dadswell, pers. obs.). Mature specimens are 2-3 m L_T in length. May occur rarely in Minas Passage and would be at extreme risk for propeller turbine strike.

8. Porbeagle *Lamna nasus* (Bonneterre, 1788). Marine, pelagic. Porbeagle is the most common shark species in the inner and outer Bay of Fundy other than dogfish shark. Until recently there was a commercial fishery for porbeagle in the inner Bay during summer (Anon 1986). Catches averaged about 10 t y^{-1} (Campana *et al.* 2002). Recently, however, the porbeagle fishery was closed because of declining stock size (CSAS 2005, Campana 2007).

Porbeagle sharks are common in Chignecto Bay and Minas Basin during summer. Dadswell *et al.* (1984a) reported two captured at night with drift gill nets off Grindstone Point in Chignecto Bay on August 5 and September 3, 1980 (Fig 14). One was captured at night with drift gill nets in Minas Passage off Blomidon during July 1984 (Dadswell, pers. obs.). These three specimens were all females from 2.1-2.2 m L_T. Another 318 kg female was captured in a herring net off Halls Harbour in Minas Channel on July 15, 1986 (Anon 1986).

Porbeagle is a fast swimming, epipelagic shark that feeds on salmon, herring, eels, alosids and squid (Scott and Scott 1988, Joyce *et al.* 2002). Porbeagles probably follow the abundant herring and alosid runs that occur in the iBoF during summer (Dadswell *et al.*

Fig 14 A 2.2 m TL Porbeagle shark captured in Cumberland Basin on August 5, 1980, while drift gill netting at night (photograph MJD).

1984a). They can be expected in Minas Basin and Passage from June to September. Estimated annual abundance is possibly about 100 individuals. They will occur near the surface at night and in deeper water during day and because of their large size would be at extreme risk of propeller turbine strike.

Order: Squaliformes

9. Smooth dogfish *Mustelus canis* (Mitchill, 1815). Marine, pelagic. Smooth dogfish are uncommon in the Bay of Fundy (Scott and Scott 1988) and has been reported only in the outer Bay during summer. They could occur in Minas Passage during summer mixed with spiny dogfish shark.

10. Greenland shark *Somniosus microcephalus* (Bloch and Schneider, 1801). Marine, pelagic and benthic. Greenland sharks are extremely rare south of the Gulf of St. Lawrence. A few specimens have been taken in the outer Bay of Fundy during winter (Templeman 1963).

Greenland shark are large (6.4 m L_T) but sluggish (Scott and Scott 1988). They feed on virtually all fishes including Atlantic salmon, as well as seals and carrion. They are common in the arctic and could be more common than known during winter in the Bay of Fundy (Scott and Scott 1988). There is a lack of fish studies in the Bay of Fundy during winter. Radiocarbon dating indicated a 5.5 m L_T specimen was 392 years old, the oldest known vertebrate (Nielsen *et al.* 2016).

Greenland shark may occur in Minas Passage during winter but probably never more than sporadically. Because of their large size they would be at extreme risk to propeller turbine strike (Table 1).

11. Spiny dogfish shark *Squalus acanthias* Linnaeus, 1758. Marine, pelagic and benthic. Dogfish shark were extremely abundant in the inner Bay of Fundy during summer until 2008 (Moore 1998, Wehrell 2005, Campana *et al.* 2008) but are now relatively rare (Dadswell *et al.* 2020). They occur in the outer Bay of Fundy all year (Scott 1988, Campana *et al.* 2008) but are found in Minas Basin only during April to October (Moore 1998).

During a survey in Minas Basin from July-October 1996, a total of 1115 dogfish shark were captured using baited long lines and drift grill nets (Moore 1998). Dogfish were predominately female (99.2%) and lengths ranged from 64-113 cm L_T for females and 74-86 cm L_T for males. Ages ranged from 10-34 years for females and 10-21 years for males. Dogfish shark are ovoviviparous, meaning eggs are laid and hatch internally with no placental attachment to the female (Scott and Scott 1988). Of female dogfish captured in Minas Basin during 1996, 56.1% were reproductively mature and were carrying pups (Moore 1998). Litter sizes ranged from 1-11 embryos with a mean of 5.23 pups.female^{-1} which is similar to other reported North Atlantic populations (Dutton and Gioia 2019).

Dogfish shark that occur in Minas Basin during summer probably represent more than one stock. A total of 995 dogfish shark were tagged with numbered, external tags inside Minas Basin during 1996 (Moore 1998). Of these 33 (3.3%) were returned by commercial fishers, scientific researchers and anglers after 93-995 days at large and traveling distances from 348-1049 km. A total of eight tags were recaptured off Massachusetts and Rhode Island, 17 between Grand Manan and Lurcher Shoal in the outer Bay of Fundy, five off southeastern Nova Scotia, one off northern Georges Bank and two in Minas Basin a year after tagging. Five of these tag returns came from dogfish captured in lobster traps after they were scavenging on lobster bait.

Dogfish shark feed on wide variety of marine organisms from jellyfish to other fishes, each other and carrion. They can be expected to occur at all depths in Minas Basin, mainly on bottom during day and at the surface at night but they usually rise to the surface at slack tide regardless of time of day (Dadswell, pers. obs.).

Commercial catches of 600-700 *t*, which would represent approximately 30,000-50,000 adults, were landed from Minas Basin annually up to 2004 (Dyer *et al.* 2005). Dogfish are taken by trawls

(Fig 11), hand line (Dyer *et al.* 2005), weirs (Baker *et al.* 2014, Dadswell *et al.* 2020) and drift gill net (Dadswell *et al.* 1984a).

Dogfish will be migrating through Minas Passage during April to October. Inward movement would largely occur during April-July and outward movement from July to October. Based on an estimated fisheries mortality of dogfish shark for the Bay of Fundy (Campana *et al.* 2008) and the annual landings in Minas Basin (Dyer *et al.* 2005) approximately 1-2 million dogfish occupied the Basin each summer prior to 2005 and had to move in and out through Minas Passage. Their medium body length would make them susceptible to propeller turbine strikes especially since they are scavengers and would be attracted to turbine sites by the presence of wounded or dead fish.

Order: Rajiformes 'skates and rays'

All 'skates and rays', except the Atlantic torpedo, are strictly benthic fishes to the point where they commonly bury themselves in the substrate during day and emerge at night (Scott and Scott 1988). They are almost always found over sand, silt and mud bottoms. All species feed largely on benthic invertebrates except the Atlantic torpedo which is a fish predator. Some of the species listed below can be expected in Minas Passage during spring to fall but probably pass through rapidly because of the absence of their preferred substrate (AECOM 2009). They are abundant in trawl catches taken over soft bottom, especially at night (Wehrell 2005), but are usually not landed as commercial catch. Their benthic habitat preference will largely exclude them from possible tidal turbine impact.

12. Atlantic torpedo *Tetronarce nobiliana* (Bonaparte, 1835). Marine pelagic and benthic. Torpedo rays are a rare species on the Canadian Atlantic coast and are known only from the outer Bay of Fundy and Scotian Shelf during summer (Scott and Scott 1988). They attack fish and stun them with electric pulses. It may occur in Minas Passage during mid-summer.

13. Little skate *Leucoraja erinacea* (Mitchill, 1825). Marine, benthic. The little skate is known from the entire Bay of Fundy and occurs from the lower intertidal zone to offshore. This species is common in Minas Basin during summer (Wehrell 2005, Whidden 2015) and would be found in Minas Passage as well. Little skate is very difficult to distinguish from winter skate (Whidden 2015).

14. Smooth skate *Malcoraja senta* (Garman, 1885). Marine, benthic. The smooth skate occurs in deeper water (30-60 m) of the outer Bay of Fundy all year (MacDonald *et al.* 1984). Deepwater habitat is absent in Minas Basin except in Minas Passage where there may be habitat for this species. It may also occur in Minas Channel, perhaps during winter.

15. Thorny skate *Amblyraja radiata* (Donovan, 1808). Marine, benthic. Thorny skate is common in the entire Bay of Fundy year around (Scott 1988). It is found in Minas Basin during summer (Wehrell 2005). It will occur over hard bottom (Scott and Scott 1988) and may be more common in Minas Passage than the other skates. Scott (1988) recorded it from Minas Channel.

16. Winter skate *Leucoraja ocellata* (Mitchill, 1815). Marine, benthic. Winter skate are very common in the entire Bay of Fundy all year and are found from the lower intertidal zone to offshore (Scott 1988). Skate egg cases (known as 'witches' purses') are commonly found on beaches in Minas Basin during summer.

This skate is abundant in Minas Basin during summer and is probably present during winter (Bousfield and Leim 1959, Wehrell 2005). Winter skate should be expected in Minas Passage but residency is probably short term. There is no directed fishery for them but they are sometimes landed for lobster bait. A total of 3753 winter and little skate were captured in the Bramber weir during 2012-2014 (Whidden 2015) and 2874 were captured in the same weir during April-July 2017 (Dadswell *et al.* 2020). Whidden (2015) estimated that the population size of winter and little skate in the Avon estuary of Minas Basin was approximately 29,500 adults.

17. Barndoor skate *Dipturus laevis* (Mitchill, 1818). Marine, benthic. Barndoor skates occur year round in the Bay of Fundy (Leim and Scott 1966) and in Minas Basin during most of the year (Bleakney and McAllister 1973) but is not abundant. The most recent verified occurrence of this species was at an Economy weir during 2013 (Fig 15). The barndoor skate is a large species and preys on both invertebrates and fishes (Scott and Scott 1988). It would occur in Minas Passage during migrations to and from the Bay of Fundy.

The barndoor skate is designated not at risk by COSEWIC (2010) and is not listed for protection by SARA. Although a larger ray its benthic habitat may make it less potentially vulnerable to tidal propeller turbines.

Fig 15 Barndoor skate captured in an Economy weir, June 2013 (photograph courtesy G. Nau, Acadia University).

Fig 16 Catch of Atlantic sturgeon in the Walton weir, July 2008 (photograph courtesy S. Wehrell, Acadia University).

CLASS: OSTEICHTHYES 'BONY FISHES'

Order: Acipenseriformes 'sturgeons'

18. Atlantic sturgeon *Acipenser oxyrinchus* (Mitchill, 1814). Anadromous, benthic. The Atlantic sturgeon was the fifth most common fish captured by trawl in Minas Basin during a summer survey (Fig 16, Wehrell 2005). The aggregation in Minas Basin

Fig 17 Atlantic sturgeon feeding trace on the tide flat at Bramber, July 2017. Note the circular shape of the hole in the sediment and the rejected large gravel which has fallen beside the hole (photograph MJD).

during May-October numbers about 10,000 individuals annually and consists of mainly juveniles of 1-1.5 m L_F with some adults up to 2.8 m L_F (Dadswell *et al.* 2016). Adult Atlantic sturgeon are known to reach 4.6 m in length (Scott and Scott 1988).

Atlantic sturgeon feed on benthic invertebrates (worms, amphipods, McLean *et al.* 2013) and small fishes (sand lance, Scott and Scott 1988) in the subtidal and over the Minas Basin mud, silt and sand tide flats at high tide (McLean *et al.* 2014). They inhale the intertidal substrate and filter out the food items with their gills, rejecting the substrate (Fig 17, Pearson *et al.* 2007). They congregate in discrete 'sturgeon holes' at low tide. These locations are well known to fishers and are usually avoided (Dadswell, pers. obs.). Sturgeon are primarily benthic fish, but they often rise to the surface and make spectacular leaps to balance the gas content of their gas bladder (Logan-Chesney *et al.* 2017).

Inward migrating Atlantic sturgeon first appear mainly along the north shore of Minas Basin during April-May, move through the Basin to the Southern Bight during June-July then exit by Minas Passage during August-September (Dadswell *et al.* 2016, Stokesbury *et al.* 2016). An unknown portion of this aggregation consisting of young juveniles and adults over winters in freshwater tributaries of Minas Basin (Dadswell, pers. obs.).

Observations on the presence of ripe adults, young juveniles and the former distribution of commercial fisheries indicate that

Atlantic sturgeon spawn in the Saint John, Annapolis, Stewiacke-Shubenacadie and Avon Rivers in the Bay of Fundy and Minas Basin drainages (Leim and Scott 1966, Dadswell 2006, Dadswell *et al.* 2017, Dadswell *et al.* 2018). Juveniles remain in estuaries for 8-10 years until they are about 1 m L_F. After emigration to sea large juveniles and adults feed and migrate along east coast of North America from Virginia to Newfoundland. Tag returns (Dadswell *et al.* 2016) and DNA population discrimination (Wirgin *et al.* 2012) indicates the Minas Basin summer aggregation of Atlantic sturgeon are primarily from the Saint John R, NB (61%), and Kennebec River, ME (38%), with a few from the Hudson, Connecticut and James Rivers in the United States (US). One Atlantic sturgeon tagged on the spawning grounds in the Hudson River in 1994 was recovered at the Bramber weir in Minas Basin during 2015 after 21 years at large. Others tagged externally or with internal acoustic tags in Minas Basin were recorded at sea off New Jersey (2), New York (2), Cape Cod, MA (1) and Maine (4), and in the Penobscot River (2) ME, in the Saint John River (29) NB, and off the coast of Gaspe (1) QC (Dadswell *et al.* 2016). Twenty-seven adult sturgeon tagged acoustically in the Saint John River were detected entering or leaving Minas Basin a total of 47 times over periods up to four years (Taylor *et al.* 2016). Repeated movement through this region of potential tidal power development means that sturgeons are at risk to propeller tidal turbine impact. Also, since Atlantic sturgeon juveniles from the Saint John River, NB, will pass in and out of Minas Basin numerous times during the 10-15 years they spend at sea before maturing (Dadswell *et al.* 2016, 2017), they are at extreme risk from propeller tidal turbines.

The commercial fishery for Atlantic sturgeon in the Bay of Fundy was closed in 2002 except in the Saint John River (Dadswell *et al.* 2017). Formerly weir catches in Minas Basin were harvested and they were also commonly caught by trawlers. Atlantic sturgeon are known to be attacked in Minas Basin by great white sharks. Attack survivors are found with large tooth marks (Fig 18).

Atlantic sturgeon will be common to abundant in Minas Passage moving inward during May-June and outward during August-September and will occur throughout the water column (Stokesbury *et al.* 2016). Up to 10,000 individuals can be expected to pass through Minas Passage twice a year (Dadswell *et al.* 2016) and

Fig 18 Atlantic sturgeon with great white shark tooth marks on the body captured in the Bramber weir in August 2013. Three sturgeon were taken in the weir that summer that had been attacked by great white shark (photograph courtesy D. Porter, Avondale, NS).

abundance can be expected to increase as sturgeon conservation efforts in Canada and the US take effect (Dadswell 2006). Like sharks, sturgeons have large body size which increases their chances of propeller turbine blade strike. A total of 24, known Atlantic sturgeon turbine mortalities have been recovered seaward of the tidal turbine at Annapolis Royal, NS since generation began there in 1985 (Dadswell and Rulifson 1994, Dadswell *et al.* 2018).

19. Shortnose sturgeon *Acipenser brevirostrum* Lesueur, 1818. Anadromous, benthic. The shortnose sturgeon is largely confined to the Saint John River estuary region of the Bay of Fundy (Dadswell 1979). The shortnose is a small species of sturgeon that only reaches a maximum length of 1.4 m L_T. It feeds primarily on various species of molluscs in fresh water and in warm estuaries (soft-shell clam).

The first verified record of a shortnose sturgeon in Minas Basin was taken June 29, 2013 in the Linkletter weir at Economy (Fig 19, Dadswell *et al.* 2013). It was a 73.7 cm L_F adult and appeared to be in fine health. Shortnose sturgeon is listed as a ‘species of concern’ by SARA and since it has a relatively large body size is at moderate risk to propeller tidal turbines.

Fig 19 Head portion of a live shortnose sturgeon captured in the Economy weir on June 29, 2013 (photograph courtesy G. Nau, Acadia University).

Order: Anguilliformes 'eels'

20*. *American eel *Anguilla rostrata* (Lesueur, 1817). Catadromous, benthic. American eel is common to abundant in all tributaries of the Bay of Fundy and Minas Basin, in estuaries and along marine shorelines (Dadswell *et al.* 1984a). Adult eels spawn in the Sargasso Sea off the Bahamas and their leptocephalus larvae arrive off Canada after drifting north in the Gulf Stream (Scott and Scott 1988). The larvae metamorphose into glass eels in coastal waters then migrate onshore and into freshwater streams. Mainly females migrate upstream while males live in estuaries and along marine shorelines (Jessop 1996). American eel inhabit warm water ecosystems during summer but hibernate in marine and freshwater mud bottoms during winter. Eel are predatory, feeding on any and all invertebrates and fishes they can ingest. They also scavenge dead and dying organisms and can cause considerable harm to commercial fish catches. Females return to the sea at maturity after 7-10 years of growth and with the mature males migrate to the Sargasso Sea to spawn (Scott and Scott 1988). After spawning the adults die.

American eel support commercial fisheries at all life stages: as glass eels entering freshwater, as yellow eels during growth in freshwater and as silver eels while migrating back to the sea (Jessop 1996). Eels are an important, local fishery in the Minas Basin tributaries (Dyer *et al.* 2005). Eel populations around the North Atlantic are in severe decline and were assessed as threatened by COSEWIC (COSEWIC 2012).

Glass eels (6-10 cm L_T) will be abundant in Minas Passage and at the mouths of Minas Basin streams during April and May. Silver eels (80-100 cm L_T) will migrate offshore through Minas Basin and Passage during August to October. The abundance of glass eels occurring in Minas Passage annually will probably be in the millions (Jessop 1996). Silver eels migrating seaward will possibly number in the range of 10,000-20,000 (Dyer *et al.* 2005). Eels are scavengers and would be attracted to a turbine sites by dead fish. With a body length up to 1 m L_T they are at moderate risk to propeller turbines. The large 'silver' eels will probably be threatened less by propeller turbines since at this stage they do not feed (Scott and Scott 1988).

Order: Clupeiformes 'herrings'

A total of five species of clupeids utilize Minas Basin and its tributaries as foraging and/or spawning locations. As a group they are the most abundant and important commercial species occurring this the region.

The clupeids lack a lateral line and instead have evolved a highly specialized gas bladder that functions to enhance sound reception (Hoss and Blaxter 1979). The system includes two, thin-walled, forward projecting tubes from the gas bladder that interface with the otic bulla of the hind brain (Fig 20). Hydrostatic pressure flux during propeller turbine passage causes rapid expansion of the gas bladder and the tubes leading to the otic bulla causing hemorrhaging of the hind brain and death (Dadswell and Rulifson 1994). All clupeids are susceptible to high levels of propeller turbine impact

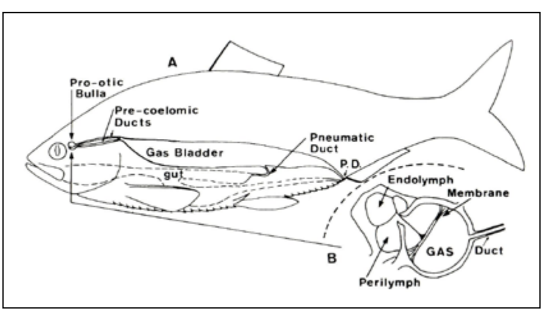

Fig 20 Gas bladder arrangement of a clupeid fish; A) gas bladder with pre-coelomic ducts leading to the pro-otic bulla of the hind brain, B) pro-otic bulla illustrating the tympanic membrane and gas chamber (adapted from Blaxter and Hoss 1979).

(Stokesbury and Dadswell 1991, Dadswell and Rulison 1994, Gibson and Myers 2002, Dadswell *et al.* 2018).

Clupeids also school into dense 'bait balls' as a predator defense mechanism when under attack by pelagic fishes or cetaceans (porpoise, Gaskin 1985). If a school of herring or alosids make propeller turbine passage during a 'bait ball' situation many would be struck or killed by blade strike because of the dense packing of the school.

21. Blueback herring *Alosa aestivalis* (Mitchill, 1814). Anadromous, pelagic, planktivorous**.** The blueback herring, 'gaspereau' or 'river herring' are common to abundant in every tributary of the Bay of Fundy with spawning habitat (riffles and rapids) and access (no waterfall at tide head, Dadswell 1985). Adults spawn in freshwater during spring (May-June) after which they return to the sea (Scott and Scott 1988). Juveniles migrate to sea during August to October at an average length of 10 cm L_F (Stokesbury and Dadswell 1989). Growth to maturity requires 4-5 years at sea while the North American Atlantic stocks migrate north and south annually (Neves 1981). Blueback herring are facultative and filter feeding predators of zooplankton and neuston in the water column and exploit the highly productive secondary production of copepods, mysids, amphipods (*Corophium*) and sand shrimp (*Crangon*) in Minas Basin (Stone and Daborn 1987).

Blueback herring are extremely abundant in the pelagic zone of Minas Basin during summer. Mid-water trawl catches up to 345 h^{-1} of 'gaspereau' were made off Economy Point during late June 1983 (Bradford 1987). Stone (1985) found adult blueback herring were most abundant in Minas Basin gill net catches during July and in weirs during August and September. The summer aggregation in Minas Basin is derived from east coast stocks from as far south as North Carolina (Rulifson *et al.* 1987). During 1983-1986 a total of 18,958 gaspereau were tagged in weirs and off vessels in Minas Basin. From these tags there were a total of 74 (0.39%) tag returns of which six were from Blueback herring caught in commercial fisheries including three from Albermarle Sound, NC 2,400 km distant, one from Maryland and two from Nova Scotia.

Blueback herring and alewife support large fisheries in the Gaspereau and Shubenacadie Rivers (Dyer *et al.* 2005) and in the intertidal weirs of Minas Basin (Rulifson *et al.* 1987, Dadswell *et al.* 2020). Adults and juveniles are taken in the intertidal weirs from

April to December but the major movement through Minas Passage is probably into Minas Basin from March to July and exiting the Basin from July to November. The timing, spatial distribution and intensity of this movement requires research but the abundance of this population will be in the 10's of millions. During 2017 an estimated total of 350,000 gaspereau were captured in the Bramber weir (Dadswell *et al.* 2020).

22. Alewife *Alosa pseudoharengus* (Wilson 1811). Anadromous, pelagic, planktivorous. Like blueback herring, alewife is common to abundant in every tributary of the Bay of Fundy with spawning habitat (lakes and slow riverine areas) and access (no waterfall at tide head, Scott and Scott 1988). They spawn in fresh water during May-June after which the adults return to sea (Scott and Scott 1988). Juveniles migrate to sea during August to October at an average length of 10 cm L_F (Stokesbury and Dadswell 1989). Growth to maturity takes 4-5 years at sea while stocks migrate north and south along the Atlantic coast annually (Neves 1981). Alewife, like blueback herring, is a facultative and filter-feeding predator on plankton and neuston in the water column (Stone and Daborn 1987). In Minas Basin they feed on plankton such as copepods and mysids and suspended benthic organisms like amphipods (*Corophium*) and shrimp (*Crangon*). Both alewife and blueback herring appear to be more adept than American shad at feeding in the turbid waters of Cobequid Bay. Their stomachs seldom contained more than 20-30% detritus when captured in this location (Stone and Daborn 1987).

Alewife are extremely abundant in the pelagic zone of Minas Basin during summer where mid-water trawl catches of 'gaspereau' were up to 345 h^{-1} (Bradford 1987) and drift gillnet catches were up to 55.0 100 m^{-3} .30 min^{-1} (Stone 1985). Like blueback herring the summer aggregation in Minas Basin is derived from many Atlantic coast stocks (Rulifson *et al.* 1987). Of the 18,958 'gaspereau' tagged in Minas Basin during 1983-1986 there were 58 tag returns of alewife; 18 from the commercial fishery in the Gaspereau River, NS, three from the commercial gill net fishery in the Shubenacadie River, NS, 34 from weirs and gill nets in Minas Basin, one each from commercial fisheries in the Tusket and Lahave Rivers, NS and one from a commercial trawler in Ipswich Bay, Massachusetts.

Alewife support commercial fisheries in the Gaspereau and Shubenacadie Rivers (Dyer *et al.* 2005) and from intertidal weirs of

Minas Basin (Dadswell *et al.* 1984a, Dadswell *et al.* 2020). The commercial catch in the Gaspereau River ranged from 64-200 *t* y^{-1} and in the Shubenacadie River, 50-363 *t* y^{-1} during the period 1965-2000 (Dyer *et al.* 2005). The spawning population of alewife in the Gaspereau River ranges from 200,000-1 million adults annually (Gibson and Myers 2003). Alewife is captured in rivers from April to June and in intertidal weirs from April to December (Rulifson *et al.* 1987).

Alewife movement through Minas Passage is probably inward during March to July and outward from August to November. Like blueback herring, the timing, spatial distribution and intensity of this movement requires research but again the abundance will be in the 10's of millions of individuals from age- 0+ to 6+.

23. American shad *Alosa sapidissima* (Wilson, 1811). Anadromous, pelagic, planktivorous**.** American shad are common to abundant in all Bay of Fundy tributaries with spawning habitat (deep, rapid flow riverine sections) and access from the sea (no waterfall at tide head, Leim and Scott 1966). Adults spawn in freshwater during spring (May-July) after which they return to sea. Juveniles depart fresh water at 10 cm L_F after 3-4 months of growth (Aug-Oct, Stokesbury and Dadswell 1989). Shad mature after 4-5 years at sea then return to their natal river to spawn (Melvin *et al.* 1986). While at sea adults and juveniles migrate along the Atlantic coast from North Carolina in winter to the Bay of Fundy, the Gulf of St. Lawrence and Labrador in summer (Fig 2, MacDonald 1884, Dadswell *et al.* 1987). From three years of research in Minas Basin during which 5790 external tags were applied to shad (Fig 21) there have been a total of 368 (6.3%) tag returns from as far south as the St. John's River, Florida and as far north as Labrador (Fig 22).

American shad of all ages are extremely abundant in the inner Bay of Fundy during May-October (Dadswell *et al.* 1983, 1984b) where the population consists of migrating stocks from all rivers on the Atlantic seaboard from Labrador to Florida. This mixture of stocks has been demonstrated with tagging studies (Dadswell *et al.* 1987), meristics and morphometrics (Melvin *et al.* 1992), otolith morphology (Williams 1985), parasites (Hogans *et al.* 1993) and DNA discrimination (Waldman *et al.* 2014). The coastal migratory population enters the Bay of Fundy along the Nova Scotia shore and follows the residual current pattern through the Bay departing on the New Brunswick shore (Fig 10). Shad become increasing dense as

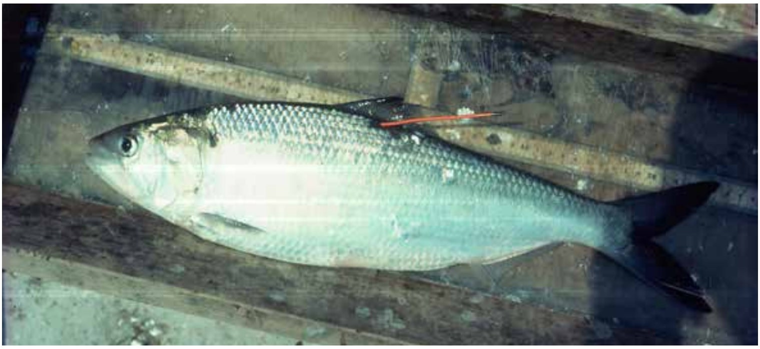

Fig 21 **American shad captured in an experimental gill net in Minas Basin with an external, numbered spagetti tag applied under the dorsal fin. This particular shad was captured on July 8, 1982 and was recaptured on Dec 18, 1982 by a commercial fisher in the St. John's River, Florida after traveling an approximate distance of 2100 km over five months (photograph MJD).**

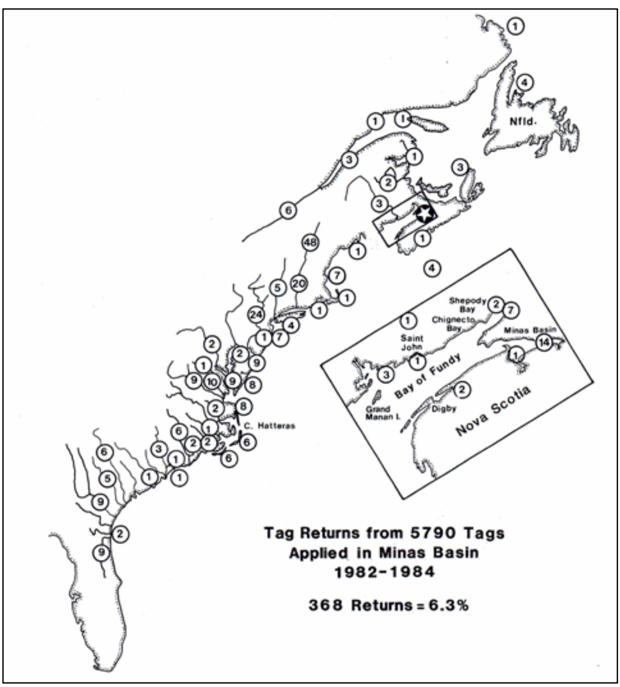

Fig 22 **Tag returns (368) from American shad tagged in Minas Basin (5790) during 1982-1984 that were recaptured by commercial and recreational fishers along the east coast of North America. Shad were recaptured in the sea and in rivers using gill nets, weirs, trawls, haul seines and by angling.**

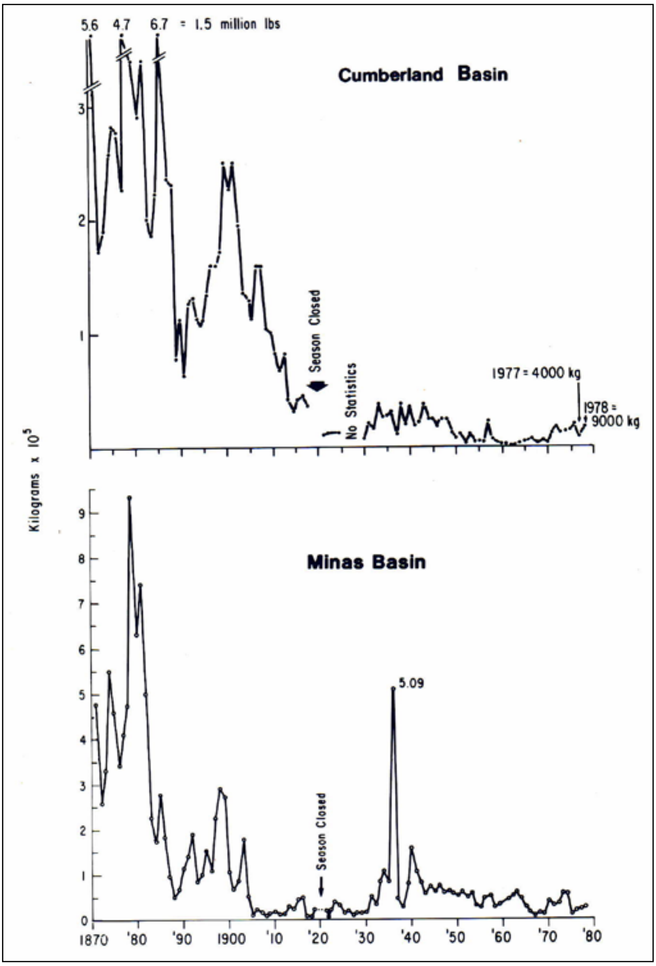

Fig 23 **Commercial shad landings (kg X 10^5) in Cumberland and Minas Basins during 1870-1980. Note the difference in scale for the two localities. Landings collapsed after 1905. The season was closed from 1919-1921 but had no effect on landings. The Royal Commission established to study the collapse of the fishery was from 1921-1924.**

they move into the embayments (Minas Basin, Cumberland Basin) at the inner end of the Bay of Fundy where the run effectively doubles back on itself. Population estimates for American shad in Minas Basin during 1982 indicated approximately 2.9 million adults were in the Basin during the 12-week period from June 1 to August 24 (Dadswell *et al.* 1984b).

Research indicated that during the summer period when shad were in the turbid regions of Minas Basin they ingested a reduced daily ration because they were relatively unsuccessful at particle feeding in the turbid water (Themelis 1986). Stomachs from shad analyzed during this period contained plant detritus (up to 95% in Cobequid Bay) and only small amounts of food (copepods, mysids, shrimp, etc.). Individuals lost condition and muscle lipid content fell from a mean of 22.7% when the shad entered Cobequid Bay in early June to 16.3% when they were departing in late July. This seeming conundrum can be explained by the fact that the shad migration path in the Bay of Fundy and Minas Basin is apparently dictated by the direction of the residual currents rather than the availability of food (Dadswell *et al.* 1984b). When shad returned to the clear water in the Bay of Fundy stomach contents contained no detritus and were full of copepods and euphausiids (100%). Their muscle lipid content rebounded to a mean of 28.9% by the time they reached Grand Manan Island at the outer Bay of Fundy during September (Themelis 1986).

Before 1900 the fishery for American shad in Minas and Cumberland Basins used to be the most important fishery in the Bay of Fundy (Prince 1912). Shad were taken with weirs and gill nets then salted and exported to the eastern United States. Annual catches ranged from 550-1100 $t\ y^{-1}$ in Minas Basin (Fig 23). Their catchability in the iBoF is a direct result of the turbid water in these regions which decreases light penetration to shallow depths causing the shad to rise in the water column and become easily accessible to fishing gear (Dadswell *et. al.* 1983). The iBoF shad fishery collapsed after 1905 because of pollution and dam construction on their major spawning rivers in the US (Stevenson 1898). The collapse of the shad fishery in the iBoF lead to a Royal Commission investigation which resulted in some of the first scientific studies on shad and other fishes in Canada (Huntsman 1922, Leim 1924).

Present day commercial fisheries for shad exist in Minas and Cumberland Basin, and the Saint John, Shubenacadie and formerly the Petitcodiac and Avon Rivers in the Bay of Fundy (Leim and Scott 1966, Dadswell *et al.* 1984a). The shad gill net fishery in the Shubenacadie River varied from 10-60 *t* annually between 1991 and 2001 (Dyer 2005). In Minas Basin shad are taken by intertidal weirs (Fig 12) and drift gill net (Fig 13) during May-August

(Dadswell *et al.* 1984b). A total of 7,176 American shad were captured in the Bramber weir during 2017 (Dadswell *et al.* 2020).

Shad migrate inward through Minas Passage to Minas Basin from April-July and outward to the Bay of Fundy during July-October. The total population (0+ juveniles to adults) migrating through Minas Passage annually is possibly in the range of 10 million fish. Since the migration speed of feeding shad in the Bay of Fundy and Minas Basin was estimated at 3.0-3.5 $km.d^{-1}$ (Dadswell *et al.* 1987), adult shad should make the crossing through Minas Passage in about 4-5 days. Smaller shad will probably take longer. The larger size of the adults (40-60 cm L_F) makes them susceptible to propeller turbine mechanical strike impact (Dadswell and Rulifson 1994) and juveniles are susceptible to pressure flux, shear and cavitation (Stokesbury and Dadswell 1991). Experimental passage of post-spawning, adult shad through the Annapolis Royal tidal turbine during 1986 resulted in an estimated mortality of 21.3 ± 15.2 % (Dadswell and Rulifson 1994). Shad that migrate to Minas Basin during summer from rivers in the United States (Connecticut to Georgia) support a large fishery for flesh and roe in that region (Hilton *et al.* 2010). The impact of potential tidal power development on this fishery could be similar to the former impact on the iBoF shad fishery after 1905 by pollution and damming of rivers in the United States.

24. Atlantic menhaden *Brevoortia tyrannus* (Latrobe, 1802). Amphidromous, pelagic, planktivorous. Menhaden filter feed on phytoplankton and detritus (Durbin and Durbin 1975). Juvenile menhaden are found in large Bay of Fundy estuaries (Annapolis and Saint John Rivers, Stokesbury and Stokesbury 1993). Adults spawn in Minas Basin off Burntcoat Head in June (Fig 24, Dadswell, unpub. data) and some adults over winter in Kennebecasis Bay in the Saint John River estuary (Scott and Scott 1988). Occasionally, southern stocks from Chesapeake Bay penetrate into the Bay of Fundy during warm summers (Bigelow and Schroeder 1953).

The population that occurs in Minas Basin is apparently small. Seldom more than 10-20 individuals are taken in intertidal weirs during summer (July-August, Dadswell *et al.* 2020). The species is not fished commercially in Canada.

Adults would traverse Minas Passage inward to spawn in Minas Basin during May-June. Adults and juveniles would depart Minas Basin via Minas Passage in late summer. Population size

Fig 24 Gravid female American menhaden captured west of Burncoat Head just outside Cobequid Bay in June 1983. Note the bright orange eggs in the gonad. Spawning was to be within days (photograph MJD). A total of 12 ripe females and 14 ripe males were captured.

moving through Minas Passsage probably consists of a few hundred adults and 100 thousand+ juveniles. Like all clupeids they would be impacted by strike, pressure flux, cavitation and shear during passage through propeller turbine draft tubes.

25. Atlantic herring *Clupea harengus* Linnaeus, 1758. Marine, pelagic, planktivorous**.** Herring are common to extremely abundant in all parts of the Bay of Fundy. Adults are marine, benthic spawners and stocks congregate on Lurcher Shoal off Yarmouth during October, in Scots Bay during August, and in Minas Basin during May to spawn (Bradford and Iles 1993). Larvae and juveniles (brit) form dense schools in the inner Bay of Fundy. Bradford and Iles (1993) found larval densities were highest inside Minas Basin (5.0-35.1 m^{-3}). Abundance of herring larvae in Minas Passage during July were about 50% of the catches inside Minas Basin (Bradford 1987). One-half hour midwater trawl tows in Minas Channel caught 1000-10,000 brit during August and brit were abundant in other parts of the inner Bay of Fundy surveyed during February (Koeller 1979). Larger juveniles aggregate in Minas Basin during early summer (Fig 25, 'June herring', Perley 1852, Dadswell *et al.* 1984a, Bradford 1987). Adult herring schools occur at all depths in the water

Fig 25 'June' Atlantic herring catch in a weir on the north shore of Cobequid Bay just inside Economy Point during June, 1983 (photograph MJD).

column but mainly near bottom during day and near surface at night. They form dense 'bait balls' when attacked by harbour porpoise (Gaskin 1985, Dadswell, pers. obs.). Herring are facultative and filter feeding planktivorous predators. Unlike other clupeid species adults generally avoid the turbid water in Cobequid Bay. Larvae and juveniles can maintain themselves in discrete areas near their spawning sites where productivity is high (Iles and Sinclair 1982). Based on observed abundance of larvae and juveniles three of these regions are inside Minas Basin near Economy Point, in Minas Passage and in Minas Channel (Koeller 1979, Bradford and Iles 1993).

Herring in Minas Basin, Minas Passage and Minas Channel are caught using intertidal weirs, intertidal gill nets and by purse seining (Bradford 1987). The weir at Bramber in Minas Basin caught an estimated 87,600 adult herring during April to June 2017 (Dadswell *et al.* 2020). The spawning stock biomass of the spring spawning group in Minas Basin is estimated to be 500 *t* which yields annual catches of about 50 $t.yr^{-1}$ (Bradford and Iles 1993). The biomass of the summer spawning group in Scots Bay-Minas Channel is estimated at approximately 100,000 *t* with an annual yield of 7,300 *t* (R. Singh, DFO, pers.comm.). Atlantic herring support the largest fishery by biomass in the Bay of Fundy (CSAS 2007). The total allowable catch (TAC) has been set at 35,000 *t* from the estimated total adult biomass of 500,000 *t*.

Herring of most life stages (larvae, juveniles and adults) are common to extremely abundant in Minas Passage during the entire year (Koeller 1979, Bradford and Iles 1993). Larvae are abundant during spring, summer and fall and brit are common during winter.

Large juveniles and adults are abundant moving inward and outward through Minas Passage during March-June (Minas Basin stock adult spawners, 'June' herring juveniles). Adult spawners from the Scots Bay spawning stock are abundant in Minas Channel during July-September and large schools probably penetrate Minas Passage during this period. Like all clupeids they are susceptible to multiple forms of mortality during passage through propeller tidal turbines (Gibson and Myers 2002). Herring are extremely sensitive to pressure flux (Hass and Blaxter 1979).

Order: Salmoniformes 'salmon and trout'

26. Brook trout *Salvelinus fontinalis* (Mitchill, 1814). Anadromous, benthic/pelagic. Populations of brook trout occur in virtually every tributary of the Bay of Fundy from small brooks to large rivers (Scott and Scott 1988). Juveniles remain in fresh water but adults enter marine waters from April to August then return to over winter in freshwater. Brook trout support the most popular recreational fishery in Nova Scotia (McMillan *et al.* 2008).

Although brook trout are common to all tributaries of Minas Basin, Minas Passage and Minas Channel they are very seldom found during sampling in Minas Basin (Dadswell *et al.* 1984a, D. Porter, commercial fisherman, pers. obs). During weir surveys in Minas Basin since 1982, brook trout have rarely been encountered even when the weirs are situated within a kilometer or two of known brook trout streams (Walton River, Harrington River). The weir at Bramber only captured one brook trout during 2017 (Dadswell *et al.* 2020). Likewise, brook trout are seldom encountered during gill net sampling or angling in marine waters (J. Broome, Acadia University, pers. comm.). Brook trout probably occur only in the mouths of freshwater tributaries of Minas Passage and are probably in estuarine waters only from April to August. Their avoidance of the open marine habitat in this region should mean they will be little impacted by propeller tidal turbines.

27. Atlantic salmon *Salmo salar* Linnaeus, 1758. Anadromous, pelagic. There were once approximately 59 iBoF tributaries which had stocks of Atlantic salmon but at least 7 of these are now extinct because of dams or causeways (Avon, Petitcodiac, Amiro 2003). The Petitcodiac River stock is now under restoration after removal of the causeway at Moncton. Inner Bay of Fundy stocks were assessed endangered by COSEWIC in 2003 and are now listed under

Schedule l by SARA (no allowable take; CSAS 2004). There were Atlantic salmon runs in most tributaries of Minas Basin including the Shubenacadie-Stewiacke, Salmon, Gaspereau, Cornwallis and Avon Rivers and all tributaries along the north shore from Truro to Parrsboro. Many of these streams now lack populations because of causeways or the collapse of inner Bay of Fundy stocks (Gibson *et al.* 2003b).

Atlantic salmon spawn in fall in freshwater streams and most adults from iBoF rivers return to sea by December (Amiro *et al.* 2003). Juveniles (parr) remain in fresh water for 1-3 years then migrate to sea during May-June as smolts. Adults remain at sea for 1-4 years migrating in the North Atlantic in regions with water temperatures of 4-10 C^{o} (Dadswell *et al.* 2010). Adults home to natal iBoF rivers from August to November. Salmon runs in most Minas Basin rivers consisted of 1 SW adults (50-60 cm L_F) and returning kelts (multiple spawners, Huntsman 1958, Amiro *et al.* 2003).

Formerly Minas Basin had both commercial and recreational salmon fisheries. The commercial fishery was closed in 1984 (Dadswell *et al.* 1984a) and angling in 1992 (Amiro *et al.* 2003). Salmon were taken by the commercial fishery in Minas Basin by drift gill nets and intertidal weirs (Huntsman 1958). Catches from 1900-1984 varied between 1-4 *t* y^{-1} (Dadswell *et al.* 1984a). Angling occurred in most Basin tributaries. Formerly, angling catches in the Shubenacadie-Stewiacke River basin were from 500-1000 y^{-1} (Morantz 1978) but catches in other tributaries seldom exceeded 100 y^{-1} (Amiro *et al.* 2003). The estimated population of returning adults to Minas Basin tributaries was around 40,000 as recently as 1989 but only 250 were counted in 1999 (Amiro 1999). Similarly, parr densities have declined in all tributaries (Gibson *et al.* 2003b). The smolt run size in the Gaspereau River during 2009 was estimated to be about 5,600 fish but only 1,100 were wild smolts, the rest were stocked hatchery fish (Quinn 2010).

Atlantic salmon smolts can be expected migrating seaward through Minas Passage during May to July. Atlantic salmon adults will occur in Minas Passage from June to December. Although most adults will be from Minas Basin tributaries some are migrants from other Bay of Fundy stocks, the US (Connecticut and Penobscot Rivers, Meister 1984) and the Gulf of Saint Lawrence (Miramichi River, Saunders 1969). Pre-spawning adults will be migrating inward during June to November. Kelts (post-spawning salmon) will be moving seaward during November-December.

