1. CANADIAN MARINE SCIENCE FROM BEFORE *TITANIC* TO THE ESTABLISHMENT OF THE BEDFORD INSTITUTE OF OCEANOGRAPHY IN 1962

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SUMMARY

Beginning in the early 1960s, the Bedford Institute of Oceanography consolidated marine sciences and technologies that had developed separately, some of them since the late 19th century. Marine laboratories, devoted mainly to marine biology, were established in 1908 in St. Andrews, New Brunswick, and Nanaimo, British Columbia, and it was in them that Canada's first studies in physical oceanography began in the early 1930s and became fully established after World War II. Charting and tidal observation developed separately in post-Confederation Canada, beginning in the last two decades of the 19th century, and becoming united in the Canadian Hydrographic Service in 1924. For a number of scientific and political reasons, Canadian marine sciences developed most rapidly after World War II (post-1945), including work in the Arctic, the founding of graduate programs in oceanography on both Atlantic and Pacific coasts, the reorientation of physical oceanography from the federal Fisheries Research Board to the federal Department of Mines and Technical Surveys, increased work on marine geology and geophysics, and eventually the founding of the Bedford Institute of Oceanography, which brought all these fields together.

Key words: Canadian marine science, Atlantic and Pacific biological stations, charting, tides, hydrography, post-World War II developments, origin of BIO.
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The Bedford Institute of Oceanography (BIO) opened formally in 1962 (Fig. 1), bringing together scientists and technologists who had worked in fields as diverse as physical oceanography, hydrographic charting, marine geology, and marine ecology. They became members of an institution that developed into one of the largest and most influential oceanographic laboratories in the world.

Figure 1. Bedford Institute of Oceanography in 1986: the ships at the finger pier are the CSS *Baffin* (rear) and CSS *Hudson*, and the CSS *Alfred Needler* (top) and CSS Dawson at the wharf (photo: Roger Belanger, BIO).

BIO grew out of marine science and technology specialties that were separate in post-World War II Canada and that had developed largely in piecemeal fashion since the beginning of the 20th century. It was the product of several unconnected or tenuously-connected strands that were brought together purposefully by scientific and institutional empire builders during a short but important time, the first decade and a half after the war, when financial and political factors were favourable. This introductory paper explores these developments, following some of the important strands from the late 19th century into the early 1960s, but concentrating on the 20th century.

THE BEGINNINGS

When Edward E. Prince (1858-1936; Fig. 2) arrived in Canada as the newly appointed Dominion Commissioner of Fisheries in 1893, he soon began to plan a way of providing scientific information on the fisheries, with the aim of establishing a marine station like those pioneered in Europe decades before. The result, achieved with the help of university biologists, was an organizational structure, the Board of Management of the Biological Station (became the Biological Board of Canada in 1912), which from 1899 to 1907 operated a mobile floating laboratory. The floating laboratory was replaced by two biological stations in 1908, one in St. Andrews, New Brunswick, the other in Nanaimo, British Columbia, that operated only seasonally for many years.

Figure 2. Edward E. Prince, Dominion Commissioner of Fisheries (right) with A.G. Huntsman (left) at the Biological Station, St. Andrews, New Brunswick, about 1920 (photo: courtesy of St. Andrews Biological Station, DFO).

The background, development, and accomplishments of the biological stations have been examined historically (e.g., Johnstone 1977, Hubbard 2006) and fêted retrospectively by scientists and historians during their centenaries (see J. Hubbard et al. in press), and so only two points need to be made about their significance. First, for many years the stations were staffed, mainly in summer, by biologists, who contributed information on many commercially-exploited marine animals, and even more that were not; there was very little physical science of any description. Second, the new biological stations attracted the attention of A.G. Huntsman (1883-1972; Fig. 2), a young biologist from the University of Toronto (Toronto, ON), who began a long association with the St. Andrews station in 1911. Huntsman soon fell under the spell of the distinguished Norwegian fishery biologist Johan Hjort (Fig. 3), who, at Prince's urging, came to Canada in 1914-15 as the organizer of the Canadian Fisheries Expedition (CFE) of 1915 (Hubbard 2006: chapter 3, Mills 2009: chapter 4). The CFE had as its ostensible aim the search for new fisheries, particularly for herring, in the Gulf of St. Lawrence. But in the hands of Hjort, fisheries science incorporated new chemical and physical techniques from Europe, notably the use of the dynamic method (Sandström and Helland-Hansen 1903), which had been developed in Scandinavia (see Hjort 1919, Sandström 1919, Mills 2009: chapter 3).

Hjort's influence on Huntsman was immense. Huntsman's immediate response to the CFE was to begin a series of summer expeditions to east coast locations which were far more comprehensive than anything done before anywhere else in Canada. These ended in 1923 with a summer-long investigation of the cod fishery of the Strait of Belle Isle region that involved physical measurements as well as biological work. But Huntsman's reach exceeded his grasp, for he was too busy to finish the analysis, and there was no one in the early 1920s who could handle the physical studies (these were only completed and published in the 1950s - see Huntsman et al. 1954). His was a lonely voice in an oceanographic wilderness in the early 1920s, and in fact for a further decade.

Figure 3. Johan Hjort (left), with an officer, probably of the CSS *Acadia* during the Canadian Fisheries Expedition of 1915 (photo: probably by A.G. Huntsman, courtesy of St. Andrews Biological Station, DFO).

CHARTING AND THE TIDES

Charting of Canadian waters started very early, during the French regime along the St. Lawrence River and in Acadia, centred on the main navigable waterways. This was true also after the British conquest of New France in the middle of the 18th century - it was the well-travelled routes and the sites of military activity that got attention, notably by outstanding cartographers like Samuel Holland, J.F.W. Des Barres, and James Cook (Thomson 1966 , Fillmore and Sandilands 1983). And in fact, British marine surveyors were active in Canadian waters until well after Confederation, among them the redoubtable H.W. Bayfield (1795-1885), who between 1816 and 1856 carried out surveys from Lake Superior to Newfoundland, and surveyors for the Board of Works who carried out surveys inland (starting in 1841) for an era of canal-building.

After Confederation, charting had to be increased in the rapidly expanding nation. In 1882, the Department of Marine and Fisheries asked the British Admiralty for help in setting up a Canadian hydrographic survey, based in part on the reaction to a disastrous steamship sinking in Georgian Bay, Ontario, that year. Staff Commander J.G. Boulton, RN (1843-1929), arrived in 1883 as head of a Georgian Bay survey, and for a time thereafter most of the charting activity was in the Great Lakes region. But gradually work on the coasts increased; the first Canadian surveys of the sea were W.J. Stewart's (1863-1925) charting of Burrard Inlet at Vancouver, British Columbia, in 1891 and work in the lower St. Lawrence River in 1905. By that time, the Royal Navy was beginning to withdraw its ships from Canadian waters in response to a perceived threat on the oceans from Germany, but British surveys continued on the West Coast until 1910 and on the East Coast until 1913 (and sporadically thereafter, especially in Newfoundland and Labrador waters).

The Hydrographic Survey of Canada evolved from the Georgian Bay Survey in 1904 (Thomson 1967, de Vecchi 1982, Meehan 2006), at first carrying out inshore surveys from small vessels. On the east coast, the Hydrographic Survey's work was put on a new footing when the new purpose-built survey vessel CSS *Acadia* came into service in 1913, and immediately went to Hudson Bay to survey potential sites for ocean shipping to meet a projected railway from the south. The Survey's world expanded during the next decade, and in 1928 it was renamed the Canadian Hydrographic Service (CHS), remaining independent of other aspects of work on the oceans except the tides until the founding of BIO in the early 1960s (for details, see MacDougall 2014).

Despite the importance of the tides to navigation, John A. Macdonald's governments resisted many requests to begin tidal surveys of Canadian waters, believing that they were unimportant, and that there was, in any case, a hydrographic survey in Georgian Bay (de Vecchi 1982, 1984). By 1884, the only systematic tidal observations that had been made in Canadian waters were on Baffin and Ellesmere islands during the First International Polar Year of 1882-83. But in 1884 the British Association for the Advancement of Science met in Montreal, Quebec, and two committees were formed to deal with the tides, the first to gather data and produce tables worldwide, the other to lobby the Canadian government for money to set up tide-monitoring stations. Year after year there was no response to the second committee's entreaties, until late in 1889 a delegation, now including influential businessmen from the shipping community in Montreal, went to the Minister of Marine and Fisheries with a new proposal. They were granted a small appropriation for 1890.

Figure 4. The CSS *Acadia*, flagship of the Canadian Hydrographic Service, shown here at Souris, Prince Edward Island, during the Canadian Fisheries Expedition of 1915 (photo: probably by A.G. Huntsman, courtesy of St. Andrews Biological Station, DFO).

Very quickly, tidal observation stations were set up at crucial locations along east coast shipping lanes, beginning at Point-au-Père, the Magdalen Islands, and Anticosti Island in Quebec, St. Paul Island, Nova Scotia, and Saint John, New Brunswick. From 1893 onward, these and an expanding network of tide-recording stations came under the control of the Canadian Tidal and Current Survey, under W. Bell Dawson (1854-1944), its superintendent until his retirement in 1924 (Fillmore and Sandilands 1983, Meehan 2006). Upon Dawson's retirement from what had in effect been his fiefdom, the Tidal Survey was incorporated as a division into the Hydrographic Survey; the united Surveys were then renamed the Canadian Hydrographic Service, a name retained through the following eight decades.

RMS *TITANIC* AND THE OCEANOGRAPHY OF CANADIAN WATERS

The new White Star liner, RMS *Titanic* hit floating ice and sank on the night of 14-15 April 1912, with great loss of life. The scientific response to the danger of icebergs in the shipping lanes was rapid, but not by Canada, which had nothing to offer by way of ships or scientific capability. Britain responded first, by sending out W.S. Bruce's auxiliary steam barque *Scotia*, with the Plymouth Laboratory's physical oceanographer D.J. Matthews (1873-1956) aboard, to do an oceanographic survey in the track of the ice across the Grand Banks of Newfoundland and off southeastern Labrador. Basing his calculations on the distribution of density in the water column, Matthews (1914) used what was then called "Bjerknes's Theorem", as simplified by J.W. Sandström and Bjørn Helland-Hansen (1903), to do a dynamic analysis of velocities and directions in the Labrador Current and a portion of the West Greenland Current. The results, overall, indicated a sluggish southward movement of the Labrador Current during the summer of 1913, and rather limited movement of the ice. This was the first, and for many years the only, systematic oceanographic study and dynamic analysis of Canadian waters, with the exception of some descriptive studies in the Bay of Fundy and Passamaquoddy region centred in St. Andrews and carried out by Huntsman's colleagues G.G. Copeland (Copeland 1912), E.H. Craigie (Craigie 1916a,b) and James Mavor (Mavor 1922, 1923) that began just before the CFE and maintained sporadically into the 1920s.