Smolt migration speeds at sea average 6-26 km.d^{-1} (Lacroix and McCurdy 1996) and most smolts would be expected to clear Minas Passage in one to two days unless countered by gyre currents (Lacroix 2008). Adult salmon make from 20-50 km.d^{-1} when migrating at sea (Meister 1984, Hansen *et al.* 1993) and movement through Minas Passage would be rapid.

Numbers of migrating smolt will probably be in the range of 10,000 to 20,000 annually (wild and hatchery fish) and numbers of migrating adults at present population levels will probably be less than 500 individuals inward and perhaps half of that outward as kelts. If, however, iBoF salmon stocks rebound in the future 20,000 to 40,000 adults could make the passage each year and the number of smolt could increase up to a million annually.

Adult salmon, because of their relatively large size, will be at risk of mechanical strike from propeller, tidal turbines (Dadswell and Rulifson 1994). While occupying a fixed, mid-water trawl survey site at the mouth of Cobequid Bay during June 1983 an adult salmon was cut in half by the propeller of the 26 m research vessel which was under power to relieve strain on the anchor (Dadswell, pers. obs.). The salmon was recovered in the research net in two pieces. Salmon smolts are susceptible to shear damage during passage through propeller turbine draft tubes (Dadswell and Rulifson 1994).

28. Brown trout *Salmo trutta* Linnaeus, 1758. Anadromous, benthic-pelagic**.** Brown trout were introduced from Europe during the late 1800's and early 1900's and have become well established in Minas Basin rivers especially the Cornwallis and Shubenacadie (Leim and Scott 1966). Their life history is similar to Atlantic salmon except brown trout remain at sea only from May to September and do not move far from their natal river. Brown trout are seen more often in intertidal weirs in Minas Basin than brook trout and are sometimes captured in drift gill nets (Dadswell *et al.* 1984a). A total of nine brown trout were captured in the weir at Bramber during 2017 (Dadswell *et al.* 2020).

There are few rivers with brown trout near Minas Passage and this species should only occur sporadically offshore in the Passage. If present it would be from May to September. Their propeller tidal turbine risk is similar to that of Atlantic salmon.

29. Coho salmon *Oncorhynchus kisutch* (Walbaum, 1792). Anadromous, pelagic. Coho salmon were introduced into Maritime rivers from western Canada during the early 1900's but most populations have since died out (Scott and Scott 1988). Coho were common in the Bay of Fundy during the 1980's when large numbers were being stocked in New Hampshire, US and adults migrated north to the Bay of Fundy (Martin and Dadswell 1983). The New Hampshire stocking was terminated in the 1990's. There was also a spawning population in the Cornwallis River which resulted either from the New Hampshire introductions or hatchery escapees (Martin and Dadswell 1983).

Coho life history is somewhat similar to Atlantic salmon except they migrate to sea at a younger age and smaller size (after one year in the river). No adults have been recorded in Minas Basin since the late 1980's and the population in the Cornwallis River may be extirpated. They may be encountered rarely in Minas Basin and Passage. There was an angling fishery for coho in the Cornwallis River.

30. Rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792). Anadromous, pelagic. Rainbow trout were introduced to the Maritimes from western Canada in the late 1800's and introductions continue into the present since rainbow trout in aquaculture operations often escape (Scott and Scott 1988). Their life history is similar to brown trout. Rainbows migrate into the sea in spring, feed in salt water during summer and return to fresh water during fall for over wintering. The species is not common in iBoF tributaries but occurs in some. A few should be expected sporadically in Minas Channel.

Order: Osmeriformes 'smelts'

31. Rainbow smelt *Osmerus mordax* (Mitchill, 1814). Anadromous, pelagic. Rainbow smelt are extremely abundant and ubiquitous in all regions of the inner Bay of Fundy (Dadswell *et al.* 1984a). Spawning stocks occur in all rivers and brooks with access from the sea and spring arrivals of ripe adults are close to the same time period every year in each stream. Two examples are: spawning smelt appear in the Gaspereau River on the south side of Minas Basin during late April and in the Portapique River on the north side during the second week of May (Dadswell, pers. obs.). Spring arrival of spawning populations are exploited by recreational fishers using dip nets but there is no directed commercial fishery in Minas Basin. After the adhesive eggs hatch in fresh water the larvae drift into the sea and there are dense concentrations of pelagic larvae in the Minas Basin from May to August (Roberts 1987, Bradford 1987). Juveniles and adults occur in the water column and along shorelines (Dadswell *et al.* 1984a). Smelt mature in their second summer of life and seldom live past age-4 (Scott and Scott 1988). They are voracious predators and eat virtually anything smaller than themselves. There is an angling fishery for them in Minas Basin off wharfs and through the ice during fall and winter (D. Porter, pers. comm.).

During April to July 2017, a total of 94,000 smelt were captured in the Bramber weir (Dadswell *et al.* 2020). Catches of 10-1000 smelt were taken in the weir during daytime low tides. Catches during low tide at night seldom exceeded ten fish. Similar catches were recorded in the Five Islands weir during 2013 (Baker *et al.* 2014).

Surveys for smelt have never been carried out in Minas Passage but they should be abundant especially near shore. They can be expected to occur in Minas Passage year round but could be more abundant during winter when colder water in Minas Basin could cause seaward migration from the Basin. Because of their small body size and high abundance their population would be at little risk from tidal turbines.

32. Capelin *Mallotus villosus* (Müller, 1776). Marine, pelagic, planktivorous. Capelin spawn in the sand of marine beaches at the high tide level during May-June (Scott and Scott 1988). They have only been captured occasionally in the Bay of Fundy (Tibbo and Humpreys 1966) but there may be one stock that spawns on beaches of the Fundy National Park (Perley 1852). Capelin probably rarely occur in Minas Passage but schools of this subarctic fish may be present during winter. They have never been taken in Minas Basin (Bleakney and McAllister 1973, Dadswell *et al.* 1984a, Dadswell *et al.* 2020).

Order: Lophiiformes 'goosefishes, anglers'

33. Monkfish *Lophius americanus* Valenciennes, 1837. Marine, benthic. Monkfish are common but not abundant throughout the Bay of Fundy and in Minas Basin (Bleakney and McAllister 1973, Scott 1988). Monkfish feed largely on fishes especially flounders and follow the flounder migration to the inner Bay of Fundy during summer. They can grow to a size of 1.0 m L_T.

This fish is a benthic, lay-in-wait predator that uses a modified dorsal fin spine over the snout as a lure-like structure to attract prey (the illicium and esca are the specialized structures). It moves onto the intertidal zone at high tide while pursuing flounders and is often stranded on tide flats by the rapid fall of the tide (Bleakney and McAllister 1973, Dadswell, pers. obs.).

Monkfish are taken in small numbers as by-catch in the groundfish and scallop fisheries and in intertidal weirs in Minas Basin and Scots Bay (Beanlands *et al.* 2000). During 2017 four monkfish were caught at the Bramber weir (Dadswell *et al.* 2020). The population in the Bay of Fundy is stable and landings from 1990 to 2000 averaged 700 *t* y^{-1} (Beanlands *et al.* 2000).

Monkfish will be passing into and out of Minas Basin via Minas Passage from April to October. They will be present in small numbers and will probably remain on or near the bottom and in near shore locations. Their risk from propeller tidal turbines is low.

Order: Gadiformes 'codfishes'

34. Fourbeard rockling *Enchelyopus cimbrius* (Linnaeus, 1766). Marine, benthic. Rockling are a small, cod-like fish that are common over mud and gravel bottom in the outer Bay of Fundy (MacDonald *et al.* 1984). They are rare inside Minas Basin and adults have only been observed twice in the intertidal zone, once by Bleakney and McAllister (1973) and again in 2018 (Fig 26, E. Porter, pers. comm.). They prefer cooler water (Scott and Scott 1988) and may be more common in Scots Bay and Minas Channel. Daborn (1984) reported their larvae were abundant in neuston samples from Minas Channel (15.4 1000 m^{-3}). Adults are small and seldom exceed 30 cm L_T.

Rockling adults should be rare in Minas Passage since the bottom consists primarily of scoured rock (AECOM 2009). Rockling larvae are abundant near the surface from May-August during some years. The potential for harm from hydrokinetic turbines is minimal.

35. Atlantic cod *Gadus morhua* Linnaeus, 1758. Marine, benthic-pelagic. Cod were once very common in the entire Bay of Fundy but stocks are now depleted (CSAS 2006). Landings in the Bay of Fundy fell from 24,000 *t* in 1990 to 3800 *t* by 2006. Overfishing is probably the root cause but some are suggesting an oceanographic regime change occurred (Bundy and Fanning 2005). Recruitment to the stock has been poor since 1990 and the spawning stock biomass remains low, so the allowable catch was set at 1800 *t* in 2008 (Clark and Emberley 2009) but is now only 825 *t* (D. Themelis, DFO, pers. comm.).

Fig 26 Fourbeard rockling found in a tide pool on the intertidal zone off Burntcoat Head during June, 2018 (photograph courtesy E. Porter, Avondale, NS).

Cod are found in Minas Basin and Minas Channel only during the seasonal coldwater period when temperatures are from 3-10° C (November to June; Scott 1987). Cod feed on invertebrates and fishes and will follow alosid spawning runs into the low salinity water of estuaries (Dadswell, pers. obs.). Cod were formerly caught commercially in Minas Basin by long lines set in the intertidal zone (Dadswell *et al.* 1984a) but the fishery is now closed. They are taken in intertidal weirs occasionally (Dadswell *et al.* 1984a, Dadswell *et al.* 2020) and as by catch in the flounder trawl fishery during June-July (Wehrell 2005). During 2004 six cod were taken in trawl surveys in Minas Basin and during 2017 a total of six were taken in the Bramber weir.

Cod can be expected in Minas Passage from November to July but are probably most common during March-May. It will occur on bottom and in mid water. Until the stock rebounds numbers will be low and probably fewer than a thousand will pass in and out of Minas Basin during a year. Adults, because of their size, will be at risk from propeller tidal turbines.

36. Haddock *Melanogrammus aeglefinus* (Linnaeus, 1758). Marine, benthic. Haddock were once very common in Bay of Fundy during summer from Scots Bay to Lurcher Shoal while on feeding migrations from Brown's Bank and the Gulf of Maine (Perley 1852, Scott 1988). After 1965, however, haddock became rare in the inner

Bay of Fundy because of overfishing and poor recruitment (Scott 1987, Frank 1992). Before the decline of the haddock stock in 1965 landings in the iBoF were substantial but all landings in the Bay of Fundy continue to remain low and were only 5-8 *t* y^{-1} from 1990-2005 (Dyer 2005). The lack of haddock in the iBoF, however, seems unexplained since the Scotian Shelf-Bay of Fundy stock is healthy and has grown to a large size. The spawning stock biomass was 33,770 *t* in 2016 and is expected to increase to 100,000 *t* because of the highest level of recruitment on record in 2013 (DFO 2017a). Perhaps haddock will once again be abundant in the iBoF.

Haddock only occur in the Bay of Fundy during summer where they feed over mud bottoms on small invertebrates. In winter they are offshore on the Scotian Shelf (MacDonald *et al.* 1984, Scott 1988). Haddock have never been recorded from Minas Basin (Huntsman 1922, Dadswell *et al.* 1984a) even though they were once abundant in Scots Bay (Scott 1987). Their absence from Minas Basin could be explained because of a lack of proper substrate and because they select temperatures of 4-8 C° (Scott and Scott 1988). Haddock will probably seldom occur in Minas Passage because of higher summer temperatures and a lack of preferred feeding substrate (AECOM 2009).

37. Silver hake *Merluccius bilinearis* (Mitchill, 1814). Marine, benthic and pelagic. Silver hake are common in the Bay of Fundy during summer from Scots Bay to Lurcher Shoal (Simon and Comeau 1994). Silver hake are often captured in intertidal weirs in Scots Bay and Minas Basin but never in large numbers (Leim 1924, Dadswell *et al.* 1984a). The weir at Bramber in Minas Basin caught 384 silver hake during April-July, 2017 (Dadswell *et al.* 2020). No directed fishery exists in the Bay of Fundy because of low abundance and a lack of markets in North America (Simon and Comeau 1994).

Silver hake can be expected in Minas Passage during July to September but numbers will be low, probably only a few thousand fish. They migrate predominately in the water column (Scott and Scott 1988) so will be at risk from propeller tidal turbines.

38. Red hake *Urophycis chuss* (Walbaum, 1792). Marine, benthic. Red Hake is common in all regions of the Bay of Fundy, especially so in the outer Bay where juveniles are commensal with sea scallops during the first year of their life (Markle *et al.* 1982, Garman 1983). Juveniles (age-1) are common to abundant in Minas Basin intertidal weir catches during July after leaving their scallop hosts and while on migration around the Bay of Fundy to the Scotian Shelf (Dadswell, pers. obs.). During 2017 the weir at Bramber caught over 7000 juvenile hake (Dadswell *et al.* 2020). Adult red hake are rare inside Minas Basin and usually only occur during the coldwater season (Dadswell *et al.* 2020).

Juvenile red hake (5-15 cm L_T) will be abundant in Minas Passage during June-August as they migrate from their scallop hosts and pass through the iBoF. Movement inward to Minas Basin will be during June, outward movement, during August. There will be large numbers of juveniles migrating, probably 100's of thousands, but since they are a small benthic fish and will remain near bottom they are probably at low risk from propeller tidal turbines. They could, however, be impacted by turbines in tidal lagoons.

39. White hake *Urophycis tenuis* (Mitchill, 1814). Marine, benthic. White hake are common throughout the Bay of Fundy especially over mud bottom of the outer bay (Scott 1987, Simon and Comeau 1994). Juveniles (5-15 cm L_T) are common in Cumberland Basin during June-August (Markle *et al.* 1982) and adults have been taken in trawls in Minas Channel (Scott 1988). White hake are tolerant of reduced salinity and there are small populations in Kennebecasis Bay of the Saint John River (Scott and Scott 1988) and Minas and Cumberland Basin (Dadswell *et al.* 1984a).

In Minas Basin they are commonly captured in small numbers by intertidal weirs and as by catch in flounder trawls (Dadswell *et al.* 1984a, Wehrell 2005, Dadswell *et al.* 2020) but there is no directed fishery. Individuals observed in the Minas Basin were mostly juveniles or small adults. White hake probably occur in Minas Passage from April to October during movement into and out of Minas Basin. Their degree of risk from propeller tidal turbines is probably minimal since they are primarily a benthic species.

40. Spotted hake *Urophycis regia* (Walbaum, 1792) Marine, benthic. A stray from deep water in the Gulf of Maine, usually found offshore (Scott and Scott 1988). The first record for this species in Minas Basin was from the Bramber weir on June 23, 2017 (Fig 27). It was a 28 cm L_T adult. Two more were captured at the same weir during May, 2018 (D. Porter, pers. comm.).

Fig 27 Spotted hake captured in the Bramber weir during June, 2017 (photograph courtesy of E. Porter, Avondale, NS).

41. Longfin hake *Urophycis chesteri* (Goode and Bean, 1878). Marine, benthic. Another stray from offshore usually found at depths of 200-1000 m (Scott and Scott 1988). The first record for this species in Minas Basin was a 11 cm T_L specimen taken in the Bramber weir during April 2017 (Dadswell *et al.* 2020).

42. Pollock *Pollachius virens* (Linnaeus, 1758). Marine, pelagic. Pollock is common to abundant in the outer Bay of Fundy (Scott 1988), but rare in the inner Bay except in Minas Passage where there has been a hand line fishery since the early 1800's (Perley 1852, Dyer 2005). Juveniles recruited from spawning in the southern Gulf of Maine (Trippel *et al.* 1997) form large schools inshore around the Bay of Fundy over gravel and pebble beaches during spring then aggregate around wharfs during summer-fall ('harbour pollock', Rangely and Kramer 1995). Pollock are a pelagic predator that feed extensively on euphausiids. Their abundance and growth rates have been declining in recent years (Trippel *et al.* 1997).

Pollock are taken commercially and recreationally using trawls, long lines, gill nets and hand lines. Aggregations of adults occur in regions of dynamic flow and upwelling, around reefs and in channels (Scott 1987). The commercial fishery in the Bay of Fundy was landing 40,000 t y^{-1} during the 1980's (Trippel *et al.* 1997) but landings declined to 4500 *t* by 2004 (Dyer *et al.* 2005). Pollack have been recorded only once inside Minas Basin when one specimen was captured at the Bramber weir in 2017 (Dadswell *et al.* 2020).

Pollock are taken by hand line in Minas Channel and Minas Passage from April to October (J. Barkhouse, commercial fisher, pers. comm.). They possibly move into and out of Minas Passage with the tides. Abundance is low at present (Simon and Comeau 1994) but could increase if the stock rebounds. Current numbers are probably in the thousands to 10's of thousands. Pollock grow to 1.0 m L_T and 20 kg in weight. Since they are pelagic and of relatively large size they are at risk from axial flow, hydraulic lift propeller tidal turbines.

43. Atlantic tomcod *Microgadus tomcod* (Walbaum, 1792). Anadromous, benthic. Tomcod are extremely abundant in turbid regions of inner Bay of Fundy, especially Cobequid Bay and Cumberland Basin. Dadswell and co-workers (1984a) caught from 10-105 individuals in each 5-minute seine haul and a Joli-Seber population estimate for one small cove was 122,000 ± 39,000 tomcod. They are also abundant along beaches in remainder of the Bay of Fundy during winter (Dadswell per. obs.). They are a small fish seldom exceeding 24 cm L_T and age-4 (Dadswell *et al.* 1984a). Over the mudflats in the iBoF they feed on benthic organisms especially the amphipod, *Corophium volutator.*

Tomcod spawn in freshwater streams close to the head of tide in December and January hence the common name 'frost fish' in English or 'punamuiku' in Mi'kmaq (Scott and Scott 1988). There is a huge run of spawning tomcod that enters the Shubenacadie River during December and attracts large numbers of bald eagle to the river (Reid 1982). Eggs are adhesive, attach to the substrate and hatch in about a month (Peterson *et al.* 1980). The larvae are swept into the sea and dense concentrations of pelagic larvae occur in Cobequid Bay and Minas Basin during February to August (Bradford 1987) after which the juveniles settle and move inshore (Dadswell *et al.* 1984a). Tomcod are commonly found marooned in the intertidal zone (Bleakney and McAllister 1973).

There is a small commercial weir fishery for tomcod in Minas Basin. During April-July 2017 the Bramber weir captured over 68,000 individuals (Dadswell *et al.* 2020). Their winter spawning runs are an important food resource for the Mi'kmaq.

Adult tomcod will occur along the shoreline of Minas Passage, especially in winter and pelagic juveniles will be abundant offshore in the Passage during February to August. Numbers of pelagic juveniles during this period will probably number in the 10's of millions. Because they have a physocleistic gas bladder and cannot release gas from it quickly (Moyle and Cech 1996), tomcod larvae may be susceptible to pressure flux mortality during passage through propeller turbine draft tubes in Minas Passage, but due to their inshore, benthic behavior juvenile and adult tomcod are unlikely to be impacted. Juveniles and adults will be impacted if propeller turbines are used for power generation in tidal lagoons.

Order: Atheriniformes

44. Atlantic silversides *Menidia menidia* (Linnaeus, 1766). Marine, pelagic. Atlantic silversides are extremely abundant in the estuaries and shore regions of the inner Bay of Fundy and common along beaches in the outer Bay. In Minas Basin silversides form large schools over gravel and sand beaches in lower turbidity regions (Gilmurray and Daborn 1981). They feed largely on small copepods, neustonic prey like mysids and shrimp and floating or swimming insects and amphipods. They are a small species which live only one to two years and grow to about 20 cm L_F. Spawning is in May and June and juveniles settle in August (Gilmurray and Daborn 1981).

There is no commercial fishery for silversides in the Bay of Fundy, but they are an important forage fish for larger predators such as striped bass. Silversides occur along the beaches of Minas Basin and Passage (Dadswell *et al.* 1984a) but are seldom encountered offshore. They are probably at low risk from propeller tidal turbines.

Order: Beloniiformes

45. Atlantic saury *Scomberesox saurus* (Walbaum, 1792). Marine, pelagic. A rare visitor to the Bay of Fundy because of lower summer water temperatures (Scott and Scott 1988). Seldom seen or captured in Minas Basin. One was captured in a weir at Economy during July 2017 (Dadswell, pers. obs.).

Order: Cyprinodontiformes

46. Mummichog *Fundulus heteroclitus* (Linnaeus, 1766). Marine, benthic. Mummichog occur along shorelines of Minas Basin but are most abundant in tide pools (28 m^{-2}, Bleakney and Bailey-Meyer 1979). They arrive in the tide pools during June and leave in October

(Brown 1983). Mummichogs are another small prey species that are forage for larger predators especially blue herons. They seldom exceed 10 cm L_T and age-4 (Brown 1983).

Mummichog should be expected in salt marsh tide pools along the shores of Minas Passage but are unlikely to be encountered in open water except near shore.

Order: Gasterosteiformes 'sticklebacks'

All sticklebacks are small fishes occurring in salt marsh, shoreline or pelagic habitats (Scott and Scott 1988). They are common to abundant in beach seine hauls (Dadswell *et al.* 1984a) and tide pools in Minas Basin (Bleakney and Bailey-Meyer 1979). They feed mostly on planktonic and neustonic prey (Imrie and Daborn 1981). None of the four species in Minas Basin exceed a maximum length of 10 cm L_T. None are fished commercially. All are prey for larger fishes. They are at little risk from propeller tidal turbines but could be impacted by development of tidal lagoon generation.

47. Fourspine stickleback *Apeltes quadracus* (Mitchill, 1815). Marine and estuarine, benthic. Fourspine stickleback are common throughout the Bay of Fundy along shorelines. They are abundant in lower salinities like the inner portions of Minas Basin (Dadswell *et al.* 1984a). If encountered in Minas Passage, they will occur along the shoreline or in tide pools.

48. Threespine stickleback *Gasterosteus aculeatus* Linnaeus, 1758. Marine and estuarine, benthic, pelagic. Threespine stickleback are the most common stickleback in the Bay of Fundy and are especially abundant along high salinity shorelines and among eel grass (Dadswell *et al.* 1984a). Unlike the other sticklebacks they often have completely pelagic populations that are found at the surface over deep water (Scott and Scott 1988).

Threespine sticklebacks will occur along the shoreline of Minas Basin and Minas Passage and there may be a small population pelagic over the deepest part of Minas Passage. The pelagic group may be present all year.

49. Blackspotted stickleback *Gasterosteus wheatlandi* Putnam, 1867. Marine, benthic. Blackspotted stickleback co-occurs with threespine stickleback along high salinity shorelines (Scott and Scott 1988). It is not pelagic. It is found along the shoreline and in tide pools of Minas Basin and the Passage during most of the year (Imrie and Daborn 1981).

50. Ninespine stickleback *Pungitius pungitius* (Linnaeus, 1758). Marine, benthic. Ninespine stickleback co-occurs with threespine and blackspotted sticklebacks in lagoons along high salinity shores. It is also abundant in lower salinity tidal 'lakes' (Scott and Scott 1988). Specimens were commonly captured in seine hauls in Minas Basin (Dadswell *et al.* 1984a). It should be found along the shoreline of Minas Basin and Passage all year but will be rare except during cold water periods (Dadswell, pers. obs.).

Order: Syngnathiformes 'pipefishes and sea horses'

51. Northern pipefish *Syngnathus fuscus* Storer, 1839. Marine, pelagic. Pipefish are a warm water species found in lower salinity tidal 'lakes' around the Bay of Fundy (Scott and Scott 1988). It is especially abundant in localities with eelgrass. It is a small species, seldom exceeding 20 cm L_T. There is no fishery.

Commonly captured in the Bramber weir (Dadswell *et al.* 2020) and in Cobequid Bay (Huntsman 1922) but probably uncommon in Minas Passage except along the shoreline and in lagoons. Juveniles are common in the surface drift among seaweed and eelgrass during August to October (Dadswell, pers. obs.).

Order: Perciformes 'basses'

52. White perch *Morone americana* (Gmelin, 1789). Estuarine and anadromous, benthic and pelagic. White perch are especially abundant in lower salinity regions of estuaries particularly those with tidal sills or barrages maintaining an upstream, lake-like situation (Annapolis, Peticodiac and Avon Rivers, Scott and Scott 1988, Daborn and Brylinsky 2004). It is rarely observed in Minas Basin and was only caught in low numbers among weir catches at Bramber (12 individuals, Dadswell *et al.* 2020). White perch will probably not be encountered in Minas Passage. White perch is taken by angling wherever common.

53. Striped bass *Morone saxatilus* (Walbaum, 1792). Anadromous, benthic and pelagic usually along marine shorelines. Striped Bass are abundant in the inner Bay of Fundy, especially Minas Basin (Broome 2016). Striped bass spawn at or near the head of tide in rivers during May-June. There is a large spawning concentration annually in the mouth of the Shubenacadie-Stewiacke River (Rulifson and Tull 1998, MacInnis 2012). Juveniles move into estuarine waters during their first summer and year-class success is dictated by warm, dry summers with an abundance of copepods in the nursery area (Duston *et al.* 2018). Growth is rapid and bass mature at age 3-5. They live to age 20-25 and reach 120 cm L_T and 45 kg in weight (Rulifson and Dadswell 1995)

The population in the Shubenacadie-Stewiacke River has had successful recruitment since the early 1990's with an exceptional year class in 1999 (Bradford *et al.* 2015, Duston *et al.* 2018). Adult abundance was estimated at 18,000-27,000 fish (Fig 28, Douglas *et al.* 2003). There is a summer migration around the Bay of Fundy which consists of Canadian and US stocks (Rulifson and Dadswell 1995) and an unknown number of US fish enter Minas Basin each summer (Wirgin *et al.* 1995, Rulifson *et al.* 2008). Striped bass tagged in Minas Basin have been recaptured in Maine (1), Massachusetts (1), Rhode Island (1), Connecticut (2), New Jersey (2) and Virginia (1) (Rulifson *et al.* 2008, Bradford *et al.* 2015). On the other hand, tagging studies in Minas Basin indicate most of the Shubenacadie stock remains in the Basin during all stages of their life history. Of 1431 tags applied to bass at a weir on the north shore of Minas Basin 249 were recaptured in the Basin, but only 10 seawards of Minas Passage (Rulifson *et al.* 2008), and of 1126 tags applied on the south shore, 250 were recaptured in the Basin and only three seawards of the Passage (Broome 2016). In November there is an annual mass movement of bass upstream from Minas Basin into

Fig 28 Striped bass school observed during the fall of 2014 under the railway bridge where the Shubenacadie River discharges from Shubenacadie Lake. The estimated size of the individual bass in the aggregation was 70-80 cm L_F (photograph courtesy G. Stephens, DFO).

Fig 29 Black sea bass captured in an Economy weir during July, 2013 (photograph MJD).

Shubenacadie Grand Lake where they over winter (Fig 28, Bradford *et al.* 2015). An unknown portion of the Shubenacadie population also over winters in marine upwelling areas such as Minas Passage (Parramore and Rulifson 2001, Keyser *et al.* 2015) or at low salinity sites around the Bay of Fundy (Andrews *et al.* 2018).

Striped bass are captured in intertidal weirs and drift gill nets in Minas Basin and used to be taken by fixed gill nets around the shoreline (Dadswell *et al.* 1984). A total of 1,388 were captured by the Bramber weir during April-July 2017 (Dadswell *et al.* 2020). The commercial fishery for striped bass has been closed since 2003 but weir fishers are permitted a bycatch (one bass day^{-1} larger than 68.5 cm L_T). There is a large angling fishery in Minas Basin (Broome *et al.* 2009). During a short-term angler survey in Minas Basin in 2009, the catch was more than 1800 bass and catch rate was estimated at 2.2 $bass.h^{-1}$ (Duston 2010).

Striped bass adults are common in Minas Passage along the shoreline and have been detected with acoustic receivers in mid water at depths of 20-95 m in the Passage during all seasons (Broome 2016, Keyser *et al.* 2016). There will be an inward migration through Minas Passage during April to July and an outward migration during July to September with numerous long-term residents in the Passage during winter. Because of their large size and mid-water residence striped bass are at extreme risk from propeller tidal turbines.

54*. *Black sea bass *Centropristis striata* (Linnaeus, 1758). Marine, benthic. One to a dozen specimens are taken regularly in the Linkletter weir at Economy, never in abundance, but commonly during most summers (Fig 29, W. Linkletter, commercial fisher, pers. comm.). Captured bass are usually 20-30 cm L_T.

55. Bluefish *Pomatomus saltatrix* **(**Linnaeus, 1766). Marine, pelagic. Bluefish are a summer visitor to the inner Bay of Fundy during years of higher summer temperatures in the Bay of Fundy (Dadswell *et al.* 1984a). Bluefish are not known to reproduce in Canadian waters (Scott and Scott 1988). It can be abundant for short periods during July-August in some years and then may not be seen for 2-3 years. It is a schooling fish that preys on smaller schooling species (herring, menhaden, butterfish). Bluefish caught in Minas Basin are from 15-80 cm L_F (Fig 30).

Abundance of bluefish will be low to nonexistence in most years then common to abundant for a short period during July-August in Minas Basin and Passage. It is a pelagic species and generally found offshore. It is taken by drift gill nets, in weirs and by anglers when schools appear. Bluefish can be dangerous when brought onto a boat deck because they have large teeth and tend to bite (Scott and Scott 1988). Because bluefish are pelagic and relatively large it will be at risk from propeller tidal turbines.

Fig 30 Adult bluefish captured by drift gillnet in Cobequid Bay during August, 1984 (photograph MJD).

56. Weakfish *Cynoscion regalis* (Bloch and Schneider, 1801). Marine, benthic. Weakfish are a very rare occasional summer visitor to the inner Bay of Fundy (Dadswell and Rulifson 1994). One specimen was taken in a weir at Economy in 1955. A few will be encountered in Minas Basin and Passage on rare occasions.

57. Scup *Stenotomus chrysops* (Linnaeus, 1766). Marine, benthic. Occasional summer visitor to the inner Bay of Fundy. One specimen was captured in each of the Economy and Bramber weirs during 2013 (Fig 31). It is abundant along sandy shorelines south of Cape Cod.

58. Black drum *Pogonias cromis* (Linnaeus, 1766) Marine, benthic. Black drum are a rare, occasional summer visitor to the inner Bay of Fundy. A 1 m specimen was captured in a weir near Minas Passage in 1947 (Scott and Scott 1988).

59. Radiated shanny *Ulvaria subbifurcata* (Storer, 1839). Marine, benthic. Radiated shanny are common in the outer Bay of Fundy (MacDonald *et al.* 1984). It is especially abundant under rocks along cliff-like shores (Dadswell, pers. obs.) and may be common in Minas Passage along the shoreline. It is a small species and seldom exceeds 20 cm L_T (Scott and Scott 1988). It will rarely be captured in any numbers except by directed searches during SCUBA sampling.

Fig 31 Scup captured in the Bramber weir during 2013 (photograph courtesy D. Porter, Avondale, NS).

60. Rock gunnel *Pholis gunnellus* (Linnaeus, 1758). Marine, benthic and intertidal. Rock gunnels are a ubiquitous and abundant fish throughout the Bay of Fundy (Scott and Scott 1988). It can remain in the intertidal zone during low tide hiding under rocks and seaweed (Bleakney and McAllister 1973). Gunnels are a small fish rarely exceeding 20 cm L_T. It is probably common along the shoreline of Minas Passage but is seldom encountered in Minas Basin. During 2017 only five individuals were captured in the Bramber weir (Dadswell *et al.* 2020).

61. Atlantic wolffish *Anarhichas lupus* Linnaeus, 1758. Marine, benthic. Wolffish are common in deep, cold water regions of the Bay of Fundy (Scott 1987). They are usually found in areas with boulders and rough bottom with available den sites (Scott and Scott 1988). Wolffish have never been observed inside Minas Basin (Bleakney and McAllister 1973, Dadswell *et al.* 1984a) but may occur in Minas Passage. Wolffish feed on scallops and lobsters and can grow to a large size (2.0 m L_T). Most caught recently are under 1.0 m L_T (Scott and Scott 1988).

The wolffish fishery in the Bay of Fundy has never been large and there is no directed fishery. Most landings are from by catch in the scallop fishery. Landings averaged 61 *t* from 1998-2001 (Anon 2002).

Since there are scallop beds in Minas Passage wolfish will probably be found there, however, they would largely be confined to the bottom. They are likely to be present all year but would probably be most common in winter. Because of their benthic habitat they would be at low risk to propeller tidal turbines.

62. Ocean pout *Zoarces americanus* (Bloch and Schneider, 1801)**.** Marine, benthic. Ocean pout are common to abundant in deep water of the outer Bay of Fundy and rare to common in the inner Bay (MacDonald *et al.* 1984, Scott 1987). Scott (1988) reported them from trawl catches in Minas Channel and Wehrell (2005) in trawl catches in Minas Basin. Bleakney and McAllister (1973) reported them stranded in the intertidal zone in Minas Basin. There is no commercial fishery for ocean pout (Scott and Scott 1988). Only one was captured in the Bramber weir during 2017 (Dadswell *et al.* 2020).

Ocean pout will occur in Minas Passage during summer but in low numbers. They are strictly benthic in habit and probably not at risk from propeller tidal turbines.

63. Sand lance *Ammodytes americanus* DeKay, 1842. Marine, benthic and pelagic. Sand lance is abundant along sand and gravel beaches of the Bay of Fundy and over deep water, sand bottoms. The species forms dense schools over intertidal zones at high tide and then penetrates the substrate to remain in the intertidal zone during low tide (Scott and Scott 1988). They are a small species seldom exceeding 10 cm L_T and a forage fish for many larger predators especially Atlantic sturgeon which vacuum sand lance from under the sand (McLean *et al.* 2013).

Sand lance are not common in Minas Basin although there is an abundance of sandy, benthic habitat but they may be locally abundant over sandy beaches. One was captured in the Bramber weir in 2017 (Dadswell *et al.* 2020). Their paucity in Minas Basin could be a factor of the warm summer temperatures. They may be more abundant in Minas Passage but there has been a lack of seine studies on beaches in that region (Dadswell *et al.* 1984a). Because of their small size and requirement for sand substrate they are at no risk from tidal propeller turbines in Minas Passage.

64. Atlantic mackerel *Scomber scombrus* Linnaeus, 1758. Marine, pelagic. Atlantic mackerel are common to abundant in the pelagic zone of the entire Bay of Fundy except in turbid regions like Cobequid Bay and Cumberland Basin (Dadswell *et al.* 1984a). Large weir catches were often made in Scots Bay (Leim 1924) but are rare inside Minas Basin (Dadswell *et al.* 2020). The only time mackerel were caught in the Bramber weir during 2017 was during neap tides when the water became clear.

Mackerel are highly migratory. They winter off Long Island then move north to the Bay of Fundy and the Gulf of St. Lawrence for the summer (Scott and Scott 1988). Mackerel appear in Minas Basin during May to August. They are caught in intertidal weirs and by drift gill nets. Because of low market demand the annual mackerel catch in the Bay of Fundy is not large even though mackerel are abundant. The allowable catch was set at 75,000 *t* for several years but catches seldom exceed 20% of this value (CSAS 2005). The TAC is now reduced to 8000 $t\ y^{-1}$ (D. Themelis, DFO, pers comm.).

Mackerel will occur in Minas Basin and Passage during May to September and in some years may be abundant. They will be pelagic in the water column and in schools. Abundance could be in the 10's of thousands. Mackerel, because of their pelagic habitat, will be at moderate risk from propeller tidal turbines (Table 1).

Fig 32 Butterfish captured in a drift gill net in Cobequid Bay during July, 1984 (photograph MJD).

65. Butterfish *Peprilus triacanthus* (Peck, 1804). Marine, pelagic. Butterfish are small forage fish (Fig 32, <20 cm L_T). Large numbers are common in the inner Bay of Fundy during summer, especially in Minas Basin (Dadswell *et al.* 1984a). In most regions of the Atlantic coast there is a limited fishery for them but there is no directed fishery in Canada (Scott and Scott 1988).

Butterfish occur in Minas Basin from June to September and are a common catch in intertidal weirs (Dadswell *et al.* 1984a, Dadswell *et al.* 2020). During 2017, 536 were captured in the Bramber weir. They are common to abundant in Minas Passage and occupy the pelagic zone. Abundance could be in the millions, but accurate estimates are unavailable. Because of their small size they are at low risk from propeller tidal turbines.

Order: Scorpaeniformes

66. Striped searobin *Prionotus evolans* (Linnaeus, 1766). Marine, benthic. Searobins are rare in Canada occurring only in the Bay of Fundy region as strays from the Gulf of Maine (Scott and Scott 1988). One specimen was collected in a weir at Economy during the summer of 2013 and one at the Bramber weir in 2017.

67. Sea raven *Hemitripterus americanus* (Gmelin, 1789). Marine, benthic. Sea ravens are a common member of benthic fish community throughout the Bay of Fundy (MacDonald *et al.* 1984, Scott 1988). They are abundant in Minas Basin all year (Fig 33, Bleakney and McAllister 1973) and are taken by trawlers and in intertidal weirs (Dadswell *et al.* 1984a, Baker *et al.* 2014). During 2017 a total

Fig 33 Juvenile sea raven found in a tide pool on the intertidal zone off Burntcoat Head during August, 2012 (photograph MJD).

Fig 34 Larvae of sea raven hatched from eggs found under sponges along the lower intertidal zone of Cape Blomidon on January 4, 1974 (photograph courtesy of J.S. Bleakney).

of 643 were captured in the Bramber weir (Dadswell *et al.* 2020). There is no directed fishery for this species in Canada.

Sea ravens are probably found in Minas Passage during most of the year. Eggs and larvae are found in the lower intertidal zone along the Passage shore during winter in association with sponges (S. Bleakney, pers. comm.). The larvae are rather unique in having a very large mouth with teeth in the jaws (Fig 34, Fuiman 1977). Since their habitat is benthic they are at little risk from instream propeller tidal turbines. If lagoon tidal power is developed they may be impacted by the turbines.

68. Grubby *Myoxocephalus aenaeus* (Mitchill, 1814). Marine, benthic. Grubby are a common, small, inshore species along hard substrate shorelines of the Bay of Fundy (Scott and Scott 1988). They are usually found in association with seaweed. Grubby seldom grow larger than 20 cm L_T. They are seldom seen or captured in Minas Basin probably because there is little hard substrate shoreline and seaweeds are rare because of winter ice scouring (Bleakney and McAllister 1973, Dadswell *et al.* 1984a).

Grubby may found along the shores of Minas Passage and could be common over hard substrates in deeper water. Because of their small size and benthic habitat, they are at little risk from propeller tidal turbines.

69. Longhorn sculpin *Myoxocephalus octodecemspinosus* (Mitchill, 1814). Marine, benthic. Longhorn sculpin are abundant in trawl catches from most parts of the Bay of Fundy (Scott 1988). They are a 'large' species of sculpin reaching about 35-45 cm L_T (Scott and Scott 1988). Longhorn sculpin are common during summer and winter in Minas Basin (Bleakney and McAllister 1973, Dadswell *et al.* 1984a). During 2017 a total of 705 were captured in the Bramber weir (Dadswell *et al.* 2020).

Longhorn sculpin are commonly captured off wharfs by recreational anglers. There is a small commercial fishery in the Bay of Fundy where they are used as lobster bait (H. Stone, DFO, pers. comm.). They are found year around in Minas Passage. Their benthic habitat should limit their interaction with propeller tidal turbines.

70. Shorthorn sculpin *Myoxocephalus scorpius* (Linnaeus, 1758). Marine, benthic. Shorthorn sculpin are common in most of the Bay of Fundy. This sculpin occurs onshore during winter and is mostly found over hard substrates (Scott and Scott 1988). They are not common inside Minas Basin (Dadswell *et al.* 1984a) but are taken occasionally in weir catches. Four were captured in the Bramber weir during 2017 (Dadswell *et al.* 2020).

Shorthorn sculpin should be common over the hard substrate bottom of Minas Passage and they will probably be present all year. This species was observed in a bottom video record taken around the FORCE tidal power test site during October 2009 (FORCE 2009). Like sea raven and longhorn sculpin they are little at risk from propeller tidal turbines.

Order: Labriformes 'wrasses'

71. Tautog *Tautoga onitis* (Linnaeus, 1758). Marine, benthic, pelagic. Tautog are a rare summer visitor to the inner Bay of Fundy. One was captured by gill net in Cumberland Basin during 1979 (Dadswell *et al.* 1984a). Tautog will probably be seldom encountered in Minas Basin or Minas Passage.

72. Cunner *Tautogolabrus adsperus* (Walbaum, 1792). Marine, benthic, pelagic. The cunner is a common resident of the outer Bay of Fundy and is especially abundant around wharfs and rocky shores (Scott and Scott 1988). It is uncommon in the inner Bay of Fundy and inside Minas Basin (Bleakney and McAllister 1973). During 2017 a total of 51 individuals were captured in the Bramber weir (Dadswell *et al.* 2020). Cunner, however, should be expected in Minas Passage. The Passage has considerable hard bottom substrate and probably abundant underwater cavities. Cunner use cavities among the rocks during winter for hibernation (Scott and Scott 1988) and it may be common along the Minas Passage shore during this period. Since cunner are a small species and usually associated with a substrate they are unlikely to be at risk from propeller tidal turbines.

Order: Cyclopteriformes 'lumpfishes'

73. Lumpfish *Cyclopterus lumpus* Linnaeus, 1758. Marine, benthic and pelagic. Lumpfish are found throughout the Bay of Fundy Bay except in the turbid inner reaches and is known from Minas Basin (Bleakney and McAllister 1973, Wehrell 2005). It is most abundant along rocky shores and over hard, rocky bottom. All Cyclopteriformes have a ventral 'sucker' that allows them to attach to the substrate or seaweeds in order to maintain position in strong currents (Scott and Scott 1988). Lumpfish caviar is the basis for a commercial fishery in Newfoundland but there is no fishery in the Bay of Fundy (Dadswell *et al.* 1984a)

Juvenile lumpfish are very abundant in the surface floating masses of seaweed drifting in the Bay of Fundy and have been taken from this habitat in Minas Channel (Daborn and Gregory 1983). Adult, spawning males turn red in spring and remain to guard the egg mass attached to rocks after spawning. The habitat along the shores of Minas Passage is excellent for lumpfish spawning (Scott and Scott 1988, AECOM 2009).

Lumpfish larvae and juveniles will be common in drifting masses of seaweed on the surface in Minas Passage during June to September. Abundance in some years could be high depending on survival of larvae (Daborn and Gregory 1983). Since they have been caught in Minas Channel and in Minas Basin (Scott 1988, Wehrell 2005), adult lumpfish may be abundant along the rocky shores of Minas Passage especially when spawning in spring. Because juveniles remain at the surface in drifting seaweed and adults are usually associated with hard benthic substrate, this species is unlikely to interact much with propeller tidal turbines and are at minimal risk.

74. Atlantic snailfish *Liparus atlanticus* (Jordan and Evermann, 1898). Marine, benthic. Atlantic snailfish are common in the Bay of Fundy in localities with kelp to which they attach with their ventral sucker (Scott and Scott 1988). They have been caught in Minas Passage by trawls that brought up kelp fronds (Dadswell *et al.* 1984a) and they have been reported from Minas Basin in tide pools during winter (Bleakney and McAllister 1973). Snailfish are small and rarely exceed 10 cm L_T (Fig 35).

Atlantic snailfish should be common among kelp beds in Minas Passage year around. Their distribution will be concentrated along the shore and probably in depths less than 10 m which is about the

Fig 35 Atlantic snailfish captured in the Minas Basin during November, 2019 (photograph courtesy of E. Porter, Avondale, NS).

deepest kelp distribution reaches in the iBoF (Dadswell, pers. obs.). They are at minimal risk from propeller tidal turbines.

75. Inquiline snailfish *Liparus inquilinus* Able, 1973. Marine, benthic. This small snailfish is usually found in association with sea scallops with whom they live commensally for their entire life (Able and Musick 1976). They are common wherever scallop beds occur such as along the Blomidon shore of Minas Basin and in Minas Channel (Dyer *et al.* 2005). They are a typical small snailfish seldom exceeding 72 mm L_T. They are often striped with yellow bands (Bigelow and Schroeder 1953).

Inquiline snailfish should be common year around in Minas Passage wherever there are sea scallops. Snailfish larvae will probably be common near the surface in Minas Passage during late winter and spring.

76. Gulf snailfish *Liparus coheni* Able, 1976. Marine, benthic. This small snailfish is usually found in association with kelp. Abundant in shallow depths along the shores of Minas Passage (Dadswell *et al.* 1984a).

Order: Pleuronectiformes 'flounders'

77. Summer flounder *Paralichthys dentatus* (Linnaeus, 1766). Marine, benthic**.** Summer flounder is a rare summer visitor to the Bay of Fundy (Scott and Scott 1988). Two were captured in the Bramber weir during 2017 (Dadswell *et al.* 2020).

78. American fourspot flounder *Hippoglossina oblonga* (Mitchill, 1815). Marine, benthic. Fourspot flounder is a southern species that is an occasional summer visitor to the inner Bay of Fundy but is never abundant (Scott and Scott 1988). It has been captured in Cumberland Basin and Minas Basin (Dadswell and Rulifson 1994). It will probably occur rarely in Minas Passage and in small numbers. It is a benthic species and likely remains on bottom at all times making it at little risk to tidal turbines.

79. Windowpane *Scophthalmus aquosus* (Mitchill, 1815). Marine, benthic. Windowpane is common throughout the Bay of Fundy especially over sandy substrate (Scott 1987). They are very abundant in Minas Basin and often the most abundant fish in intertidal weir catches (Leim and Bousfield 1959, Baker *et al.* 2014). During 2017 a total of 18,860 were taken in the Bramber weir (Dadswell *et al.* 2020). They are seldom fished commercially in Canada but are taken for lobster bait in Minas Basin weirs (Scott and Scott 1988).

Windowpane is probably uncommon in Minas Passage because of the low incidence of sandy substrate (AECOM 2009). It could, however, be locally abundant along shore lines where there are sandy beaches since it is common in Minas Channel (Scott 1988) and was abundant in Minas Basin trawl catches (Wehrell 2005). Similar to other smaller flatfish species it is probably at little risk from propeller turbines because of its benthic nature.

80. Witch flounder *Glyptocephalus cynoglossus* (Linnaeus, 1758). Marine, benthic. Witch flounder is a common resident of deep water, mud bottom locations in the Bay of Fundy (MacDonald *et al.* 1984, Scott 1987). It is an important commercial flounder and is marketed in Canada as sole.

Witch have never been captured in Minas Basin and are rare in the inner Bay of Fundy (Scott 1988). They may occur in Minas Channel and/or Minas Passage.

81. Atlantic halibut *Hippoglossus hippoglossus* (Linnaeus, 1758). Marine, benthic. Halibut are found throughout Bay of Fundy (Scott 1988) but only juveniles penetrate into Minas Basin during spring and early summer (M. Brylinsky, pers. comm., Wehrell 2005). Only two juvenile halibut were observed in the Bramber weir during 2017 (Dadswell *et al.* 2020), but 15 were observed during June and July by the 2004 trawl survey (Wehrell 2005).

Halibut are the largest flatfish and 200 cm L_T fish are taken in the commercial fishery (Scott and Scott 1988). Large adults are common around the Advocate region of the inner Bay of Fundy and support a small commercial fishery (Simon and Comeau 1994). Juveniles and adults are taken by hand lines and bottom set long lines. Annual landings in the inner Bay of Fundy are about 10 *t* (Dyer *et al.* 2005).

Halibut are a predatory flatfish and large individuals eat fish exclusively (Scott and Scott 1988). They are known to pursue herring schools (Bigelow and Schroeder 1953). Large and small individuals should be expected in Minas Passage during spring. They will occur throughout the water column during bouts of foraging. Juvenile individuals probably follow herring schools into Minas Basin from March to June before warm water temperatures restrict halibut occurrence inside the Basin (Wehrell 2005). Abundance in Minas Passage is probably in the range of a few hundred to a few thousand individuals annually. Because of their pelagic behavior and large size adults are at extreme risk from propeller tidal turbines (Table 1).

82. American smooth flounder *Pleuronectes putnami* (Gill, 1864). Estaurine, benthic. Smooth flounder are found in inshore, warm water habitats throughout the Bay of Fundy (Scott and Scott 1988). They are most abundant in the iBoF (Minas and Cumberland Basins) but also common in Passamaquoddy and St. Mary's Bay. In Minas Basin smooth flounder feed over mud flats at high tide. In these sites a few thousand individuals can occur daily (Scully 1983).

They are a common catch in intertidal weirs. During 2017 a total of 5,841 individuals were captured in the Bramber weir (Dadswell *et al.* 2020). They are not usually utilized as a commercial species in Canada (Scott and Scott 1988) but some are taken for lobster bait from weir catches in Minas Basin (Dadswell, pers. obs.). Smooth flounder are probably not common in Minas Passage except in localized, inshore mud habitats.

83. Winter flounder *Pseudopleuronectes americanus* (Walbaum, 1792). Marine, benthic. Winter flounder are the most abundant and ubiquitous flounder in the Bay of Fundy. They are a dominant resident of most benthic fish communities in both the inner and outer Bay of Fundy (MacDonald *et al.* 1984, Scott 1987). Winter flounder spawn inshore in May. Juveniles are common along shorelines in fall (Dadswell *et al.* 1984a). Growth is rapid and they reach maturity at age-3 (Scott and Scott 1988).

Winter flounder migrate in and out of the Bay of Fundy between spring and fall (MacDonald *et al.* 1984). Their abundance peaks in Minas Basin during July then declines during summer both from the effects of migration and the intense fishery (Wehrell 2005). They leave the Basin by October. Flounder spawn in Minas Basin during April-May and juveniles settle in the shallows during August. Minas Basin represents one of the most valuable nursery areas for winter flounder in the Bay of Fundy (Scott and Scott 1988).

Winter flounder support important commercial and recreational fisheries in the Bay of Fundy (Simon and Comeau 1994). They are captured commercially by trawls and intertidal weirs in Minas Basin. During April-July 2017, an estimated 24,200 were taken in the Bramber weir (Dadswell *et al.* 2020). They are also taken in large numbers by drags in Scots Bay and Minas Channel (Wehrell 2005). Flounder landings in the region peaked at 200 *t* in 1992-93 but declined to 100 *t* by 2006 (Dyer *et al.* 2005).

Winter flounder will be migrating inward through Minas Passage from April to June and outward from July to October. There has never been a population estimate for the stock in Minas Basin during summer. But since the annual landings in the recent past were approximately 100 *t* (Dyer *et al.* 2005), the average weight of flounder in the Minas Basin catch is approximately 500 gm (Wehrell 2005) and annual exploitation rate (μ) probably in the order of 0.25 (DFO 2017b); a minimum adult stock size can be estimated at about 800,000 fish. All these adult flounder as well as juveniles pass through Minas Passage twice annually. But since they are a benthic species, winter flounder are probably not at risk from propeller tidal turbines.

84. Yellowtail flounder *Limanda ferruginea* (Storer, 1839). Marine, benthic. Yellowtail flounder are taken consistently in the outer and inner Bay of Fundy in association with winter flounder but they are never abundant (MacDonald *et al.* 1984, Scott 1987). Wehrell (2005) observed three yellowtails taken in Minas Basin during a summer-long trawl survey when thousands of winter flounder were taken daily.

A few yellowtail flounder may occur in Minas Basin and Passage annually during summer. Since they are strictly benthic in habitat. they are at little risk from propeller tidal turbines.

Order: Tetraodontiformes "filefishes"

85. Ocean sunfish *Mola mola* (Linnaeus, 1758). Marine, pelagic. Ocean sunfish are a common but never abundant summer visitor to the Bay of Fundy (Scott and Scott 1988). Large specimens have been captured in weirs of the outer and inner Bay during summer, but seldom more than one or two individuals. Parasites from an individual caught in a Scots Bay weir are stored in the Acadia University museum.

Ocean sunfish feed on jellyfish and attain a large size (2-3.3 m L_T; Scott and Scott 1988). They have a habit of 'basking' on the ocean surface laying on their side. A single, large individual was observed 'basking' on the surface near Blomidon in Minas Basin during late June 2017 (G. Travis, commercial fisher, pers. comm.). There is no fishery for ocean sunfish.

Ocean sunfish will probably occur in Minas Basin and Passage during most summers but abundance will rarely exceed 1-2 individuals. Because they have a large body size, ocean sunfish will be at risk from propeller turbine strikes. Since they spend a considerable time on or near the surface and abundance is low in the iBoF, their overall risk to turbines is probably low.

CONCLUSIONS

The fish community in Minas Basin can be characterized into four assemblages. There is an assemblage of mainly smaller fish species that live, reproduce in and occupy Minas Basin year around. This grouping consists of tomcod, rainbow smelt, Atlantic silversides, smooth flounder, windowpane flounder, mummichog, skates, striped bass, seasnails, sculpins and sticklebacks. A second assemblage consists of summer migrants into Minas Basin including marine species and diadromous fishes that reproduce in or utilize the local streams for growth. This group consists of sea lamprey, porbeagle, great white shark, spiny dogfish shark, Atlantic sturgeon, American eel, Atlantic herring, American shad, blueback herring, alewife, Atlantic salmon, silver hake, Atlantic mackerel, butterfish, monkfish and winter flounder. They are the dominant community that supports the commercial fishery. A cold-water assemblage enters the Basin in early spring and possibly in fall and winter and departs when water temperatures surpass about 10 C^{o}. Atlantic cod, pollock, white hake, ocean pout and halibut are some representatives. Rare cold-water and/or offshore species among this grouping are spotted hake and longfin hake. The final assemblage consists of warm-water migrants that arrive from the south when Basin water temperatures reach their annual maximum. Some members of this group are basking shark, sand tiger shark, bluefish, black sea bass, scup, fourspot flounder, tautog and striped searobin.

Minas Basin is a northern terminus for coastal migrant fishes migrating along the North American Atlantic coast in summer (Dadswell *et al.* 1987, Moore 1998, Rulifson *et al.* 2008, Dadswell *et al.* 2016). A large portion of the coastal migrant fish stocks pass through the inner Bay of Fundy each year including spiny dogfish shark, Atlantic sturgeon, American shad, alewife, blueback herring, winter flounder and striped bass. Tagging and DNA discrimination studies demonstrate that these species represent populations from as far south as Florida, North Carolina, Virginia, New York and Massachusetts (Wirgin *et al.* 2012).

The diversity and abundance of the Minas Basin-Minas Passage fish community will be impacted to greater or lesser degree by the development of tidal power in this region with the largest tides in the world. Fishes that could be impacted severely by propeller tidal turbines deployed in Minas Passage are: endangered great white shark and endangered iBoF Atlantic salmon and other commercially or recreationally important species including Atlantic sturgeon, American shad, Atlantic herring, alewife, blueback herring, halibut and striped bass (Table 1).

Tidal power development in Minas Passage using instream propeller turbines would impact both Minas Basin and distant commercial and recreational fisheries. The Minas Basin weir fishery catches would probably decline in response to turbine mortality of Atlantic herring, alewife, blueback herring and American shad. The recreational fishery for striped bass in Minas Basin would be impacted especially from the loss of large adults over wintering in Minas Passage. Distant commercial fisheries that would be affected by declines in abundance are the Atlantic sturgeon fishery in the Saint John River, NB and the American shad fishery on the east coast of the US. Repeated movement of sturgeon through Minas Passage annually over a long period of their life span (20-30 years) means they are at extreme risk (Dadswell *et al.* 2016, Stokesbury *et al.* 2016, Taylor *et al.* 2016).

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REFERENCES

Able, K.W. & Musick, J.A. (1976). Life history, ecology and behavior of *Liparis inquilinus* (Pisces: Cyclopteridae) associated with the sea scallop, *Placopecten magellanicus. Fisheries Bulletin* 74: 409-421.

AECOM. (2009). Environmental assessment registration document – Fundy tidal energy demonstration project. Volume 1: environmental assessment. Fundy Ocean Research Centre for Energy Pro. # 107405.

Amiro, P.G. (2003). Population status of inner Bay of Fundy Atlantic salmon (*Salmo salar*) to 1999. Canadian Fisheries and Aquatic Sciences Technical Report 2488.

Amiro, P.G., Gibson, J. & Drinkwater, K. (2003). Identification and exploration of some methods for designation of critical habitat for survival and recovery of inner Bay of Fundy Atlantic salmon (*Salmo salar).* Canadian Scientific Advisory Secretariat (CSAS) WP. 2003/120.

Amos, C.L. (1984). An overview of sedimentological research in the Bay of Fundy. Canadian Technical Report of Fisheries and Aquatic Sciences 1256: 31-44.

Andrews, S.N., Wallace, B., Gautreau, M., Linnansaari, T. & Curry, R.A. (2018). Seasonal movements of striped bass *Morone saxatilis* in a large tidal and hydropower regulated river. *Environmental Biology and Fisheries* 101: 1549-1558.

Anon. (1986). The one that didn't get away. The Advertiser, Kentville, NS. July 15, 1986: 1.

Anon. (2006). Eastern Georges Bank haddock. Transboundary Research Assessment Committee Status Report 2006/02.

Baker, M., Reed, M. & Redden, A.M. (2014). Temporal patterns in Minas Basin in intertidal weir catches and presence of harbour porpoise during April-August 2013. Acadia Centre for Estuarine Research Technical Report 120.

Beanlands, D.R., Branton, R. & Mohn, R. (2000). Status of monkfish in 4VWX5Zc. Canadian Scientific Advisory Secretariat, Research Document 2000/143.

Big Moon Power Canada. (2018). www.Bigmoonpower.com

Bigelow, H.B. & Schroeder, W.C. (1953). Fishes of the Gulf of Maine. *Fisheries Bulletin of the Fish and Wildlife Service* 53. US Government Printing Office, Washington, D, USA.

Bleakney, J.S. & Bailey-Meyer, K. (1979). Observations on salt-marsh tide pools, Minas Basin, NS. *Proceedings of the Nova Scotian Institute of Science* 29: 353-371.

Bleakney, J.S. & McAllister, D.E. (1973). Fishes stranded during low tides in Minas Basin, NS. *Canadian Field-Naturalist* 87: 371-376.

Bousfield, E.L. & Leim, A.H. (1959). The fauna of Minas Basin and Minas Channel. *National Museum of Canada, Bulletin* 166: 1-30.

Bradford, R.G. (1987). The biology and ecology of the Minas Basin spring-spawning herring. M.Sc. Thesis, University of New Brunswick, Fredericton, NB.

Bradford, R.G. & Iles, T.D. (1992). Unique biological characteristics of spring-spawning herring (*Clupea harengus* L.) in Minas Basin, NS, a tidally dynamic environment. *Canadian Journal of Zoology* 70: 641-648.

Bradford, R.G. & Iles, T. D. (1993). Retention of herring *Clupea harengus* larvae inside Minas Basin, inner Bay of Fundy. *Canadian Journal of Zoology* 71: 56-63.

Bradford, R.G., Halfyard, E.A., Hayman, T. & LeBlanc, P. (2015). Overview of 2013 Bay of Fundy striped bass biology and general status. Canadian Scientific Advisory Secretariat, Research Document 2015/024.

Broome, J.E. (2014). Population characteristics of striped bass (*Morone saxatilis* Walbaum, 1792) in Minas Basin and patterns of acoustically detected movements within Minas Passage. M.Sc. Thesis, Acadia University, Wolfville, NS.

Broome, J.E., Redden, A.M., Dadswell, M.J., Vaudry, K. & Stewart, D. (2009). Population characteristics, movement and angling of the striped bass (*Morone saxatilis*) summer aggregation in Minas Basin, NS. In. Resource development and its implications in the Bay of Fundy and Gulf of Maine. (eds) Redden, A.M., Percy, J.A., Wells, P.G. and Rolston, S.J. Proceedings 8th BoFEP *Fundy Science Workshop Technical Report* 4: 203-213.

Brown, J.F.S. (1983). The ecology of *Fundulus heteroclitus* at Kingsport salt marsh, Minas Basin, NS. M.Sc. Thesis, Acadia University, Wolfville, NS.

Bucklund, H.C., Masters, I., Orme, J.A. & Backer, T. (2013). Cavitation inception and stimulation in blade element momentum theory for modelling tidal stream turbines. Proceedings of the Institution of Mechanical Engineers: Journal of Power and Energy, Part A. *Journal of Power and Energy* 227: 479-485.

Bundy, A. & Fannin, L.P. (2005). Can Atlantic cod (*Gadus morhua*) recover? Exploring trophic explanations for the non-recovery of the cod stock on the eastern Scotian Shelf. *Canadian Journal of Fisheries and Aquatic Science* 62: 1474-1489.

Cammen, L.M. (1984). Microbial ecology of the Bay of Fundy. Canadian Fisheries and Aquatic Sciences Technical Report 1256: 115-134.

Campana, S.E. (2007). Shark fisheries. Canadian Shark Research Laboratory. www.marinebiodiversity.ca/shark.

Campana, S.E., Gibson, A.J.F., Marks, L., Joyce, W., Rulifson, R.A. & Dadswell, M.J. (2008). Stock structure, life history, fishery and abundance for spiny dogfish *(Squalus acanthias*) in Atlantic Canada. Canadian Scientific Advisory Secretariat, Research Document 2007/2008.

Campana, S.E., Joyce, W., Marks, L., Natanson, L., Kohler, N.E., Jensen, J.F., Mello, J.L., Pratt, H.L. Jr. & Myklevoll, S. (2002). Population dynamics of the porbeagle in the Northwest Atlantic Ocean. *Journal of Fisheries Management* 22: 106-121.

Cape Sharp Tidal. (2018). Cape Sharp Tidal scores Bay of Fundy touchdown. www.marineenergy.biz/2018/07/24/cape-sharp-tidal.

Carey, F.G., Kanwisher, J.W., Brazier, O., Gabrielson, G., Casey, J.G. & Pratt, H.L. Jr. (1982) Temperature and activities of a white shark, *Carcharodon carcharias. Copeia* 2: 254-260.

Case, G.R. (1968). Inland shark occurrence. *Underwater Naturalist* 5: 20-21, 37.

Casey, J.G. & Kohler, N.E. (1990). Long distance movements of Atlantic sharks from the NMFS Cooperative shark tagging program. Pp 87-90. *In:* Discovering sharks.

Clark, D.S. & Emberley, J. (2009). Assessment of cod in Division 4X in 2008. Canadian Scientific Advisory Secretariat, Research Document 2009/018.

Cornett, A., Cousineau, J. & Nistor, I. (2013). Assessment of hydrodynamic impacts from tidal power lagoons in the Bay of Fundy. *International Journal of Marine Energy* 1: 33-54.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). (2010). COSEWIC assessment and status report on barndoor skate *Dipturus leavis* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ont.

COSEWIC. (2012). COSEWIC assessment and status report on the American eel *Anguilla rostrata* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ont.

COSEWIC. (2014). COSEWIC assessment and status report on the Porbeagle *Lamnus nasus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ont.

CSAS. (Canadian Science Advisory Secretariat. (2005). Atlantic mackerel of the Northwest Atlantic in 2004. Canadian Scientific Advisory Secretariat, Scientific Advisory Report 2005/014.

CSAS. (2006). Cod on the Scotian Shelf and in the Bay of Fundy (Div. 4X/5Y). Canadian Scientific Advisory Secretariat, Scientific Advisory Report 2006/046.

CSAS. (2007). 2007 assessment of 4VWX herring. Canadian Scientific Advisory Secretariat, Scientific Advisory Report 2007/023.

CTV News (2018). Great white shark snatches striped bass from fisherman. https://atlantic.ctvnews.ca/great white shark.

Daborn, G.R. (1984). Zooplankton studies in the upper Bay of Fundy since 1976. Canadian Technical Report of Fisheries and Aquatic Sciences 1256: 135-161.

Daborn, G.R. & Brylinsky, M. (2004). Fish population studies of the Avon estuary, Pesaquid Lake and the lower Avon River, 2003. Acadia Centre for Estuarine Research Technical Report 76.

Daborn, G.R. & Gregory, R.S. (1983). Occurrence, distribution and feeding habits of juvenile lumpfish, *Cyclopterus lumpus* L. in the Bay of Fundy. *Canadian Journal of Zoology* 61: 797-801.

Dadswell, M.J. (1979). Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* LeSueur, 1818 (Osteichthyes: Acipenseridae), in the Saint John River estuary, NB, Canada. *Canadian Journal of Zoology* 57: 2186-2210.

Dadswell, M.J. (1979). The Canso Causeway and its possible effects on the regional inshore fisheries – an overview. *In.* Canso Environmental Workshop. Ed. McCracken, F.D. Department of Fisheries and Environment, Fisheries and Marine Service Technical Report 834 (Part 1): 1-13.

Dadswell, M.J. (1985). Status of blueback herring, *Alosa aestivalis*, in Canada. *Canadian Field-Naturalist* 99: 409-412.

Dadswell, M.J. (1997). Stock structure of American shad, *Alosa sapidissima*, in the Gulf of Maine and the Bay of Fundy. Canadian Atlantic Fisheries, Scientific Advisory Committee, Research Document 86/97.

Dadswell, M.J. (2006). A review of the status of Atlantic sturgeon, *Acipenser oxyrinchus* Mitchill, 1814, in Canada, with comparisons to Europe and the United States. *Fisheries* 31: 218-229.

Dadswell, M.J., Bradford, R, Leim, A.H., Scarratt, D.J., Melvin, G.D. & Appy, R.G. (1984a). A review of research on fishes and fisheries in the Bay of Fundy between 1976 and 1983 with particular attention to its upper reaches. Canadian Fisheries and Aquatic Sciences Technical Report 1256: 163-294.

Dadswell, M.J., Ceapa, C., Spares, A.D., Stewart, N.D., Curry, R.A., Bradford, R.D. & Stokesbury, M.J.W. (2017). Population characteristics of adult Atlantic sturgeon captured by the commercial fishery in the Saint John River estuary, NB, Canada. *Transactions of the American Fisheries Society* 146: 318-330.

Dadswell, M.J., Melvin, G.D. & Williams, P.J. (1983). Effects of turbidity on the temporal and spatial utilization of the inner Bay of Fundy by American shad *Alsoa sapidissima* (Pisces: Clupeidae) and its relationship to the local fisheries. *Canadian Journal of Fisheries and Aquatic Science* 40 (Supp. 1): 322-330.

Dadswell, M.J., Melvin, G.D., Williams, P.J. & Brown, G.S. (1984b). Possible impact of large-scale tidal power developments in the upper Bay of Fundy on certain migratory fish stocks of the Northwest Atlantic. Canadian Fisheries and Aquatic Sciences Technical Report 1256: 577-599.

Dadswell, M.J., Melvin, G.D.,Williams, P.J. & Themelis, D.E. (1987). Influence of origin, life history and chance on the Atlantic coast migration of American shad. *American Fisheries Society Symposium* 1: 313-330.

Dadswell, M.J. Nau, G. & Stokesbury, M.J.W. (2013). The first verified record for a shortnose sturgeon *Acipenser brevirostrum* LeSueur, 1818 in Minas Basin, Bay of Fundy, NS Canada. *Proceedings of the Nova Scotian Institute of Science* 47: 273-279.

Dadswell, M.J. & Rulifson, R.A. (1994). Macrotidal estuaries: a region of collision between migratory marine animals and tidal power development. *Biological Journal of the Linnean Society* 51: 93-113.

Dadswell, M.J., Rulifson, R.A. & Daborn, G.R. (1986). Potential impact of large-scale tidal power developments in the upper Bay of Fundy on fisheries resources of the Northwest Atlantic. *Fisheries* 11: 26-35.

Dadswell, M.J., Spares, A.D., McLean, M.T., Harris, P. & Rulifson, R.A. (2018). Long term effect of a tidal, hydroelectric turbine on the populations of three anadromous fish species. *Journal of Fish Biology* 93: 192-206.

Dadswell, M.J., Spares, A.D., Porter, E., & Porter, D. (2020). Diversity, abundance and size structure of fishes and invertebrates captured by intertidal fish weir at Bramber, Minas Basin, NS. *Proceedings of the Nova Scotian Institute of Science* 50: 283-318.

Dadswell, M.J., Spares, A.D., Reader, J.M. & Stokesbury, M.J.W. (2010). The North Atlantic subpolar gyre and the marine migration of Atlantic salmon *Salmo salar*: the merry-go-round hypothesis. *Journal of Fisheries Biology* 77: 435-467.

Dadswell, M.J., Wehrell, S.H., Spares, A.D., McLean, M.T., Beardsall, J.W., Logan-Chesney, L.M., Nau, G.S., Redden, A.M. & Stokesbury, M.J.W. (2016). The annual feeding aggregation of Atlantic sturgeon *Acipenser oxyrinchus* in the inner Bay of Fundy: population characteristics and movements. *Journal of Fisheries Biology* 89: 2107-2132.

Deng, Z., Guensch, G.R., McKinstry, C.A., Mueller, R.P., Dauble, D.D. & Richmond, NS. (2005). Evaluation of fish injury mechanisms during exposure to turbulent shear flow. *Canadian Journal of Fisheries and Aquatic Science* 62: 1513-1522.

Desplanque, F.B. & Mossman, D.J. (1998). A review of ice and tide observations in the Bay of Fundy. *Atlantic Geology* 34: 195-209.

DFO. Department of Fisheries & Oceans Canada. (1997). Gaspereau, Maritimes Region Overview. DFO Science Stock Status Report D3-17.

DFO. (2017a). Assessment of 4X5Y haddock, 2016. Canadian Scientific Advisory Secretariat, Scientific Advisory Report*,* 2017/006.

DFO. (2017b). Stock assessment of Winter Flounder (*Pseudopleuronectes americanus*) of the southern Gulf of St. Lawrence (NAFO Div. 4T) to 2018. Canadian Scientific Advisory Secretariat, Scientific Advisory Document 2017/022.

Douglas, S.G., Bradford, R.G. & Chaput, G. (2003). Assessment of striped bass (*Morone saxatilis*) in the Maritime provinces in the context of species at risk. Canadian Scientific Advisory Secretariat, Research Document 2003/008.

Durbin, A.G. & Durbin, E.G. (1975). Grazing rates of the Atlantic menhaden *Brevoortia tyrannus* as a function of particle size and concentration. *Marine Biology* 333: 265-275.

Duston, J. (2010). Bay of Fundy striped bass recreational angler survey, 2009. Department of Plant and Animal Sciences, Nova Scotia Agricultural College.

Duston, J., Mauriquez-Hernanadez, J., Macinnis, G.M., Reesor, C.M. & Astatkie, T. (2018). Striped bass early life history in the macrotidal Shubenacadie River. *Transactions of the American Fisheries Society* 147: 919-938.

Dutton, J & Gioia, K.A. (2019). Fecundity and embryonic development of spiny dogfish in the Northwest Atlantic Ocean. *Transactions of the American Fisheries Society* 148: 48-57.

Dyer, C., Wehrell, S. & Daborn, G.R. (2005). Fisheries management issues in the upper Bay of Fundy. Acadia Centre for Estuarine Research Technical Report 80.

Ellis, J.E., Rowe, S. & Lotze, H.K. (2015). Expansion of hagfish fisheries in Atlantic Canada and worldwide. *Fisheries Research* 161: 24-33.

Elson, P.F. (1964). Post-smolt Atlantic salmon in the Bay of Fundy. Pp. E20-E23 In. Hart, J.L. Fisheries Research Board of Canada, Biological Station. St. Andrews, NB. Annual Report and Investigators Summaries 1963-64: E-7.

FORCE. (Fundy Ocean Research Centre for Energy) (2009). Fisheries, landings and communities in Minas Basin. Appendix 9. www.fundyforce.ca/research.

FORCE. (2010). Fish surveys in Minas Channel 2010. Appendix H. www.fundyforce.ca/research.

FORCE. (2010). Oceanographic measurements: salinity, temperature, suspended sediment and turbidity, Minas Passage. August 2008 – September 2009. Appendix G. www.fundyforce.ca/research.

FORCE. (2017). Cape Sharp tidal venture. www.fundyforce.ca/technology.

Fuiman, L.A. (1977). Notes on the early development of the sea raven *Hemitripterus americanus. Fishery Bulletin.* 75: 467-470.

Garman, G.C. (1983). Observations on juvenile red hake associated with sea scallops in Frenchman Bay, Maine. *Transactions of the American Fisheries Society* 112: 212-215.

Garrett, C.J.R. (1972). Tidal resonance in the Bay of Fundy and Gulf of Maine. *Nature* 238: 441-443.

Gaskin, D.E., Read, A.J., Watts, P.F. & Smith, G.J.D. (1985). Population dispersal, size and interactions of harbour porpoise in the Bay of Fundy and Gulf of Maine. *Canadian Fisheries and Aquatic Sciences Technical Report* 1291.

Gibson, A.J.F., Amiro, P.G. & Robichaud-LeBlanc, K.A. (2003b). Densities of juvenile Atlantic salmon (*Salmo salar*) in inner Bay of Fundy rivers during 2000 and 2002 with reference to past abundance inferred from catch statistics and electrofishing surveys. CAFSAC Research Document 2003/121.

Gibson, A.J. & Myers, R.A. (2002). Effectiveness of a high-frequency sound fish diversion system at the Annapolis tidal hydroelectric generating station, Nova Scotia. *North American Journal of Fisheries Management* 22: 770-784.

Gibson, A.J. & Myers, R.A. (2003a). Biological reference points for anadromous alewife (*Alosa pseudoharengus*) fisheries in the Maritime region. Canadian Fisheries and Aquatic Sciences Technical Report 2468.

Gill, A.B. (2005). Offshore renewable energy: ecological implications of generating electricity in the coastal zone. *Journal of Applied Ecology* 42: 605-615.

Gilmurray, M.C. & Daborn, G.R. (1981). Feeding relations of the Atlantic silversides *Menidia menidia* in the Minas Basin, Bay of Fundy. *Marine Ecology – Progress Series* 6: 231-235.

Godin, G. 1968. The 1965 current survey of the Bay of Fundy. A new analysis of the data and an interpretation of the results. Marine Sciences, Energy, Mines and Resources Manuscript Report Ser 8.

Gordon, J. (1993). The woven weirs of Minas. Nova Scotia Department of Education, Curatorial Report 73.

Greenberg, D.A. (1984). A review of the physical oceanography of the Bay of Fundy.*Canadian Fisheries and Aquatic Sciences Technical Report* 1256: 9-30.

Greenberg, D.A. & Amos, C.L. (1983). Suspended sediment transport and deposition modelling in the Bay of Fundy, Nova Scotia- a region of potential tidal power development. *Canadian Journal of Fisheries and Aquatic Science* 40 (Suppl. 1): 20-34.

Halliday, R.G. (1991). Marine distribution of the sea lamprey (*Petromyzon marinus*) in the Northwest Atlantic. *Canadian Journal of Fisheries and Aquatic Science* 48: 832-842.

Hammer, L. Eggertsen, L., Andersson, S., Ehnberg, J., Arvidsson, R., Gullstrom, M. & Molander, S. (2015). A probabilistic model for hydrokinetic turbine collision risks: exploring impacts on fish. *PLoS ONE* 10(3): e0117756.

Hansen, L.P., Jonsson, N. & Jonsson, B. (1993). Oceanic migration of homing Atlantic salmon, *Salmo salar*. *Animal Behaviour* 45: 927-941.

Hilton, E.J., Latour, R., Watkins, B. & Rhea, A. (2011). Monitoring relative abundance of American shad in Virginia Rivers. 2010 Annual Report, Virginia Institute of Marine Science www.doi.org/10.21220/V5G314.

Hogans, W.E., Dadswell, M.J., Uhazy, L.S. & Appy, R.G. (1993). Parasites of American shad, *Alosa sapidissima* (Ostreicththyes: Clupeidae) from rivers of the North American Atlantic coast and the Bay of Fundy, Canada. *Canadian Journal of Zoology* 71: 941-946.

Hoss, D.E. & Blaxter, J.H.S. (1979). The effect of rapid changes of hydrostatic pressure on the Atlantic herring *Clupea harengus* L. 1. Larval survival and behaviour. *Journal of Experimental Marine Biology and Ecology* 41:75-85.

Huntsman, A.G. (1922). The fishes of the Bay of Fundy. *Contributions to Canadian Biology* 3: 49-72.

Huntsman, A.G. (1958). Shubenacadie salmon. *Journal of the Fisheries Research Board of Canada* 15: 1213-1218.

Iles, T.D. & Sinclair, M. (1982). Atlantic herring: stock discreteness and abundance. *Science* (Washington, D.C.) 215: 627-633.

Imrie, D.M.G. & Daborn, G.R. (1981). Food of some immature fish of Minas Basin, Bay of Fundy. *Proceedings of the Nova Scotian Institute of Science* 31: 149-153.

Jessop. B. (1996). Eel fisheries in the Maritimes (*Anguilla rostrata*). Department of Fisheries and Oceans, Atlantic Fisheries Stock Status Report 96/14E.

Joyce, W., Campana, S.E., Natanson, L.J., Kohler, W.E., Pratt, H.L. & Jensen, J.F. (2002). Analysis of stomach contents of the porbeagle shark (*Lamna nasa*) in the Northwest Atlantic. *ICES Journal of Marine Science* 59: 1263-1269.

Karsten, R.A., McMillan, J.M., Lickley, M.J. & Hynes, R.D. (2008). Assessment of the current energy in Minas Passage, Bay of Fundy. Proceedings of the Institution of Mechanical Engineers, Part A. *Journal of Power and Energy* 222: 493-507.

Karsten, R., Swan, A. & Culma, J. (2013). Assessment of arrays of in-stream tidal turbines in the Bay of Fundy. *Philosophical Transactions of the Royal Society of Canada* 371: 20120189.

Kendall, V.J., Stewart, P.L. & Levy, H.A. (2018). Spatial and temporal delineation of ecological features of the Evangeline-Cape Blomidon-Minas Basin Ecologically and Biologically Significant Area (EBSA). Department of Fisheries and Oceans, Canadian Scientific Advisory Secretariat, Research Document 2018/013.

Ketchum, B.H. & Keen, D.J. (1953). The exchanges of fresh and salt waters in the Bay of Fundy and Passamaquoddy Bay. *Journal of the Fisheries Research Board of Canada* 10: 97-124.

Keyser, F.M., Broome, J.E., Bradford, R.G., Sanderson, B. & Redden, A.M. (2016). Winter presence and temperature related diel migration of striped bass *Morone saxatilis* in an extreme high flow passage in the Bay of Fundy. *Canadian Journal of Fisheries and Aquatic Science* 73: 1777-1786.

Knapp, L., Mincarone, M.M., Harwell, H., Polidoro, B., Sanciangco, J. & Carpenter, K. (2011). Conservation status of the world's hagfish species and the loss of phylogenetic diversity and ecosystem function. *Aquatic Conservation* 21: 401-411.

Koeller, P. (1979). Distribution and movements of herring in the Bay of Fundy from juvenile surveys. CAFSAC Research Document 79/32.

Lacroix, G.L. (2008). Influence of origin on migration and survival of Atlantic salmon (*Salmo salar*) in the Bay of Fundy, Canada. *Canadian Journal of Fisheries and Aquatic Science* 65: 2063-2079.

Lacroix, G.L., Knox, D. & Stokesbury, M.J. (2005). Influence of tidal flow on Atlantic salmon post-smolt migration and behavior in a coastal habitat. *Journal of Fisheries Biology* 66: 485-498.

Lacroix, G.L. & McCurdy, P. (1996). Migratory behaviour of post-smolt Atlantic salmon during initial stages of seaward migration. *Journal of Fisheries Biology* 49: 1086-1101.

Lauzier, L.M. (1967). Bottom residual drift on the continental shelf area of the Canadian Atlantic coast. *Journal of the Fisheries Research Board of Canada* 24: 1845-1859.

Leim, A.H. (1924). Life history of the shad {*Alosa sapidissima* (Wilson)} with special reference to the factors limiting its abundance. *Contributions of Canadian Biology* 2: 163-284.

Leim, A.H. & Scott, W.G. (1966). Fishes of the Atlantic coast of Canada. – *Fisheries Research Board of Canada Bulletin* 155.

Logan-Chesney, L.M., Dadswell, M.J., Karsten, R.H., Wirgin, I. & Stokesbury, M.J.W. (2018). Atlantic sturgeon *Acipenser oxyrinchus* surfacing behavior. *Journal of Fish Biology* 92: 929-943.

MacDonald, J.S., Dadswell, M.J., Appy, R.G., Melvin, G.D. & Methven, D. (1984). Fishes, fish assemblages and their seasonal movements in the lower Bay of Fundy and Passamaquoddy Bay, Canada. *Fisheries Bulletin* 82: 121-139.

MacDonald, M. (1884). The shad-*Clupea sapidissima*. p. 594-607. In. The fisheries and the fisheries industries of the United States. G.B. Goode and Associates. 47th Congress, 1st Session Senate Misc. Doc. 124.

MacInnis, G.M. (2012). Spatio-temporal distribution of eggs and age-0 striped bass (*Morone saxatilis*) in the Shubenacadie River estuary. M.Sc. Thesis, Dalhousie University, Halifax, NS.

Markle, D.F., Methven, D.A. & Coates-Markle, L.J. (1982). Aspects of spatial and temporal co-occurrence in the life history stages of the sibling hakes, *Urophycis chuss* (Walbaum 1792) and *Urophycis tenuis* (Mitchill 1815) (Pisces: Gadidae). *Canadian Journal of Zoology* 60: 2057-2078.

Martin, J.D. & Dadswell, M.J. (1983). Records of coho salmon (*Oncorhynchus kisuth*, (Walbaum, 1792), in the Bay of Fundy and its tributary drainage. Canadian Fisheries and Aquatic Sciences Technical Report 776.

McCracken, F.D. (1963). Seasonal movements of the winter flounder *Pseudopleuronectes americanus* (Walbaum) on the Atlantic coast. *Journal of the Fisheries Research Board of Canada* 20: 551-586.

McKenzie, R.A. & Tibbo, S.N. (1961). Herring movements in the Bay of Fundy and Gulf of Maine, 1957 and 1958. *Journal of the Fisheries Research Board of Canada* 18: 221-252.

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

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

McMillan, J.L., Caissie, D., Marshall, T.J. & Hinks, L. (2008). Population indices of brook trout (*Salvelinus fontinalis*), Atlantic salmon (*Salmo salar*), and salmon competitors in relation to summer water temperature and habitat parameters in 100 streams in Nova Scotia. Canadian Fisheries and Aquatic Sciences Technical Report 2819.

Meister, A.L. (1984). The marine migration of tagged Atlantic salmon (*Salmo salar* L.) of USA origin. ICES CM 1984/M 27.

Melvin, G.D., Dadswell, M.J. & Martin, J.D. (1986). Fidelity of American shad *Alosa sapidissima* (Ostreichthyes; Clupeidae) to its river of previous spawning. *Canadian Journal of Fisheries and Aquatic Science* 43: 640-646.

Melvin, G.D., Dadswell, M.J. & McKenzie, J.A. (1992). The usefulness of meristics and morphometric characters in discriminating populations of American shad, *Alosa sapidissima* (Ostreichthys: Clupeidae) inhabiting a marine environment. *Canadian Journal of Fisheries and Aquatic Science* 49: 266-280.

Moore, T.M. (1998). Population characteristics of the spiny dogfish (*Squalus acanthias* Linneaus, 1758) from geographically distinct locations in Atlantic Canada during the summer of 1996. M.Sc. Thesis, Acadia University, Wolfville, NS.

Morantz, D.L. (1978). A review of existing information of the fisheries of the Shubenacadie-Stewiacke River basin. Shubenacadie-Stewiacke Basin Fisheries Research Technical Report 1.

Moyle, P.B. & Cech, J.J. (1996). Fishes: an introduction to ichthyology. Prentice – Hall, NJ, USA.

Neves, R.J. (1981). Offshore distribution of alewife, *Alosa pseudoharengus*, and blueback herring, *Alosa aestivalis*, along the Atlantic coast. *Fisheries Bulletin* 79: 473-485.

Nielsen, J., Hedeholm, R.B., Heinemeir, J., Bushnell, P.G. & Christian, J.S. (2016). Eye lens radiocarbon revels centuries of longevity in the Greenland shark (*Somniosus microcephalus*). *Science* 353: 702-704.

Parker, M., Westhead, M. & Service, A. (2007). Ecosystem overview report for Minas Basin, NS, Fisheries and Oceans Canada, Oceans Habitat Report 2007-05.

Parramore, L.M. & Rulifson, R.A. (2001). Dorsal coloration as an indicator of different life history patterns for striped bass within a single watershed of Atlantic Canada. *Transactions of the American Fisheries Society* 130: 663-674.

Pearson, N.J., Gingras, M.K., Arimitage, I.A. & Pemberton, S.G. (2007). Significance of Atlantic sturgeon feeding excavations, Mary's Point, NB, Canada. PALAIOS 22: 457-464.

Perley, M.H. (1852). Reports on the sea and river fisheries of New Brunswick, 2nd ed. Queens Printer, Fredericton, NB.

Peterson, R.H., Johansen, P.H. & Metcalfe, J.L. (1980). Observations on early life stages of Atlantic tomcod, *Microgadus tomcod*. *Fisheries Bulletin* 78: 147-158.

Piers, H. (1934). Accidental occurrence of the man-eater or great white shark *Carcharodon carcharias* (Linn.) in Nova Scotian waters. *Proceedings of the Nova Scotian Institute of Science* 18: 192-203.

Prince, E.E. (1912). The shad fishery of Canada and its restoration. Sea fisheries of eastern Canada. Canada Commission of Conservation p. 120-136.

Quinn, D. (2010). Characteristics of the smolt migration of Atlantic salmon (*Salmo salar*) in the Gaspereau River, NS. Honours Thesis, Acadia University, Wolfville, NS.

Redden, A.M., Stokesbury, M.J.W., Broome, J.E., Ketser, F.M., Gibson, A.J.F., Halfyard, E.A., McLean, M.F., Bradford, R., Dadswell, M.J., Sanderson, B. & Karsten, R.A. (2014). Acoustic tracking of fish movements in the Minas Passage and FORCE demonstration area: preturbine baseline studies (2011-2013). Acadia Centre Estuarine Research Technical Report 118.

Rees, M. (2016). White shark one year later. *The Shoreline Journal.* August 2016: 21.

Reid, P.R. (1982). Aspects of the winter ecology and behaviour of bald eagles (*Haliaectus leucocephalus alaseanus* Townsend) on the Shubenacadie River, NS. M.Sc. Thesis, Acadia University.

Roberts, L.A. (1987). Spatial and temporal distributions of the larvae of herring (*Clupea harengus* L.) and rainbow smelt (*Osmerus mordax* Mitchill) in Minas Basin, NS. Honours thesis, Acadia University, Wolfville, NS.

Rulifson, R.A. & Dadswell, M.J. (1995). Life history and population characteristics of striped bass in Atlantic Canada. *Transactions of the American Fisheries Society* 124: 477-507.

Rulifson, R.A. & Dadswell, M.J. (2020). Alewife and blueback herring captured by intertidal weirs in the inner Bay of Fundy, Canada display seasonal demographics that suggest multiple migrating stocks. *Marine and Coastal Fisheries* (in press).

Rulifson, R.A., McKenna, S.A. & Dadswell, M.J. (2008). Intertidal habitat use, population characteristics, movement, and exploitation of striped bass in the inner Bay of Fundy, Canada. *Transactions of the American Fisheries Society* 137:23-32.

Rulifson, R.A., McKenna, S.A. & Gallager, M.L. (1987). Tagging studies of striped bass and river herring in the upper Bay of Fundy, NS. Institute of Coastal Marine Research Technical Report 82-02. East Carolina University, Greenville, NC, USA.

Rulifson, R.A. & Tull, K.A. (1998). Striped bass spawning in a tidal bore river: the Shubenacadie estuary, Atlantic Canada. *Transactions of the American Fisheries Society* 128: 613-624.

Sanderson, B.G. & Redden, A.M. (2015). Perspective on the risk that sediment-laden ice poses to in-stream tidal turbines in Minas Passage, Bay of Fundy. *International Journal of Marine Energy* 10: 52-69.