As a result of the sinking of the *Titanic*, ice observations had been carried out during the summer of 1912 by two United States Navy cruisers and in 1913 by two United States Coast Guard cutters. Matthew's work in 1913 barely preceded a meeting held by the United States Coast Guard (then called the Revenue Cutter Service) and others in London, England, in November 1913. This was the prelude to a full-blown international treaty on the ice problem, the International Convention for the Safety of Life at Sea (SOLAS) of 1914, which stipulated that there should be an annual international patrol of ice-infested waters impinging on the North Atlantic shipping lanes. And the only organization with the willingness and capability to carry out such a patrol was the United States Coast Guard, which began its International Service of Ice Observation and Ice Patrol (soon shortened to the International Ice Patrol) that summer, using radio to transmit the location of dangerous ice and plotting its distribution during each ice season. This early start, given impetus by the example of Titanic, led to the next major - and non-Canadian - study of the Western North Atlantic adjacent to Canada.

The United States Coast Guard's Ice Patrol cruises centred on the southeastern Grand Banks of Newfoundland area and collected temperature (T) and salinity (S) data in a relatively hit and miss way at first. This changed with the appointment of a young Coast Guard officer, Edward H. Smith (1889-1961; Fig. 5), about 1920. Smith soon came under the influence of the Harvard biologist/oceanographer H.B. Bigelow (1879-1967) who was a technical adviser to the Ice Patrol. After completing a Master's degree under Bigelow, Smith began Ph.D. studies on Arctic ice, and increasingly began to apply mathematical analysis to the growing body of oceanographic data collected on the Ice Patrol cruises. To refine his skills, he went to Norway in 1924-25 to learn mathematical physical oceanography from Bjørn Helland-Hansen (1877-1957) in the Geophysical Institute in Bergen, Norway. This resulted in charts of the circulation around the Grand Banks of Newfoundland, and also in a major publication – 'A practical method for determining ocean currents' (Smith 1926), that served as a how-to manual for the dynamic analysis of currents for many years (see Mills 2009).

The Ice Patrol cruises had surveyed only the southern part of the ice-infested area, the edges of the Grand Banks of Newfoundland primarily, but under Smith interest shifted north, and in 1928 the United States Coast Guard cutter *Marion* (Fig. 6) was sent north to the calving grounds of North Atlantic icebergs, the coast of West Greenland (Ricketts 1932).

Between July and September 1928, *Marion's* crew, under Smith's direction, made more than 190 oceanographic stations along 16 transects between the Labrador coast and Disko Island, West Greenland, at 70°N. Coincidentally, a Danish study was underway during the same summer using the Royal Danish Navy's schooner-rigged vessel *Godthaab* (Fig. 7). The two vessels coordinated their surveys and shared data, with the Danes working from Disko Island to the entrances to Lancaster and Smith sounds (the latter at about 78.5°N). Out of that busy summer came the first systematic dynamic analysis of Labrador Current waters, which, when combined with data from further Greenland cruises by the United States Coast Guard into the mid 1930s, led in 1935 to the first major monograph on the area, by Smith et al. (1937). The Danish results were also published (Kiillerich 1939), making West Greenland, Baffin Bay, and the Labrador Current areas the best known of Western North Atlantic waters, although without a single Canadian contribution.

Although the *Marion* cruise had the most significant effect on knowledge of the oceanography of northern waters adjacent to Canada, the United States Coast Guard was not alone in its attention to the area (see Smith et al. 1937 for a list of work to mid-1930s). John Murray and Johan Hjort had traversed the Grand Banks of Newfoundland in 1910 on their Norwegian North Atlantic Expedition (Murray and Hjort 1912). Helland-Hansen's analysis of the physical results appeared in 1930, as part of a synoptic monograph on the oceanography of the whole North Atlantic Ocean. Even after the limitation of its fishing areas around

Figure 5. Lieut. Edward H. Smith, USCG, during the United States Coast Guard's *Marion* expedition of 1928 to Baffin Bay and West Greenland (from Ricketts 1932).

Figure 6. The United States Coast Guard cutter *Marion* off West Greenland during the summer of 1928 (from Ricketts 1932).

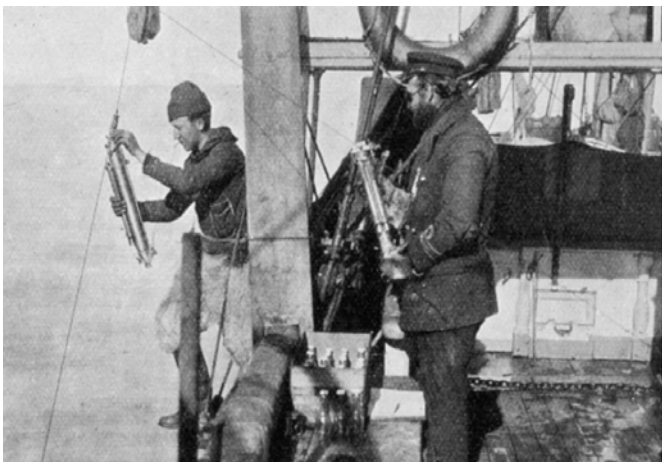

Figure 7. A hydro station being taken in West Greenland waters from the Royal Danish Navy ship *Godthaab* during the summer of 1928 (from Riis-Carstensen 1931).

Newfoundland after the British/French Entente Cordial of 1904, France maintained its colony of St. Pierre et Miquelon, held some seasonal fishing rights along the west and north coasts of Newfoundland, and conducted fishery patrol and research cruises. The oceanographer Edouard Le Danois (1887-1968) reported on the temperature structure of the Grand Banks of Newfoundland in 1924 in the course of developing a theory of basin-wide water movement governing fish production and devoted a later monograph to the area (Le Danois 1924, 1937). And in 1926, the young Harvard oceanographer Columbus Iselin, another of Bigelow's protegés, spent July and August on his schooner *Chance* between Cape Race, Newfoundland, and Nachvak Bay, Labrador (59°N), delineating some of the characteristics of the Labrador Current in that region (Iselin 1930). His analysis was published in the same year that the first mathematical physical oceanography study by a Canadian took place.