Sandru, M. (2011). World's biggest tidal power plant opened in South Korea. Wave Power.
www.greenoptimistic.com/korea-biggest-tidal-power-plant.

Saunders, R.L. (1969). Contributions of salmon from the northwest Miramichi River, NB, to various fisheries. *Journal of the Fisheries Research Board of Canada* 26: 269-278.

Scott, J.S. (1987). Matrices of co-occurrences of fish species on the Scotian Shelf and in the Bay of Fundy. Canadian Fisheries and Aquatic Sciences Technical Report 1581.

Scott, J.S. (1988). Seasonal spatial distribution of groundfish of the Scotian Shelf and the Bay of Fundy 1974-79 and 1980-84. Canadian Fisheries and Aquatic Sciences Technical Report 1853. 81 p.

Scott, W.B. & Scott, M.G. (1988). Atlantic Fishes of Canada. *Canadian Bulletin of Fisheries and Aquatic Sciences* 219. 731 p.

Scully, B.W. (1983). The utilization of an intertidal salt-marsh-mudflat system as a nursery area by smooth flounder *Liopsetta putnami* (Gill). M.Sc. Thesis, Acadia University, Wolfville, NS.

Simon, J.E. & P.A. Comeau. (1994). Summer distribution and abundance trends of species caught on the Scotian Shelf from 1970-92, by the research vessel groundfish survey. Canadian Fisheries and Aquatic Sciences Technical Report 1953.

Stevenson, C.H. (1898). The restricted inland range of shad due to artificial obstructions and its effects on natural reproduction. *Bulletin of the United States Fisheries Commission* 17: 265-271.

Stokesbury, K.D.E. & Dadswell, M.J. (1989). Seaward migration of juvenile alsoids from an estuary in Atlantic Canada. *Canadian Field-Naturalist* 103: 338-393.

Stokesbury, K.D.E. & Dadswell, M.J. (1991). Mortality of juvenile clupeids during passage through a tidal, low-head hydroelectric turbine at Annapolis Royal, NS. *North American Journal of Fisheries Management* 11: 149-154.

Stokesbury, M.J.W., Logan-Chesney, L.M., McLean, M.F., Buhariwalla, C.F., Redden, A., Breadsall, J.W., Broome, J.E. & Dadswell, M.J. (2016). Atlantic sturgeon spatial and temporal distribution in Minas Passage, NS: a region of future tidal energy extraction. *PLoS ONE* 11: e0158387.

Stokesbury, M.J.W. & Stokesbury, K.D.E. (1993). Occurrence of juvenile Atlantic menhaden, *Brevoortia tyrannus*, in the Annapolis River, NS. *Estuaries* 16: 827-829.

Stone, H.H. (1985). Composition, morphological characteristics and feeding ecology of alewifes (*Alosa pseudoharengus*) and blueback herring (*A. aestivalis*) (Pisces: Clupeidae) in Minas Basin. M.Sc. Thesis, Acadia University, Wolfville, NS.

Stone, H.H. & Daborn, G.R. (1987). Diet of alewifes, *Alosa pseudoharengus* and blueback herring, *A. aestivalis* (Pisces: Clupeidae) in Minas Basin, NS, a turbid, macrotidal estuary. *Environmental Biology and Fisheries* 19: 55-67.

Taylor, A.D., Kyoko, O., Sheng, J. & Litvak, M.K. (2016). Oceanic distribution, behavior, and a winter aggregation area of adult Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus,* in the Bay of Fundy. *PloS ONE* 11(4): e0152470.

Tee, K-T. (1975). Tide-induced residual current in Minas Channel and Minas Basin. Ph.D. Thesis, Dalhousie University, Halifax, NS.

Templeman, W. (1963). Distribution of sharks in the Canadian Atlantic. Bulletin of the Fisheries Research Board of Canada 140. 77 p.

Themelis, D.E. (1986). Feeding ecology of American shad, *Alosa sapidissima,* in the upper and lower Bay of Fundy, Canada. M.Sc. Thesis, Acadia University, Wolfville, NS.

Tibbo, S.N. & Humpreys, R.D. (1966). An occurrence of capelin (*Mallotus villosus*) in the Bay of Fundy. *Journal of the Fisheries Research Board of Canada* 43: 463-467.

Tobey, A. (1977). Shrimp midwater trawl development 1976 Gulf of St. Lawrence. Department of Fisheries and Environment, Fisheries and Marine Service Technical Report 701.

Tollit, D., Wood, J., Broome, J. & Redden, A. (2011). Detection of marine mammals and effects monitoring at the NSPI (Open Hydro) turbine site in Minas Passage during 2010. Acadia Centre for Estuarine Research Technical Report 101.

Towse, K. (2014). The Scott's Bay tidal Power project: a new approach to tidal power. www.halcyontidalpower.com/projects.

Trippel, E.A., Morgan, M.J., Fréchet, A., Rollet, C., Sinclair, A., Annad, C., Beanlands, D. & Brown, L. (1997). Changes in age and length at sexual maturity of Northwest Atlantic cod, haddock and pollock stocks, 1972-1995. Canadian Fisheries and Aquatic Sciences Technical Report 2157.

Viehman, H.A. & Zydlewski, G.B. (2015). Fish interactions with a commercial scale tidal energy device in the natural environment. *Estuaries and Coasts* 38 (Suppl. 1): 241-252.

Von Raben, K. (1957). Regarding the problem of mutilation of fishes by hydraulic turbines. Die Wasserwirtschaft 4: 97-100. Fisheries Research Board of Canada, Translation Series 448.

Waldman, J., Hasselman, I.D., Bentzen, P., Dadswell, M.J., Maceda, L. & Wirgen, I. (2014). Genetic mixed stock analysis of American shad at two Atlantic coast locations: Delaware Bay and the inner Bay of Fundy. N.A. *North American Journal of Fisheries Management* 34: 1190-1198.

Walters, R.A., Tarbotten, M.R. & Hiles, C.E. (2013). Estimation of tidal power potential. *Journal of Renewable Energy* 51: 255-262.

Wehrell, S. (2005). A survey of the groundfish caught by the summer trawl fishery in Minas Basin and Scots Bay. Honours Thesis, Dept. of Biology, Acadia University, Wolfville, NS.

Wehrell, S., Dadswell, M.J. & Redden, A. (2008). Population characteristics, movements and a population estimate of Atlantic sturgeon (*Acipenser oxyrinchus*) in Minas Basin, Bay of Fundy during the summer of 2007. Acadia Centre for Estuarine Research Technical Report 90.

Whidden, J.A. (2015). Population demographics and species identification of two at risk skates: little shark *Leucoraja erinacea* and winter skate *Leucoraja ocellata* in Minas Basin, Bay of Fundy. M.Sc. Thesis, Acadia University, Wolfville, NS.

Williams, P.J. (1985). Use of otoliths for stock differentiation of American shad *Alosa sapidissima* Wilson. M.Sc. Thesis, Acadia University, Wolfville, NS.

Wirgin, I. Jessop, B., Courtenay, S., Pederson, M., Maceda, S. & Waldman, J.R. (1995). Mixed stock analysis of striped bass in two rivers of the Bay of Fundy as revealed by mitochondrial DNA. *Canadian Journal of Fisheries and Aquatic Science* 52: 961-970.

Wirgin, I., Maceda, L., Waldman, J.R., Wehrell, S., Dadswell, M.J. & King, T. (2012). Stock origin of migratory Atlantic sturgeon in the Minas Basin, inner Bay of Fundy, Canada. *Transactions of the American Fisheries Society* 141: 1389-1398.

Won, S.O. (1980). Korea tidal power study-1978. Science Report, Taiwan University 11: 32-39.

Zangiabadi, E., Masters, L., Williams, A.J., Croft, T.N., Malki, R., Edmunds, M., Mason-Jones, A. & Horsfall, I. (2016). Computational prediction of pressure change in the vicinity of tidal stream turbines and consequences for fish survival rate. *Journal of Renewable Energy* 101: 1141-1156.

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SEAFLOOR AND SEDIMENT CHARACTERISTICS OF PULP MILL WASTE DISCHARGES IN THE 20TH CENTURY: FRAMEWORK DATA FOR BOAT HARBOUR, NOVA SCOTIA, REMEDIATION PROJECTS AND FOR BASELINE SURVEYS OF NEW PULP WASTE OUTFALL INSTALLATIONS IN NORTHUMBERLAND STRAIT

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ABSTRACT

During the 20th century, contamination of marine environments by Canadian pulp and paper mill effluent (PPE) resulted in the imposition of federal government regulations in 1971 that were revised and strengthened in 1992. This report reviews seafloor sediment features for three marine settings (intertidal, subtidal and prodelta) arising from 20th century PPE discharges from four pulp and paper mills, one located near New Richmond, Quebec, and three situated along the lower reaches of the Saguenay River, Quebec. The four mills began operations between 1965 and the early 1900's. Observations of their proximal and distal sediment and Foraminifera characteristics in relation to PPE discharge outfalls offer guidance for the remediation of potentially toxic, multi-decadal waste accumulations in several lagoons of Boat Harbour, Nova Scotia. Seafloor environmental data discussed for a fifth mill's subtidal outfall, located on the eastern shore of Canso Strait, may be particularly germane for selecting the site and baseline environmental survey criteria for a new PPE submarine outfall that has been proposed (presently rejected) by Northern Pulp Company for the Caribou Harbour area of the Northumberland Strait coast, in the event that the currently closed mill is permitted to be reactivated in the future.
Keywords: effluent, environmental effects, organic matter, pulp mill waste, sediments

INTRODUCTION

The latter part of the 20th century witnessed the introduction by Canada of federal government environmental regulations regarding acceptable physical and chemical characteristics of Pulp and Paper Mill Effluent (PPE) and saw mill discharges into riverine, estuarine and open marine environments. The first of these regulations

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appeared in the early 1970's and were subsequaently revised and strengthened in the early 1990's (Environment Canada 2012, Open Canada 2020). Physical characteristics of pulp and paper mill effluents deposited prior to 1971 ranged from small visible wood chips to fine fibrous wood-derived particles mixed with fine sediment-laden liquids containing metallic and chemical contaminants (e.g., Pelletier and Canuel 1988, Smith and Loring 1981). The solids, in these fibrous organic matter-enriched (OM) deposits, were often subject to resuspension and transport from their point of origin to adjacent subaqueous or intertidal environments by river, tidal and/or wind-driven currents. Revision of former Environment Canada and climate change Pulp and Paper Mill Regulations (PPERs) in 1992 included assessment of PPE biochemical oxygen demand (BOD), total suspended solids concentration, and various acute aquatic toxicity tests (Environment and Climate Change 2020). As such, Northern Pulp Company's waste discharges into several Boat Harbour lagoons between 1967 and 2020 were predicted to have a range of chemical and physical variation with respect to seafloor sediment depth. By 2001, Canadian pulp and paper mills were said to be meeting 90% of tests as defined in the PPE regulatory standards under the Fisheries Act (1985).

The present paper provides information on: (1) PPE deposits observed at a 10 m deep outfall site at Black Cape, New Richmond, Quebec, along with observations at a nearshore intertidal location on the northwest shore of Chaleur Bay, lying west of the Black Cape outfall (Schafer and Cole 1974); and (2) PPE deposits from a river-mouth subaqueous prodelta setting that was sampled by a piston corer in 1982 and again in 2011 at a depth of c.88 m in the North Arm of the Saguenay Fiord (Schafer 1973, Schafer and Cole 1978, Smith and Schafer 1987, Schafer *et al.* 1990). The three environments (intertidal, subtidal, prodelta) likely span the range of conditions that can be expected at seafloor environments that occur in proximal and distal seafloor areas of Boat Harbour lagoons in relation to the location of the Northern Pulp mill's outfall.

PULP MILL HISTORIES

In 1963, Bathurst Power & Paper Company began construction of a new liner board mill in New Richmond (formerly Chaleurs), Quebec. It was completed in 1965 when the name of the Company was changed to Consolidated Bathurst Ltd. The mill continued to operate until 1989 when it was purchased by Stone Container Corporation and renamed to Stone Consolidated and later to Les Emballages Stone. Its final name, before the mill was shut down in 2005 was Smurfit – Stone (Willett 2010). In 2010, SSPM L.P., an affiliate of Green Investment Group Inc. purchased the mill for 3 million dollars (Green Investment Group 2010). The mill's submerged concreate discharge pipe enters Chaleur Bay at Black Cape, about 4 km east of New Richmond. Its mouth is located about 600 m offshore at a depth of 10 m (Fig 1). The mill's effluent was discharged through a series of diffusers positioned near the end of the pipe and through its 61 cm-diameter mouth. In 1969, PPE pH ranged from 8.5 to 9.5 and, at the surface of the Bay just above the outfall and its discharge generated a visible "boil" that appeared to enhance dispersal and dilution processes. During the late 1960's, the mill's PPE discharge was about 68 m^3 per day that included between 9000-18,000 kg of bark fiber and lime mud along with 36,000-45,000 kg of dissolved pulping process chemicals (C. Rimmer 1969, pers. comm.).

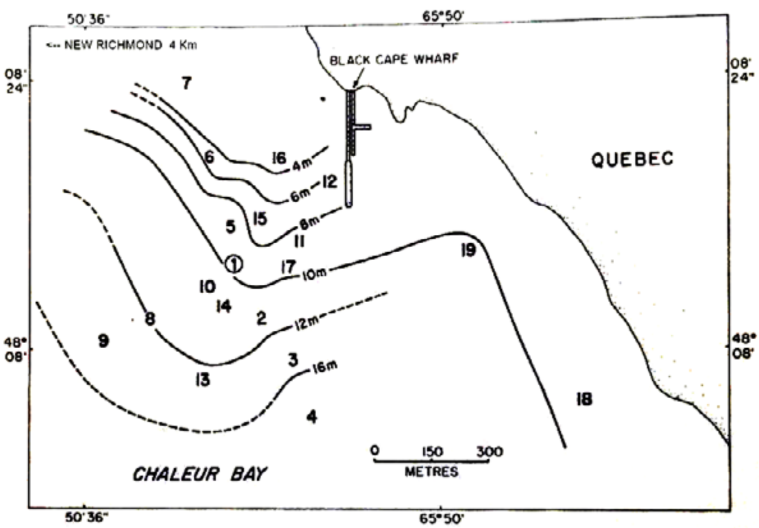

Fig 1 Map showing 19 sediment grab sample locations in the seafloor area surrounding the mouth of the Consolidated Bathurst PPE pipe. Station 1 marks the location of the pipe's mouth (modified after Schafer and Cole 1974).

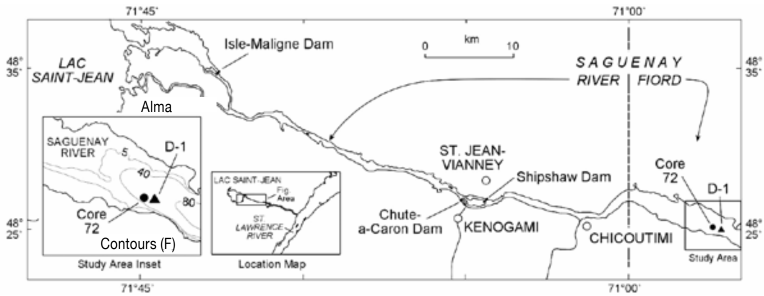

Fig 2 **Lower reach of the Saguenay River between Lac St. Jean and the study area in the North Arm of the Saguenay Fiord. Piston core 82008-72 (1982) and Lehigh gravity core D-1 (1979) were raised from the fore-slope of the Saguenay River prodelta on the south side of the North Arm between the 40 and 80 fathom (70-145 m) contour lines (inset). Coriolis piston core 2011060-0001 was collected from a depth of c. 88 m at the Core 82008-72 location in 2011 to allow inspection of annual deposit characteristics in X-radiographs for the 1982-2011 interval (modified after Schafer *et al.* 1990).**

In 1900, a group of citizens built a pulp mill on the shores of Rivière aux Sables which flows into the lower reaches of the Saguenay River, just east of the present-day Chute-a-Caron Dam (Fig 2). The mill was soon purchased by William Price who turned it into a paper mill that produced 18 tons per day of ground wood pulp used to manufacture cardboard (Resolute Blog 2016). In 1911, the Price Brothers Company constructed a second large mill on the shores of Rivière aux Sables in the town of Kenogami (now part of the larger Municipality of Saguenay). It manufactured about 150 tons of newsprint per day from the time it started production in 1912. Presently, the mill produces about 375 tons per day of “supercalendered” paper (Pulp and Paper Canada 2015). In the early 1920’s, Price Brothers constructed a third mill in the town of Alma, located about 27 km due west and upstream from the Rivière aux Sable’s intersection with the lower Saguenay River channel and southwest of the Isle-Maligne Dam. It went into production in 1925 but shut down one of its three pulping machines in 2015 with a loss of 88 jobs and 75000 metric tonnes per year of specialty paper production. Before that downsizing event, the mill claimed an annual production capacity of 350,000 tonnes (Pulp and Paper Canada 2015) . Collectively, 20th century studies related to these four mills cover intertidal, subtidal and relatively deep (>75 m) prodelta environmental settings. These provide background information useful for considering remediation strategies at Boat Harbour, NS.

METHODS

The Black Cape outfall survey (originally the Bathurst Power and Paper Company) was conducted with a small inshore fishing vessel capable of deploying a 15x15 cm Ekman Dredge sediment sampler. About a 2 cm-thick volume of surface sediment was removed through the top of the dredge at each sampling location and placed into a small vial containing a solution of Sudan Black stain and alcohol. In the laboratory, stained surficial sediment samples were washed through a 63μm sieve. The >63μm fraction was dispersed in a 500 ml beaker of water to float off PPE organic matter (OM). The water was stirred and decanted several times to remove as much organic matter as possible. Following decantation, the samples were dried and split to a manageable size for counting Foraminifera tests, using a 20 x binocular microscope (Scott *et al.* 2001). Sample positioning for the Black Cape outfall survey was done by triangulation using a horizontal sextant and confirmed with reference to Canadian Hydrographic Service charted water depths. A subsequent seafloor photography program was also carried out at the outfall area in 1969 using a model PC-8 manned submersible operated by the Perry Submarine Company of Riviera Beach, Florida.

The most recent Saguenay prodelta core sample was collected in 2011, at a location core sampled in 1982, using Benthos piston corer technology deployed from the *Coriolis II* research vessel. On deck, the raised piston core's plastic liner was removed from the corer barrel and cut into 2m sections, capped and labelled for transport. In the laboratory, the piston core liner samples were split, described visually, and then examined using the 2011 version of the Bedford Institute of Oceanography's X-ray profiler.

OBSERVATIONS

Black Cape – Chaleur Bay

The seafloor area immediately surrounding the mouth of the Black Cape PPE discharge pipe is littered with water-logged wood chips (Fig 3). Submersible observations showed that as the effluent exited the pipe, wood fibers and associated wood and fine particulate detritus appeared initially to rise toward the surface. However, relatively large water-saturated particulates quickly settled very close to the mouth of the outfall, forming a lobe that extended to the north and northwest, giving a general indication of the typical near-bottom, suspended particulate, effluent transport direction. The distribution pattern of several species of living arenaceous Foraminifera (e.g., *Spiroplectammina biformis*) appeared to confirm this pattern (Fig 4).

Fig 3 Photograph of the seafloor at about 10 m depth near the mouth of the Black Cape PPE pipe as seen through the forward viewport of the Perry PC-8 submersible. The deposit consisted of relatively coarse waterlogged wood chips that are easily resuspended by wave turbulence or by currents that are able to scour the seafloor in this part of the Bay. The dark bar on the left side of the photograph is a metal bumper frame that protects the submersible's relatively large forward viewport (author's personal photo collection, Circa late 1960's).

Within the 300x400 m, *S. biformis* was absent within a 300x 400 m footprint surrounding the outfall, but there were rare occurrences of living specimens of other pollution-tolerant estuarine taxa such as *Eggerella advena*. The distribution pattern of these two relatively pollution-tolerant arenaceous species was used to map polluted, OM-enriched, seafloor environments at other locations in the western end of the Bay (Schafer 1973, Schafer *et al.* 1991).

At deeper distal locations, adjacent to the Consolidated Bathurst PPE outfall. features of the contaminated deposits included less than 10% of coarse (>62µ) organic matter, a total population of as many as 14 living arenaceous and calcareous Foraminifera species (Schafer and Cole 1974). During the early 1970's, occasional surveys

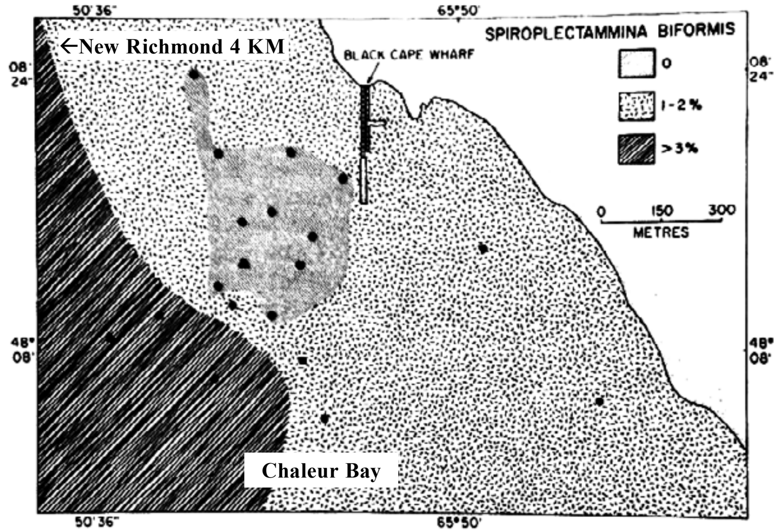

Fig 4 Distribution of living (as opposed to empty skeletons) of *Spiroplectammina biformis* surrounding the Consolidated Bathurst PPE outfall. Living specimens of this species were absent at the seafloor locations covered by a carpet of coarse wood chips (modified after Schafer and Cole 1974).

Fig 5 Photograph of the lower section of a Chaleur Bay beach west of New Richmond showing wave-generated ripple troughs that have concentrated transported PPE wood particles. The white ruler at the bottom of the photo is 30 cm long (author's personal photo collection, *Circa* late 1960's).

of Chaleur Bay beaches west of the Black Cape PPE outfall often found them littered with wood chips and other tree-processing waste that appears to have been resuspended and transported by wave turbulence and/or tidal currents toward the northwestern end of the Bay (Fig 5) (e.g., Moreau *et al.* 2006).

Saguenay River Prodelta

X-radiographs of sediment cores retrieved from the head of the Saguenay Fiord's North Arm prodelta environment, from time-to-time between 1979 and 2011, clearly demonstrate the impact of transported PPE OM for a relatively deep water prodelta setting. The Saguenay prodelta PPE deposits sampled between 1979 and 2011 comprise a relatively large area (>14 km^2) of more than a century of sediment deposition of annual varve-like layers. Each of these layers consists of an upper part comprising very fine organic fibers and other contaminants that overlies, relatively clean, fine sandy-silt sediments. These basal particles are carried to the prodelta during the river's annual spring freshet, typically in May and June. OM-enriched layers reach the prodelta coring location as part of the river's suspended load, mostly during low river discharge in summer and fall months. The decay of annually-deposited OM-enriched layers observed at the prodelta coring site created continuous anoxic seafloor conditions over a large portion of the prodelta. This condition rendered it inhospitable for the local community of sediment bioturbating species for more than 60 years (Schafer *et al.* 1990, Schafer in prep). X-radiographs of Core 2011060-0001 shows the onset of completely unbioturbated deposits starting at the 1912 core horizon and becoming less distinct in the upper 110 cm section above horizon B (Fig 6). The year 1912 witnessed the installation of new, high capacity, pulp processing machinery at the paper mill situated upstream on a tributary of the lower Saguenay River channel, near the town of Kenogami (Schafer *et al.* 1990). PPE from that mill quickly raised the OM content of the upper part annually-deposited prodelta sediment layers from 9.3% to more than 13%. As a result of the oxygen consumption impact of the higher OM percentages, a unique textural proxy signal of spring freshet magnitude has been preserved within the lower part of each annual layer (e.g., Schafer 2011, Schafer *et al.* 1990, Schafer in prep.).

Results published by Pocklington and Leonard (1979) show that the PPE OM footprint is traceable downstream from the North Arm prodelta to the deep and distal Inner Basin of the Saguenay Fiord's main channel that lies downstream from the North Arm. At the North Arm prodelta study site, the eventual decline of continuous anoxic conditions caused by the OM-enriched layers reflects the impact of 1970 PPE regulations that are manifested by renewed partial bioturbation features in seafloor surface deposits (Fig 6, horizon A). The initial mitigating effect of PPE regulations in the early 1970's is reflected by the development of diffuse, annual layer, deposit contact surfaces caused by small bioturbators. However, distinct annual layers can still be recognized well into the mid-1980's (Fig 6, A-B interval). These post-1970 PPE regulations deposits likely include organic matter sourced from older PPE lag deposits transported from the lower Saguenay River channel floor during relatively high summer and fall discharge events. Near the top of the 2011 core, the annual layer structure becomes less distinctive and erratic, suggestive of increased bioturbation activity that is consistent with the revision and strengthening of government PPE regulations in 1992.

Fig 6 **Positive x-radiograph print of the upper 110 cm section of a 5 m long piston core (# 2011060-001) collected from the prodelta study area in the North Arm of the Saguenay Fiord during a Coriolis II survey in 2011. The older part of the core section (right end) shows the distinctive lighter-shaded organic matter (OM) layers (mats) that define the tops of annual deposits consisting of fibrous PPE-sourced OM. Based on the average sedimentation rate determined for prodelta deposits in earlier studies, the relatively thick dark layer at horizon B is approximately temporally consistent with the exceptionally high spring freshet of May, 1976 (Schafer *et al.* 1990). The two circular, and the one rectangular lighter-shaded features, mark subsampling activities carried out prior to x-radiography of the working half of the core.**

DISCUSSION

The PPE deposits of the four pulp mills described above offer a framework for considering some of the issues related to the eventual remediation of Boat Harbour's three lagoons, and to PPE disposal constraints that a future restart of Nova Scotia's Northern Pulp Company may be facing. The Boat Harbour PPE disposal site is owned by the Province and has received PPE discharges for almost five decades. Its western aeration lagoon has a network of approximately 21 aeration mechanisms that are manifested by air-enriched patches of water which are visible on satellite images (Fig 7). They apparently assist in supporting ambient seafloor oxygen conditions for deposits of relatively coarse OM particulates discharged by the

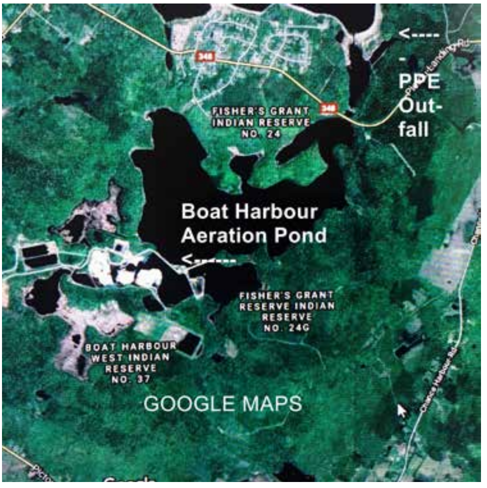

Fig 7 **Google Maps satellite image of the Pictou area of Nova Scotia's Northumberland Strait coast. The white dots within the aeration lagoon are likely a reflection from approximately 21 aerator ports that keep the water column oxygenated. The main lagoon and the waste outfall lagoon, lying northeast of the aeration lagoon, are presumably recipients of suspended particulates discharged from the aeration lagoon.**

PPE outfall. As such, the seafloor condition of the western lagoon would be expected to be comparable to those surrounding the Black Cape outfall. The deeper (older) layers of the aeration lagoon's bottom sediment are likely contaminated by a suite of toxic metals such as cadmium and mercury, along with dioxins and furans. However, according to an Environmental Assessment Document (DCEARD) prepared by Dillon Consulting in 2019 for Northern Pulp Company, dioxins and furans have been virtually eliminated from the mill's PPE since the company's conversion to a chlorine dioxide bleaching process in 1998. The main lagoon and the smaller waste outfall lagoon connect to the Northumberland Strait and are likely sinks for fine fibrous OM particulates, in conjunction with silt and clay-size lithic particulates that are maintained in suspension until exiting the aeration lagoon. This environment may be somewhat comparable to what was witnessed in post-late 1980's North Arm deposits, i.e., relatively homogeneous and structure-less (bioturbated) sediments with their content of toxic metals and organic chemicals confined mostly to deeper sediment layers. Deeper (older) intervals of pre-aeration main lagoon deposits may show annual deposition features similar to those observed in the Saguenay prodelta, depending on climate conditions that control nearshore particle erosion and transport to relatively quiescent deep offshore environments. The DCEARD report notes that Northern Pulp Company has never exceeded the limits of dioxins and furans as set out by government Pulp and Paper Effluent Chlorinated Dioxins and Furans Regulations (Dillon Consulting 2019). Nevertheless, the sedimentary record of the first three decades of the company's operations has a diverse chemistry of trace metals that must eventually either be isolated by a cover of clean, low permeability sediment, or dredged and removed completely for safe disposal. The Province's initial estimated cleanup costs for Boat Harbour are in the $133 million range (Environmental Science and Engineering Magazine 2017).

The anonymous Environmental Science and Engineering Magazine article published in November 2017, notes that the Northern Pulp Company's plan for its proposed PPE pipeline to the Northumberland Strait near Caribou Harbour, Nova Scotia called for an open-ended system for disposal of its bleached kraft mill effluent and mentions that the province awarded a $6.7 million Boat Harbour cleanup contract to GHD Consulting in May, 2017 (*Environmental Science and Engineering Magazine* 2017). Before its closure at the end of January 2020, the mill was producing about 280,000 tonnes of pulp per year. The local fishing community had called for a closed PPE loop system contained completely on land. Northern Pulp Company argued that this was impossible due to the nature of its current bleaching process which is predicted to release about 75,000 m^3 of PPE per day. A *Halifax Examiner* article (Baxter, 2019) presents a series of options about how the proposed new PPE pipeline issue might be resolved. It also comments on how local communities have been affected by the mill's air pollution during past decades and how they are preparing their case if the mill is reopened in the Future. The article speculates further that, even if the Nova Scotia Minister of Environment "were to approve the new treatment facility, Northern Pulp Company would still have no place to dispose of its effluent until a [new] facility is completed because of the Boat Harbour Act" (Baxter 2019). Perhaps, most importantly, at least 19 proposed deficiencies in Northern Pulp Company's Dillon Consulting submission have resulted in many calls for additional environmental surveys (Dillon Consulting 2019).

Thus, the Northern Pulp Company's position, as well as that of the Province, appears to be a classic example of an economic benefit-versus-environmental risk problem. This leaves many Nova Scotian's wondering if a sustainable development solution can ever be achieved? At this stage along the final decision pathway concerning the proposed new pipeline, there has been sufficient publicity that has provoked professional responses from many locally-concerned sectors including industry, marine environmental, chemistry, ecology, biology, and fisheries (Williams 2019). A comprehensive history of this environmental tragedy and the struggle of local Pictou community organizations in arguing for remedial action has been presented in a well-referenced book (Baxter 2017). As such, should the mill ever seek to reopen, its owners will likely be steered toward a sustainable development and natural resource conservation philosophy approach. This has been described by arms-length environmentalists such as Patrick Moore and will need to be taken into account when considering the many scientific recommendations published in recent government reports (Moore 2013, Government of Nova Scotia 2019). Chapter 14 of Moore's book offers some general tradeoffs and suggestions that can point the way for new operators of a 21st century version of this mill.

From a forward-looking perspective, the success and longevity of Nova Scotia's pulp mills appears to be mostly dependent on: (1) the nature of their environmental footprint (e.g., the Northern Pulp Company mill); (2) underestimating excess mill capacity versus product demand (e.g., the Resolute Forest Products mill in Brooklyn, near Liverpool, that was shut down in 2012); or (3) successfully predicting new investment requirements for mill infrastructure to meet changing market demand (e.g., the Port Hawkesbury Paper mill (PHP) on the eastern shore of Canso Strait). In 1998, the owners of the PHP mill announced a multi-million dollar investment for a state-of-the-art, super calendar paper machine (CBC News 2013). A multidisciplinary environmental survey of the Canso Strait industrialized shoreline completed by a team of Bedford Institute of Oceanography scientists in the early 1970's describes sediments near the waste outfall of its former 20th century PHP owners as comprising up to 40% OM (Buckley *et al.* 1974). The survey report also shows maps of benthic species barren zones (foraminifera, ostracods and mollusks) extending over various seafloor areas between the south side of the Canso Causeway and the southern outlet of the Strait near Bear Head. The smallest of these is the Foraminifera seafloor barren zone that was mapped adjacent to the Strait's eastern industrialized shoreline between Port Hastings and Port Hawkesbury. Consequently, even this currently very competitive mill is associated with a legacy of marine environmental contamination that will likely take many decades to self-remediate. In his perspective on reducing Nova Scotia Government expenditures during the tenure of a past NDP government, Graham Steele, its Minister of Finance at that time, remarked that the "mill file was our government at its best – the best people doing the best work of which the provincial government was capable – but I do understand that the final mill bill tested the public's limits for how far a government should go to save jobs" (Steele 2014).

The positive side of these unfortunate environmentally-damaging situations is the coincidental research that has enabled documentation of PPE-sourced organic matter (OM) deposited in the prodelta region of the Saguenay Fiord's North Arm for more than 70 years. Distinct definition of OM-defined PPE annual layers has been observed in several piston and gravity cores of Saguenay River prodelta deposits, starting just above the 1912 time horizon. Below this horizon, less sharp but still distinguishable, diffuse annual layer boundaries are present. Both annual layer formats have assisted in developing a prodelta deposit chronology. For example, centimetre-scale subsampling of the unbioturbated annual layer sequence, retrieved from core 82008-72, has provided proxy textural data on Saguenay River spring freshet magnitude inter-annual variation. These results have been used as a framework for generating a longer texture-based proxy river discharge magnitude variation record. To date, the record has been extended back to the early 19th century, or about 100 years before the initiation of monthly Saguenay River discharge data collections by local Quebec industries and municipalities (Schafer *et al.* 1990).

CONCLUSIONS

The impact of PPE discharges into a 10 m deep subtidal environment at Black Cape was mapped using benthic Foraminifera species that respond to certain changes in physical, chemical and oxygen concentrations of seafloor surficial sediments. The azoic zone developed at this site was comparatively small and located close to the mouth of the outfall. The distribution of PPE in seafloor areas close to the outfall was marked by reduced abundances of living *S. biformis* specimens. A larger anomalous crescent-shaped zone of increased species diversity circumscribed the *S. biformis* zone at deeper distal locations that featured relatively lower seafloor concentrations of OM. These conditions were attractive to some members of the Bay's indigenous foraminiferal community. Evidence for a presumed westerly transport direction for relatively coarse OM PPE occurs in intertidal environments lying to the west of the Black Cape outfall. Collectively, the information briefly reviewed in this study for three types of 20th century PPE sink environments provides observations on the size of PPE "footprints", sediment characteristics and time-series, marine pollution baseline data. These findings may have application in future investigations of environmental impacts recorded in older deposits of 20th century, PPE coastal discharge locations before remedial action is taken. In addition, they may help to estimate the degree and spatial extent of possible contamination effects arising from the dispersal of 21st century more extensively treated PPE from outfalls discharging into the Northumberland Strait and other coastal locations in the Gulf of St. Lawrence. Two arenaceous species of Foraminifera (*S.biformis* and *Eggerella advena*) have particular utility in establishing a pre-PPE discharge natural baseline of seafloor environmental gradients, prior to the installation and activation of a new proposed PPE outfall in the Northumberland Strait associated with the modernization or replacement of the currently shuttered Northern Pulp Company facility.

An increase in the annual load of fibrous PPE-sourced organic matter transported into the prodelta area of the Saguenay Fiord's North Arm, especially between 1912 and the mid – 1980's, resulted in continuous seafloor anoxic conditions that profoundly altered the benthic ecology in this part of the Fiord and eliminated most, if not all, bioturbation activity by local seafloor-living organisms. In May, 1971, the St. Jean Vianney landslide capped much of the contaminated prodelta seafloor with a 5 mm to 1 m-thick layer of low permeability Leda Clay that, inadvertently, isolated the exposure of transient marine species to a large area of older contaminated seafloor sediments and their content of mercury and PCB's.

However, this temporary environmental condition was itself superseded by renewed OM-enriched sediment deposition until the mid-1980's, after which time the more restrictive 1992 government PPE regulations apparently forced a further reduction of OM deposition to levels that allowed re-oxygenation of the prodelta's surficial sediments. This led to their recolonization by some local seafloor-bioturbating species (e.g., Leduc *et al.* 2002). Unfortunately, resumed sediment mixing activity through post-regulatory recolonization by a suite of larger-sized and deeper-burrowing species, that can reach sediments underlying the landslide layer, enhances the possibility of restarting the bioavailability of buried toxic contaminants to recolonizing local marine faunas and transient species. This possibly applies especially in the deeper distal parts of the prodelta where the annual deposition rate is relatively low. These observations suggest that the only permanent solution for Boat Harbour pulp and paper mill effluent deposits is their complete removal by various modes of sediment dredging of the three lagoons, as opposed to capping the respective seafloors with clean, low permeability clayey sediment.

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REFERENCES

Baxter, J. (2017). *The Mill: Fifty Years of Pulp and Protest.* Pottersfield Press, Nova Scotia, Canada 351 p.

Baxter, J. (2019). Northern Pulp's political game, its decision time for the Nova Scotia Government. Halifax Examiner, November 21, 2019. www.halifaxexaminer.ca/environment/northern-pulps-political-game/

Buckley, D., Owens, E., Schafer, C., Vilks, G., Cranston, R., Rashid, M., Wagner, F. & Walker, D. (1974). Canso Strait and Chedabucto Bay: A multidisciplinary study of the impact of man on the marine environment. In*:* Offshore Geology of Eastern Canada. Geological Survey of Canada Paper 74-30, 1: 133-160.

CBC News. (2013). Port Hawkesbury Paper to diversify as newsprint mill demolished. November 4th, 5:53 PM Atlantic Time. www.cbc.ca/news/canada/nova-scotia/port-hawkesbury-newsprint/

Dillon Consulting. (2019). Environmental Assessment Registration Document: Replacement Effluent Treatment Facility. Internal manuscript, Dillon Consulting, Halifax, NS.

Environment and Climate Change Canada. (2020). Canadian Environmental Sustainability Indicators: Pulp and paper effluent quality. www.canada.ca/en/environment-climate-change/services/environmental-indicators/pulp-papereffluent-quality.html

Environment Canada. (2012). Fifth National Assessment of Environmental Effects: 3145 – Monitoring Data from Pulp and Paper Mills Subject to the Pulp and Paper; 3146 – Effluent Regulations. En14-84/2013E-PDF. Public Works and Government Services of Canada, Ottawa, Ontario. 27 pp.

Environmental Science and Engineering Magazine. (2017). Northern Pulp's replacement effluent treatment facility under scrutiny in Nova Scotia. Nov 27, 2017. www.esemag.com/2017/northern-pulp's-replacement-effluent-treatment-facility-under-scrutiny-in-nova-scotia

Fisheries Act. (1985). https://laws-lois.justice.gc.ca/eng/acts/F-14/.

Government of Nova Scotia. (2019). Environmental Assessment: Replacement Effluent Treatment Facility. www.novascotia.ca/nse/ea/Replacement_effluent_Treatment_Facility_Project/

Green Investment Group. (2010). Project - New Richmond, Quebec. Smurfit-Stone Mill, Redevelopment Plan & Progress. www.greeninvgroup.com/projects/project-new-richmond-quebec.html

Leduc, J., Bilodeau, G., de Vernal, A. & Mucci, A. (2002). Distribution of benthic foraminiferal populations in surface sediments of the Saguenay Fiord, before and after the 1996 flood. *Palaeogeography, Palaeoclimatology, Palaeoecology* 180: 207-223.

Moore, P. (2013). Confessions of a Greenpeace Dropout: The Making of a Sensible Environmentalist. (Revised, 2013). Beatty Street Publishing, Vancouver, British Columbia.

Moreau, A-l., Locat, J., Hill, P., Long, B. & Ouellet, Y. (2006). Resuspension potential of surficial sediments in Saguenay Fiord (Quebec, Canada). *Marine Geology* 225: 85-101.

Open Canada. (2020). Searching the Open Data Portal for datasets - Open Government open canada.ca/data/en/dataset/2ca77dd7-6482-49ef-a9a1-06dbb792bd51.

Pelletier, E. & Canuel, G. (1988). Trace metals in surface sediments of the Saguenay Fiord. *Marine Pollution Bulletin* 19: 336-338.

Pocklington, R. & Leonard, J. (1979). Terrigenous organic matter in the sediments of the St. Lawrence Estuary and the Saguenay Fiord. *Journal of the Fisheries Research Board of Canada* 33: 1250-1255.

Pulp and Paper Canada. (2015). Resolute closes PM9 at Alma paper mill, March 10, 2015.
www.pulpandpapercanada.com/resolute-closes-PM9-at-alma-paper-mill-1003516610/

Resolute Blog. (2016). Resolute Roots: A brief profile of company founder William Price, October 17, 2016.
www.blog.resolutefp.com/2016/10/resolute-roots-brief-profile-company-founder-william-price

Rimmer, C. (1969). Consolidated Bathurst Company, personal communication.

Schafer, C. (1973). Distribution of Foraminifera near pollution sources in Chaleur Bay. *Water, Air and Soil Pollution* 2: 219-233.

Schafer, C. (2011). Inferred spring freshet discharge magnitude of the Saguenay River between the last decade of the 18th century and the early 1980's. Geological Survey of Canada Open File Report No. 8190. 46 p.

Schafer, C. (in prep). Impact of 1971 Pulp and Paper Mill Effluent Regulations on the flux of organic matter to the head of the Saguenay Fiord, Quebec, Canada.

Schafer, C. & Cole, F. (1974). Distribution of benthic Foraminifera: Their use in delimiting local nearshore environments. In: Offshore Geology of Eastern Canada. Geological Survey of Canada, Paper 74-30, 1: 103-108.

Schafer, C. & Cole, F. (1978). Distribution of Foraminifera in Chaleur Bay, Gulf of St Lawrence. Geological Survey of Canada Paper 77-30. 55 p.

Schafer, C., Collins, E. & Smith, J. (1991). Relationship of Foraminifera and Thecamoebian distributions to sediments contaminated by pulp mill effluent: Saguenay Fiord, Quebec, Canada. *Marine Micropaleontology* 17: 255-283.

Schafer, C. & Smith, J. (1988). Evidence of the occurrence and magnitude of terrestrial landslides in recent Saguenay Fiord sediments. In: El-Sabh, M.I. & Murty, T.S. (eds.). Natural and Man-Made Hazards, Reidel Publishing, Amsterdam, Netherlands. pp. 137-145.

Schafer, C., Smith, J. & Côté, R. (1990). The Saguenay Fiord: A Major Tributary to the St. Lawrence Estuary. In: El-Sabh, M.I. & Murty, T.S. (eds.). Coastal and Estuarine Studies 39: Oceanography of a Large-Scale Estuarine System, the St. Lawrence. Springer-Verlag, New York, USA. pp. 378-420.

Scott, D., Medioli, F. & Schafer, C. (2001). Monitoring Coastal Environments Using Foraminifera and Thecamoebian Indicators. Cambridge University Press, Cambridge, United Kingdom. 177 p.

Smith, J. & Loring, D. (1981). Geochronology for mercury pollution in the sediments of the Saguenay Fiord, Quebec. *Environmental Science and Technology* 15: 944-951.

Smith, J. & Schafer, C. (1987). A 20th-century record of climatologically modulated sediment accumulation rates in a Canadian Fiord. *Quaternary Research* 27: 232-247.

Steele, G. (2014). What I Learned About Politics; Inside the Rise – and collapse – of Nova Scotia's NDP Government. Nimbus Publishing, Halifax, Nova Scotia. 200 p.

Willett, P. (2010). Edwards & MacLean, Bathurst Power& Paper Co. Ltd. In: Gaspesian Heritage Web Magazine. www.gaspesie.quebecheritage.com/article/edwards-maclean-bathurst-power-co-ltd.