A ROLE FOR CANADIANS

A.G. Huntsman had been convinced since his experience with Johan Hjort in 1914-15 that there must be a relationship between the physical environment and the production of marine animals, including fish. His summer expeditions had foundered, in part because of the lack of a physical oceanographer, and by the late 1920s he was increasingly concerned about being able to predict the fishery effects of a proposed tidal dam that would enclose Passamaquoddy Bay off St. Andrews, New Brunswick. The result was that Huntsman requested, and got the funds to hire, a physical oceanographer for the Biological Station at St. Andrews. This was Harry Hachey (1901-85; Fig. 8), who joined the Station staff in 1928 after teaching physics at the University of New Brunswick (Mills 2009).

Hachey very rapidly began an ambitious series of descriptive studies on the east coast, ranging from the circulation of Passamaquoddy Bay to the collection of temperature information from steamers crossing the North Atlantic. And within 18 months of his appointment, in the summer of 1930, he went north to Hudson Bay on the Canadian Hydrographic Service's steamer CSS *Acadia* as part of a group organized by Huntsman to assess the possibility of a commercial fishery there. The fishery came to nothing, but Hachey carried out the first dynamic analysis by a Canadian in Canadian waters, showing (admittedly on very scanty data) that the central waters of Hudson Bay were highly stable and thus unlikely to support much biological production (Hachey 1931). For the following ten years, Hachey worked increasingly on the oceanography of the Bay of Fundy region and especially the Scotian Shelf, until, with the outbreak of war in 1939, he joined the Canadian army and was out of oceanography for a time.

Coincidentally, only a short time after Hachey's appointment at St. Andrews, physical studies began on the West Coast, based in Nanaimo, and carried out by J.P. Tully (1906-87; Fig. 9), who was hired in 1931 as an assistant to the chemical oceanographer Neal Carter (Mills 2002). Tully was energetic, extroverted, and ambitious. He was also not averse to changing fields. Within a year he began to collect sea-surface temperatures taken for him by lighthouse keepers, accompanied

Figure 8. Harry Hachey (left), Canada's first physical oceanographer, in St. Andrews, New Brunswick, probably during the summer of 1928 (photo: courtesy of St. Andrews Biological Station, DFO).

Canadian Hydrographic Service steamers to remote parts of the British Columbia coast and the open Pacific, and began to develop a working relationship with the Royal Canadian Navy (RCN) that would allow him to use naval vessels for oceanographic work.

Like Hachey, Tully taught himself dynamic oceanography, using Sandström's (1919) classic monograph and Smith's (1926) more recent one, and applied it to a number of areas, including the west coast of Vancouver Island and the approaches to the Strait of Juan de Fuca. With the onset of the war in 1939, prevented from serving overseas by an artificial leg, he soon began to develop working ties with United States oceanographers, especially in San Diego, who were developing oceanographic work in support of anti-submarine warfare.

Hachey's and Tully's entrances into oceanography came at a time that was truly transitional. In 1919, a proposal had been put forward to dam Passamaquoddy and Cobscook bays, along the Maine-New Brunswick border, for tidal power. The proposal dragged on, was revived in the late 1920s, and eventually was placed before the North Atlantic Council on Fishery Investigations (NACFI), in which Huntsman and his friend H.B. Bigelow were major players, for an assessment of the potential effect on fisheries. Huntsman had been concerned for several years by the possibility that the tidal power project would have an adverse effect on all aspects of commercial marine animal production in Passamaquoddy Bay, and it was this in part that led to his promotion of a need for a physical oceanographer at St. Andrews - and to Harry Hachey's appointment in 1928. But when an international program to assess the effect of tidal dams was created, the International Passamaquoddy Fisheries Commission of 1931-33, at the suggestion of NACFI, Hachey, as a member of the St. Andrews staff, was not permitted to take part and, as a result, the physical results of the scientific work were truncated (for details, see Hubbard 2006). This was the last time that the Canadian government looked outside for scientific expertise on the oceans; Hachey's and Tully's increasing visibility in physical oceanography and the increasing competence of the St. Andrews and Nanaimo biological stations in other aspects of marine science put Canadians front and centre in national problems related to the oceans after the early 1930s. This was especially true after the outbreak of war in 1939.

A SCIENCE FORGED IN WAR

Before World War II, oceanography, including physical oceanography, marine biology and fishery biology, was done entirely in the two Biological Board laboratories, one on each coast (the Biological Board was renamed the Fisheries Research Board of Canada in 1937). The war made little difference to this situation initially, but it did lead, perforce, to increased attention to the physical sciences of the oceans when acoustic mines and particularly submarines became a threat to the North Atlantic shipping lanes and eventually to the whole east coast of North America. The Battle of the Atlantic, beginning in 1941, and attempts to counter submarines during the next three years, made it clear to the Canadian Navy that, although it recognized the utility of detecting submarines by sound (Asdic to the British, sonar to Americans) it did not have the scientific capability to use the early sonar gear effectively, nor to understand its use under varying oceanographic conditions (see Tunnicliffe 2010 on this problem and later events; also Campbell 1976 and Mills 1994).

To increase the effectiveness of anti-submarine measures, very early in 1941 the National Research Council of Canada became the research branch of the RCN. This grew out of a request by the British Admiralty to have the Acoustics Section of the NRC's Division of Physics and Electrical Engineering (the latter directed by R.W. Boyle) become involved in defences against acoustic mines. George S. Field (1905-2000) of the Acoustics Section visited laboratories in Britain and the United States early in 1941 and began to organize work on defence-related acoustics. During a later visit to the United States, Field returned to Canada with the first bathythermographs (BTs) seen in the country, essential tools in assessing the effectiveness of sonar in detecting submarines when the water column was stratified. By 1943, Acoustics Section scientists and RCN officers had made an extensive survey of temperature conditions off the East Coast.