Williams J. (2019). Commentary: St. F.X. marine ecologist myth busts Northern Pulp effluent pollution. Chronicle Herald, Dec. 07, 2019. www.thechronicleherald.ca/opinion/local-perspectives/commentary-st-fx-marine-ecologist-myth-busts-northern-pulp-effluent-pollution-383668/.

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HISTORICAL AIR PHOTO MISSIONS IN THE MARITIMES DURING THE EARLY 1920s: COVERAGE, THEMATIC SCOPE, AND UTILITY 100 YEARS LATER

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ABSTRACT

The historical and technological developments of powered flight and aerial photography have early connections in the Maritimes. Following the Great War (1914-18), a series of pioneering survey missions were initiated by the Canada Air Board in the civilian domain. From a science perspective, the air photos offer a unique opportunity for the detection of environmental change at an unusual centennial time scale. The missions of the early 1920s initially relied on military surplus seaplanes and innovative camera equipment that yielded several thousand high-resolution vertical air photos. This paper is focussed on the scope and outcome of the first experiments carried out over Nova Scotia and New Brunswick between 1921 and 1925, prior to more systematic use for topographic mapping during the remainder of that decade. The research is based on archival records and partial reconstruction of the digitized air photos into image mosaics. Photo interpretation and comparison with recent high-resolution satellite imagery offer insights concerning land use and land cover changes, coastal dynamics, and transformation of urban, rural and industrial landscapes. Experience todate with these early air photos and mosaics of the Maritimes holds promise for examining similar aerial survey missions in other parts of Canada.

INTRODUCTION

The convergence of powered flight and aerial photography more than a century ago initiated technical and scientific innovation in the practice of surveying and mapping that reverberated throughout the 20th century. The view-from-above, with its ancient connotation of command and privilege, has since extended beyond the exclusive domain of military and civilian authorities. It has become an indispensable tool for surveying and mapping, as well as Earth and environmental sciences. Captured by sophisticated imaging

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instruments aboard fleets of airborne and satellite vehicles, aerial views have even entered popular culture through digital networks and online services. A key feature and commonality of both early aerial survey photography and modern high-resolution remote sensing imagery is their *vertical* perspective; this renders them directly comparable and scalable for unusually long time series, change detection and geospatial analysis concerning local and regional scientific inquiries.

Historically, some of the origins of aerial photography and flight can be traced to pioneering activities in the Maritimes of Canada. In 1882/83 Henry Elsdale, a Captain with the Royal Engineers, successfully captured the first remotely controlled aerial photographs of the Halifax Citadel. He employed a light-weight camera, an automatic timing mechanism, and a small tethered balloon; lacking institutional support, Elsdale used his own funds to conduct the experiments (Elsdale 1884, Werle 2019a). In 1909, Douglas McCurdy piloted the first flight of "Silver Dart", a powered aircraft, at Baddeck in Nova Scotia; the inventor Alexander Graham-Bell and his wife Mabel supported early aeronautical trials and financed them through their Aerial Experimental Association (MacDonald 2017).

Only 10 years after McCurdy's historic flight, aviation and aerial reconnaissance had entered a new phase following the rapid expansion of air forces and air photo know-how during World War 1 under enormous human and financial cost. In Canada, post-war technological and institutional developments relied on veteran personnel and military surplus equipment to apply aerial photography to civilian uses. Size and scope of these activities during the 1920s were small and tentative at first. Under the authority of the newly appointed Canada Air Board, a series of experimental missions were initiated across the country, including the Maritimes (Air Board 1921, 1922; Shaw 2001).

The objective of this study was threefold: 1) (re-)establish a comprehensive record of the aerial survey missions in the Maritimes during the 1920s; 2) determine location, purpose and detail of the actual photography; and 3) assess the potential use of these earliest examples of vertical aerial photography for scientific studies today. Following an outline of the methodological approach and previous work, the location, extent, and thematic scope of seven air survey missions over parts of the Maritimes were examined. This study suggests that the century-old photos, especially in aggregate mosaic form, constitute a unique and valuable source of local and regional geospatial information.

STUDY APPROACH

This study relied on the search, collection and analysis of archival air photos as well as information in the scientific literature and institutional records. Searches concentrated on the Earth Observation Data Management Systems (EODMS) of the Department of Natural Resources Canada and on-site searches at the National Air Photo Library (NAPL) in Ottawa. The work focused on a series of experimental air photo missions initiated by the Canada Air Board (CAB) in the Maritimes during the first half of the 1920s. Annual reports by the Department of National Defence (DND) were reviewed regarding air photo missions conducted during the remainder of the decade. In addition, CAB and DND reports as well as other sources were analyzed to place vertical air photo coverage and its utility for scientific study into the larger regional environmental context. The search for aerial photography cited in this study can be replicated either through public, on-site access at NAPL using flight line index maps and Roll reference numbers, or it can be repeated and extended online through the EODMS. The latter accepts entries of date, location and NAPL Roll reference numbers to render digital air photo footprints and metadata displays and, in a growing number, low-resolution previews of digitized air photos. The NAPL offers both hard copy and digital air photo reproduction services for a fee (www.eodms-sgdot.nrcan-rncan.gc.ca/index_en.jsp).

In terms of technical procedures, this study used individual 300 dot-per-inch scanned NAPL air photos for analysis and annotation and for digital assembly into uncontrolled photo mosaics by fitting them to a suitable reference or remotely sensing image map. Alignments of the road network and features common to both air photos and background map or image served as a guide to geometric fidelity. The individual vertical air photos were arranged sequentially along flight lines and marked with thin frames to emphasize the composite nature of the montage. Once assembled into a mosaic, subsets or individual photos representative of specific analysis topics were compared with recent remote sensing imagery of similar spatial detail. This reference imagery was retrieved online through open-access geospatial data platforms, such as Google Earth. Standard photo-interpretation methods were applied to both data sets in order to identify features or areas of interest and assess change.

PREVIOUS WORK

Previous work on the emergence of aerial photography in Canada during the early 1920s are linked to post-World War I historical accounts of powered flight and its various applications. For this study, primary sources include archival materials and official fiscal year-end reports of the Canada Air Board, the Militia Service, and the Department of National Defence, DND (Air Board 1921, 1922, 1923; DND 1923-1931). They referred to institutional, budgetary and personnel activities as well as equipment and logistical issues, including those connected with the Dartmouth Air Station in the Maritimes. This documentation also reflected the evolution of early aeronautical affairs in Canada. The Air Board served as the first, impermanent, post-World War I governance body for Canadian air defence, civil flying operations and licensing issues. By the mid 1920s, mandates and responsibilities were re-organized with a clear separation of military and civilian responsibilities principally between the Department of National Defence and the Department of the Interior. However, the Canadian Air Force arm of DND frequently provided flying services for both military and civilian aerial photography for years to come (Narraway 1924, Thomas 1950).

Secondary sources of early Canadian aeronautical and photographic achievements at a national scale consist of monographs and learned journal articles. Historical accounts, technical evaluations and thematic studies include those by Kealy and Russell (1965), Thompson (1969, 1975), Hitchins (1972), McAndrew (1981), Shaw (2001), Cronin (2007), Dyce (2013), and Banks (2015). Wheeler and Lambart (1923), Wilson (1924), Parminter (1985), and Smith (1997) assessed activities for western Canada. There are only few details of early air photo missions for eastern Canada. Wilson (1924) provided examples for uses in forestry and hydrology in Quebec during the 1920s. Werle (2016) re-assembled and interpreted air photos of a 1921 mission over the city of Halifax in Nova Scotia and pointed at the utility of these images for historical urban studies and detailed change analyses.

Giordano and Mallet (2019), as well as Collier *et al.* (2001), have emphasized the need to systematically compile information on archives with historical air photo collections in order to support scientific studies. For many locales in North America and Europe, vertical air photo coverage for change analysis goes back to the 1950s; fewer examples are openly available for the World War II decade because of security concerns. Although their operational use in surveying and mapping emerged during the 1930s, there are only rare cases where the historical value and cultural-technological significance of aerial photography between the two wars has been explored (Weems 2011).

As an early adopter of air photo technology, Canada is in a fortunate situation of having archived and curated collections. Next to NAPL, which was established in 1925, municipal and university archives also contain sets of individual air photos going back to the 1920s and 1930s. In the past, it was a common practice to produce air photo mosaics that show the ensemble of vertical photography resulting from a particular survey mission. Examples include reproductions and digital re-assemblies of mosaics for the cities of Halifax, NS (1921), Calgary, AB (1924), Edmonton, AB (1925), Hamilton, ON (1927), the Municipality of Richmond, BC (1935), and the Kitchener-Waterloo area in Ontario (1945).

Apart from post-World War I vertical aerial photography, collections of high-quality survey photographs from mountaintops in the Rocky Mountains of western Canada go back to the late nineteenth and early twentieth century (MacLaren 2005). These oblique photographs of alpine topography have attracted attention from researchers studying land cover change on an unusual centenary time scale. They have examined and compared the old photography with recent photography taken from the same location and depicting the same locales in a quasi-panoramic way (Fortin *et al.* 2018). In a similar vein, vertical aerial photographs of coastal areas in the Maritimes from the 1920s may lend themselves well as an early photographic benchmark for coastal mapping and monitoring studies with a focus on areas that have a high sensitivity to sea-level rise (Taylor *et al.* 2014).

RESULTS

The archival searches and literature analyses yielded numerous results. During the early 1920s, approximately 1500 high-resolution air photos were collected during seven experimental missions in Nova Scotia and New Brunswick (Fig 1, Table 1). They include coverage of Halifax (1921), the St. Croix River at St. Stephen and Calais (1921), sections of the Northumberland Shore (1923) and Pictou County (1923-24), the Fredericton area (1924-25), the Yarmouth area (1925), and a section of Hants County in Nova Scotia between Walton and Windsor (1925). Excerpts of individual air photos and corresponding recent high-resolution satellite imagery are contained in Fig 2. The National Air Photo Library is engaged in a multi-year project to digitize its holdings of early Canadian aerial photography for access through Canada's Earth Observation Data Management System (EODMS). This process has resulted in indexing the majority of vertical and oblique aerial photography missions of the Maritimes for online queries. The missions have retained their original letter designation "K" or "KA" for the respective mission film rolls. Far less encompassing in coverage compared to NAPL, major Canadian university map libraries as well as provincial archives contain

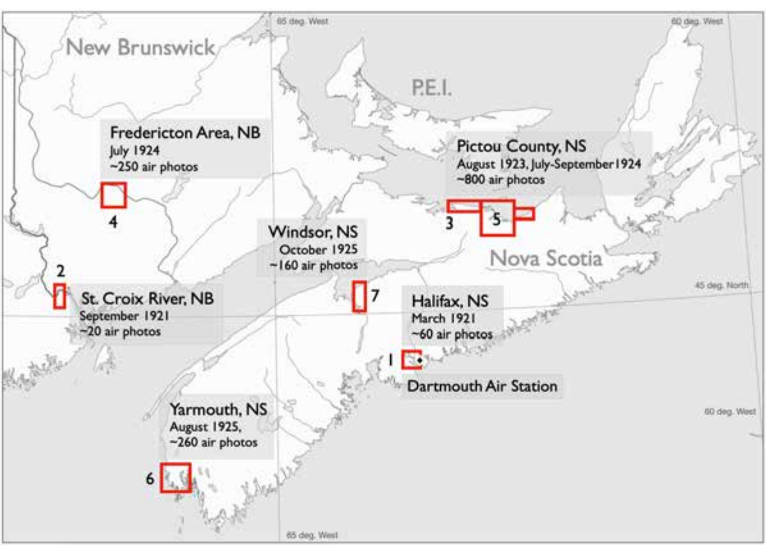


Fig 1 Location map of early vertical air photo survey missions in the Maritimes, 1921-1925.

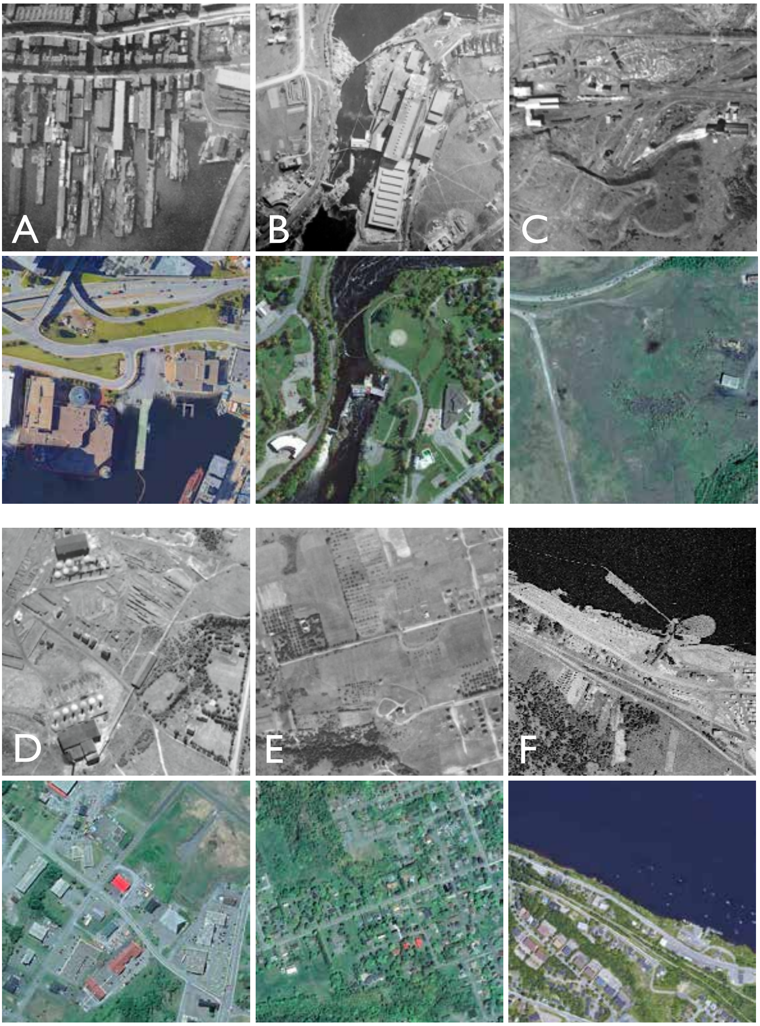


Fig 2 **Comparison of 500 m by 500 m excerpts of selected early 1920s black-and-white aerial photography with modern high-resolution, natural colour satellite imagery of the same locale: (A) finger-piers on the Halifax waterfront (1921); (B) cotton mill and timber rafts on the St. Croix River (1921); (C) coal mining operations, (D) clay mining and kiln operations, and (E) orchards in Pictou County (1923, 1924); and (F) Victoria lumber mill along the Saint John River near Fredericton (1925).** ***Source:*** **Air photos courtesy of NAPL; satellite imagery courtesy of Google Earth.**

Table 1 Vertical aerial photography collections over Nova Scotia and New Brunswick during the early 1920s*.

Month / Year	# Area / Province	NAPL Roll #	Photos (7x9”)	Scale	Scope of Mission
March 1921	1 Halifax NS.	K2	61	1:5,000	Experimental urban survey
October 1921	2 St. Croix River, N.B.	K3	20	1:4,000	US-Canada boundary survey, Int’l. Boundary Commission
September 1923	3 Pictou County, NS.	KA2, KA3, KA4, KA5	343	1:8,000	Urban-rural-coastal survey
July 1924	4 Fredericton, N.B.	KA31, KA32, KA33	253	1:5,000	Urban-rural survey
July-September 1924	5 New Glasgow, NS.	KA16, KA1, KA23, KA29, KA30	424	1:8,000	Urban-rural survey
August 1925	6 Yarmouth, NS.	KA34, KA35, KA36, KA37	256	1:12,000	Experimental topographic
survey					
October 1925	7 Windsor, NS.	KA38, 39	160	1:12,000	Corridor mapping (?)

* Based on searches of NAPL and EODMS metadata catalog (www.eodms-sgdot.nrcan-rncan.gc.ca)

Table 2 Oblique aerial photography collections over Nova Scotia and New Brunswick during the early 1920*.

Month / Year	Area / Province	NAPL Roll #	Photo #	Quality	Scope of Mission
March 1921	1 Halifax NS.	K2	61	1:5,000	Experimental urban survey
Aug. 6 1923	Head of St. Margarets Bay, NS.	KA1	1-12	modest	Hydropower, St. Margarets watershed
Aug. 6 1923	Halifax, NS.	KA1	16-33	modest	Halifax Harbour, islands, Dartmouth shore
Sept. 7 1923	Pictou, NS.	KA8	30	modest	Town and wharfs
Sept. 7 1923	Halifax, NS.	KA8, KA9	1-48	modest	Peninsula, Harbour entrance, Eastern Passage
Sept. 9 1923	South Shore, SW Nova Scotia	KA10	1-70	modest	Lunenburg, LaHave, Port Medway, Liverpool, Port Mouton, Lockport, Shelburne, Roseway River, Bear River

* Based on searches of NAPL holdings KA1 to KA10.

select regional sets of 1920s and 1930s air photos in either digital or analog format. However, their holdings of coverage for areas in the Maritimes are very sparse.

Next to the vertical air photos, there are also approximately 150 oblique aerial photographs on record dating back to sorties during the late summer and early fall of 1923. These individual rather than serial photos were acquired as a "photographic reconnaissance of coastline" and water resource assessments, as noted in the Canada Air Board report for that year (CAB 1923). The NAPL has copies of modest quality for some of these photos in its holdings, but there is no record of them on the EODMS. NAPL rolls KA1 and KA7 to KA10 contain low oblique imagery of the Halifax Harbour area, Pictou, Lunenburg (Fig 3), LaHave, Port Medway, Liverpool, Port Mouton, Lockport and Shelburne of Nova Scotia, and of the city of Saint John in New Brunswick. Several oblique photos were collected over the Head of St. Margarets Bay, and the Roseway, Bear and Musquash rivers (Table 2). The potential use of the oblique air photos may be limited to interpretative studies and comparison with more recent and systematic oblique videography of Nova Scotia's coastline acquired for scientific work (Taylor *et al.* 2014).

Fig 3 Example of low-oblique aerial photography collected over selected areas along the South Shore of Nova Scotia; Lunenburg Harbour, September 9, 1923. *Source:* Air photo courtesy of NAPL, Roll KA10-002.

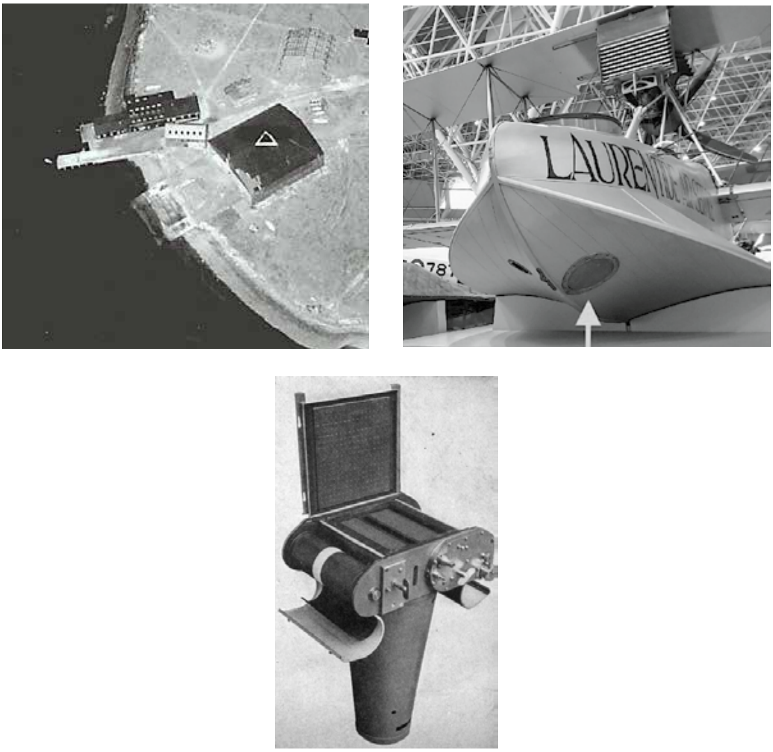


Fig 4 **High-oblique aerial photograph of the Dartmouth Air Station at Baker Point in 1923 (top left), depicting the main 30m by 30m large hangar, slipway for launching flying boats, scaffolding of a WW-1 vintage Bessenneau hangar, and an older fish plant buildings and wharf; Curtiss HS-2L flying boat (top right) with air photo camera bay indicated by arrow; and K-type aerial camera (bottom).** ***Source:*** **Air photo courtesy of NAPL, Roll KA9-7, 7.9.1923; HS-2L photo by D. Werle; K-type camera photo courtesy of Ives (1920, Fig. 65).**

The Air Station at Baker's Point in Dartmouth

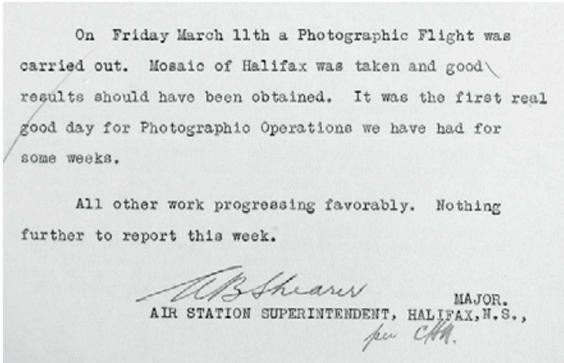
For the aerial survey activities during the early 1920s, the Air Station at Baker's Point in Dartmouth, Nova Scotia, served as a logistical centre and operational base (Fig 4). The station was originally established in 1918 by the United States Naval Air Service for seaplane patrols along the Atlantic coast to counter the German U-boat threat (Orr 2018, Boileau 2016, Halliday 1987). Following the establishment of the Canada Air Board by the Government of Canada in late 1919, the Baker's Point seaplane base became part of a country-wide network of six main air stations. During these formative years, the station operated year-round as one of two designated aircraft maintenance facilities for a small fleet of 12 Curtiss HS-2L sea planes that the US Navy had deeded over to Canada after World War I. Combined with the allocation of trained ground personnel and veteran pilots, the Air Station at Baker's Point supported some of the earliest aerial survey work in the country (Canadian Air Board 1921).

At least two of the HS-2L aircraft, G-CYAC and G-CYAH, were equipped with air photo camera fittings to accommodate the new K-2 and K-3 cameras developed by the Fairchild company in the United States (Fig 4). These cameras included a roll-film magazine with the capacity of exposing up to one hundred 7" by 9" air photos per roll (Sanders 1944). The HS-2L aircraft could nominally fly for four hours at a modest cruising speed of 70 mph, enabling air photo missions over parts of mainland Nova Scotia and southern New Brunswick (Terry 2004, Anonymous 1919).

Station activities and flying operations were recorded in weekly reports submitted by the Commanding Officer to the Air Board in Ottawa. Squadron Leader A.B. Shearer, a veteran flier, served as the first commanding officer of the Dartmouth Station and as pilot of several air photo missions. His report for the month of March 1921 mentioned air photo collection for the Halifax mosaic on March 11 (Fig 5, top). Incidentally, there is no entry of this pioneering aerial survey in the official annual Air Board report for that year (Canada Air Board 1921), although on-site inspection reveals that an uncatalogued print set of the actual air photos was deposited at NAPL; the physical flight index map for early aerial photography of Halifax at NAPL contains a handwritten note that the original film was destroyed.

Experimental Air Photo Missions during the early 1920s (1921-1925)

The operating parameters of the Curtiss HS-2L aircraft, its relatively low flight altitude, and the 12-inch focal length of the survey cameras had notable implications for the scale of the aerial photography of the early 1920s. It varied between 1:5,000 and 1:10,000 (Table 1). Although this apparent limitation precluded large area coverage, the photographs reveal excellent spatial detail on the order of several tens of centimeters, depending on the quality of the original film, film duplicate, paper print, and resolution of the digital


On Friday March 11th a Photographic Flight was carried out. Mosaic of Halifax was taken and good results should have been obtained. It was the first real good day for Photographic Operations we have had for some weeks.

All other work progressing favorably. Nothing further to report this week.

MAJOR.
AIR STATION SUPERINTENDENT, HALIFAX,N.S.,

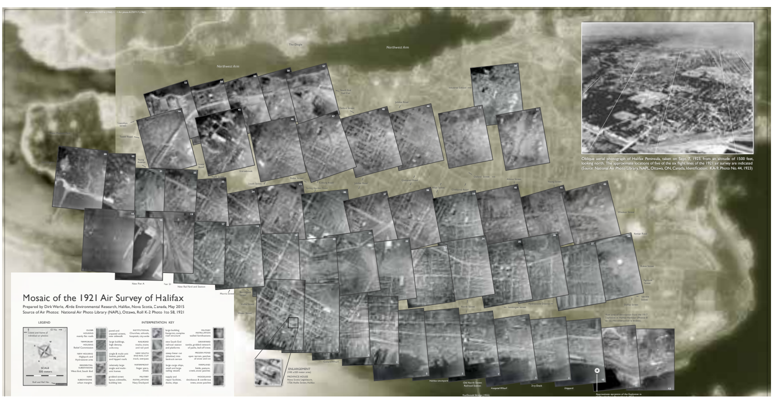


Fig 5 Excerpt of the Dartmouth Air Station "Weekly Report, ending Sunday March 13, 1921" (top) by Major A. B. Shearer, noting photographic operations for the Halifax air photo mosaic (bottom). ***Source:*** **Shearwater Aviation Museum Library, Dartmouth, NS.; reproduction courtesy of J.L. Orr, June 2018; mosaic by Werle (2016).**

reproduction. In principle, the detail matches that of modern high-resolution satellite imagery and enables change detection analyses at a rare temporal scale approaching 100 years. All of these surveys were explicitly carried out for civilian purposes.

Halifax survey, 1921. The aerial survey of the city of Halifax on March 11, 1921, is one of the earliest in the country. The survey was clearly experimental and likely initiated for urban planning purposes. The 60 photographs cover the built-up area of the Halifax peninsula in five partially overlapping flight lines (Table 1, Fig 2, Fig 5). This rare portrayal of a post-World War I cityscape reveals a series of infrastructure improvement projects. They include old and completely new harbour facilities, new or extended transportation networks and urban designs, while still marking the aftermaths of the catastrophic explosion in Halifax Harbour of December, 1917. A digital mosaic and annotation of the Halifax survey was prepared by Werle (2016).

St. Croix River boundary survey, 1921. Conducted on behalf of the International Boundary Commission to assist in boundary delineation, the St. Croix River boundary survey of October, 1921, is a comparatively small one. It consists of two short overlapping flight lines of 20 photographs covering the course of the river between Milltown, St. Stephen and Calais (Werle 2019b). The density of industrial facilities, on both sides of the US-Canada border, notably cotton and lumber mills at Milltown (Fig 2), had rendered ongoing boundary delineation difficult. Analysis of the detailed aerial photography contributed to a resolution of the problem. The survey not only represents one of the first applications of this kind, but it also portrays the geospatial ensemble of an historic industrial landscape that has since vanished.

Pictou County survey, 1923-1924. The air photo coverage acquired over large parts of Nova Scotia's Pictou County and the Northumberland Shore during the summer months of 1923 and 1924 is extensive. It consists of approximately 800 individual air photos along nine flight lines, none of which have been assembled to form a cohesive mosaic of the urban, rural and industrial land use. The main focus of the aerial survey at the time was on land use mapping and topographic map updates. The air photos reveal a significant part of the industrial heartland of Nova Scotia as it existed a century ago. Partial mosaics assembled by the author provide a detailed visual account of coal mining activities around the town of Stellarton, including significant environmental side effects in the form of sinkholes over the extensive network of subsurface mine shafts and mined coal seams; other portions of the data set show clay mining and kiln operations and agricultural land use patterns (Fig 2). Several flight lines contain vertical photography with detailed delineations of the shoreline; these reveal significant change as a result of coastal erosion and accretion processes extending over the course of the past century (Fig 6).

Fredericton area survey, 1924. The aerial survey of the Fredericton area of New Brunswick comprises approximately 250 air

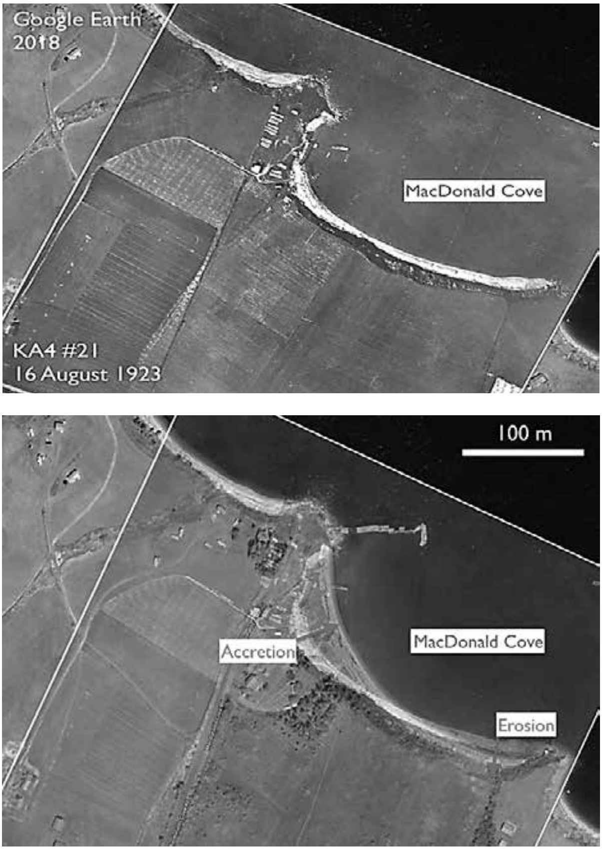


Fig 6 **Coastline change over a 95-year period along the Northumberland Shore of Nova Scotia illustrated by co-registration of 1923 aerial photography (left) and 2018 Google Earth satellite imagery (right), involving erosion and accretion on the order of several tens of meters within the 300 m long embayment of MacDonald Cove.** ***Source:*** **Air photo courtesy of NAPL, Roll KA4-21; satellite image courtesy of Google Earth.**

photos at a scale of 1:5,000. They cover the eastern portion of the city, parts of the St. John River with logging booms and the Victoria saw-mill operation (Fig 2f), as well as extensive woodlands and agricultural land to the south of the city. The latter portion roughly coincides with the woodland endowment of the University of New Brunswick. Mapping the endowment between the southern outskirts of the city and the settlement of New Maryland may have been the main reason for the survey. A partial mosaic was assembled digitally by the author in 2019 (unpublished).

Windsor area survey, 1925. The 160 aerial photographs of the Windsor survey of Nova Scotia, in the fall of 1925, cover a narrow North-South corridor between the village of Walton on the Minas Basin and the Avon Peninsula near Windsor, Nova Scotia. The original objective of the survey is unknown. The configuration of the flight lines points toward a corridor mapping exercise. The planners of this survey made a conscientious effort to acquire air photos of high and low tide conditions at Walton (Fig 7).

Yarmouth area surveys, 1925. In August of 1925, a survey over Yarmouth and surrounding coastal areas of southwestern Nova Scotia obtained some 260 vertical air photos. The layout of the four parallel, East-West oriented flight lines suggest that the experiment was geared toward topographic mapping or map updating. The coverage of coastal locales with their frequent changes in reflectance of land and water surfaces posed initial challenges for adjusting exposure settings of the air photos. However, this problem was resolved as shown by an expansion of the survey in subsequent years.

Air Photo Missions during the late 1920s (1927-1931)

The successful completion of the experimental surveys of the early 1920s set a pattern for topographic mapping activities in the

Fig 7 Example of early aerial photography of tidal conditions along the Minas Basin at Walton, NS. captured at high tide on October 18 (left) and low tide on October 19, 1925 (right). ***Source:*** **Air photos courtesy of NAPL, Roll KA38-3 (left) and KA38-37 (right).**

Maritimes during the latter part of the decade and beyond. The Yarmouth air photo mission of 1925 served indeed as a precursor for a much larger survey of southwestern Nova Scotia by the Topographic Survey Branch of the Department of the Interior. During the summer of 1927, it collected approximately 1400 photos for updating its topographic maps; 10 flight lines cover the Pubnicos, Cape Sable Island, Shelburne and adjacent landward areas with predominantly boggy and sparsely forested terrain. In 1929, more than 80 hours of flying resulted in the collection of additional vertical as well as oblique photographs of western Nova Scotia.

The practice of aerial photography clearly gained momentum during the late 1920s based on the steadily increasing number of missions and their areal extent. The DND records reveal that 25 air photo missions were conducted in the Maritimes between 1927 and 1931 (Table 3); 15 of them covered parts of Nova Scotia and 10 took place in New Brunswick. There is no mention of air photos taken over Prince Edward Island during that time. It appears from the metrics of flying hour and area coverage that a significant number of air photos were acquired over areas in northeastern and southeastern New Brunswick. The total number of air survey related flying hours in the Maritimes amounted to more than 900, increasing steadily from approximately 10 hours in 1927 to 129, 224 and 553 hours in subsequent years. The Topographic Survey carried out more than half of the 25 missions, followed by the Geographic Section of DND with five missions, thus (re-)emerging as a significant user of aerial photographs. Individual surveys were carried out on behalf of interests in national parks, hydrology, forestry and transportation (Table 3). The potential use of these air photos for change detection of coastal areas, wetlands, and estuarine environments is illustrated in Fig 8.

Much of the coverage awaits further assessment in terms of completeness and potential utility for environmental change detection in conjunction with recent imagery. A preliminary inspection of the air photos of the late 1920s and early 1930s suggests that the practice of aerial surveying was evolving and expanding beyond the trials of the early 1920s, as shown in two examples (Table 3). The 1931 survey of the greater Halifax area included the collection of more than 450 air photos at a scale of 1:15,000, exceeding that of the 1921 survey almost by an order of magnitude in terms of air

Table 3 Vertical and oblique aerial photography collections over Nova Scotia and New Brunswick, 1927-1931 (*Source:* DND 1929, DND 1930, DND 1931).

Year	# Area, Province* (sqml = square miles)	Purpose / Department	FlyingTime (in hours)
1927	Southwestern Nova Scotia, NS	Topographic Survey / Interior Dept.	10
1928	Newcastle, NB (1820 sqml)	Topographic Survey / Interior Dept.	112
	Coastal area, NS	Geogr. Section / National Defence	5
	Fredericton area, NB	Topographic Survey / Interior Dept.	4
	Chipman area, NB	Topographic Survey / Interior Dept.	2
	Nova Scotia interior, NS	Topographic Survey / Interior Dept.	6
1929	Moncton area, NB	Topographic Survey / Interior Dept.	120
	Saint John area, NB	Geological Survey / Mines Dept.	8
	Western Nova Scotia	Topographic Survey / Interior Dept.	80
	Windsor Reservoir area, NS	Topographic Survey / Interior Dept.	5
	Bedford Basin, Halifax, NS	Geogr. Section / National Defence	8
	Lake Charlotte area, NS	Topographic Survey / Interior Dept.	3
1931	Newcastle, NB (300 sqml)	Topographic Survey /Interior Dept.	69
	Chipman area, NB (200 sqml)	Topographic Survey / Interior Dept	39
	Fort Louisbourg area, NS	National Parks / Interior Dept.	3
	Annapolis Valley area, NS	Geogr. Section National Defence	5
	Cambellton, NB (200 sqml)	Topographic Survey / Interior Dept.	24
	Shediac area, NB (117 sqml) [1]	Topographic Survey / Interior Dept.	13
	Halifax area, NS (920 sqml) [2]	Geogr. Section National Defence	55
	Annapolis V., NS (330 sqml)	Geogr. Section National Defence	21
	Bridgewater, NS (1100 sqml) [3]	Topographic Survey / Interior Dept.	59
	Coal Fields, NS (225 sqml)	Geological Survey / Dept. Mines	45
	Saint John R., NB (corridor)	Hydrological Survey / Marine Dept.	38
	Sherbrooke area, NS	Forest Service / Interior Dept.	94
	Truro-Halifax, NS (corridor)	Highway Dept. / NS Government	8

[1] Coverage of the "Shediac" area survey is contained on NAPL Roll # 3526, 3527, 3528 and 3529 (335 air photos); NAPL Roll # 3517 and 3529 contain coverage of the Chignecto Isthmus subset (116 air photos).

[2] Coverage of the "Halifax" area is contained on NAPL Roll# 3522, 3523, 3524 and 3525 (458 air photos).

[3] Coverage of the "Bridgewater" area is contained on NAPL Roll# 3518, 3519, 3520, 3521 and 3530 (509 air photos).

photos taken, and by a hundred-fold in terms of area covered, albeit at smaller scale and lower spatial resolution. The 1931 survey of the Chignecto Isthmus separating the Provinces of New Brunswick and Nova Scotia formed part of a larger "Shediac, N.B." mission that resulted in the overall collection of 450 air photos. Then and now, these low-lying marshes contain critical transportation infrastructure that is increasingly threatened by the effects of climate change and sea level rise.

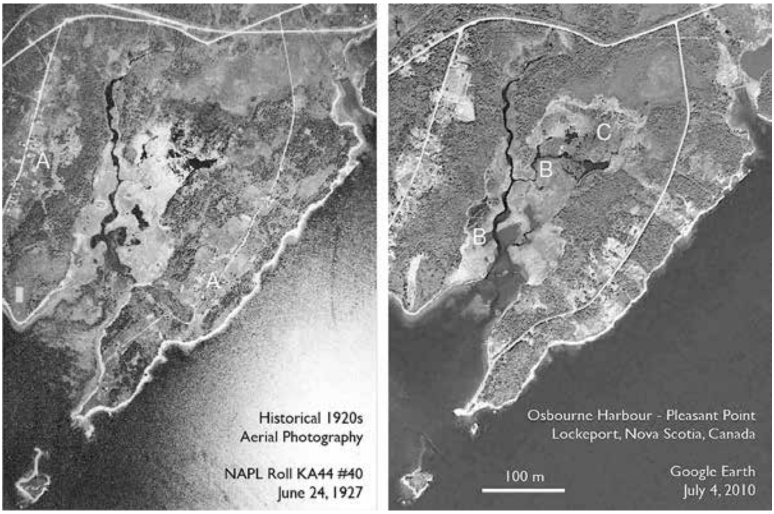


Fig 8 Example of coastal salt marsh changes and influence of sea level rise, as shown by aerial photography taken on June 24, 1927, and Google Earth satellite imagery taken on July 4, 2010, over the Osbourne Harbour – Pleasant Point area near Lockeport, NS. In terms of land use, greater areas of pasture (A) appear to prevail in 1927. Given satellite data acquisition during low tide, notable differences between the 1927 and 2010 imagery include slightly larger extent of open waterways and surfaces (B) in the salt marsh area, as well as extension of low marsh vegetation at the head of the salt marsh (C) in 2010, pointing to generally elevated water levels with that zone. *Source:* Air photo KA44-40 courtesy of NAPL; satellite image courtesy of Google Earth; 2010 tidal data courtesy of Fisheries and Oceans Canada.

DISCUSSION AND CONCLUSION

In general terms, the adaptation of aerial photography to civilian application during the years immediately following World War I represented a complete turn-around from massive war theatre surveillance and targeting to peaceful experimental use in surveying and mapping. In post-war Canada, political direction and institution-building, combined with enormous mapping and surveying requirements, clearly altered the scope of aerial photography in favour of civilian application. The initial aerial surveys in the Maritimes were guided by the Canada Air Board and its survey committee until the mid 1920s. Nonetheless, the logistical effort was still heavily reliant on veteran personnel for mission planning and surplus war planes for completing the surveys. Vertical air photo collections between 1921 and 1931 predominantly served the Topographic Survey Branch, Department of the Interior; missions on behalf of the Department of National Defence only started to emerge during the late 1920s.

The study results indicate that the pioneering aerial survey activities in the Maritimes progressed promptly during the early 1920s because of remaining wartime infrastructure and a core of air station personnel at Dartmouth, NS., yielding high-resolution air photos. Today, these largely unnoticed collections are accessible in analog and digital formats at the National Air Photo Library and to a limited extent through university archives. The air photos may have outlived their original purpose to support thematic mapping or map revision at the time. Yet, conception and outcome of the surveying missions deserve to be assessed not only in an historic light but also from contemporary social, historical and environmental science perspectives.

A comparison of the century-old coverage with recent high-resolution satellite imagery of selected sites yields insight concerning the usefulness of the historic data sets for present-day investigations and inquiries. This study suggests that the thematic focus could be on land use and land cover, coastal environmental change, transformation of urban, rural and industrial landscapes, as well as educational aspects regarding local and regional heritage. For example, municipal planners, scientists, historians, and the general public stand to benefit from geospatial information derived through analysis of Canada's oldest air photos in conjunction with more recent multi-temporal data layers. Experience to-date with the early 1920s air photos and mosaics in the Maritimes holds promise for examination of the more extensive surveys conducted in the region during the late 1920s. The goal and potential outcome would be three-fold: determine physical location of the actual air photos; exploring quality and geographic extent of the coverage; and tying actual photo content to the analysis of modern geospatial data sets to address present day environmental challenges.

A critical aspect is the digital reconstruction of the individual photographs into cohesive image mosaics for comparison with more recent remotely sensed data sets collected for the purpose of coastal research and mapping. Candidate areas with extensive vertical aerial photography include the Northumberland Shore and the entire southwestern region of Nova Scotia. Likewise, time, location and spatial detail of the 116 air photos covering the low-lying marshes of the Chignecto Isthmus could make this so-far unnoticed data set a unique and useful source of geospatial information for assessing long-term land cover, land use changes and environmental risk in light of sea level rise, expectation of severe storm surges and exposure of critical transportation infrastructure.

The air photo collections of the 1920s represent an early legacy of aerial surveying in the Maritime Provinces of Canada. While the actual view-from-above may not capture any historically significant *events* at the time, detailed coverage of selected areas in Nova Scotia and New Brunswick offers a rare opportunity for geospatial assessments of important natural, cultural and industrial features that are either different or no longer present today. From a scientific perspective, the air photos offer an opportunity for detailed environmental change detection at an unusual centennial time scale when compared with modern imagery. While search and access of individual air photos has become less problematic with the use of online platforms and archives, their ultimate value lies in the composition of image mosaics and thus spatially cohesive reference layers for historical, cultural and scientific inquiries.

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REFERENCES

Air Board (1921). *Report of the Air Board for the year 1920.* Thomas Mulvey Printer, Ottawa, ON 16 p.

Air Board (1922). *Report of the Air Board for the year 1921.* F.A. Acland Printer, Ottawa, ON 20 p.

Air Board (1923). *Report of the Air Board for the year 1922.* F.A. Acland Printer, Ottawa, ON 75 p.

Amad, P. (2012). From God's-eye to Camera-eye: Aerial photography's post-humanist and neo-humanist visions of the World. *History of Photography* 36 (1): 66-86.

Anonymous (1919). The U.S. Navy HS-1L and HS-2L flying boats. *Flight,* Issue of December 4, 1919: 550-552.

Banks, B. (2015). Drawn from victory. *Canadian Geographic* October 2015: 45-50.

Boileau, J. (2016). Byrd at Bakers's Point. *Halifax Military Heritage Preservation Society Paper Series*, HMHPS Paper No. 3, Halifax, NS, 19 p.

Canadian Air Board (1921). Report on an Experimental Aerial Survey at Ottawa 1920. *The Air Board Bulletin* No. 2, March 31, 1921: 1-16.

Collier, P., Inkpen, R. & Fontana, D. (2001). The use of historical photography in environmental studies. *Cybergeo: European Journal of Geography* journals.openedition.org/cybergeo/4019.

Cronin, M. (2007). Northern visions: Aerial surveying and the Canadian mining industry1919-1928. *Technology and Culture* 48 (2): 303-330.

Department of National Defence (DND) (1925). Report of the Department of National Defence Canada for the Fiscal Year ending March 1925 (Militia & Air Services). F.A. Acland, Ottawa, ON 54 p.

Department of National Defence (1929). Report on Civil Aviation and Civil Government Air Operations for the Year 1928. F.A. Acland, Ottawa.

Department of National Defence (1930). Report on Civil Aviation and Civil Government Air Operations for the Year 1929. F.A. Acland, Ottawa.

Department of National Defence (1931). Report on Civil Aviation and Civil Government Air Operations for the Year 1931. F.A. Acland, Ottawa.

Deville, E. (1889). Photographic Surveying, Including the Elements of Descriptive Geometry and Perspective. Ottawa, ON, Canada, Government Printing Bureau 1889, 324 p.

Dorrian, M. & Pousin, F. (eds.) (2013). Seeing from Above – The Aerial View in Visual Culture. London and New York, I.B. Tauris Ltd., 312 p.

Dyce, M. (2013). Canada between the photograph and the map: Aerial photography, geographical vision and the state. *Journal of Historical Geography* 29: 69-84.

Elsdale, H. (1884). Balloon photography from small balloons, and its application in war and peace. *Extracts from the Proceedings of the Royal Engineer Committee during the year 1883*. War Office, London, 1884, Memorandum I (October 18, 1882) Memorandum II (July 26, 1883) and Memorandum III (August 9, 1883), Appendix No. 1: 1-43.

Finnegan, T. J. (2011). Shooting the Front. Allied Aerial Reconnaissance in the First World War. The History Press, Spellmount, Stroud, UK, 408 p.

Fortin, J., **Fisher, J.T., Rhemtulla, J.M. & Higgs, E.S**. (2018). Estimates of landscape composition from terrestrial oblique photographs suggest homogenization of Rocky Mountain landscapes over the last century. *Remote Sensing in Ecology and Conservation* 5 (3): 224-236.

Halliday, H. (1987). Seaplane base – Captured in art. *The Atlantic Advocate*, Nov. 1987: 6-8.

Hitchins, F.H. (1972). Air Board, Canadian Air Force and Royal Canadian Air Force. Ottawa, ON: Canadian War Museum Paper No. 2, Canadian War Museum, 475 p.

Ives, H.E. (1920). Airplane Photography. J.B. Lippincott Company, Philadelphia and London, 422 p.
www.gutenberg.org/files/53508/53508-h/53508-h.htm

Kealy, J.D.F. & Russell, E.C. (1965). A History of Canadian Naval Aviation 1918-1962. Naval Historical Section, Canadian Forces Headquarters, Department of National Defence, Ottawa, ON, 159 p.

MacAndrew, W.J. (1981). The evolution of Canadian aviation Policy following the First World War. *Journal of Canadian Studies* 16 (3,4): 86-99.

MacDonald, T.W. (2017). Firsts in Flight – Alexander Graham Bell and his innovative airplanes. Formac, Halifax, NS. 96 p.

MacLaren, I.S. (2005). Mapper of Mountains: M.P. Bridgland and the Canadian Rockies 1902-1930. Edmonton, AB: The University of Alberta Press, 294 p.

Narraway, A.M. (1924). Preliminary report of aerial survey operations season 1924 of the Topographical Survey of Canada in co-operation with the Royal Canadian Air Force National Archives of Canada, R12365-0-4-E. Volume/box number: 1, MIKAN No. 3783624.

Orr, J.L. (2018). An east coast air station: Shearwater 1918-2018. *Canadian Naval Review* 14 (1): 13-18.

Parminter, J. (1986). Guardians in the sky: Aircraft and their use in forestry in B.C. 1918-1926. Whistle Punk – *B.C. Forest History Magazine* 1 (4): 3-10.

Payne, S.R. (1999). A History of the Rockcliffe Airport Site: Home of the National Aviation Museum. Ottawa, ON: National Aviation Museum, 39 p.

Saint-Amour, P. (2013). Photomosaics: Mapping the front, mapping the cities. Chapter 5 in: Adey, P., Whitehead, M., and Williams, A. (eds.) From Above: War, Violence, and Verticality, New York, NY: Hurst Publishers, 356 p.

Sanders, R.G. (1944). Aerial cameras and photogrammetric equipment: A quarter century of progress. *Photogrammetric Engineering & Remote Sensing* 10 (3): 136-159.

Shaw, S.B. (2001). Photographing Canada from Flying Canoes. Burnstown, ON: GSPH, 301 p.

Smith, D. (1997). Those magnificent men and their flying machines: Aerial reconnaissance in the Alberta Rocky Mountains during the 1920s. *Western Geography* 7: 73-96.

Taylor, R.B., Forbes, D.L. Frobel. D., Manson, G.K. & Shaw, J. (2014). Coastal geoscience studies at the Bedford Institute of Oceanography, 1962-2012. Chapter 23 in: Voyage of Discovery: Fifty Years of Marine Research at Canada's Bedford Institute of Oceanography. (Eds. D.N. Nettleship, D.C. Gordon, C.F.M. Lewis, M.P. Latremouille) BIO Oceans Association: 203-210.

Terry, C. (2004). Anti-submarine warfare pioneer to bush pioneer: The HS-2L in Canada. Canada Aviation Museum Photo Essay, Ottawa, ON, 10 p.

Thomas, R.I. (1950). Photographic operations of the Royal Canadian Air Force. *Arctic* 3 (3): 150-165.

Thomson, D.W. (1969). Men and Meridians: The History of Surveying and Mapping in Canada, Volume 3, 1917 to 1947. Ottawa, ON: Department of Energy, Mines and Resources, 370 p.

Thomson, D.W. (1975). Skyview Canada: A Story of Aerial Photography in Canada. Ottawa, ON: Department of Energy, Mines and Resources, 270 p.

Weems, J. (2011). Images, technology, and history. Interpreting a 1930s aerial survey photograph: the artfulness of technological images. *History and Technology* 27 (2): 223–231.

Werle, D. (2016). Early aerial photography and contributions to Digital Earth - The case of the 1921 Halifax air survey mission in Canada. *IOP Conference Series: Earth and Environmental Sciences* 34: 1-8.

Werle, D. (2019a). Tinker, mapper, soldier, spy – Captain Henry Elsdale's pioneering 1882–83 experiment with small balloons and vertical aerial photography in Halifax. Canadian Journal of Remote Sensing 45 (5): 603-617.

Werle, D. (2019b). Good air photos make good neighbours – A pioneering 1921 aerial survey over the Calais and St. Stephen area in support of US-Canada boundary delineation along the St. Croix River. Proceedings of the 40th Canadian Symposium on Remote Sensing, Fredericton, NB, extended abstract, 2 p. + air photo mosaic.

Wheeler, A.O. & Lambart, H.F. (1923). Mountain reconnaissance by airplane. *The Canadian Alpine Journal* 13: 146-157.

Wilson, E. (1924). The use of the aeroplane in surveying and engineering. *The Engineering Journal* VII: 3-7.

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APPROPRIATE ABDOMINAL IMAGING FOR THE EMERGENCY DEPARTMENT PATIENT

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ABSTRACT

Abdominal x-ray series (AXR) and abdominal CT scans (ACT) are commonly performed to aid in the diagnosis for patients who present to the emergency room with abdominal pain. Patients commonly receive both an AXR and ACT, due to a lack of knowledge regarding imaging appropriateness among healthcare professionals who order these exams. A primary simple retrospective data-analysis was performed to understand the prevalence of how often both exams were ordered in three Nova Scotia emergency departments. A literature review was also conducted to compare the diagnostic accuracy of each diagnostic imaging modality. Several articles showed that patients who have an AXR also have an ACT that demonstrates an abnormal finding. Emergency department physicians are not reassured when abdominal x-rays are negative and do not show abnormal findings, and as a result, a CT scan is also performed. Radiation dose must be considered when ordering multiple diagnostic imaging exams. A low-dose CT (LDCT) can be used to reduce the radiation exposure to the patient, while maintaining high diagnostic quality images. Image quality can be enhanced at a reduced radiation dose by using an image reconstruction technique such as adaptive statistical iterative reconstruction (ASIR). Understanding the most appropriate abdominal imaging modality for emergency department patients allows for fewer examinations being ordered and a reduction of radiation dose to the patient. When the most appropriate imaging is performed, a definitive diagnosis can be made and the best treatment can be provided to patients. This information can help to create an imaging appropriateness protocol for emergency departments. Additional research can help determine the cost differences between the two exams and the influence a protocol change could have on the emergency and diagnostic imaging departments.

Keywords: AXR – Abdominal x-ray series, ACT – Abdominal computed tomography scan, CT – Computed tomography, SDCT – Standard-dose CT, LDCT – Low-dose CT, ASIR – Adaptative statistical iterative reconstruction FBP – Filtered back projection, $CTDI_{vol}$ – Volume computed tomography dose index

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INTRODUCTION

Diagnostic imaging is a tool commonly used by hospital emergency departments that helps to determine the cause of a patient's symptoms. If a patient's history, physical examination, and laboratory testing does not identify the underlying cause of their symptoms, imaging is indicated as the next step in the diagnostic process (Cartwright & Knudson 2015). Indications for patient's presenting to the emergency department that would require abdominal imaging include suspected bowel obstruction, abdominal pain, constipation, suspected bowel perforation, and foreign bodies within the abdomen (Bertin *et al.* 2019). Imaging for these clinical indications is either an abdominal x-ray series (AXR) and/or an abdominal computed tomography (ACT) scan. An AXR consists of two images: an image of the abdomen with the patient flat on their back and an upright abdominal image (or an image with them on their left side) to demonstrate free air and fluid within the abdomen (see Fig 1)

Fig 1 Abdominal x-ray (AXR) demonstrating the entire abdomen from the diaphragm to the symphysis pubis (Gans, Stoker & Boermeester, 2012).

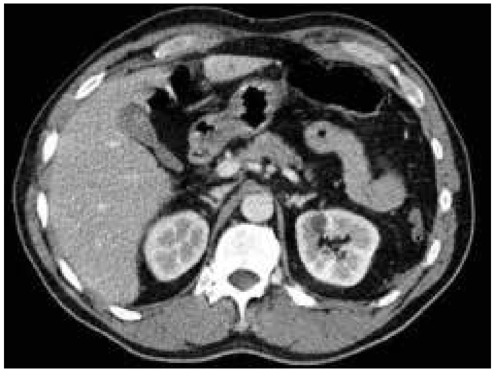

Fig 2 Abdominal Computed Tomography scan (ACT) demonstrating an image taken as the level of the kidneys and liver (Gans, Stoker & Boermeester, 2012).

(Gans, Stoker & Boermeester 2012). An ACT includes a low-dose x-ray called a topogram to plan the scan and includes anatomy from the patient's diaphragm to the symphysis pubis of the pelvis (see Fig 2) (Nguyen *et al.* 2011). The scan combines multiple x-rays from different angles around the patient and uses computer processing to create cross-sectional images. This creates a three-dimensional image of the patient's abdomen (Ngyuen *et al.* 2011). It can be difficult for the emergency room physician to determine the most appropriate abdominal imaging exam for a patient, due to a lack of knowledge that exists among physicians and health care professionals regarding which tests provide the best diagnostic performance (Bertin *et al.* 2019). This results in emergency physicians and other healthcare professionals, such as nurse practitioners, ordering both the AXR and the ACT to ensure that a definitive diagnosis can occur. Performing both exams results in an increase of radiation dose to the patient, so it is important to compare the diagnostic sensitivity of both imaging modalities to comprehend which is the most appropriate abdominal imaging examination. Increasing awareness and education regarding imaging appropriateness for the abdomen can help hospitals create imaging protocols that will minimize additional imaging exams for those emergency department patients who require abdominal exams.

METHODOLOGY

Primary Data-Analysis

A primary retrospective simple data-analysis was performed through the picture archive computer system (PACS) to retrieve data from May 1-31, 2019.

Eligibility Criteria

A secondary literature review was performed. Articles eligible for this must adhere to the comparison of AXR and ACT for abdominal pain. Articles from the last five years will be considered to provide recent research. To maintain a high level of evidence, studies will be limited to retrospective cohort studies, literature reviews, prospective and systemic reviews.

Sources and Search Strategy

Three electronic databases were searched, including PubMed database, Google Scholar, and the Cochrane Library. A search example is described when using the PubMed database. The key search terms include *abdominal x-ray*, *abdominal CT, radiation dose* and *abdominal pain.* The dates were filtered to the past five years (2015-2020) and limited to randomized control trials, meta-analysis' and systematic reviews. Specifically, the results were narrowed by using the Boolean operator AND. The other databases were similarly searched. A secondary literature search was performed by reviewing references from relevant and appropriate publications.

A RELEVANT ISSUE

The Canadian Association of Radiologists (CAR) currently promotes the use of the Diagnostic Imaging Referral Guidelines (2012) to aid physicians in selecting the appropriate diagnostic imaging exam depending on the patient's symptoms. These guidelines are divided into thirteen sections depending on the area of the body and the appropriate indications (Canadian Association of Radiologists 2012). The recommended diagnostic imaging exam is "graded as being indicated for the patient, to be used for specialized investigation, not indicated initially, indicated only in specific circumstances or not indicated entirely", cited in the Canadian Association of

Radiologists "Referral Guidelines at a Glance" (2012). The possible imaging exams include computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine, positron emission tomography (PET), and ultrasound (Canadian Association of Radiologists 2012). This resource is available to physicians and healthcare professionals, yet observations have been made that both AXR and ACT are being ordered in emergency departments, promoting the need to investigate the best and most appropriate diagnostic imaging modality for certain clinical indications.

Data Collection

A simple retrospective data-analysis of three emergency departments within the Nova Scotia Health Authority, including the Dartmouth General Hospital, the Cobequid Community Health Centre, and the Halifax Infirmary, was completed to investigate how frequently both an AXR and ACT were ordered by emergency room physicians during a one-month period. The relationship between sequential imaging, common indications, and suspected pathologies were reviewed. Excluded from this data collection for all emergency departments was ACT indicated for renal colic and hematuria. This was due to the fact that an imaging protocol is already in place for these indications within these emergency rooms (Nova Scotia Health Authority 2019). A limitation to this study includes the short collection timeline. An expansion of this timeline may be needed in order to elaborate and support results.

RESULTS

Emergency room physicians at the Dartmouth General Hospital ordered 86 AXR and 144 ACT during the study date, for a total of 230 abdominal imaging exams (PACS 2019). Thirty patients had both the AXR and ACT performed. The most common indications for abdominal imaging was abdominal pain. It is noted that the symptoms include nausea, vomiting, and constipation (PACS 2019). Location of the abdominal pain for each patient was detailed on the emergency room requisition provided to the diagnostic imaging department. The pain presented was between all four main abdominal quadrants. Common pathologies investigated were possible bowel obstruction and diverticulitis. The Dartmouth

General Hospital emergency department demonstrated most, if not all, AXR being performed before the ACT. The most common finding on the AXR was air-fluid levels and a visualization of constipation (PACS 2019). A large number of findings within the reports for these AXR were normal or inconclusive, while the ACT for the same patient provided results that are "conclusive or highly suspicious of disease" (PACS 2019). It was common for the patients from this emergency department to have their AXR performed during the daytime diagnostic department imaging hours. The ACT was performed the following day. In a few instances for this emergency department, the AXR would report that the ACT was subsequently obtained and reported separately (PACS 2019). This could indicate that the AXR was not reported prior to the CT being ordered by the emergency room physician.

The emergency room at the Cobequid Community Health Centre requested 98 AXR within the same month and 115 ACT, for a total of 213 abdominal imaging examinations requested (PACS 2019). Thirty-seven patients had both an AXR and an ACT. Similarly to the Dartmouth General Hospital emergency department patients, the most common indications for both abdominal imaging exams were also abdominal pain and constipation. There were some cases where a prominent history of abdominal pathology indicated both imaging exams, with pathologies such as Crohn's, ischemic gut, recent surgery, pancreatitis, and endometriosis being the most prevalent (PACS 2019). The Cobequid Health Centre emergency room physicians were suspicious of diverticulitis and small bowel obstruction when ordering both the AXR and ACT. While obtaining data for this emergency room, it can be noted that a majority of sequential exams on one patient are performed 3-4 hours apart, with the AXR completed first on the patient and the ACT a few hours later (PACS 2019). Within AXR reports of patient's who also received an ACT, very few radiologists suggested an ACT. There was one instance where the radiologist noted on an AXR report that a CT of the abdomen and pelvis was subsequently performed and to refer to the report for more details on the patient's condition (PACS 2019).

The Halifax Infirmary emergency room ordered 95 AXR and 217 ACT, for a total of 312 abdominal imaging exams (PACS 2019). Fifty-four patients received both scans. Although constipation as a symptom was not as common for Halifax Infirmary patients who received sequential abdominal imaging, abdominal pain with nausea and vomiting continued to be most common (PACS 2019). The most commonly suspected pathology was small bowel obstruction. Some other pathologies included bowel perforation, abscess, and incarcerated hernia (PACS 2019). Radiologists at this hospital were more likely to add in the report if they believed an ACT should also be performed, due to a suspicion evidenced on the AXR. There was one case that the radiologist believed there was a bowel obstruction on the AXR, and they alerted the emergency room physician to arrange for an ACT (PACS 2019). There were also some cases where the AXR and ACT were completed before the AXR report was completed (PACS 2019). See Table 1 for companions between hospital results.

Data Interpretation

A significant number of emergency room patients who present with abdominal pain received both an AXR and ACT in several Nova Scotia hospitals. A majority of emergency room physicians and healthcare professional have requested both imaging exams without the AXR report, which was the first diagnostic exam completed. One hypothesis could be that emergency room physician believes an ACT is necessary given the patient's symptoms. To properly perform an ACT, patients require oral preparation. Oral preparation involves having the patient drink a contrast agent, commonly known as x-ray dye, over a span of 2 hours, to allow for the contrast to uniformly coat the lining of the gastrointestinal tract (Prakashini *et al.* 2013). Completing the AXR before this oral preparation allows for some visualization of the patient's abdomen while the patient prepares for the ACT. There is minimally conclusive data provided from an AXR when the patient has abdominal pain or constipation, as evidenced

Table 1 Abdominal Imaging Data Collection for Nova Scotia Health Authority Hospitals.

Hospital	AXR	ACT	AXR and ACT	Total abdominal imaging examinations
Dartmouth General Hospital	86	144	30	230
Cobequid Community Health Centre	98	115	37	213
Halifax Infirmary	95	217	54	312

by some of the reporting radiologist's. The reporting radiologist notes in the AXR report that the emergency room physician should refer to the ACT report, as it provides a better representation of the patient's condition. It seems that an AXR is a diagnostic exam that the emergency room physician has to obtain before they can order the ACT. As the ACT is ultimately performed, it can be investigated if it is necessary to request the AXR based on the diagnostic ability of both tests. This information can help provide the patient with a more accurate test and a more accurate diagnosis and treatment can be provided.

DISCUSSION

Comparing Diagnostic Sensitivity of Abdominal Imaging Modalities

The main goal of completing abdominal imaging exams is to provide significant information that allows for the emergency room physician or healthcare professional to make an informed diagnostic decision for the patient (Martin *et al.*, 2015). Having an accurate imaging examination allows improved diagnostic accuracy of the patient's condition, promotes surgical planning and approach, speeds up the discharge or admission decision process, reduces hospital stays, and diminishes mortality and morbidity (Martin *et al.* 2015). A retrospective review by Kellow *et al.* (2008) characterized the utility of abdominal radiography for non-trauma emergency patients. Adults who underwent abdominal radiography over a 6 month period after presenting to the emergency department were included in this study. The specific institution used for this study permits the abdominal radiograph to be interpreted by the ordering physician, whose management decisions are made before a formal radiologic interpretation is provided by the radiologist (Kellow *et al.*, 2008). Medical records were then reviewed to determine if the patient did or did not receive follow-up imaging, with the follow-up imaging consisting of ACT, abdominal ultrasound or an upper gastric study. A sub-analysis was performed to determine whether AXR was more sensitive for certain abnormalities (Kellow *et al.*, 2008). Abdominal radiography was performed in 955 patients during the study period, with 50% of these patients undergoing further abdominal imaging; of those, CT was performed for 64% of patients.

Of the 42% of patients who had normal AXR results, 72% were found to have abnormal findings on follow-up imaging (Kellow *et al.* 2008). Seventy-eight percent of patients with nonspecific results on the AXR received follow-up imaging (Kellow *et al.* 2008). In this study, follow-up imaging was performed more frequently for patients presenting with abdominal pain (55%) and obstruction (49%) (Kellow *et al.* 2008). Due to the large percentage of additional imaging after the normal AXR results, Kellow *et al.* (2008) concludes that emergency physicians are not sufficiently reassured by the lack of abnormal radiographic findings, as additional imaging is then revealing an abnormality not shown on AXR. AXR can be determined to have low diagnostic sensitivity, as AXR results that are nonspecific are then demonstrating abnormal results on other imaging (Kellow *et al.* 2008). AXR does not help the emergency room physician determine the cause of the patient's symptoms. It is recommended for patients who present to the emergency department with abdominal symptoms to skip the AXR and have more definitive imaging exams performed (Kellow *et al.* 2008). It has been concluded that AXR does not aid in the diagnosis of the patient's condition. Determining the most appropriate method of ACT imaging is also critical in correctly diagnosing patients.

Standard-Dose CT vs. Low-Dose CT

Haller, Karlsson & Nyman (2010) evaluated whether a CT without the use of x-ray dye provides more diagnostic information than AXR in patients with acute non-traumatic abdominal pain and if the use of CT can reduce the total number of additional radiographs the patient receives. A total of 222 patients received an AXR, standard-dose CT (SDCT) or low-dose CT (LDCT) from three time periods and were retrospectively reviewed (Haller, Karlsson & Nyman 2010). For each of these patients, the indication for the exam was acute abdominal pain of unknown cause. The diagnosis in the AXR and ACT reports were compared with the diagnosis confirmed through operative or endoscopy methods. This comparison can help inform healthcare providers whether the imaging modality successfully diagnosed the associated etiology. From these comparisons, the percentage of ACT with correct diagnosis was significantly higher than the AXR. The SDCT and LDCT group were found to give a 50% correct diagnosis, compared to a 20% correct diagnosis provided with an AXR (Haller, Karlsson & Nyman 2010). Surprisingly, LDCT was found to provide better diagnostic results than SDCT. Haller, Karlsson & Nyman (2010) discuss that this is most likely due to radiologists increased experience in interpreting unenhanced ACT during the 2 years until LDCT was started.

Low-Dose CT vs. AXR

Nguyen *et al.* (2011) compared the use of LDCT and AXR in the primary investigation of acute abdominal pain and their diagnostic yield. Included in this study were patients with acute abdominal pain who would require an AXR through the emergency department and included patients during a 7 month period. These patients were randomized to either receive a LDCT or the standard AXR protocol. Of the 124 patients included in this trial, 60 received an AXR and 64 received an LDCT of the abdomen (Nguyen *et al.* 2011). A diagnosis was made in 12 (21.8%) of patients who has an AXR, with the diagnosis's being bowel obstruction, fecal loading, and a pneumoperitoneum (Nguyen *et al.* 2011). After having an abdominal LDCT, 34 (64.2%) patients received a diagnosis, with bowel obstruction, diverticulitis and acute pancreatitis being causes of the patients' symptoms (Nguyen *et al.* 2011). Patients were more likely to require further imaging investigations when AXR was performed (50.9% of patients), whereas only 14 additional tests (26.4%) were obtained when using the LDCT. These results indicate that LDCT provides sufficient diagnostic quality, producing a superior yield compared to AXR, with only a slight increase in radiation dose (Nguyen *et al.* 2011). This also concludes that the use of LDCT significantly reduces the number of subsequent imaging investigations during a patient's admission (Nguyen *et al.* 2011). An efficient and accurate diagnosis through one diagnostic imaging exam reduces the use of other diagnostic tests, allowing for radiation dose to be reduced.

Effective Radiation Dose

Many physicians rely on AXR as a first diagnostic imaging modality as it is widely available and has a lower radiation exposure than ACT (Gans, Stoker, & Boermeester 2012). As ionizing radiation is used in both AXR and ACT imaging, radiation dose must be considered when determining the appropriate exam as it can have harmful effects to the body if. According to Health Canada and Safety Code 35 (2008), the yearly radiation dose an individual should receive is an effective dose of 1 mSv. Effective dose is the measure of the total risk due to an exposure to ionizing radiation (Canadian Nuclear Safety Commission 2019). AXR typically results in an effective dose of 0.7 mSv of radiation, whereas a standard-dose ACT produces roughly 10 mSv of radiation (Gans, Stoker, & Boermeester 2012). Although the ACT exceeds the dose limit, 10 mSv is considered a reasonable radiation dose when used in moderation with appropriate dose reduction methods, as someone must receive close to 1,000 mSv to have radiation sickness symptoms (Canadian Nuclear Safety Commission 2019). As evidenced by data collection, patients are receiving two diagnostic imaging exams when presenting to the emergency department for abdominal symptoms in these Nova Scotia facilities, which leads to a higher total radiation dose. As the ACT is ultimately performed in these cases due to its high diagnostic ability, it is worthwhile noting that that by eliminating a test, a reduction in the patient's overall radiation dose can be made.

Methods for Reducing Radiation Dose in Abdominal Imaging

Strategies can be used to reduce the dose while maintaining the diagnostic image quality that it provides. Haller, Karlsson & Nyman (2010) suggests reducing the x-ray current and time product from 120-260 mAs to 30-76 mAs to generate a LDCT. Fewer x-rays will be emitted over a period of time, resulting in a reduction of radiation that the patient receives. Previous discussion states that LDCT is diagnostically sufficient, even with the reduction of radiation. The effective dose of a LDCT of the abdomen is approximately 4.2 mSv, which is still higher than an AXR, but is approximately a 58% reduction of dose in comparison to using a SDCT (Haller, Karlsson & Nyman 2010). Alshamari *et al.*, (2016) declared even lower dose calculations for AXR and LDCT of the abdomen. During their study, the AXR resulted in an effective dose of 1.0 mSv, while the low-dose ACT provided an effective dose of 1.2 mSv (Alshamari *et al.*, 2016). This lower dose level is sufficient for CT to detect fluid-filled dilated bowel and free intra-abdominal gas (Alshamari *et al.* 2016), deeming it diagnostically capable at a lower radiation dose to the patient. This demonstrates how creating a low-dose protocol on hospital CT scanners to be used for these specific emergency room cases is optimal as the ACT provides more information than the AXR and is performed at a low enough dose that it does not significantly impact the patient.

Adaptive Statistical Iterative Reconstruction vs. Filtered Back Projection

ASIR is a technique that can be used to decrease radiation dose. A reduction in image quality called noise can be evident when a reduction of radiation is used, but ASIR can help to reduce image noise by using a statistical reconstruction algorithm (Sagara *et al.* 2010). Sagara *et al.* (2010) completed a study to compare image quality and dose for patients who either received a LDCT reconstructed with ASIR or a SDCT reconstructed with filtered back projection (FBP). The study group for this article comprised 169 LDCT scans using ASIR, with 53 of these 169 patients previously having a SDCT that used FBP. The volume CT dose index ($CTDI_{vol}$), a standardized measurement of radiation for a CT scanner, was obtained for LDCT with ASIR and SDCT with FBP by using PACS. The LDCT with ASIR averaged 17 mGy $CTDI_{vol}$ compared to 25 mGy CTDIvol for the SDCT with FBP, providing a 33% dose reduction by using LDCT with ASIR (Sagara *et al.* 2010). In regards to effective dose, 13 mSv is provided for LDCT compared to 18 mSv for SDCT (Sagara *et al.* 2010). The LDCT has a significantly less amount of image noise as compared to the SDCT (see Figs 3 and 4), demonstrating that the LDCT with ASIR does not reduce diagnostic acceptability and maintains the diagnostic quality at a lower dose (Sagara *et al.*, 2010).

CONCLUSION

Abdominal imaging is frequently requested by emergency departments to determine the cause of a patient's abdominal pain. In three multiple Nova Scotia hospitals, it is common for both an AXR and ACT to be ordered for these patients. Research shows that an ACT demonstrates higher diagnostic quality than an AXR and is ultimately ordered. Imaging techniques, such as LDCT and ASIR, can reduce the radiation dose of an ACT while maintaining diagnostic quality. The results of this research demonstrate the need for increased education on proper exam ordering practice for AXR versus ACT. Emergency departments should be encouraged to develop appropriate imaging protocols when patients present with abdominal pain. This will impact the ordering practice and reduce radiation dose by avoiding additional imaging. More research into this topic will help determine the cost differences between an AXR

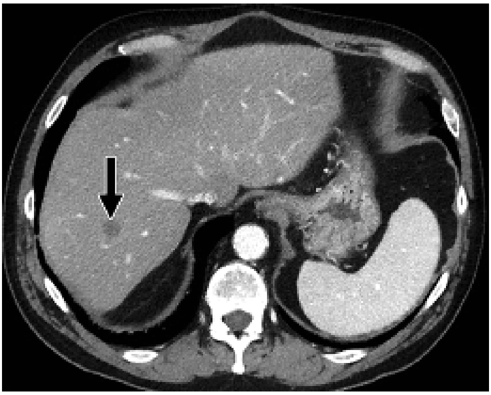

Fig 3 LDCT with ASIR (Sagara *et al.* 2010).

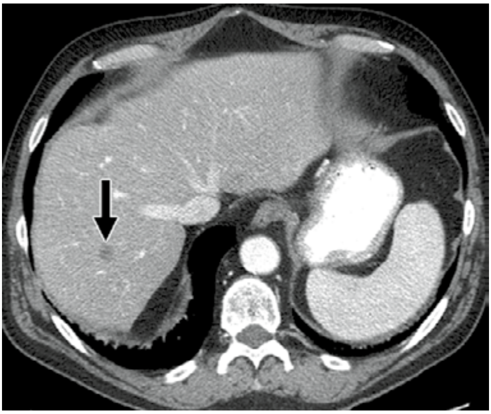

Fig 4 SDCT with FBP (Sagara *et al.* 2010).

and ACT and the impact with this protocol change could have on the workload of the emergency and diagnostic imaging departments.

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REFERENCES

Alshamari, M., Norrman, E., Geijer, M., Jansson, K. & Geijer, H. (2016). Diagnostic accuracy of low-dose CT compared with abdominal radiography in non-traumatic acute abdominal pain: prospective study and systemic review. *European Radiology* 26(6): 1766-1774. doi:10.1007/s00330-015-3984-9.

Bertin, C., Ponthus, S., Vivekanantham, H., Poletti, P-A., Kherad, O. & Rutschmann, O. (2019). Overuse of plain abdominal radiography in emergency departments: a restrospective cohort study. *BMC Health Services Research 19: 36*. doi.org/10.1186/s12913-019-3870-2.

Canadian Associations of Radiologists. (2012). Diagnostic Imaging Referral Guidelines. Retrieved from: car.ca/patient-care/referral-guidelines/

Canadian Nuclear Safety Commission. (2019). Radiation doses. Retrieved from the Government of Canada website: nuclearsafety.gc.ca/eng/resources/radiation/introduction-to-radiation/radiation-doses.cfm.

Cartwright, S. & Knudson, M. (2015). Diagnostic Imaging of Acute Abdominal Pain in Adults. *American Family Physician* 91(7): 452-459. Retrieved from: www.aafp.org/afp/2015/0401/p452.html.

Gans, S., Stoker, J. & Boermeester, M. (2012). Plain abdominal radiography in acute abdominal pain; past, present and future. *International Journal of General Medicine* 12(5): 525-533. doi:10.2147/IJGM.S17410.

Haller, O., Karlsson, L. & Nyman, R. (2010). Can low-dose abdominal CT replace abdominal plain film in evaluation of acute abdominal pain? *Upsala Journal of Medical Sciences* 115: 113-120. doi:10.3109/03009730903294871.

Health Canada. (2008).Safety Code 35: Procedures for the Installation, Use and Control of X-ray Equipment in Large Medical Radiological Facilities. Retrieved from the Government of Canada website: www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/radiation/safety-code-35-safety-procedures-installation-use-control-equipment-large-medical-radiological-facilities-safety-code.html.

Kellow, Z., MacInnes, M., Kurzencwyg, D., Rawal, S., Jaffer, R., Kovacina, B. & Stein, L. (2008). The Role of Abdominal Radiography in the Evaluation of the Nontrauma Emergency Patient. *Radiology* 248(3): 887-893. doi:10.1148/radiol.2483071772.

Martin, J., de Gracia, M., Torres, C., Martinez, D. & Herranz, P. (2015). Routine abdominal x-rays in the emergency department: A thing of the past? *Radiologia* 57(5): 380-390. doi:doi.org/10.1016/j.rxeng.2015.08.001.

Nguyen, L., Wong, D., Fatovich, D., Yeung, J., Persaud, J., Wood, C., de Vos, D. & Mendelson, R. (2011). Low-dose computed tomography versus plain abdominal radiography in the investigation of an acute abdomen. *ANZ Journal of Surgery* 82(1-2). doi:doi.org/10.1111/j.1445-2197.2010.05632.x.

Nova Scotia Health Authority. (2019). CT Protocols and Policies.

Picture Archive Computer System (PACS). (2019). Retrieval date: October 20th, 2019.

Prakashini, K., Kakkar, C., Sambhaji, C., Shetty, C.M. & Rao, V.R. (2013). Quantitative and qualitative bowel analysis using mannitol, water and iodine-based endoluminal contrast agent on 64-row detector CT. *The Indian Journal of Radiology & Imaging* 23(4): 373–378. doi:10.4103/0971-3026.125594.

Sagara, Y., Hara, A., Pavlicek, W., Silva, A., Paden, R. & Wu, Q. (2010). Abdominal CT: Comparison of Low-Dose CT with Adaptive Statistical Iterative Reconstruction and Routine-Dose CT with Filtered Back Projection in 53 Patients. *Medical Physics and Informatics* 195. doi:10.2214/AJR.09.2989.

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HUMANS ARE INTERPERSONAL BEINGS – WHY ISN'T SCIENCE COMMUNICATION INTERPERSONAL?

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ABSTRACT

Weak science communication coupled with misinformation and disinformation has resulted in major challenges for environmental decision-makers, particularly in areas of climate change and marine renewable energy. Interpersonal communication strategies provide the means of facilitating a shift to two-way communication, as they encourage science conversations between communicators and citizens. Science communicators should make themselves more personally known to their audiences. They should communicate using shared stories and conversational language to enable them to relate better with their audiences. In addition, institutions, agencies, networks, and organizations should adapt and support the use of interpersonal strategies by their science communicators.

INTRODUCTION

Humans are interpersonal beings; our relational behaviour differentiates us from other social vertebrates (Shultz *et al.* 2011), and human communication evolved because of the need for cooperative action (Bohn 2016, Tomasello 2014). Speech and language are critical, but a significant part of communication is non-verbal (Phutela 2015). Non-verbal cues have great influence in the communication process, enhancing or detracting from the message (Hartley 1999, Phutela 2015). Communication is also dependent on social context and shared facts/beliefs (Bohn 2016, Clark 1996). In short, human communication is inherently interpersonal, so why isn't science communication interpersonal? This commentary will explore this question.

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THE CURRENT STATE OF SCIENCE COMMUNICATION

The internet and social media tools have transformed the way people access information and are now the main information sources (National Science Board 2012, Purcell, Brenner, & Rainie 2012). As of 2019, an estimated 4.4 billion people use the internet, with nearly 3.5 billion active on social media (We Are Social 2019). The internet and social media break down traditional communication barriers, facilitating near-instantaneous information sharing between people globally (Berger & Milkman 2012, Faulkes 2014, Ferguson *et al.* 2014, Shiffman 2012, Sublet, Spring, & Howard 2011, Wilson 2016, Winkless 2013). Although barriers still exist, the internet and social media are generally user-friendly, inexpensive, and accessible internationally (Peters, Dunwoody, Allgaier, Lo, & Brossard 2014, Voytek 2017). People can engage in personal exchanges and form social networks (Connor *et al.* 2016, Mello & Rodrigues 2012, Peters *et al.* 2014, Sublet *et al.* 2011, Voytek 2017, Wilson 2016).

Despite many benefits, broadly accessible information has also created problems. Perhaps the most prominent is socio-political misinformation (the spread of false information) and disinformation (deliberate sharing of false information to mislead). It is now easier than ever to perpetuate "truths" to a vast audience, and virtually any view on any issue can be "substantiated" with information if one searches hard enough. In some cases the proliferation of false (mis- or dis-) information has been particularly detrimental to environmentally-focused public policy issues, polarizing the public and dismantling trust in scientists and decision-makers (e.g., Aitken, Cunningham-Burley, & Pagliari 2016, Arimoto & Sato 2012, McCright, Dentzman, & Charters 2013). False information sometimes has stalled crucial environmental policy on the international front, and can paralyze the prospect of citizens contributing to public discourse on global environmental issues.

The international "poster child" example of mis- and dis-information continues to be climate change. Although there is broad scientific consensus that climate change is real and human-caused, citizens have become polarized, with part of the population denying the human link to climate change, and others dismissing the issue entirely (Lawrence & Estow 2017, Linden, Leiserowitz, Rosenthal, & Maibach 2017). Much of this polarization is along political lines, limiting progress on solutions (Benegal & Scruggs 2018, Berinsky 2017, McCright & Dunlap 2011, Nyhan, Reifler, & Ubel 2013). A central cause has been the strategic dissemination of misinformation and disinformation regarding the scientific consensus surrounding climate change (Benegal & Scruggs 2018, Oreskes & Conway 2011). Such efforts have elevated falsehoods and altered public opinion on the cause of and solutions to climate change (Benegal & Scruggs 2018). As a result, the proactive policies needed for climate change mitigation and adaptation are not being implemented at the necessary scale internationally. Many nations are failing to reach their own climate action targets (Cubasch *et al.* 2013).

Shifting to a local example, Nova Scotians have experienced similar challenges with the development of marine renewable energy. Atlantic Canada's Bay of Fundy has tidal energy potential among the highest in the world, with the prospect of reducing Nova Scotia's reliance on fossil fuels (Doelle 2009, Nova Scotia Department of Energy and Mines n.d.). Many stakeholders – including private interest groups, not-for-profits, and government – have been collaborating to capitalize on tidal energy availability for many years, but have faced numerous setbacks. In addition to technological issues, tidal energy proponents have been stymied by public opposition despite early calls for transparency in decision-making and effective citizen engagement (Doelle 2009, Quon 2013, Younger 2016). Local citizens continue to claim that environmental concerns are not being adequately addressed by developers, regardless of scientific evidence (MacLean 2017, The Canadian Press 2016). A local Fishermen's Association went so far as to initiate a legal battle with the province of Nova Scotia, applying for a judicial review of the province's decision to approve testing (MacDonald 2016, The Canadian Press 2016). The legal bid was later dismissed in court but the project has now stalled (Anon 2018). This marine renewable energy saga in the Bay of Fundy illustrated how ineffective science communication resulted in public opposition to environmental action, despite the use of scientific evidence in governance.

DEFICITS AND DIALOGUES

Why do we continue to see ineffective science communication on important environmental policy issues? In the past, much of this failure could be traced back to transmission-style models of science communication, in which it was assumed that citizens lacked knowledge and acted as passive receivers of information (Aitken *et al.* 2016, Irwin 2008, Salmon, Priestley, & Goven 2017, Wakeford 2010). It is now understood that a dialogue model that emphasizes deliberative information exchanges between science communicators and citizens is more effective (Irwin 2008, Salmon *et al.* 2017, Wakeford 2010). The dialogue model promotes knowledge co-production, value-sharing, and the formation of trust relationships (Aitken *et al.* 2016, Corner, Markowitz, & Pidgeon 2014, Dietz 2013, Salmon *et al.* 2017, Soomai, MacDonald, & Wells 2013, Wynne 2006). Although the two-way model is now widely accepted as more effective for science communication with citizens, science communicators have struggled to implement two-way exchanges in practice (Collins *et al.* 2016, Kent 2013, Kent, Taylor, & White 2003, Sweetser & Lariscy 2008).

MAKING SCIENCE COMMUNICATION PERSONAL

Recent studies on science communication suggest that interpersonal communication can improve participation. Citizens are more likely to participate in exchanges with communicators they know (Fauville, Dupont, von Thun, & Lundin 2015, Kent 2013, Lee & VanDyke 2015, Martin 2018). “Face-to-face” interactions, including those taking place digitally through social media, can connect science communicators personally with their audiences (Cummins & Cui 2014, Ferchaud, Grzeslo, Orme, & LaGroue 2018, Labrecque 2014, Martin 2018). Citizens are also more likely to respond to scientific information if they find it relatable. Framing has contextualized the scientific information within public value systems by aligning messages with citizen interests (e.g., Hendricks 2017). However, framing can be expanded. For example, shared stories can connect members of the public with the science, making science communicators more approachable (Fauville *et al.* 2015, Hitlin & Olmstead 2018, Martin 2018).

The language used for science communication is also important. More personal pronoun-rich language better reflects how citizens tend to communicate with one another. Using such language conveys authenticity and establishes trust between communicators and their audiences, leading to more effective communication (Martin 2018, Rubin & Rubin 1985).

All of the communication strategies outlined above aid science communicators in establishing relationships with the public. This is crucial because relationships and two-way conversations act in a positive feedback loop. Once relationships are formed, a greater number of exchanges take place, strengthening existing relationships or leading to new ones (Martin 2018). Such two-way conversations are more likely to take place over extended periods, leading to more effective science communication efforts (Martin 2018).

It is important that science communicators seek out opportunities to apply these interpersonal strategies. Offline, this will likely require communicators to engage citizens in face-to-face meetings and not be limited to a single meeting. Additionally, interpersonal communication practices are easier to incorporate in less formal settings where conversational language, shared stories, and relationship building can take place (Martin 2018). Online, a growing avenue for such exchanges is social media, particularly Instagram. As a relatively intimate platform, Instagram is considered a safe space for personal exchanges, making it a tool through which science communicators can employ interpersonal communication strategies (Martin 2018).

SYSTEMS FOR SCIENCE COMMUNICATORS

Science communicators are not solely responsible for the shift, nor the difficulties in shifting, to an interpersonal two-way model of communication. Science communicators must be supported by institutions that encourage communicators to engage in conversations with their audiences. Communicators must be granted flexibility to apply interpersonal communication strategies to science communication. Too frequently, researchers (or research groups) are not encouraged to share scientific findings openly with citizens in non-expert formats. Researchers are sometimes actively discouraged from communicating science (e.g., Boyd 2018, Fox 2018, Gaston 2018). At a time when transparency is increasingly important to citizens, scientific information which mostly comes from publicly-funded research is frequently locked behind paywalls. If science communication is to be more effective, scientific institutions must change the way in which they communicate with citizens. Only then will we create opportunities to bring about the environmental policy changes at a scale necessary to address issues such as climate change and maintain our well-being.

REFERENCES

Aitken, M., Cunningham-Burley, S. & Pagliari, C. (2016). Moving from trust to trustworthiness: Experiences of public engagement in the Scottish Health Informatics Programme. *Science and Public Policy, 43*(5), 713-723. doi:10.1093/scipol/scv075.

Anon. (2018). Fundy tidal project leaves string of unpaid debts. (2018, September 14). *CBC,* Retrieved from www.cbc.ca/news/canada/new-brunswick/tidal-energy-turbine-fundy-minas-banruptcy-liquidation-ireland-claim-1.4822065.

Arimoto, T. & Sato, Y. (2012). Rebuilding public trust in science for policy-making. *Science, 337*, 1176-1177. doi:10.1126/science.1224004.

Benegal, S.D. & Scruggs, L.A. (2018). Correcting misinformation about climate change: the impact of partisanship in an experimental setting. *Climatic Change, 148*(1), 61–80. doi:10.1007/s10584-018-2192-4.

Berger, J. & Milkman, K.L. (2012). What makes online content viral? *Journal of Marketing Research, 49*(2), 192–205. doi:10.1509/jmr.10.0353

Berinsky, A.J. (2017). Rumors and Health Care Reform: Experiments in Political Misinformation. *British Journal of Political Science, 47*(2), 241–262. doi:10.1017/S0007123415000186.

Bohn, M. (2016). Information and the evolution of human communication. In M. Burgin & W. Hofkirchner (Eds.), *Information Studies and the Quest for Transdisciplinarity* (pp. 345–362). doi:10.1142/9789813109001_0011

Boyd, I. (2018). Be very cautious indeed. *Research Fortnight*, *532*, 20-21.

Clark, H.H. (1996). *Using language.* Cambridge: Cambridge University Press.

Collins, K., Shiffman, D. & Rock, J. (2016). How are scientists using social media in the workplace? *PLOS ONE, 11*(10), e0162680. doi:10.1371/journal.pone.0162680.