During the early years of the war, of Canada's two physical oceanographers, only Tully was in Canada. At Field's request, in 1943 Tully was seconded to the RCN from his position at Nanaimo to conduct research on acoustics in seawater, particularly on submarine detection, using the calm, stratified - and also safe - inshore waters of southern British Columbia as a natural laboratory. He soon established links with United States scientists doing similar work at Woods Hole Oceanographic Institution (Woods Hole, MA), at the University of Washington (Seattle, WA), and, increasingly, in what became the U.S. Naval Electronics Laboratory (USNEL) in San Diego, California (a link that became even more important after World War II - see Leary 1999). Hachey, for his part, was with the Canadian Army in England. He returned to Canada in 1943, first to the defence laboratory in Suffield, Alberta, and then at Field's request returned to St. Andrews in 1944, where he was assigned the task of preparing acoustic transmission charts for submarine detection in east coast waters. Each became head of a research group, Tully's the Pacific Oceanographic Group (POG) in Nanaimo and Hachey's the Atlantic Oceanographic Group (AOG) in St. Andrews. Nanaimo and the POG were assigned the use of a converted seiner, CNAV *Ehkoli* for their work (Fig. 10) and this became the main centre for Canadian work on anti-submarine acoustics, particularly when submarine attacks made research at sea too dangerous on the east coast. Both rapidly gained experience in defence-related research and expanded into major research groups by the war's end in 1945. Tunnicliffe (2010) summarizes the war-end situation aptly:

> *"For the Canadians ... it meant that the oceanographers, with their fisheries background would have to explore an area of "oceanography" that was essentially new to them for military oceanography was rapidly becoming defined as the merging of classical physical oceanography, acoustics, sonar engineering and naval tactics. A new discipline was emerging."*

Figure 9. J.P. Tully (centre) and colleagues at the Pacific Biological Station, Nanaimo, British Columbia, in 1935 (photo: from J.P. Tully retirement scrapbook, courtesy of Pacific Biological Station Scientific Archives, DFO).

Figure 10. The CNAV *Ehkoli* towing an acoustic target in British Columbia waters in 1949 (photo: from J.P. Tully retirement scrapbook, courtesy of Pacific Biological Station Scientific Archives, DFO).

ORGANIZING OCEANOGRAPHY

The POG and the AOG, housed in FRBC laboratories and linked closely with the NRC, RCN, and newly-formed (1946) Defence Research Board (DRB), evolved after the war and for the next decade and a half into Canada's main oceanographic research groups. The environment in which they existed was at first a relatively unorganized one, but this did not last for long. Just before the start of the war in 1939, an attempt had been made to coordinate marine science activities by organizing a Canadian Committee on Oceanography. It lasted only a few months after the outbreak of war and was disbanded in 1940. After the war, several branches of government found themselves with interests in the oceans - or perhaps in some cases believed that they should. A Canadian Joint Committee on Oceanography (JCO) was established in 1946 involving the FRBC, RCN, NRC, and later the CHS, Meteorological Service of Canada, Department of Transport, and DRB, to promote cooperative oceanographic research and to allocate resources. Only the FRBC and the RCN brought real resources to the table - scientific expertise in the first case and ships in the second - but all of the organizations believed that they could not proceed alone because of the scarcity of resources available to each individually. The FRBC provided administration and laboratories (in Nanaimo and St. Andrews), and the RCN a ship on each coast (on the east coast HMCS *Sackville*, on the west coast CNAV *Ehkoli*, followed by HMCS *Cedarwood*), all nominally under the eye of the newly-appointed Chief Oceanographer of Canada, Harry Hachey.

By 1945, Jack Tully's links with the USNEL group were increasing and the POG was growing, especially after the Canadian and United States groups began to work together on acoustic studies in inshore British Columbian waters. This led to an extended period of collaboration, the Canadian-United States Beaufort Sea Expeditions, that moved into the open Pacific and the Western Arctic beginning in 1948, culminating in 1954 when the Canadian icebreaker HMCS *Labrador* traversed the Northwest Passage to meet a pair of United States vessels (with some Canadian oceanographers, including W.M. Cameron of the DRB and POG) at the western end of the Passage. The exploit was noteworthy, but behind it lay the first serious efforts to understand the water column structure and circulation of the Bering, Chukchi and Beaufort seas, albeit with Cold War defence considerations in mind. Tully and the POG were also involved in the routine monitoring of the Subarctic North Pacific at Ocean Station "P" that was taken on by Canada in 1950 and in providing information for the work of the International North Pacific Fisheries Commission beginning in 1955. Tully had begun a hydraulic modelling study of Alberni Inlet based on a series of surveys during the early war years; although this had to be shelved for the duration, he returned to hydraulic modelling of inshore British Columbia waters after the war.

With a capable ship regularly available, Tully and his co-workers also expanded their work closer to home, determining the circulation of the offshore waters between Cape Flattery and Dixon Entrance to 140°W, and making a Canadian contribution to the American-organized NORPAC, a multi-ship study in 1955 of the little-known central North Pacific waters north of 20°N. With limited resources but unlimited ambition and optimism, Tully and his POG colleagues took West Coast Canadian oceanography well beyond the bounds of limited national surveys. Hachey on the East Coast had fewer international links; instead he and his growing group of colleagues in the AOG expanded their earlier studies of the Bay of Fundy and Scotian Shelf and began work on the Gulf of St. Lawrence and northeastern Newfoundland waters. In 1950, these (with the exception of Newfoundland) became regular seasonal surveys in support of the St. Andrews laboratory's fisheries program. As the AOG's interests turned offshore, it also began work on the relatively little known Slope Water just inside the Gulf Stream south of Nova Scotia, and in 1950 collaborated with American oceanographers in Operation Cabot, a study of the Gulf Stream off northeastern North America.