Connor, P., Harris, E., Guy, S., Fernando, J., Shank, D.B., Kurz, T. & Kashima, Y. (2016). Interpersonal communication about climate change: How messages change when communicated through simulated online social networks. *Climatic Change, 136*(3), 463–476. doi:10.1007/s10584-016-1643-z.

Corner, A., Markowitz, E. & Pidgeon, N. (2014). Public engagement with climate change: The role of human values. *Wiley Interdisciplinary Reviews: Climate Change, 5*(3), 411–422. doi:10.1002/wcc.269.

Cubasch, U., Wuebbles, D., Chen, D., Facchini, M.C., Frame, D., Mahowald, N. & Winther, J.-G. (2013). Introduction. In T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y.

Xia, V. Bex & P.M. Midgley, (Eds.), *Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge and New York: Cambridge University Press.

Cummins, R.G. & Cui, B. (2014). Reconceptualizing address in television programming: The effect of address and affective empathy on viewer experience of para-social interaction. *Journal of Communication, 64*(4), 723–742. doi:10.1111/jcom.12076.

Dietz, T. (2013). Bringing values and deliberation to science communication. Proceedings of the *National Academy of Sciences, 110* (Supplement 3), 14081– 14087. doi:10.1073/pnas.1212740110.

Doelle, M. (2009). Role of Strategic Environmental Assessments in Energy Governance: A Case Study of Tidal Energy in Nova Scotia's Bay of Fundy. *Journal of Energy & Natural Resources Law, 27*(2), 112–144. doi:10.1080/02646811.2009.11435210.

Faulkes, Z. (2014). The vacuum shouts back: Postpublication peer review on social media. *Neuron, 82*(2), 258–260. doi:10.1016/j.neuron.2014.03.032.

Fauville, G., Dupont, S., von Thun, S. & Lundin, J. (2015). Can Facebook be used to increase scientific literacy? A case study of the Monterey Bay Aquarium Research Institute Facebook page and ocean literacy. *Computers & Education, 82*, 60–73. doi:10.1016/j.compedu.2014.11.003.

Ferchaud, A., Grzeslo, J., Orme, S. & LaGroue, J. (2018). Parasocial attributes and YouTube personalities: Exploring content trends across the most subscribed YouTube channels. *Computers in Human Behavior, 80*, 88–96. doi:10.1016/j.chb.2017.10.041.

Ferguson, C., Inglis, S.C., Newton, P.J., Cripps, P.J.S., Macdonald, P.S. & Davidson, P.M. (2014). Social media: A tool to spread information: A case study analysis of Twitter conversation at the Cardiac Society of Australia & New Zealand 61st Annual Scientific Meeting 2013. *Collegian, 21*(2), 89–93. doi:10.1016/j.colegn.2014.03.002.

Fox, F. (2018). The public is missing out, *Research Fortnight, 532*, 20.

Gaston, N. (2018). Uncertainty is healthy. *Research Fortnight, 532*, 21-22.

Hartley, P. (1999). *Interpersonal Communication.* New York: Routledge.

Hendricks, R. (2017). Communicating climate change: Focus on the framing, not just the facts. *The Conversation, March 5th*. Retrieved from theconversation.com/communicating-climate-change-focus-on-the-framing-not-just-the-facts-73028.

Hitlin, P. & Olmstead, K. (2018). *The science people see on social media.* Retrieved from www.pewinternet.org/2018/03/21/the-science-people-see-on-social- media/.

Irwin, A. (2008). Risk, science and public communication: Third order thinking about scientific culture. In M. Bucchi & T. Brian (Eds.), *Handbook of public communication of science and technology* (pp. 199-212). London: Routledge.

Kent, M.L. (2013). Using social media dialogically: Public relations role in reviving democracy. *Public Relations Review, 39*(4), 337–345. doi:10.1016/j.pubrev.2013.07.024.

Kent, M.L., Taylor, M. & White, W.J. (2003). The relationship between web site design and organizational responsiveness to stakeholders. *Public Relations Review, 29*(1), 63–77. doi:10.1016/S0363-8111(02)00194-7.

Labrecque, L.I. (2014). Fostering consumer–brand relationships in social media environments: The role of para-social interaction. *Journal of Interactive Marketing, 28*(2), 134–148.

Lawrence, E.K. & Estow, S. (2017). Responding to misinformation about climate change. *Applied Environmental Education & Communication, 16*(2), 117–128. doi:10.1080/1533015X.2017.1305920.

Lee, N.M. & VanDyke, M.S. (2015). Set it and forget it: The one-way use of social media by government agencies communicating science. *Science Communication, 37*(4), 533–541. doi:10.1177/1075547015588600.

Linden, S. van der, Leiserowitz, A., Rosenthal, S. & Maibach, E. (2017). Inoculating the public against misinformation about climate change. *Global Challenges, 1*(2), 1600008. doi:10.1002/gch2.201600008.

MacDonald, M. (2016). Opponents of Bay of Fundy tidal power project ask judge to suspend testing. *Global News, Sept 27th.* Retrieved from globalnews.ca/news/2967134/opponents-of-bay-of-fundy-tidal-power-project-ask-judge-to-suspend-testing/.

MacLean, A. (2017). 'Grinding Nemo' billboard aims to raise awareness about Bay of Fundy tidal turbines. *Global News, Jan. 24th.* Retrieved from globalnews.ca/news/3203071/grinding-nemo-billboard-meant-to-turn-heads/.

Martin, C. (2018). "It Feels Like Engaging With a Friend": Using Interpersonal Communication Strategies to Encourage Science Conversations With Lay Audiences on Social Media (Master's graduate project report). Halifax: Dalhousie University.

McCright, A.M., Dentzman, K., Charters, M. & Dietz, T. (2013). The influence of political ideology on trust in science. *Environmental Research Letters, 8*, 044029. doi:10.1088/1748-9326/8/4/044029.

McCright, A.M. & Dunlap, R.E. (2011). The Politicization of Climate Change and Polarization in the American Public's Views of Global Warming, 2001–2010. T*he Sociological Quarterly, 52*(2), 155–194. doi:10.1111/j.1533-8525.2011.01198.x.

Mello, D. & Rodrigues, R. (2012). From constructivism to dialogism in the classroom. Theory and learning environments. *International Journal of Educational Psychology, 1*(2), 127–152.

National Science Board. (2012). *Science and engineering indicators 2012.* Washington, DC: National Science Foundation.

Nova Scotia Department of Energy and Mines. (n.d.). *Top 10 things you need to know about tidal energy in Nova Scotia.* Retrieved from energy.novascotia.ca/featured-stories/top-10-things-you-need-know-about-tidal-energy-nova-scotia.

Nyhan, B., Reifler, J. & Ubel, P.A. (2013). The hazards of correcting myths about health care reform. *Med Care 51*(2): 127–132.

Oreskes, N. & Conway, E.M. (2011). *Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming*. USA: Bloomsbury Press.

Peters, H.P., Dunwoody, S., Allgaier, J., Lo, Y.-Y. & Brossard, D. (2014). Public communication of science 2.0: Is the communication of science via the "new media" online a genuine transformation or old wine in new bottles? *EMBO Reports, 15*(7), 749–753. doi:10.15252/embr.201438979.

Phutela, D. (2015). The importance of non-verbal communication. *The IUP Journal of Soft Skills, 9*(4), 43-49.

Purcell, K., Brenner, J. & Rainie, L. (2012). *Search engine use 2012.* Washington, DC: Pew Internet & American Life Project.

Quon, A. (2018). Cape Sharp Tidal turbine was 'damaged beyond repair' in September. *Global News,* November 13th.
Retrieved from globalnews.ca/news/4644316/cape-sharp-tidal-turbine-damaged/.

Rubin, A.M. & Rubin, R.B. (1985). Interface of personal and mediated communication: A research agenda. *Critical Studies in Mass Communication, 2*(1), 36–53. doi:10.1080/15295038509360060.

Salmon, R.A., Priestley, R.K. & Goven, J. (2017). The reflexive scientist: An approach to transforming public engagement. *Journal of Environmental Studies and Sciences, 7*(1), 53–68. doi:10.1007/s13412-015-0274-4.

Shiffman, D.S. (2012). Twitter as a tool for conservation education and outreach: What scientific conferences can do to promote live-tweeting. *Journal of Environmental Studies and Sciences, 2*(3), 257–262. doi:10.1007/s13412-012-0080-1.

Shultz, S., Opie, C. & Atkinson, Q.D. (2011). Stepwise evolution of stable sociality in primates. *Nature, 479*(7372), 219–222. doi:10.1038/nature10601.

Soomai, S.S., MacDonald, B.H. & Wells, P.G. (2013). Communicating environmental information to the stakeholders in coastal and marine policy-making: Case studies from Nova Scotia and the Gulf of Maine/Bay of Fundy region. *Marine Policy, 40*, 176–186. doi:10.1016/j.marpol.2013.01.017.

Sublet, V., Spring, C. & Howard, J. (2011). Does social media improve communication? Evaluating the NIOSH science blog. *American Journal of Industrial Medicine, 54*(5), 384–394. doi:10.1002/ajim.20921.

Sweetser, K.D. & Lariscy, R.W. (2008). Candidates make good friends: An analysis of candidates' uses of Facebook. *International Journal of Strategic Communication, 2*(3), 175–198. doi:10.1080/15531180802178687.

The Canadian Press. (2016). Nova Scotia fishermen head to court to stop Bay of Fundy tidal power project. *Global News, August 26.*
Retrieved from globalnews.ca/news/2905270/nova-scotia-fishermen-head-to-court-to-stop-bay-of-fundy-tidal-power-project/.

Tomasello, M. (2014). *A natural history of human thinking*. London: Harvard University Press.

Voytek, B. (2017). Social media, open science, and data science are inextricably linked. *Neuron, 96*(6), 1219–1222. doi:10.1016/j.neuron.2017.11.015.
Wakeford, T. (2010). Third-order thinking in science communication. *Japanese Journal of Science Communication, 7*, 87–93.
We Are Social. (2019). *Digital in 2018*. Available from wearesocial.com/global-digital-report-2019. 2019.
Wilson, M. (2016). The good news about science communication in the social media age. *Fisheries, 41*(9), 506–506. doi:10.1080/03632415.2016.1220224.
Winkless, L. (2013). Science and the #hashtag: Laurie Winkless considers the impact social media is having on the scientific community. *Materials Today, 16*(1), 2–3. doi:10.1016/j.mattod.2013.01.003.
Wynne, B. (2006). Public engagement as a means of restoring public trust in science – hitting the notes, but missing the music? *Public Health Genomics, 9*(3), 211–220. doi:10.1159/000092659.
Younger, A. (2016). Nova Scotia needs to fully engage with stakeholders on tidal energy. *Huffington Post,* December 12. Retrieved from www.huffingtonpost.ca/andrew-younger/tidal-energy-nova-scotia_b_13535578.html.

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SNAPSHOT PICTURE OF MICROPLASTIC POLLUTION IN HALIFAX REGIONAL MUNICIPALITY

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ABSTRACT

Microplastic pollution is a pervasive problem. Many species have been found to ingest microplastics and this poses a risk to biodiversity (Fauna and Flora International, 2013). In Nova Scotia, there are few quantitative data on microplastic pollution. As quantifying microplastic pollution has only recently attained attention in Nova Scotia, no standardized methods for collection and analysis have been established. This project, although limited in scope, identified and quantified microplastic pollution on McNabs Island and Lake Banook beaches using established sampling and processing methods. The samples were evaluated using a combination of density separation, microscopic identification and RamanTM spectroscopy. This provided information to compare with other research.

Keywords: Biodiversity, Microplastic Filtration System$_{TM,}$ Microplastic pollution, Nova Scotia

INTRODUCTION

Microplastics have gained attention in recent years with the first reports being in the early 1970's. Defined as plastic particles less than 5mm in size, interest in microplastic pollution has risen recently. This is due, in part, to the global demand for plastics which has steadily increased. "Production trends, usage patterns and changing demographics will result in a further increase in the incidence of plastics debris and microplastics" (Andrady 2011). Microplastics threaten biodiversity. "It is clear that our biodiversity is under threat from competing land uses, pollution, population growth and human activities" (Government of Canada 2019). A wide range of marine life has now been found to ingest microplastic particles, including mussels, worms, fish, waterfowl and even plankton that support the whole marine food chain. Microplastics are also known

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to concentrate potentially toxic chemical contaminants, which have been washed into our oceans up to one million times background levels. These chemicals include DDT and PCBs (Fauna and Flora International 2013). Beach cleanups concentrate on the removal of large plastic debris but fail to remove microplastics which can be smaller than a grain of sand. Some species are so sensitive to microplastics that they can be lethal in very small amounts (Fauna and Flora International 2013). Waterfowl can die after ingesting just 7 grams of microplastics (Sea Turtles Forever 2016).

With over 13,000 km of coastline and 2,300 hectares of sandy beach in Nova Scotia, a need exists to determine the quantity and concentration of microplastic contamination and pollution (where levels are causing or likely to cause adverse toxic effects)[1]. Many reports point to the lack of data and information on marine litter (David 2016).

The aim of the present research was to assess the scope of microplastic pollution within Halifax Regional Municipality and to determine possible remediation.

METHODS

The sample sites were chosen because of their proximity to Halifax. Variations may exist between ocean marine and freshwater environments. Three sample sites in two contrasting environments were chosen. Maugers beach on McNabs Island, in Halifax Harbour, is here after referred to as the McNabs site. As well, the beach front properties of the Banook Paddling Club and the Mic Mac Aquatic Centre on Banook lake, Dartmouth, are here after referred to as the Banook site and the Mic Mac site. McNabs Island is located in the outer part of the harbor (44° 36′ 34.7″ N, 63° 31′ 1.9″ W). It has a slate and metasiltstone bedrock geology and has several drumlins.

[1] Editor's comment – in this paper, the term "pollution" is used in the generic sense, covering both the presence of the chemical or material (contamination), in this case microplastics, and the possibility or evidence of the material causing toxic or other adverse effects (pollution). Pollution has a formal, internationally recognized definition, distinguishing it from the term "contamination" – the presence of a chemical or other agent at levels not shown to be causing harm or adverse effects. This distinction is important if one is to control the presence and levels of chemicals or other substances in the environment that may cause harm to biota, including humans.

The island is used mostly for recreation and is accessible only by boat. Lake Banook also has a slate and metasiltstone bedrock geology and is in the heart of downtown Dartmouth (44° 40′ 51.2″ N 63° 33′ 24.9″ W). Again, it is used for recreation but to a greater extent, as the lake is home to three paddling clubs, has a public beach and is accessible by foot (Government of Nova Scotia 2019).

All of the sample sites are similar in that they are sandy beaches, but there is distinction between the McNabs site and the Banook/Mic Mac sites. The McNabs site is a marine environment whereas the Banook and Mic Mac sites are on the margin of a freshwater lake environment. The McNabs site is affected by tides and storm surges to a greater extent than the Banook and Mic Mac sites. As a result, a slight variation in the method of sample collection was used. While it is generally believed that microplastic pollution concentrates along the high tide mark in an intertidal marine environment, there is an absence of significant tidal energy in freshwater lake environments. Therefore, microplastic pollution along the beach in a lake environment is likely to be more uniform.

Samples were collected using Microplastic Filtration System$_{TM}$. This was purchased by Nova Scotia Community College from Sea Turtles Forever, Oregon USA. The method of collection was based on that by the National Oceanic and Atmospheric Administration or NOAA (Sartain *et al.* 2018). To avoid contamination of the samples, the equipment was treated with care. It consisted of natural materials such as organic fibers, glass and stainless steel. The clothing worn during sample collection was also made of natural fibers such as cotton.

Samples were collected in the early part of the fall, September 2019-October 2019, while the weather was still warm and dry. Transects on the beach sites were selected at random. Three transects were selected for each of the three sites. Samples collected at the McNabs site concentrated along the high tide mark, while samples collected at the Banook and Mic Mac sites were taken at the fore, back, and middle of the beaches.

The method of analysis was adapted from NOAA (Masura *et al.* 2015). Samples were processed using density separation method at the Nova Scotia Community College, Ivany Campus, Water Resources Laboratory. A calcium chloride solution was prepared by adding 35mg/100mL of calcium chloride to distilled water.

The calcium chloride solution had a density of 1.2g/mL. Quantification of the microplastics was performed using calculations of mass to mass, as well as mass to matrix(m^2) and quantity to matrix (m^2) (Table 1). The microplastics were categorized according to size and type by microscopic examination using a dissecting microscope of 40X magnification (Fig 1). Representative samples from each site were identified using Raman$_{TM}$ spectrometer in the Physics Laboratory, Dalhousie University (Fig 2).

RESULTS AND DISCUSSION

The quantity of microplastic pollution among the three sample sites was varied. While there was variation between sites, the values at each site were similar. The smallest amount of microplastics were found at the Mic Mac site. The highest amount was recorded at the McNabs site. Similarly, the greatest mass of microplastics was obtained from the McNabs site and the least amount of mass was from the Mic Mac site (Table 1). Consideration of both mass and amount are necessary for determining toxicity levels. "Unlike larger plastic objects, microplastics are small enough to be eaten by a wide range of marine life" (Liboiron 2015), which then bioaccumulate and possibly biomagnify, the concentrations increasing up the food web. These results indicate that the marine environment is more at risk with respect to microplastic pollution than the freshwater environment, in Halifax.

Table 1 Amount of Microplastic.

Location		Mass (microplastic) / Mass (sediment)	Mass (microplastic) / Matrix (m^2)	Quantity (microplastic) / Matrix (m^2)
Banook	T1	0.1427.0g/2512.6g	0.1427g/m^2	19/m^2
	T2	0.1456g/2073.0g	0.1456g/m^2	16/m^2
	T3	0.3669g/2015.3g	0.3669g/m^2	34/m^2
McNabs	T1	0.0877g/515.3g	0.0877g/m^2	22/m^2
	T2	0.8334g/682.7g	0.8334g/m^2	46/m^2
	T3	0.5739g/1434.3g	0.5739g/m^2	41/m^2
MicMac	T1	0.0774g/1458.5g	0.0774g/m^2	8/m^2
	T2	0.0807g/2292.0g	0.0807g/m^2	6/m^2
	T3	0.0561g/1711.7g	0.0561g/m^2	6/m^2

Fragments represented the highest concentration of microplastic type at all three sites accounting for 53.57% of the total (Fig 1). Fragments are secondary microplastics in that they form by breaking down over time as a result of solar radiation and wave action. Other secondary microplastics include fibers, foam and film. Primary microplastics, on the other hand, remain in their original state and include nurdles, microbeads or industrial pellets. In this study, 3.57% of the total microplastics found represented primary microplastics (Fig 1).

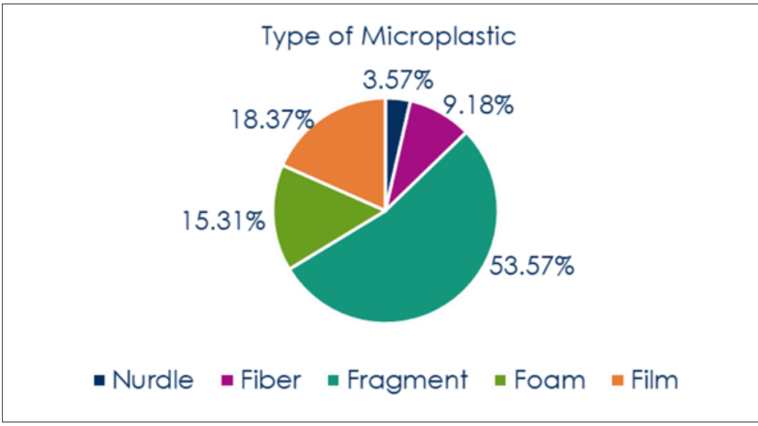

Fig 1 Microplastic Classification.

Spectroscopic analysis identified some of these fragments as polypropylene (Fig 2). Polypropylene is used in both household and industrial applications. It is a widely used commodity and often used in packaging and labelling. Results from this study indicate that over half of the microplastics found were likely to have come from consumer goods such as shopping bags, disposable water bottles and plastic food containers.

Although the spectrometer is an excellent tool for identifying the chemical composition of microplastics, there are analytical difficulties. Of the 15 samples analysed by spectrometry, only 8 came back with readable results. This was the result of microplastic particles being jagged and nonuniform rather than smooth and clean. More research is needed. "Describing, and eventually intervening in, plastic pollution requires research" (Liboiron 2016).

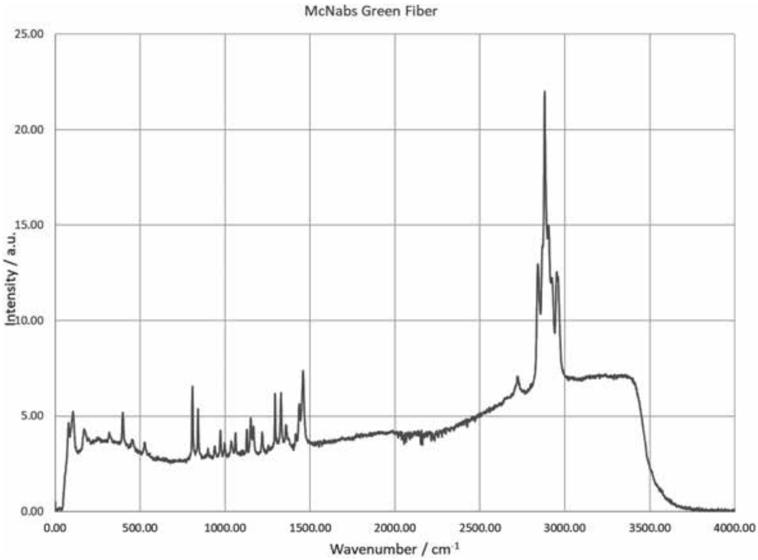

Fig 2 Spectrometry of Polypropylene

CONCLUSIONS

Microplastic pollution is a widespread problem. This project, though limited in scope, helps to fill a data gap that exists in Nova Scotia. The results obtained can now be compared with other findings. Incorporating established methods has contributed to standardization and the possibility for such comparisons.

It is recommended that further samples should be collected to assess microplastic pollution throughout Nova Scotia. This would help protect biodiversity and ensure a healthy environment for all species. Such results would also lead a focus on remediation. One way to reduce microplastic pollution in our oceans, lakes and waterways is to reduce the amount of plastics used and increase the amount recycled. Engaging the public in community science projects involving the collection and identification of microplastic pollution will also aid in identifying the scope of the problem. This would “encourage interventions that change linear plastics consumption habits” (Schnurr & Walker 2019), while fostering accountability with respect to the impact of microplastics.

REFERENCES

Andrady, A. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin* 62(8): 1596-1605.

David, A.D. (2016). Marine Microplasticand Nanoplastic Litter in Nova Scotia:Confronting the Rising Tides of Plastics in our Marine Waters, Coastlines and Organisms. Halifax: Ashley Dawn David.

Fauna and Flora International. (2013). Microplastic Pollution Confirmed to be a Threat to Biodiversity. Fauna and Flora International. Retrieved from fauna-flora.org/news/microplastic-pollution-confirmed-to-be-a-threat-to-marine-biodiversity.

Government of Canada. (2018). Importance of Biodiversity. Government of Canada. Retrieved from canada.ca/en/environment-climate-change/services/biodiversity.html.

Government of Nova Scotia. (2017). Bedrock Geology Map of Halifax Nova Scotia. Government of Nova Scotia. Retrieved from novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2014-010.asp.

Liboiron, M. (2016). "Redefining pollution and action: The matter of plastics." *Journal of Material Culture* 21(1): 87-110.

Masura, J., Baker, J. & Foster, G. (2015). Laboratory methods for the analysis of microplstatics in the marine environment: recommendations for quantifying synthetic particles in water and sediment. Silver Springs: National Oceanic and Atmospheric Administration.

Sartain, M., Sparks, E. & Wessel, C. (2018). Microplastics Sampling and Processing Guidebook. Mississippi State: Mississippi State University.

Schnurr, R.E.J. & Walker, T.R. (2019). Should Canada's Foreign Aid Policy Help Address the Environmental Impact of Single-use Plastics? *Proceedings of the Nova Scotian Institute of Science* 50(1): 35-39.

Sea Turtles Forever. (2016). Microplastics. Sea Turtles Forever. Retrieved from seaturtlesforever.org/programs/marine-plastic-debris/.

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BOOK REVIEW

***Discerning Experts. The Practices of Scientific Assessment for Environmental Policy.* M. Oppenheimer, N. Oreskes, D. Jamieson, K. Brysse, J. O'Reilly, M. Shindell, & M. Wazeck. 2019. The University of Chicago Press, Chicago, IL. 304 pp.**

INTRODUCTION

Anyone interested in the role that science plays in "evidence-based decision making", when it comes to environmental issues and what the last few decades have to teach us about this, will be interested in this book. In the growing literature on science and policy, *Discerning Experts* fills a quite specific niche and has a relatively narrow focus, while simultaneously raising and attempting to answer some rather deep questions with broad applications.

The book is a joint effort of scholars renowned in their respective fields: climate scientist, Michael Oppenheimer (Princeton), historian of science Naomi Oreskes (Harvard), philosopher of science Dale Jamieson (NYU), and four post-doctoral fellows. Their focus is a particular type of science: "assessment science". Examples of this type discussed in this book are the complex, multi-disciplinary and inter-disciplinary, international, large-scale kind of applied science projects that span many years. Most people are familiar with this sort of work in the form of the Intergovernmental Panel on Climate Change (IPCC), with its Reports. Some readers of this journal might resist such attention to context, averring that "science is science", no matter the context. Others might argue that reviews of past science such as the IPCC Reports contain should be distinguished from "pure" science research. The authors of this book contend that this distinction between review and research is less clear in reality; more importantly, they argue that major questions of scientific importance, both regarding content and method, were developed in the context of such assessments.

Assessments treated in this book

The book focusses on three major environmental assessments, reflecting the respective authors' areas of expertise. Chapter Two addresses the US National Acid Precipitation Assessment Program

(NAPAP), which ran from 1980-1991. Canada's disagreements with how things were handled in the US over this issue are given some coverage, so those of us old enough to remember those disputes will find interest here. Chapter Three treats the national and international efforts to detect ozone depletion, especially above the Antarctic Circle, which began in the 1970s. These efforts first reached international levels of cooperation in the 1980s, and are still ongoing under the auspices of the World Meteorological Organization and UN Environmental Program. Chapter Four deals with various national and international collaborations that developed between 1981 and 2007, for predicting sea level rise resulting from melting of the Antarctic Ice Sheet, and the eventual inclusion of such work within the various Assessment Reports of the IPCC from 1990 onward.

The three assessment cases have some common features. First, they were big, involving hundreds of scientists. Second, they involved international collaborations. Third, they were long term, two or more decades, and fourth, they were expensive, costing tens to hundreds of millions of dollars. The three central chapters are preceded by Chapter One, a short history of US science as a source of "expert judgement" for policy decisions, which puts into historical relief the developments of assessment science over the last few decades. The book's final chapters reflect on the nature of the science/policy borders that evolved in the context of these assessment cases (Chapter Five), and on some central features of both the sociology and epistemology of science in the context of those cases (Chapter Six).

The book's historical sections

The book's central three chapters are largely descriptive history, with a focus on recording the experiences of practising scientists engaged in these assessments. The research for the book includes both extensive use of archival and published sources, as well 47 interviews of 42 key scientists involved in these projects, conducted over the period 2009-11. As such it is an attempt at "reconstructing the deliberations of expert participants, who reach judgments about what is known and what is uncertain in the scientific and political context of their times" (ix). On one level, this is old-school history of science applied to relatively unchartered territory. The authors contend that the science undertaken in such assessment projects constitute examples of a late 20th century kind of science that is relatively unstudied by historians and philosophers of science. One of the goals of the book is to spur those of us working in those fields to pay attention. This kind of science, the authors contend, constitutes "…a significant locus of scientific knowledge production [versus mere revision] and therefore is important to study along with fieldwork, laboratory practices, and other more familiar topics of sciences studies" (xi).

The central historical chapters are written in fairly accessible language and detail, showing the evolution of research paradigms over time and geographical context. These chapters are valuable as clear accounts of the scientific substance of the interdisciplinary scientific fields of research into acid rain, ozone depletion and ice-sheet melting/sea level rise modelling. As such, the book provides a briefer treatment than can be found in the few existing monographs covering these respective topics. Readers should note that the book has a decided emphasis on the US experience of, and contributions to, these fields. This is explained as a pragmatic choice due to the subject matter expertise of the authors.

Separating science from policy

However, the historical description has a point beyond this, for as its subtitle suggests, "environmental policy" is also a core focus of the book in a very precise sense explained in Chapter Five, "Patrolling the science/policy border". Assessments of the type studied here necessarily involve scientists and processes of scientific deliberation in unavoidably policy-oriented contexts. That is, the scientific reviews undertaken are intended to have policy implications. The authors argue that for those engaged in "assessment science" of this type, it is generally assumed by all participants that what makes an assessment "successful" is that it has a beneficial impact on policy and the consequent societal decisions. The 'science' itself is judged on standards that are inherently implicated in questions beyond the mere factual or truth-telling 'quality' of the science. That means that what makes an assessment "credible" depends on considerations that go beyond the normal canons of scientific rigour and quality used within the academy of scientific practice.

Can we separate science from policy?

This is what makes the field of assessment science so interesting for those concerned with the science-policy border. As is widely recognized in the literature regarding environmental assessments generally, there is an inescapably political rationale for the scientific work done in assessment projects. It is inescapable because the science is always for determining directly political (or more loosely, 'policy') questions of what should be done. What good should be pursued by politically authorized bodies in the name of the public interest (however defined) based on that science? What science is still needed, and thus, what funds should be allocated in order to achieve this good through further science?

The archival and interview evidence indicated to the book's authors that scientists were quite conscious that the scientific evidence being amassed could be threatening to the economic priorities of respective countries. This continues to be true in the case of IPCC reports. The book challenges the contemporary currency of a clear cut distinction between science on the one hand, as a trusted source of judgements of fact about the world, and more dubious value judgements (roughly equated to 'policy') on the other hand. Examples include the inevitable decisions regarding what would be the right cut in ozone emissions of ozone-depleting substances that prove sufficient to protect both economic and environmental goals. These are scientific and policy decisions occurring simultaneously.

Chapter Five goes on to argue, on the basis of the evidence of preceding chapters, that "in the practice of assessment, there are no absolute (or even consistent relative) standards for the relationships between facts and values, science and policy, and the technical and the political" (p. 171). Take the example of the case of a seemingly straightforward factual determination such as whether the West Antarctic Ice Sheet is melting, how much, and with what consequences. There were (and still are) numerous value judgements built into the very scientific process of assessment. For example, how "dangerous" would this physical event be? The authors comment: "In any case, what constitutes 'dangerous' goes beyond emissions profiles and the physics of ice sheets. It also involves social, economic and biological facts that bear on not only disruptive effects but also the capacity to adapt. The [related] choice of 2°C as the marker of "dangerous anthropogenic interference" emerged from a complex process in which science and policy mutually informed (some would say deformed) each other" (p. 173). To use a variation on an ancient metaphor, the authors summarize: "values are present all the way down" (p. 194).

At the same time, as the three cases of large scale assessment projects reviewed in this book attest, the value of science for policy is thought to lie precisely in it remaining isolated from 'political' interference, direction or even influence. Terms like 'pure' research in our modern lexica refer not only to purely interest-driven or curiosity-driven research. The word 'pure' carries with it an unmistakably moral connotation that draws its power partly from its contrary: the assumed impurity of science that is directed by motives other than pure discovery.

The authors argue that the science done within assessments of this type offers a kind of revealing tension in which to explore empirically how in fact science-policy interfaces were constructed, defined, and maintained during this period. This was occurring when the boundaries themselves were not that self-evident and the political contexts were shifting. The tension is between the ideal and the reality. The ideal is that science is science when there are no motives, no interests, and no concerns weighing on deliberations of truth other than truth. The reality for scientific deliberations carried out in assessments is the science cannot be abstracted from policy considerations if they are to remain valuable as scientific assessments.

So how did the scientists address this tension? Based on both direct interviews and archival evidence, the authors posit that international assessment structures such as those studied in this book were themselves the result of an attempt to deal with this tension. The scientists interviewed, for example, "came to believe that international assessments would be viewed as more objective–and would therefore carry more authority–than national assessments, which would be perceived as tethered to the policy aims of the governments of the countries involved" (p. 180). The result provided the scientists involved with a kind of safety in numbers, allowing them to remain on the 'science' side of the 'science-policy border'. It allowed them "to situate their work as deeply as possible in the technical domain, and to become even more scrupulous about avoiding any suggestion of policy recommendation" (p. 183), while maintaining the very efficacy of their scientific determinations for determining policy. They tried to have their cake and eat it too.

Overall, the book's authors clearly have an agenda in their discussion of the science-policy border as it emerged from these case studies. It is to reinstate for the 21^{st} century what Chapter Five explores as a mid-20^{th} century ideal. Mid-twentieth century science, in the USA at least, enjoyed a kind of policy relevance because of the sense that the scientist was society's "sentinel and problem solver" (p. 174). In the USA, scientists working within President Eisenhower's President's Science Advisory Committee (PSAC) operated under a clear and presidentially encouraged freedom to regard their science as directly relevant and important for political decision making. That is the ideal of the scientist as "sentinel": actively pursuing scientific knowledge, yet willing to apply that knowledge for policy determinations. "Society needs scientists to be sentinels on issues like ozone or acid rain or climate change…because laypeople are not in a position to appreciate these sorts of threats or in some cases to even know that they exist…." This ideal, somewhat nostalgically entertained, gives the title to the book. In the 1970s, ozone scientists (alone) understood the threat that ozone depletion presented. We needed them to be sentinels. We needed them to be discerning experts" (p. 190).

Ultimately, the authors wish to replace the idealized hard border between science and policy, and instead to recognize not so much a border but rather a continuum between science and policy, between fact and value. Scientists and policy makers need to work out collaboratively, in different contexts, their respective placements on that continuum. Scientists engaged in research on policy relevant questions, such as whether and how much to reduce emissions of ozone-depleting substances to prevent deleterious effects on plant and animal health, cannot be asked to refrain from drawing policy conclusions that are proximate to their scientific knowledge.

In a general sense the lessons learned are not new, although the authors seem somewhat unaware of this. Perhaps these conclusions appear as self-evident to any scientist reading this review who has done work within assessment contexts. The book is nevertheless refreshing in its attempt to address the actual practice of science within assessment contexts, in order to determine how scientists have collectively and individually walked back and forth across the 'border' that our culture seems to maintain between fact and value, between science and policy. As such, the book concludes with recommendations for both scientists and policy makers to eschew simplified pictures of the work that experts at either end of the continuum engage in. They wish us to allow more contingent and less idealized norms of behaviour and discourse to guide the practices of assessment, at whatever level. The authors call this the "process of discernment", to capture the multiple valences of what we mean by 'knowledge' in assessment contexts along the science-policy continuum. The authors invite, for example, more generous attitudes to what constitutes 'research', to allow assessment contexts the possibility of generating new research questions and answers. Such freedom is otherwise precluded if current rigid distinctions are maintained, such as are enforced by IPCC, between "assessment as review of existing knowledge" and "research as new knowledge". They further point to a more generous attitude to concepts such as uncertainty, ignorance, bias, objectivity and value-neutrality, which can hamper the capacity of scientists to make forays into value-laden, policy relevant domains. Idealizing objectivity, for example, can come with the cost of silencing a scientist from much needed engagement in policy decisions. And finally, there is a call to what science policy experts would identify as adaptive management (though the authors do not use the term), in which the feedback loops and iterative approaches to knowledge questions are embraced. Assessments can be valuable for indicating frankly where 'progress' in science has in fact not occurred, through failing to perform adaptive management.

A final comment concerns the most obvious limitation of the book. Rather sweeping generalizations are made about 'science' and 'policy' when these are rather narrowly handled within the context of three case studies, limited by time, topic and place. But if we take the book's conclusions in a provisional light, this only underscores the value of the case-study approach to understand the crucial role of "Discerning Experts".

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BOOK REVIEW

SCIENCE COMMUNICATION: UNDERSTANDING ITS CHALLENGES AND OPPORTUNITIES – REVIEW OF THREE BOOKS

The Oxford Handbook of the Science of Science Communication. **Jamieson, K.H., Kahan, D., & Scheufele, D.A. (Eds.). (2017). Oxford University Press, New York. xxii, 486 p. ISBN 978-0-19049-762-0 (hardcover); 9780190668969 (Ebook).**

Communicating Climate Change Information for Decision-Making. **Serrão-Neumann, S.M., Coudrain, A., & Coulter, L. (Eds.). (2018). Springer, Cham. xiv, 219 p. 978-3-319-74668-5 (hardcover); 978-3-319-74669-2 (Ebook).**

Creative (Climate) Communications: Productive Pathways for Science, Policy, and Society. **Boykoff, M.T. (2019). Cambridge University Press, Cambridge. xvii, [i], 302 p. ISBN 978-1-107-19538-7 (hardcover); 978-1-316-64682-3 (pbk). doi.org/10.1017/9781108164047**.

In a world overflowing with information, much of which is freely accessible through a multitude of channels, who needs books about the communication of information, especially a large handbook? Would we not be better off with less information rather than dealing with a continuing flow of books and avalanche of information that confronts us everyday? If we stop for a moment for a reality check, however, a different view comes to mind. This can account for the recent spate of books on the subject. The COVID-19 pandemic, climate change, and other challenges facing society are amply demonstrating, now more than ever, that an understanding is needed of how information is communicated and used, particularly scientific information. Politicians, health advisors and practitioners, public sector managers, business leaders, and every citizen need access to credible, relevant, and legitimate scientific information to inform critical public and personal decisions. Our lives today and the future of society hinge on well-informed decisions.

Since at least the mid-seventeenth century, with the launch of scientific journals in London and Paris, scientists (even before this label became common) have been interested in communicating their discoveries. However, the science of science communication is much more recent and broader in scope than scientists simply disseminating results of their studies to other researchers. As the editors of the *Oxford Handbook* point out, the science of science communication means "an empirical approach to defining and understanding audiences, designing messages, mapping communication landscapes, and—most important—evaluating the effectiveness of communication efforts" (p. 1). Although largely the product of the last three decades, the science of science communication now occupies the attention of a broad diversity of scholars who are studying how science can best be communicated in different social and political settings and who are testing a variety of approaches that employ both established and emerging technologies. Numerous books on this subject have been published over the past five years, ranging from "how-to" guides, to detailed research agendas, compendia, and other approaches. The three volumes reviewed here illustrate the diversity of treatment of the subject, ranging from broad coverage to focused attention on the major issue of climate change.

A Comprehensive Perspective: The Science of Science Communication

The *Oxford Handbook* emphasizes the breadth and depth of this field of research and practice. Edited by three notable science communication scholars and with contributions from 54 other academics and experienced practitioners, the *Handbook* provides extensive coverage through 47 chapters, plus the introduction and conclusion. The *Handbook* presents largely an American perspective as most of the contributors are based in the United States, with a smattering of authors from the UK and Europe.

As Dietram Scheufele, co-editor and professor of science communication at the University of Wisconsin-Madison, noted, the *Handbook* is both problem and solution oriented. This approach allowed the authors of the chapters to frame evidence about each theme for an audience that was envisioned to include "scholars and students interested in understanding the pitfalls and promise of a scientific approach to science communication, as well as but not primarily, those on the front lines tasked with communicating complex and sometimes controversial science to policymakers and the public" (p. 1). After the introduction by the editors, the chapters are organized in six parts: 1) The science of communicating science; 2) Identifying and overcoming challenges to science featured in attacks on science; 3) Science communication in action: failures and successes; 4) The roles of elite intermediaries in communicating science; 5) The role, power, and peril of media for communication of science; and 6) Challenges in communicating science in a polarized environment. A "recap" essay at the end of each part provides an informative overview of the research discussed in the preceding chapters. The final chapter, an overall conclusion by the editors, wraps up the book.

Obviously, the *Handbook* is not designed as a "how-to guide" for practitioners. Instead, the intent of the book is to provide "clear-eyed" understanding of challenges in science communication and to learn from successes and failures. Science communication operates within a multifaceted system occupied by scores of intermediaries who are influenced by many factors. For example, in some jurisdictions, scientific subjects have become highly politicized, which presents a seemingly insurmountable hurdle in showing that scientific information offers solutions for environmental and health issues.

In the first part of the book, Kathleen Hall Jamieson, co-editor and professor in the Annenberg School of Communication at the University of Pennsylvania, outlines why science communication stands apart from communication in other disciplines, particularly political communication. As she states, "science communication must faithfully reflect relevant scientific norms or risk undercutting the trust that enshrines science in its privileged rhetorical place" in society. That privilege is open to partisan critique when communication fails to account fully for uncertainty in evidence or when the process to retract faulty science is slow, as was the case with *The Lancet* which took 12 years of mounting evidence that failed to confirm an association between measles-mumps and rubella vaccine and autism before retracting a paper containing the bogus claim. In contrast with political communication, which often relies on selective use of evidence and deliberate ambiguity to convince audiences of particular positions, science communication needs to "take into account the available relevant evidence, specify the level of certainty attached to a claim, and precisely specify the phenomena being analyzed or reported" (p. 22). Describing how science communication lives up to this expectation, or not, takes up most of the remainder of the *Handbook*.

After providing an overview of key features of science communication in Part 1 (e.g., the complexity of science, levels of science literacy of various audiences, changing media landscape), the second and third parts of the book address challenges encountered in attacks on science and observations arising from failures and successes in science communication. Two chapters in Part 2, for example, consider how problems with peer review and retractions of papers open up science to questions about the validity of research findings, which in turn presents communication challenges, opportunities for misinformation and misuse of evidence to be promulgated, and public trust in science to weaken. The chapters in Part 3 discuss various subjects that have received considerable attention in both the research and popular media, namely, information regarding bovine spongiform encephalopathy (BSE) or mad cow disease as it played out in the UK; risks associated with nanotechnologies; deployment of biotechnologies, especially genetically modified organisms (GMOs) in Europe; and concerns about vaccines. The chapter on vaccines, for example, highlights how some subjects became highly politicized (human papillomavirus (HPV) vaccine), whereas others (Hepatitus B (HBV)) did not. The authors of this latter chapter (Dan Kahan, Asheley R. Landrum) argue that institutions, both governmental and non-governmental, which are involved in dissemination of information about decision-relevant science, need to consciously protect the science communication environment.

In Part 4 of the *Handbook,* attention is focused on "elite intermediaries" that fulfill roles in communicating science, among which are prominent American scientific institutions (the American Association for the Advancement of Science and the National Academies of Sciences, Engineering and Medicine); scholarly presses and journals; American federal governmental organizations, e.g., the Environmental Protection Agency; museums, primarily in the US; and funding agencies, specifically American foundations. Less obvious as qualifying as "elite intermediaries," three chapters in Part 4 describe science communication via social networks, public policy participation mechanisms, and evidence-informed, policy making processes. These chapters are particularly informative regarding the pathways of scientific information from research to public policy and practice; they may be most relevant to readers wishing to gain an understanding of activities at the science-policy interface.

The role of news and popular media takes up Part 5 of the *Handbook,* where transformations in journalism and the media landscape of late are treated. Interestingly, four chapters provide an overview of how the entertainment industry influences public understanding of science, e.g., through image, narrative, and satire. These chapters alone highlight the wide diversity of actors and the complex environment that science communicators need to appreciate and understand. For example, in chapter 30 ("Citizens making sense of science issues: Supply and demand factors for science news and information in the digital age"), Michael A. Xenos, professor of Communication Science, University of Wisconsin-Madison, points out that the recent massive increase in media choices means that individuals with a low interest in scientific subjects, who may be the majority, "face an information environment awash in content that is potentially both too specialized and too one-sided to be of use in developing informed and deliberative opinions on science issues" (p. 286-287). Thus, greater research "attention to the processes by which ordinary citizens learn more about science issues and the processes by which individuals form initial attitudes about policy questions related to emerging scientific developments" is needed (p. 287).

In Part 6, the largest section in the *Handbook*, today's highly politicized and polarized context forms the overall backdrop of the 12 chapters. The prevalence of misinformation, difficulties in dealing with philosophical obstacles to science, problems in explaining uncertainties and overcoming innumeracy with many persons, and addressing public fears about powerful technologies such as genetic engineering, are subjects that pose both challenges and opportunities for science communicators. As the summary essay in this part notes, these issues emphasize the importance of understanding audiences, "specifically how audience choices, attention, biases, and heuristics affect interpretation of complex scientific subjects" (p. 455). In their introduction to the *Handbook,* the editors stated that "people are imperfect information processors" (p. 7). The pertinence of this statement becomes particularly obvious in the chapters in Part 6, which consider the multiplicity of audiences for scientific information.

A Focused Perspective: Climate Change

While the *Oxford Handbook* was designed to be comprehensive in its treatment of the science of science communication, *Communicating Climate Change Information for Decision-Making* and *Creative (Climate) Communications* are focused on communication about the defining environmental issue of this century, namely the impact of climate change. Together, the two volumes present insights from research and practice but they serve different purposes. *Communicating Climate Change Information* is the product of 45 authors, whereas *Creative (Climate) Communications* is the output of a single scholar. The former provides an international perspective; in contrast, the latter is written from a largely American point of view. The former pays particular attention to the use of information in decision making. The latter describes alternative, i.e., "creative," methods for reaching audiences about the negative consequences of environmental deterioration.

The three editors of *Communicating Climate Change Information for Decision-Making*, based in New Zealand, France, and Australia, produced the book because they believed that credible information about communication practices was needed, as well as "examples of how such information can liberate us from the traps of economic and short-sighted discourses and project us into a future of solidarity and respect for one another" (p. vii). The prevalence of misinformation disseminated by climate change deniers, and deliberate resistance to global efforts to reverse or mitigate anthropogenic forces contributing to climate change, motivated production of this book. In 15 chapters, the contributors provide a "snapshot of how climate change information is bridging natural/technological sciences and social sciences," and also describe "aspects of evidence for policy implementation and participatory approaches to knowledge generation" (p. 7). The snapshot is actually quite wide in scope, as studies conducted in North and South America, Europe, Asia, and Oceana are included. This book warrants notice because of its attention to the many factors involved in the interplay of information and people in policy development and practice. For example, in a chapter entitled "Transforming Climate Change Policymaking: From Informing to Empowering the Local Community," Michael Howes, an adaptation scientist at Griffith University, drew on several research projects and case studies in Australia, the USA, and UK to derive a policy proposal that "uses climate change knowledge to inform, engage, and support democratic, local community-based adaptation" (p. 139). This proposal identified three key steps: "1) Provide credible, salient, and legitimate public information that is easy to use; 2) Create decision-making processes that are participatory and transparent; and 3) Provide well-targeted financial support and incentives" (p. 146). While these steps are not new ideas, Howe's synthesis adds weight to similar conclusions of numerous other studies, which together emphasize that the content of information products and communication processes are closely interlinked in effective science communication. Gaining an understanding of this interaction is not a trivial task, but that understanding is needed to overcome the "patchy" uptake of the available climate change information by decision-makers (p. 6).

Overall, the chapters in this book describe results arising from studies around four questions: 1) What climate change information is needed and known? 2) How is new climate change information developed and shared? 3) Who shapes and applies climate change information? and 4) When is climate knowledge useful from local to global scales? In considering these questions, the contributors highlighted both research perspectives and practical experiences. Since circumstances affecting the communication of information vary widely, even within settings of close proximity, their discussion of methods and tools created and tested in several developed and developing countries are instructive. As the editors noted in the introductory chapter, interdisciplinary research and experience is central to advancing understanding about the communication of climate change information, which includes "interactions between scientists and citizens or representatives of entities at risk (cities, ocean, biodiversity, climate)" (p. 3).

The overall tone of *Communicating Climate Change Information for Decision-Making* is both hopeful and positive, even though the editors emphasized the urgent need for climate change mitigation and adaptation compounded by the seeming limited use of relevant scientific information. Maxwell Boykoff, Director for Science and Technology Policy Research at the University of Colorado in Boulder, also took a positive stance in *Creative (Climate) Communications*. He proposes "out of the box" thinking about how to confront obstacles in communicating information on the impending societal fallout from climate change. Rather than directing efforts only on overcoming problems with communication methods already deployed, he argues that attention could be more productively focused on other approaches and techniques.

Although *Creative (Climate) Communications* suffers from repetition, cumbersome writing style, too many examples and citations, and instances of theoretical models dropped into the text without adequate integration, all of which could have been resolved by competent editing, this book offers a perspective about science communication that merits careful consideration. Boykoff takes readers through a review of the troubled landscape of communication and responses to climate change, particularly in the United States, where many efforts have been caught up in an immensely polarized atmosphere about this subject. Like other science communication researchers, including the editors of the other books in this review, Boykoff critiques the long-standing information-deficit model, which assumes that the reason decision makers (both public and personal) have not taken action on problems is due to a lack of information. This model implies that, because the facts will speak for themselves, supplying more information will resolve the matter. As Boykoff shows from a review of the literature, the deficit model inadequately accounts for the wide array of information pathways common in society. However, rather than fixating on the shortcomings of an inadequate model, he urges readers to consider creative communication strategies that "involve experimentation, risk-taking, openness to other points of view, suspension of stigmatism, and a willingness to possibly make mistakes" (p. 44). This perspective is well-illustrated in Chapter 4, "Ways of Learning, Ways of Knowing," where Boykoff highlights the use of comedy and laughter as effective communication techniques. Drawing on examples from theatre, movies, and television shows as well as his own experience in conducting a student video competition, "Stand Up for Climate Change," over several years, Boykoff demonstrates that communication employing comedy has the ability and capacity to increase the "salience of climate change." In addition, humour offers the opportunity to expose audiences "to new ways of learning about associated threats, challenges and opportunities" (p. 106). Overall, Boykoff shines a spotlight on the unfilled potential of creative communication methods that attend to experience, effect, emotion, and aesthetics, which could be applied in the context of the significant issue of climate change, as well as "many analogous political, cultural and societal issues coursing through the veins of collective society" (p. 37).

Overall Perspective: The Three Books Together

The editors of the *Oxford Handbook* state in their introduction that how scientists and other science communicators "express themselves can affect the career of information as it makes its way through the complex of intermediaries and institutions and processes that the science communication environment comprises" (p. 4). While some intermediaries, e.g., environmental non-governmental organizations, received short shrift in all three volumes, these books amply show that in today's society, the expressions and pathways of scientific information constitute a very complex subject. Whether one examines the subject with an internal facing lens, i.e., looking at the social and cultural functions of information within scientific communities themselves, or with an external focus, i.e., considering the dissemination and value of scientific information in society at large, there is much to consider and understand. Yes, more and more books about the subject are being published, and more will be needed. Jamieson, Kahan and Scheufele framed the *Oxford Handbook* within the context of communication about the health threats of the Zika virus that dominated attention as they were preparing the volume in 2016. Four years later, a much worse health crisis, the COVID-19 epidemic, has gripped the globe. The significance of scientific information and communication processes has taken centre stage. Every actor in the information system – scientists, information intermediaries, decision makers, and citizens alike – needs to appreciate the value of scientific information in today's society. For the most comprehensive current treatment of the subject, readers should consult the *Oxford Handbook*, which though large, is structured to aid selective reading. To gain an understanding of the role of scientific information for policy and practice regarding climate change, readers can turn to *Communicating Climate Change*. Readers wishing to "think outside the box," about strategies and methods for communicating scientific information, can check *Creative (Climate) Communications*. The science of science communication has come of age but understanding communication activities is by no means complete. Thus, we should not be perplexed by a continuing stream of books on this subject.

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BOOK REVIEW

***Mammals of Prince Edward Island and Adjacent Marine Waters*. R. Curley, P-Y. Daoust, D.F. McAlpine, K. Riehl, & J.D. McAskill. 2019. Island Studies Press at UPEI (University of Prince Edward Island), Charlottetown, PEI. 300 pp.**

A comprehensive guide to Prince Edward Island's mammals was published recently as a superbly produced soft-cover book. It covers in detail the 38 terrestrial mammals and 29 marine mammals of the island province and its surrounding waters, respectively, showing a remarkable biodiversity for this part of Canada. The book sections are organized taxonomically, covering seven Mammalian Orders, one of which (Order Carnivora) includes both terrestrial and aquatic species. For each species, there is a section for description, measurements, global range, the status on PEI, the animals' history on PEI, and its ecology, diet, reproduction, and behaviour.

Of special interest is the inclusion and details of species now extirpated from the Island. These include the wolf, black bear, Canada lynx, and caribou, and species introduced to the island, such as the woodchuck (unknown status) and white-tailed deer (no longer present). The book is beautifully illustrated with a full coloured drawing of each species, a range map, detailed drawings of tracks for the land mammals, and line drawings of each skull. The text is easy to read, with clear font. There is an excellent Glossary, an exhaustive and invaluable Reference listing, and an Index covering both common and scientific names of all the species.

The authors deserve great praise for researching and producing such a handsome and highly useful book. It is bound to become a classic reference. Sadly, it may be too large and heavy to be a practical field companion. This book should be of interest to every biologist engaged with the fauna of the Maritime Provinces, as well as to biology teachers in local schools and universities, and the outdoor-oriented public.

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NSIS COUNCIL REPORTS

Reports from the Annual General Meeting
September 14, 2020 - 6 pm

AGENDA

159TH ANNUAL GENERAL MEETING
(This meeting will be virtual, via Zoom)

1. Minutes of the 158th AGM, 6 May 2019
2. Vote to accept Minutes of the 158th AGM
3. President's Annual Report (Tana Worcester)
4. Treasurer's Annual Report (Angelica Silva)
5. Editor's Annual Report (Peter Wells)
6. Librarian's Annual Report (Michelle Paon)
7. Lecture Programme for 2020-2021 Report (Tamara Franz-Odendaal)
8. Excursions Annual Report (Hank Bird)
9. Student Science Writing Competition Annual Report (Hank Bird)
10. Publicity Annual Report (Nicole LeBlanc)
11. Webmaster's Annual Report (Patrick Upson)
12. Membership Annual Report (Dylan Miller)
13. Vote to accept the 10 Reports
14. Nomination of 2020-2021 Council (Sherry Niven)
15. Vote to approve the new Council
16. Any Other Business
17. Adjournment

Note: Following the AGM, at 7:30 pm, there will be a Public Lecture via a separate Zoom Call. The Zoom address will be posted on the NSIS Website (www.nsis1862.ca) prior to the Lecture.

Dr. Anne Dalziel of SMU will present "Diversity Through a Minnow Trap".

Dr. Tamara Franz-Odendaal
NSIS President

MINUTES OF THE 158TH NSIS ANNUAL GENERAL MEETING

May 6, 2019
Dalhousie University Club

Council Members present: Tana Worcester (President), Sherry Niven (Past President), Michelle Paon (Librarian), Angelica Silva (Treasurer), Lorraine Hamilton (Secretary), Dylan Miller (Membership Officer), Hank Bird (Excursions and Student Science Writing Competition Co-ordinator), Patrick Upson (Webmaster), David Richardson (Associate Editor), Tim Fedak (Nova Scotia Museum), Tamara Franz-Odendaal (Councillor), Carol Morrison (Councillor)

Members present: Michael Sinclair, Alan Ruffman, Judy Bird, Patrick Ryall, David Richardson

Regrets (Council Members): Darlene Smith (Vice President), Nicole LeBlanc (Publicity Officer), Peter Wells (Editor), Richard Singer (Councillor), Donald Stoltz (Councillor), Alexa Kirste (Student Representative)

The President welcomed members and called the 158th Annual General Meeting (AGM) to order. The President noted that presentations would be kept short and informal and 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 157th Annual General Meeting of 5 May, 2018:**
   Motion to accept the minutes of the 157th AGM
   Moved: Alan Ruffman
   Seconded: Michael Sinclair
   All in favour: Carried

2. **President's Annual Report (Tana Worcester):**
   The President thanked the 2018-2019 Council for their work, the public lecture speakers for sharing their work and knowledge, the Nova Scotia Museum and the Halifax Convention Centre for hosting the NSIS lectures.

   Overall the report indicated that it was a successful public lecture series, despite some weather and/or unexpected circumstances that affected a couple of the lectures.

The President reported that in addition to the public lectures, the Institute supported other public lectures notably panel discussions in the Science in Public Life series, a lecture by the A.G. Huntsman Award recipient for 2018, Dr. Terry Hugues, and a lecture by Dr. Scott of the hit children's TV series "The Dinosaur Train".

The President's report described the Strategic Planning Meeting that was held February 16, 2019. She highlighted that:

- Members are encouraged to volunteer for items in the action plan or put names forward for people that may be able to volunteer for items on the action plan.
- There aren't that many young people involved so there is a need to focus on young faculty.
- There has been a decline in membership. To help address this it has been suggested to pinpoint people from each facility and carry around a copy of the *Proceedings* to encourage joining.
- This may be a way to capture new faculty as the information is not passed along when new staff are hired.
- Young retirees are a good demographic to target for membership as they may have time to join.

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

3. Logo Renewal (Tim Fedak)

Tim Fedak's report summarized the history of the current and previous logos as well as the three new logos.

4. Editor's Annual Report (David Richardson on behalf of Peter Wells)

The Editor reported that Volume 50, Part 1 of the *Proceedings* has been published in hard copy and will be digitally available (6 months following publication). Volume 50, Part 2 of the *Proceedings* is in progress.

The Editor thanked the Editorial Board and especially Associate Editor, David Richardson and Production and Layout Editor, Gail LeBlanc, for their work.

For future editions, one suggestion for content is write-ups from the public lecture speakers on their presentations, at a minimum, an extended abstract on their presentation (300-500 words).

5. Librarian's Annual Report (Michelle Paon):

The Librarian reported that in 2018-2019, sales of the *Proceedings,* from the Reference and Research Services office of the Killam Library, yielded $195.00. The Librarian thanked Eric Mills (member) and Killam Library Administrative Assistant Carol Richardson for bringing copies of Birds of Brier Island (v. 46.1) to Wally DeVries (R.E. Robicheau Ltd.) who has been selling the publication to island visitors.

Other results of note were that digital object identifiers (DOIs) have now been assigned to all of the online issues of the *Proceedings* of the NSIS that have been published on the Open Journal System (OJS) platform (the DOIs will be automatically assigned to new issues of the *Proceedings*); during the year, 294 complimentary copies of the *Proceedings* (from the overstock inventory) were distributed; the required forms to Access Copyright for the repertoire payment to publishers were submitted and NSIS received a payment of $344.78; 11 institutional partners renewed their subscriptions, currently there are 15 institutional members and 85 NSIS exchange partners; and 104 journal issues and society publications were delivered to Dalhousie's Killam Library from the Institute's exchange partners.

6. Treasurer's Annual Report (Angelica Silva):

As of 31 March 2019, the net worth of the NSIS was $41,812.09 with $ 8,910.26 at BMO account plus current Investments of $32,901.83. There was a revenue from all sources of $4,383.61 and expenditures of $12,997.43. This past year was the 3rd and last year of support to Nova Scotia Regional Libraries as per Dr. Alan Taylor's bequest to NSIS.

The Treasurer noted that her reporting period was 1 April 2019 – 31 March 2019 and reported that the NSIS has 63 regular, 13 life, 4 student and 14 institutional members

Once balance in the BMO account decreases below $25K, there will be service charges (estimated as $300-400).

Motion to cash in investment (maturing in June) to the BMO account
Moved: Tana Worcester
Seconded: Sherry Niven
All in favour: Carried

7. Lecture Program for 2019-2020 – Report of the organizing committee (Tana Worcester on behalf of Darlene Smith):

Oct 7, 2019 – To Be Determined

Nov 4, 2019 – Jonathan Ferrier (Native Science and Medicine Laboratory, Department of Biology, Dalhousie University). Indigenous Food Security, Conservation, Native Medicine and Ethnobiology

Dec 2, 2019 – Sean Haughian. Lichens

Jan 6, 2020 – To Be Determined

Feb 3, 2020 – Maryanne Fisher (Maryanne Fisher).
Human Sexuality

March 2, 2020 – Craig Brown (Nova Scotia Community College Applied Oceans Research Group).
Sea-floor imaging and its applications

April 6, 2020 – To Be Determined

May 4, 2020 – To Be Determined

Potential speakers:
Sarah Wells (School of Biomedical Engineering, Dalhousie University) – Strength and Potential of Women's Hearts

Andrew Wright (NSERC Post-Doctoral Research Fellow, Fisheries and Oceans Canada) – North Atlantic Right Whale

Kevin Hewitt (Department of Physics & Atmospheric Science, Dalhousie University) – Science outreach including Imhotep's Legacy Academy

Anne-Marie Ryan (Department of Earth Sciences, Dalhousie University) – Socially Responsible Research – Ethics in Geoscience

8. Proposed Excursions for 2019-2020 (Hank Bird):

Hank Bird reported that successful excursions took place in 2018-19:

- Habits and Habitats of NS Birds in June 2018 in association with the NS Birding Society
- Otter Ponds Demonstration Forest in October 2018
- 2 crows Brewing Company April 2019

The following excursions are in the works 2019-2020:

- Petroglyphs and Guided Nature Hike (Kejimkujik N.P.)
- Discovery Centre (incl. behind the scenes) (Halifax)
- Geological Museum + Tidal Power Exhibit (Parrsboro)

The following excursions are being held in reserve (likely to take place in 2020):

- Cape Split Nature Hike (Scots Bay)
- Waterfalls of Nova Scotia (various sites)
- NS Museum of Industry (New Glasgow)

9. Student Science Writing Competition Annual Report (Hank Bird):

Hank Bird reported that the overall quality of the papers was quite high. He thanked the judges (Sally Marchand, Tom Rand, Pat Ryall, Rick Singer) for their diligence, insights, and assessments.

There was a single winner for each of the undergraduate and post-graduate categories. There were no honourable mentions this year. As the NSIS Public Lecture on April 1st was cancelled due to bad weather, the awards were mailed to the winners.

10. Membership Report (Dylan Miller)

By the end of the 2018-2019 year, we had:

89 total members (up 11 from last year)
8 from the student writing competition (up 3 from last year)
5 from speakers (down 3 from last year-several were already members)
2 Honorary members (no change from last year)
11 lifetime members (no change from last year)
63 paid members (up 12 from last year)

11. Webmaster's Report (Patrick Upson):

The Webmaster reported numerous updates to the content on the website. One of the new initiatives for the website is inclusion of a PayPal option for paying for membership; this work is underway and will continue into the next year.

12. Publicity Report (Nicole LeBlanc):

The publicity report summarized the results for NSIS in 2018-19:

- Facebook: Increase of 124 followers (to 389)
- Writing competition: Redesigned poster; boosted the post for students 18-25 in HRM which reached 1,252 people (up from 340 in 2018), 12 post likes (up from 3 in 2018)
- Lecture events on Social media: 100 Wild Islands on the Eastern Shore talk resulted in increased interest for NSIS resulting in likes, post engagements, and event interest
- Eventbrite was used to promote lectures
- Print promotion continued for the lectures and the writing contest
- Email requests to promote lectures continued to be sent monthly to *Metro News, The Coast,* and *The Chronicle Herald*

Motion to accept the Annual Reports:
Moved: Tamara Franz-Odendaal
Seconded: Hank Bird
All in favour: Carried

13. Report of the Nominating Committee for the 2018-2019 Council (Sherry Niven):

The President, as Chair of the Nominating Committee, asked the AGM to elect the following to NSIS Council for 2019-20:

President	Tana Worcester
Vice-President	Vacant
Past-President	Sherry Niven
Secretary	Lorraine Hamilton
Treasurer	Angelica Silva
Publicity Officer	Nicole LeBlanc
Membership Officer	Dylan Miller
Librarian	Michelle Paon
Editor	Peter Wells

Webmaster	Patrick Upson
Councillor	Tamara Franz-Odendaal
Councillor	Hank Bird
Councillor	Donald Stoltz
Councillor	Richard Singer
Councillor	Darlene Smith

There was a call for additional nominations from the floor, including the vacant position for Vice President; Tamara Franz-Odendaal nominated for Vice President; Alan Ruffman nominated for Councillor.

Motion to accept the Nominations
Moved: Pat Ryall
Seconded: Angelica Silva
All in favour: Carried

14. Any Other Business:
Is a new location required for the AGM? This issue could not be fully addressed at the AGM, the issues to be considered include:

- Is it cheaper to rent downstairs?
- Can it be flexible in the date for the AGM?
- History of medicine is not happy with the downstairs
- SMU is an option (via Tamara Franz-Odendaal)
- This location is not accessible.

Sherry Niven invited all present to enjoy the food prior to the lecture.

15. Adjournment:
Motion by Tana Worcester to adjourn the 158th Annual General Meeting of the NSIS.

Respectfully submitted
Lorraine Hamilton
Secretary

PRESIDENT'S REPORT 2019-2020

Welcome to the Annual General Meeting for the 159th year of the Nova Scotian Institute of Science. What a memorable year it has been! It started off so well with our first meeting in October followed by a lovely lecture on the *Drawings of the Sighted and the Blind* by Dr. John Kennedy, up in the gallery of the Natural History Museum, and ended with having to cancel our final lecture and AGM in May due to COVID. Despite various challenges, the 2019-2020 Council did an excellent job of working together on common goals, and getting some productive work done. Thanks so much to Council members for all their hard work:

Officers: Sherry Niven (Past President); Tamara Franz-Odendaal (Vice President); Lorraine Hamilton (Secretary); Angelica Silva (Treasurer); Nicole LeBlanc (Publicity Officer); Dylan Miller (Membership Officer); Michelle Paon (Librarian); Peter Wells (Editor); and Patrick Upson (Webmaster). Councillors: Hank Bird (Excursions and the Student Writing Competition); Alan Ruffman; Richard Singer; and Darlene Smith. Observers: Jilian Philips (Discovery Centre); Tim Fedak (Nova Scotia Museum); Sarah Kuehm (Schools); Sally Marchand (Schools); Shea McInnes (Student Representative). And thank-you also to David Richardson, Associate Editor of the NSIS Proceedings, Gail LeBlanc, and all members of the editorial board.

We have many achievements to celebrate this year, including the addition of a PayPal option to the NSIS website, for those who wish to donate electronically; the development of a beautiful publicity pop-up banner; several great excursions, including a behind-the-scenes tour of the Discovery Centre; the production of the Proceedings of the NSIS Volume 50, Part 2, which came out just before COVID did; and others that will be detailed in reports we review during this AGM.

Public Lectures

I would like to thank Darlene Smith and Nicole LeBlanc for organizing the Public Lecture Series this year. I would also like to thank all the lectures for sharing their knowledge, experience, and time on such diverse and wide-ranging topics.

Oct 7, 2019: Dr. John Kennedy (University of Toronto) Drawings of the Blind and Sighted.

Nov 4, 2019: Jonathan Ferrier (Dalhousie University) Ethnobiology of Northern Turtle Island Food, Medicine & Material Security.

Dec 2, 2019: Sean Haughian (Nova Scotia Museum) Lichens in Nova Scotia: An overview of lichen diversity, conservation & current research.

Jan 15, 2020: Dr. Kevin Hewitt (Dalhousie University) Science, Technology, Engineering & Mathematics success for African Nova Scotian Learners: The Imhotep's Legacy Academy model.

Feb 3, 2020: Dr. Maryanne Fisher (Saint Mary's Univeristy) How do Women Compete for Mates?

Mar 2, 2020: Dr. Andrew Wright (Fisheries and Oceans Canada) RoboScientist: Whale Research in Collaboration with Machines.

Council extends our thanks to the Museum of Natural History for hosting our lectures again this year, and to Nicole LeBlanc for making some of these available to a virtual audience through live streaming.

Strategic Planning

In August, 2020, there was a strategic planning session that I was unable to attend, but which I understand was quite productive. Efforts are underway to update the strategic planning document that was presented at the AGM last year, with updated priorities for action. All are welcome to provide input and set the direction of the NSIS for the years to come!

Respectfully submitted
Tana Worcester
2019-2020 NSIS President

TREASURER'S REPORT 2019-2020

April 1, 2019 - March 31, 2020

AGM NSIS delayed due to COVID 19 directives until September/October 2020

ASSETS 2019-2020 as of March 31, 2020	
Bank Account BMO (as of March 31, 2020)	16,973.08
Investments (as of March 31, 2020)	20,853.21
Total Assets as of March 31, 2020	**$37,826.29**

INVESTMENTS as of March 31, 2020	
Renaissance High Interest Savings Account @1.0%	4,225.32
Equitable Bank GTD Investment Cert A (due March 9, 2021 @ 1.91%)	5,000.00
Equitable Bank GTD Investment Cert A (due March 8, 2021 @ 2.72%)	11,627.89
Total Investments as of September 30, 2020	**$20,853.21**

REVENUES AND EXPENDITURES 2019-2020

REVENUE 2019-2020 as of March 31, 2020	
Membership dues Regular	$ 597.66
Membership Life	610.83
Membership Institutions	270.00
AGM Dinner	140.00
Sales NSIS Proceedings, Birds of Brier Island, Flora Nova Scotia	190.00
Income/ACCESS Copyright Royalties	473.59
TOTAL REVENUE	**$ 2,282.08**

EXPENSES 2019-2020 as of March 31, 2020	
Proceedings PNSIS /Printing-Layout	$ 3,547.75
NSIS Brochures	40.25
PNSIS Mailing postage to members	282.62
Lecture Sponsorships	250.00
Nova Scotia Regional Science Fairs contributions	1,400.00
NSIS 2019 Writing Science Competition (Undergraduate/Graduate)	1,250.00
NSIS website Chebucto Community Net	70.00
MNHNS Lecture space rental	206.50
Bank BMO charges	5.00
TOTAL EXPENSES	**$ 7,052.12**

Finances

The net worth of Nova Scotian Institute of Science as of March 31, 2020 is **$37,826.29** from a total of $16,973.08 at BMO account plus current Investments of $20,853.21.

Fort this past 2019-2020 period, NSIS had a total income of $2,282.08 that resulted from all paid NSIS Memberships of $1478.49 (regular, Life Memberships and institutions), Sales of $190 from PNSIS Proceedings, Birds of Brier Island and Flora of Nova Scotia, Access Copyright Royalties of $473.59.

Total Expenditures of $ 7,052.12 did result from costs associated to Printing of Proceedings of Nova Scotia Institute of Science (PNSIS) for $3,547.75, plus expenses related to Publicity brochures of $40.25, maintaining a NSIS website with Chebucto Community Net for $70, mailing costs to NSIS Members of $ 282.62, NSIS lecture Sponsorships $250, Contribution to Nova Scotia Regional Science Fairs of $1,400, Contribution to NSIS Student writing Competition of $1,250, rental space at MNHNS of $ 206.50 and BMO Bank charges of $5.

NSIS will maintain its current $20,853.21 investments with CIBC Wood Gundy and at their suggestion, these funds might be transferred to Investors Edge in the fall of 2020 if confirmed.

Membership

2019/2020: NSIS had a total of 74 paid members that include 40 regular memberships, 4 student memberships, 16 Life Memberships (3 New) and 14 Institutional memberships paid during the year. Additional NSIS memberships were awarded to NSIS lecturers and University students. New this year is that with Patrick Upson's assistance NSIS CURRENT and NEW NSIS Members are now able to pay NSIS dues using paypal directly from the website nsis.chebucto.org

The Nova Scotian Institute of Science continues to dedicate all its resources towards communication and support of scientific issues relevant to all Nova Scotians. Historically NSIS continues to support science lectures, conferences, student science writing competitions, printing and producing the Proceedings of the Nova Scotian Institute of Science (PNSIS) that it is distributed to all members. Another important NSIS contribution has been the funding support to all ten Regional Science Fairs in the Province of Nova Scotia.

I recommend that we ask Dr. Robert Cook for his availability to conduct an audit of the 2019-2020 Financial Report.

Respectfully submitted in anticipation of the 2020 NSIS AGM to take place in the Fall of 2020, TBD

Angelica Silva PhD
NSIS Treasurer
Angelica.Silva@dal.ca

EDITOR'S REPORT
2019-2020

Production of the *Proceedings* continues to run smoothly, thanks to having an excellent Editorial team and continued interest in the NSIS from across the Province. The PNSIS 50(2) was completed in February 2020, with some of the printed Issues distributed at the March meeting. The remaining printed Issues are with Carol Richardson at the Killam Library, awaiting distribution, once the Covid-19 virus situation is contained.

The new Issue is up on the website, for members only for six months, then open access at end of August. Many thanks are due to Gail LeBlanc, who once again did a splendid job working with me to copy edit and complete the Issue, and to get it to the Printers in late February (before life became very complicated!). Many thanks are once again due to Dr. David Richardson, Assoc. Editor, and the Editorial Board and external reviewers, for their work moving papers along for this issue.

Work continues on the next Issue – PNSIS 51(1) 2020-21. To date, we have a line-up of five Commentaries; four Research Articles, including a major one on Fishes of Minas Basin, Bay of Fundy; four student papers; and two book reviews. Thanks are due to Hank Bird for encouraging the students to submit papers for this Issue. As well, there will be an Editorial and a complete set of May 2019 Council Reports.

All members of Council are encouraged to either write articles, especially Commentaries, or to help seek articles for the PNSIS. This includes obtaining articles from past and present speakers, and from current members – a constant plea! In this prolonged period of pandemic shutdown and uncertainty, we all have lots of time to think and write, or to encourage people whom you know could contribute an article.

Suggestions for Editorials are welcomed too. Of interest - the Editorial penned for Vol. 50(2) blossomed into a full paper on the Nova Scotia *Arrow* oil spill, by three of us associated with the Bedford Institute of Oceanography, and is now published in the journal Marine Pollution Bulletin (Lee, K., Wells, P.G., Gordon, D.C., August 2020).

The Editor's report is respectfully submitted to the 2020 AGM.

Peter G. Wells,
Editor, PNSIS

LIBRARIAN'S REPORT
2019 / 2020

(submitted June 13, 2020 for the 2020 AGM)

The NSIS Librarian serves as a liaison between the Dalhousie University Libraries and the Nova Scotian Institute of Science. The Librarian communicates with NSIS journal exchange partners from around the world and oversees the receipt of partner journals. She also works with Dalhousie Libraries' staff members in the Killam Memorial Library 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

During 2019/2020, sales of the *Proceedings* from the Killam Library's Reference & Research Services office generated $30.00 in revenue (see Appendix A). The office's Administrative Assistant Carol Richardson packaged and mailed copies of the new issue (vol. 50.1) to NSIS members.

Indexing and Abstracting Services

NSIS also sent complimentary copies of the most recent issue of the *Proceedings* to Library & Archives Canada, the Library of Congress, and several indexing services. In July 2019 the NSIS Librarian noticed that Biological Abstracts database provided incorrect bibliographic information (typographical errors) related to five PNSIS articles (in issues 47.2 and 49.1). She alerted the company (Clarivate Analytics), and their staff corrected the errors.

Distribution of Overstock Issues of the Proceedings

During the year, NSIS distributed 210 complimentary copies of the *Proceedings* from the overstock inventory stored in the Killam Library. Distribution details for the year are provided in Appendix B. Plans to provide additional free issues at the library during the month of March were put on hold when the Dalhousie University campus closed due to the COVID-19 pandemic.

Access Copyright

During the summer of 2019, the NSIS Librarian submitted the required forms to Access Copyright for the repertoire payment to publishers. NSIS subsequently received a payment of $473.59.

Institutional Members and Exchange Partners

NSIS sent renewal invoices to its institutional partners,11 of which have renewed their subscriptions. During the year, the Natural History Museum of Los Angeles County cancelled their exchange program. There are currently 15 institutional members and 84 NSIS exchange partners.

NSIS Exchange Journal Collection

NSIS receives journal issues from exchange partners around the world. As an example, from

April 2019 to mid-March 2020, NSIS received 76 journal issues and society publications from the Institute's exchange partners. These items were delivered to the Dalhousie Libraries (Killam Memorial Library location), where they are processed and added to the NSIS collection in the library. Due to the COVID-19 pandemic, the Dalhousie University campus, including its libraries, closed on March 18th. When the Libraries reopen, receipt and processing of print exchange journals will resume.

On behalf of NSIS, I would like to thank the Killam Library's Administrative Assistant Carol Richardson and the Dalhousie Libraries' Resources staff, who process the exchange journals and make them shelf-ready.

Report respectfully submitted by
Michelle Paon, NSIS Librarian
June 13, 2020

APPENDIX A

Proceedings sold by Killam Library Reference & Research Services Office (April 2019 – March 2020)

Date (2019-20)	Volume/Issue of *Proceedings of the Nova Scotian Science Journal*	# Sold	Price	Amount Received ($)
April-October 2019	Birds of Brier Island (v.46.1)	2	$15.00	$30.00
Total				$30.00

APPENDIX B

Distribution of Complimentary Copies of the Proceedings (Apri 2019 – March 2020)

Date	Event	# Copies distributed
May 8	At sponsored lecture: "How to Raise a Wild Child"	18
May 30-June 8	Oceans Week - Killam Library	36
Sept. 16-22	Science Literacy Week	74
Oct. 23	At Sable Island Update event: PNSIS 2016 issue (20 copies), and Birds of Sable Island (6 copies)	26
Jan. 2020	Killam Library display	56
Total distributed during April 2019 to March 2020:		210

WEBMASTER'S REPORT
2019-2020

Work completed:

1. General maintenance of the NSIS website:
   a. Added PayPal feature to Members website
   b. Bought and Setup nsis1862.ca
   c. Updated Executive Page
   d. Add all 2019-2020 lectures to the website

Work in progress:

1. Re-organized NS Hall of Fame index to use persons last name, then first name.

Submitted by
Patrick Upson
Webmaster

STUDENT SCIENCE WRITING COMPETITION 2020

In this year's competition a total of 22 students (13 undergrad and 9 postgrad) said they planned to compete. By the submission deadline 11 students (7 undergrad and 4 postgrad) actually sent in manuscripts. (See chart below.) This is a typical ratio for submissions-to-interest.

The 5 Judges – Tim Fedak, Sally Marchand, Pat Ryall, Antony Simpson, and I – reviewed the papers and met in the latter part of March and made our final collective decisions. There was one Winner in the undergraduate category (which has a $500 award), and two co-Winners (for the first time) in the postgraduate category. With Council's approval, rather than just splitting the $750 postgrad award between the two, we awarded each of them $500. Due to the coronavirus shutdown the winners received their cheques and certificates via postal mail.

The winners were:

Undergraduate: Danielle Knott of Dalhousie University, for the paper *"Abdominal Imaging for the Emergency Department Patient".* Danielle's paper describes a study of high significance and which could have a major impact on diagnosis and treatment of certain emergency abdominal issues. It showed that in many cases a standard X-ray, usually the first diagnostic step, may provide little information of value, while a subsequent CT scan may have better diagnostic accuracy. Going directly to a CT scan could result in lower total radiation exposure while improving the diagnostic results significantly.

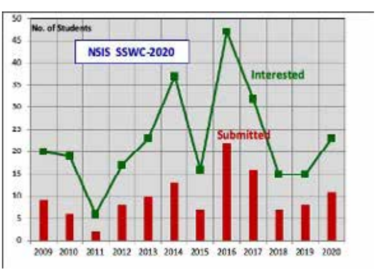
1st Postgraduate: Michael Smith of Saint Mary's University, for the paper *"The Silent Sirens – The Importance of Lichens as Environmental Health Indicators in Nova Scotia".* Michael's essay is of significance to maintaining the environmental health of Nova Scotia. It described how lichens are very useful in assessing air quality, determining ecological hotspots in the environment, monitoring climate change, and the identifying presence of invasive species in the province. He showed how lichens can be sirens, which tell us about the health of our environment.

2nd Postgraduate: Jennifer Kolwich of Saint Mary's University, for the paper *"Fighting Fungus with Fungus: A Microbe-Based Solution to Bat White-nose Syndrome".* Jennifer's paper relates to an issue of ecological concern to Nova Scotia, as well as the rest of eastern North America. This is white-nose syndrome, caused by a fungus. It has led to the decline, endangerment and extinction of many bat populations. This study describes experiments that have identified other fungi which can inhibit the growth of the particular fungus that causes the disease.

I have enjoyed serving as the Coordinator of the competition for the past eight years, since 2013. But I believe that it's time for someone else to take over and bring some new ideas. Two post-doctoral fellows from Dalhousie – Yashar Monfared and Evans Monyoncho – offered to take over as co-Coordinators. I met with them to explain the responsibilities and I have begun to transfer files and templates to them. I'll be available to support them as the SSWC activity begins again (not before October 2020).

My thanks and appreciation to the judges, and to all others who have helped with various aspects of the competition in this and previous years, particularly Nicole Leblanc.

Hank Bird
SSWC Coordinator



Univ.	Interest	Submitted
Acadia	3	1
CBU	1	1
Dalhousie	15	7
MSVU	0	0
SFX	1	0
SMU	3	2
NSCC	0	0
Total =	23	11

NSIS EXCURSIONS 2020

In 2019 we had three excursions:

April – (Halifax) *The Science and Art of Making Beer*,
at the 2 Crows Brewing Company.

July – (Parrsboro area) *Fundy Geological Museum*,
Ottawa House, and the Tidal Power Exhibit.

December – (Halifax) *Discovery Centre*
(including "behind the scenes").

We had started to plan the following excursions for early in 2020, but had to put them on hold due to the coronavirus shutdown.

Petroglyphs and Guided Nature Hike (Kejimkujik N.P.)
Jillian Phillips

Waterfalls of Nova Scotia (various sites)
Carol Morrison

If the shutdown is lifted sufficiently early, we hope to be able to have them later in the year. We will also keep the following in reserve for late 2020 or early 2021:

Cape Split Nature Hike (Scots Bay)
Jillian Phillips

NS Museum of Industry (New Glasgow)
Hank Bird

Shubenacadie Wildlife Park (Shubenacadie)
Carol Morrison?

We welcome additional suggestions and possibilities.

For the record, we did ten excursions in late 2016, in 2017, and 2018:

Natural History of McNab's Island
Annapolis Royal Historic Gardens
The Science and Art of Making Beer
Burke-Gaffney Observatory
Joggins Fossil Cliffs
Shubenacadie Canal

Bedford Institute of Oceanography
Dalhousie Planetarium
Habits and Habitats of NS Birds
(in association with the NS Birding Society)
Otter Ponds Demonstration Forest

Hank Bird
Excursions Coordinator

MEMBERSHIP OFFICER REPORT
2019-2020

By the end of the 2019-2020 year, we had:

101 total members (up 12 from last year) including:

- 14 free members from the writing competition and speakers (up 1 from last year)
- 2 Honorary members (no change from last year)
- 13 lifetime members (up 2 from last year)
- 72 other paid members including regular and students (up 9 from last year)

We continued our policy of offering free 1-term memberships to both speakers and the students who submit for the writing competition.

We tested and implemented a system for online applying and paying for membership-primarily done by our Webmaster, Patrick Upson. This will make the process of advertising for membership, applying for membership, and record keeping all significantly easier-especially considering the current pandemic.

Shea McInnis

NOMINATIONS FOR NSIS COUNCIL 2020-2021

President	Tamara Franz-Odendaal
Vice-President	Vacant
Past-President	Tana Worcester
Secretary	Hank Bird
Treasurer	Angelica Silva
Publicity Officer	Nicole LeBlanc
Membership Officer	Shea McInnes
Librarian	Michelle Paon
Editor	Peter Wells
Webmaster	Patrick Upson
Councillor	Sherry Niven
Councillor	Tamara Franklin
Councillor	Stephanie McQuarrie
Councillor	Anne Dalziel

NOVA SCOTIAN INSTITUTE OF SCIENCE

MEMBERSHIP FORM 2021-2022

Please fill out and make copy, then forward in mail together with membership fee.

Name: ____

Address: ____

____

____

Phone: H ____________________ W ____________________

Email: ____

Memberships (please check one):

Regular member $30 _____

Student member $10 _____

Life membership $300 _____

Enclosed is cheque for ___________ to cover dues for ____ years.

Voluntary Donation (Tax receipt will be issued): ___________

Mail to:

Attention: Treasurer, Nova Scotian Institute of Science
c/o Reference and Research Services
Killam Memorial Library | 6225 University Avenue
PO Box 15000 | Halifax, NS Canada B3H 4R2

INSTRUCTIONS TO AUTHORS

The Proceedings accept original research papers, commentaries, reviews of important areas of science and science history, student award papers, and book reviews.

Papers may be submitted in either English or French and sent as a WORD document to the Editor, Dr. Peter G. Wells, at oceans2@ns.sympatico.ca, with a copy to nsis@dal.ca. Submission of a manuscript will be taken to indicate that the work is completely original, i.e., it is the author's own work and has not been published before, in part or in whole, and is not being considered by another publication. All authors of a submission must approve it prior to it being submitted. Please include this information in the submitted manuscript.

Commentaries are short (less than 2000 words) discussions of topical scientific issues or biographies of prominent regional scientists who have been members of NSIS.

For **review papers**, authors wishing to include figures, tables, or text passages that have already been published, must obtain permission from the copyright owner(s) prior to submission. Please include this information in the submitted manuscript.

PAPERS SUBMITTED ARE TO STRICTLY FOLLOW THE INSTRUCTIONS BELOW. IF NOT, PAPERS WILL BE SENT BACK TO AUTHOR TO UPDATE.

For the **general layout of papers**, refer to recent issues of the Journal. Pages of the submitted WORD document should be numbered. **PROVIDE A RUNNING HEAD FOR THE PAPER.**

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

An **abstract** of up to 200 words should follow, together with a list of five keywords or less.

As appropriate, **sections within the paper** entitled Introduction, Methods, Results, Discussion, Conclusions, and References should follow. Canadian spelling and SI units should be used wherever possible. References cited in the text in brackets should be separated by commas and personal communications should be as follows: Smith A.J. (2001, pers. comm.). *Latin* or *scientific* names should be in italics, as well as abbreviations such as *et al.* **PLEASE GO OVER YOUR PAPER TO AVOID ERRORS OR DELETIONS. SPELL CHECK THE ENTIRE PAPER BEFORE SUBMITTING.**

All **tables, figures, photographs** and **other illustrations** should be numbered and have a self-explanatory caption. **THEY ARE TO BE ATTACHED TO THE SUBMISSION AS SEPARATE HIGH RESOLUTION FILES AND NOT EMBEDDED IN THE WORKING WORD DOCUMENT. DO NOT SEND PAPER AS A PDF.** Authors should indicate where each item might be placed in the manuscript.

Authors are encouraged to submit **figures, photographs** and **illustrations** in colour. Colour versions will be placed on the NSIS website and in the PDFs provided to authors. **Black and white versions will be in the print copies, unless color output is otherwise requested. There will be a charge ($10 per page) containing color in the printed papers.**

REFERENCES ARE TO BE IN ALPHABETICAL ORDER – NAME FIRST, FOLLOWED BY INITIALS, WITH NO SPACE BETWEEN INITIALS. For cited papers, **GIVE THE FULL TITLE OF THE JOURNAL (IN ITALICS)**, volume and issue numbers where appropriate. Examples of formatted references, covering monographs, chapters in monographs and papers, and with close attention to spacing, follow:

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, UK. pp. 137-147.

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.

Website Citation should follow this pattern: Author (year) title, URL and date accessed. An example follows:

Graymont Western Canada Inc. (2015). Giscome Quarry and Lime Plant Project Application for an Environmental Assessment Certificate. Environmental Assessment Office.
projects.eao.gov.bc.ca/p/giscome-quarry-and-lime-plant/docs (Accessed Dec. 18, 2017).

PLEASE NOTE:

Authors will receive page proofs and are responsible for correcting them as soon as possible after receipt from the Editorial Board and resubmit to the Assoc. Editor. Particular attention should be made to the correct formatting of references, and to the general formatting of the manuscript. **Submissions not adhering to these guidelines will be returned to the authors.** Authors are responsible for correcting and returning page proofs within 48 hours.

Authors will be provided with a printed copy of the Issue and a PDF of their article, free of charge. NSIS members are able to access the new Issue as soon as published as part of their annual membership. All new Issues of the Proceedings become open access after a six months embargo. All articles are copyrighted with the NSIS, but contributors are free to distribute their articles to interested parties as they wish.

Non-NSIS members will be charged a page charge for their articles - $25/per page for black and white, with extra charges of $50/per page for color.

Each Issue will continue to be printed for members and other associated 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 website www.nsis.chebucto.org/ for details.

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