LOOKING NORTH

Before 1948, Canadian scientific work in the Arctic was practically non-existent, although there had been sporadic contributions by other nations during the preceding century (particularly the United States, as discussed before - on other work through the 1940s - see Dunbar 1951). But the pace of activity picked up rapidly in 1947 with the beginning of the Cold War, and the strategic interests of the United States, in which Canada had to play a role, involving submarine activity in northern waters and the threat of attack by air across the North Pole. In particular, the DRB developed a close link with the United States armed forces' civilian and military research. Tully and the POG's work on the West Coast was one component of this.

Although Tully and the POG had not hesitated to move into Arctic waters when they could, Hachey, lacking the American resources available to Tully, had been reluctant to move north. But large political forces were at work, including the building of five joint United States-Canadian weather stations in the Canadian Arctic between 1947 and 1950, and by 1957 the building of several Distant Early Warning Line (DEW Line) radar stations along 70°N by United States contractors was well under way. Between then and the mid 1960s, when intercontinental missiles made the DEW Line obsolete, American interest in the Canadian Arctic was high. This was an opportunity for Canadian scientists, but at the same time a potential threat to Canadian sovereignty in the north. Both of these played a significant part in the marine research carried out in Canadian arctic waters from just after the war into the 1960s.

The pressure to do oceanographic work in the eastern Canadian arctic became very strong in 1947-48 when the USCG ships *Edisto* and *Eastwind* made forays into Canadian northern waters, making BT observations from Newfoundland to Greenland and then in Smith and Lancaster sounds. The first tentative step by Canadians into the eastern Canadian arctic took place in 1948, when a small flotilla of RCN ships, including *Magnificent, Haida,* and *Nootka* was sent north (Elliott-Meisel 1999, Campbell 2010) for strategic reasons centred mainly in the RCN's changing postwar role but certainly with concern about Canadian sovereignty as well. Only *Haida* and *Nootka* actually entered Hudson Bay, where *Haida* provided a platform for a series of temperature, salinity, and BT observations by W.B. Bailey (1924-82) (who would become a member of Hachey's AOG two years later) every 100 miles from the Labrador Coast into the Bay. When the RCN's icebreaker HMCS *Labrador* came into service, it too provided the facilities for Arctic oceanography, beginning with its cruise through the Northwest Passage in 1954 (mentioned earlier, in connection with United States/Canadian cooperation in the western Arctic) accompanied by Bailey and two others from AOG, and during five further cruises through 1962. These resulted in more work on Arctic oceanic circulation by Bailey, N.J. Campbell (b. 1926), and by A.E. Collin (b. 1929) (Campbell 1958, Collin and Dunbar 1964, Mills 2001). Paradoxically, as American interest in joint operations like those in the western Arctic from 1948 through 1954 was waning, in 1954 the POG was officially designated to represent Canada in joint work there, and Hachey and the AOG were named to represent Canada in the eastern Canadian arctic. Although the POG did not work again in a significant way in the Arctic, Hachey took advantage of the opportunity to get information from the *Labrador* cruises into the 1960s, and from a cruise of the CNAV *Sackville*, which had been refitted by the RCN and the DRB for oceanographic work, to Davis Strait in July-August 1958 as a contribution to the International Geophysical Year.

In many respects, the most significant marine science work in the Canadian Arctic just after World War II was not in physical oceanography, but in biological oceanography in which physical oceanography played a part (Dunbar 1982). The stimulus came from M.J. Dunbar (1914-95), a Scot who had immigrated to Canada in 1939, becoming a graduate student at McGill and then a faculty member. In 1947 he began to develop a program of research in the eastern Canadian arctic that eventually became institutionalized as the Arctic Unit of the FRBC (1955) and later (1965) as the Arctic Biological Station in Sainte Anne de Bellevue, Quebec. The small motorized ketch *Calanus* (Fig. 11) was built in 1948 for Dunbar's FRBC work and sent north to allow open water and coastal studies throughout the eastern Canadian arctic that ended in 1979. Dunbar's work had begun in 1947 as an attempt to provide information on resources in Ungava Bay for native peoples. It expanded in the hands of his students and colleagues into broadly-based studies of plankton, fisheries, and marine mammals which almost always included the collection of physical oceanographic information. In a classic and heroic study, E.H. Grainger (1926-2012) and a colleague overwintered in Foxe Basin off Igloolik (Nunavut) during the winter of 1955-56; during their nine month stay, they gathered the first year-round information anywhere in the Canadian Arctic on water column properties and on the biological production cycle.

Although Dunbar's deep interest in the Arctic developed into a broad program of research in the hands of the FRBC, at McGill it involved his graduate students, several of whom joined the FRBC Arctic Unit. This was an early example, easiest for the biological sciences of the ocean, of training in universities that provided marine scientists for government laboratories. It was an informal arrangement at McGill (formalized in 1963 as the university's Marine Science Centre), but one that was impossible to match anywhere else, especially in the physical sciences, as senior government scientists realized early in the post-war period.

Figure 11. The MV *Calanus*, built in 1948 and the mainstay of Fisheries Research Board of Canada work in the eastern Canadian arctic under M.J. Dunbar until the late 1970s (photo: I.A. McLaren).

SUPPLY AND DEMAND – OCEANOGRAPHY IN THE CLASSROOM

Shortly after the end of World War II in 1945, the various organizations involved in the JCO found themselves with expanding programs of marine research, but with a scanty supply of trained marine scientists. The supply problem was particularly critical in physical oceanography, which had obvious links to Cold War defence concerns, the need to expand fisheries, and increasing interest in northern resources. New oceanographers were trained on the job, a situation that, as Tully noted in a memo in 1948, took time that could better be devoted to research and that was second-best anyway without a solid basis in the sciences to begin with. There were no physical oceanography training programs in Canadian universities, nor were there faculty members able to contribute to them.

Tully's concern about the supply of oceanographers was shared by George Field, who by mid 1949 was deputy director-general of the DRB. They, with president N.A.M. Mackenzie of the University of British Columbia (UBC, Vancouver, BC), had been discussing the problem for some time, and there had been a formal discussion of it, suggested by the JCO, at a meeting of the Royal Society of Canada in Vancouver in June 1948, resulting in a resolution that an institute of oceanography be formed in Canada (Mills 1994). This seems to have been only a formality, for in fact Field, concerned about the supply of oceanographers for the DRB and other governmental organizations, had already suggested to Mackenzie that UBC establish an Institute of Oceanography, and that it would be supported by the DRB. By early in 1949 there was substantial support for this proposal from within and outside UBC, including, crucially, Tully, who had agreed to coordinate and take part in the initial teaching program. Field proposed to pay from DRB funds one salary in the new institute, to pay for a UBC faculty member's retraining in oceanography, to make available for teaching the physical oceanographer W.M. Cameron (1914-2008; Scripps Institution of Oceanography trained, and at the time on the staff of the DRB's Pacific Naval Laboratory [PNL] in Esquimalt, BC). By late in August 1949 the UBC senate had approved the new program and it was underway within days, establishing a lone beachhead in the teaching of oceanography in Canada.

Taught at first by Tully commuting from Nanaimo and by Cameron from Victoria, Vancouver Island, many of the first students were government scientists looking for professional qualifications in oceanography. The curriculum was largely centred on physical and chemical oceanography, the main interest of its sponsor, the DRB. Biological oceanography took a position in the wings until 1959, when the NRC agreed to support through block grants not just the program at UBC, but a new one on the east coast at Dalhousie University (Halifax, NS), where biology bulked larger. Hachey too, by the late 1950s was providing space for trainee oceanographers with the AOG in St. Andrews, but never with a strong institutional academic base. Nonetheless, the training of oceanographers had gone from being largely an apprentice system at the end of World War II to well organized programs by 1959. The Bedford Institute of Oceanography was a legatee of this academic revolution.

OCEANOGRAPHY ON A BIG STAGE

By 1950, just after the teaching program at UBC began, World War II and its Cold War aftermath had expanded the scale of oceanographic research in Canada, but had not radically changed its direction or the way it was done in the early post-war years. Fisheries research was still in the hands of the FRBC, which fell outside the federal departmental structure, and the FRBC also maintained the two physical oceanography research groups, Tully's POG on the west coast and Hacheys' AOG on the east coast. Hydrographic charting and tidal studies were done by the CHS, and there was also a small but growing body of work on marine geology by scientists of the Geological Survey of Canada (GSC), within the federal Department of Mines and Technical Surveys (DMTS) after it came into being in January 1950. Marine geology first became a significant component of work by the GSC under J.M. Harrison (1915-90), director from 1956 to 1964. A marine geology unit was established in 1959 under B.R. Pelletier, with much of its early work done in the Arctic, including links with the Polar Continental Shelf Project (1958-62). Marine geophysics, with the exception of some magnetic and gravity surveys off the east coast, came later, with the establishment of BIO (Zaslow 1975, Keen 1990).

Immediately after the war in 1945, the JCO brought together the principal actors (with the exception of UBC and GSC), but in a way that was regarded as being increasingly unsatisfactory because it did not

Figure 12. W.E van Steenburgh, the architect of the expansion of Canadian oceanography during the post-World War II period; portrait in the foyer of the Bedford Institute of Oceanography (photo: K. Bentham).

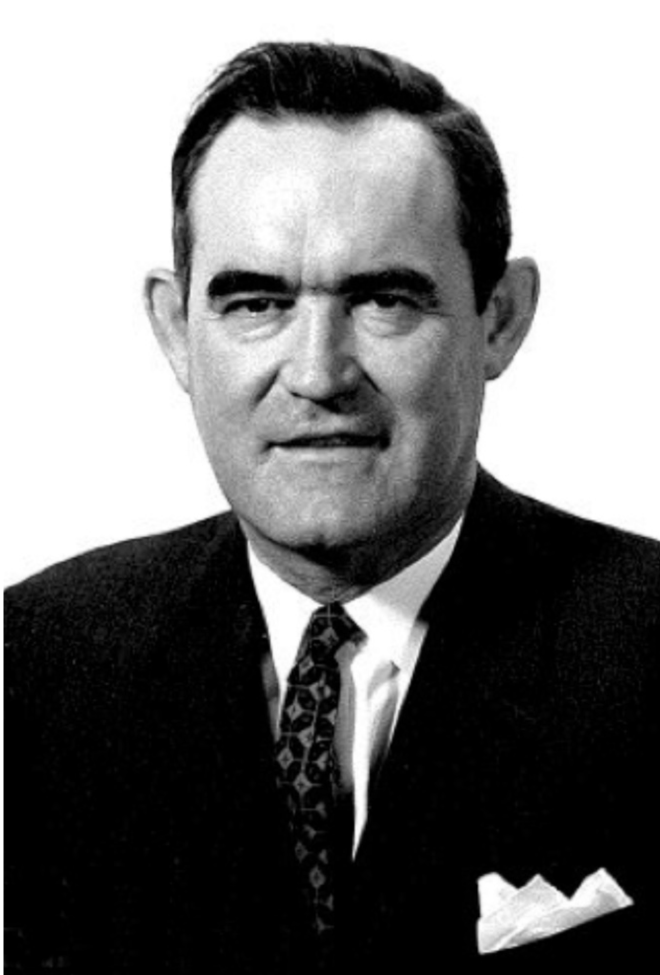

Figure 13. William M. Cameron (ca. 1963), Director of the Marine Sciences Branch, DMTS, 1962-1971, and earlier a participant in the Canada–United States Beaufort Sea Expeditions, 1949-1954, and one of the first teachers in the University of British Columbia Institute of Oceanography; he received the Order of Canada for his contributions in 2004. (photo: courtesy of Department of Mines and Technical Surveys Canada, Editorial and Information Division/ BIO Archives carton 11, April 1964 SCOR participants).

represent changing aims and organizations within the marine science communities. The dissatisfaction became focussed in 1953 when J.L. Kask (1906-98) was appointed the first full-time Chairman of the FRBC, with instructions to bring together its largely autonomous branches and to transform the FRBC into a world-class fisheries organization (Johnstone 1977). Oceanography was only one of the problems that Kask faced, but it was one that recurred in FRBC and JCO deliberations - how the FRBC could maintain and even increase its work in oceanography while attempting to increase the organization's significance in fisheries research. In Kask's eyes, the solution was to find another home for all but fisheries-related oceanographic research. This decision neatly coincided with the entry on the scene of an oceanographic program within DMTS.

W.E. van Steenburgh (1899-1974; Fig. 12) joined DMTS in 1956 as director-general of science services. He became deputy-minister in 1963. Originally an entomologist, he served as a military administrator during the war, then with the DRB, and returned to the federal Department of Agriculture in 1947, where, during nearly a decade, he supervised a remarkable expansion of Agriculture laboratories across the country. In DMTS he was to supervise the department's scientific programs and to develop new projects (Glen 1974). How his attention turned to oceanography is not clear - W.M. Cameron (Fig. 13), later a senior administrator under van Steenburgh, believed that it was at least partly due to an accident suffered by the CHS's survey ship *Baffin,* which van Steenburgh credited to lack of professionalism (Mills 2004). Whatever the precipitating factor or factors, by 1957 van Steenburg was promoting DMTS's intention of going into oceanography to the JCO - an idea that Cameron, who had worked with Tully in Nanaimo, who had inaugurated the teaching program at UBC, and who at the time was director of scientific services for the RCN (and shortly thereafter director of plans for DRB), found appalling. In his words (Mills 2004):

> *"So van Steenburgh went to the early meeting (of the JCO), went to the meeting almost immediately after this decision, he was going to get into this ... and he made this declaration: I thought, oh my God, this is the end of oceanography, and so I bitterly opposed it. I strenuously opposed it, I said, We've fragmented far enough. We've got to get some scientists into the traditional fields. There was no research tradition in Mines and Technical Surveys ... And he says, Cameron, I don't give a goddamn how you feel, but I'm going into oceanography."*

Cameron and others in the JCO tried to drum up support for an alternative to oceanography in DMTS with NRC, where they were rebuffed by its president, E.W.R. Steacie (1900-62), and with Jack Kask of the FRBC, who was intent on narrowing the Board's approach to the field, not expanding it. Within a couple of years Cameron had been won over by van Steenburgh and had joined the effort at DMTS (in 1960) as its director of oceanographic research, then (in 1962) as director of the newly-founded Marine Sciences Branch, including responsibility for a large new laboratory on the east coast (Dartmouth, NS) and a major research vessel.

Well before Cameron's conversion, van Steenburgh had been at work on the expansion of oceanography in DMTS, centred on the east coast. It was by no means an easy task to persuade west coast oceanographers (Tully, in particular) of the necessity of expanding oceanography in the east before the west. But Halifax was a natural site to start - it already housed a DRB laboratory (Defence Research Establishment Atlantic, DREA), as early as 1958 the FRBC was proposing to move the AOG to Halifax, the FRBC's and RCN's arctic oceanography was supported there by HMCS *Labrador*, and negotiations were at an advanced stage to teach oceanography at Dalhousie University. By December 1958, van Steenburgh had received approval from Treasury Board for a ship, and was attempting to recruit W.L. Ford (1913-92), at that time directing DRB's PNL in Victoria, to direct the new east coast laboratory. By June 1959, Treasury Board had approved the plans for the new laboratory (the first contract was let early in 1960), which would provide space for the AOG, the CHS, and marine geologists, and a new coordinating body was being organized for Canadian oceanography.

The idea that the JCO be reorganized and expanded originated with the NRC's president Steacie, who suggested to van Steenburgh that the JCO should be expanded by adding the universities (UBC, Toronto, and Dalhousie - the last opened its Institute of Oceanography in 1959, funded by NRC) to form a 'National Committee on Oceanography'. A press release by DMTS dated 17 December 1959 announced the organization of the Canadian Committee on Oceanography (CCO), with van Steenburgh as chairman and Hachey as secretary, to "coordinate and direct work in oceanography and to represent [the Canadian government] internationally in the field of oceanographic research" through links to SCOR (Special Committee on Oceanographic Research – now Scientific Committee on Oceanic Research), the ICSU (International Council of Scientific Unions), and the NATO Scientific Committee on Oceanographic Research. It also announced formally plans to open the Bedford Institute of Oceanography (BIO), and to provide the first of several new scientific vessels, the CSS *Hudson*, for the newly expanded Canadian oceanographic programs in Atlantic Canada.

By fall 1962, van Steenburgh's plans had materialized in the BIO, with a building, a director (not W.L Ford at first, but W.N. English (b. 1915), also of the PNL), a small scientific staff, and the prospect of a fine new ocean-going research vessel. In an address on 24 October 1962 (written by W.M. Cameron) to a convocation of Dalhousie University on the day before BIO opened, van Steenburgh expressed his hopes for the new institution:

> *"We hope that the new Institute will encourage close coordination and provide an integrated oceanographic program. If our plans and hopes materialize, this Institute will become an important national and international research establishment."*

The rest of this book is about just that!

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