2002 version

PACIFIC WATERS AND THE P.O.G. THE ORIGIN OF PHYSICAL OCEANOGRAPHY ON THE WEST COAST OF CANADA

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"It is not an easy job being a scientist before the job exists".

* *

"Every time you hear about a successful application of science, look for the progressive extension of a network."

Bruno Latour 1987, *Science in Action*, pp.150, 249

Viewed from a distance, the origins of oceanography - a hybrid discipline unlike the pure sciences that fathered it - are hard to discern. Was there a single origin of the ocean sciences, or a number of responses to local needs? How did the sciences that are called oceanography come to be grouped together? The purpose of this study is to examine how a scientific specialty, physical oceanography, spread to a specific setting, a laboratory on the West Coast of Canada, between the 1920s and the mid 1950s. Rather than concentrating on origins *per se*, it shows how physical science was applied to the oceans as habitat for fish, first tentatively, then with increasing self-assurance, and eventually with near-autonomy from the conditions that fostered its first application. It attempts to lift the lid of a Latourian black box before it has quite closed,that is, to open the past of an important research group in Canadian marine science .[2]

The contribution of Canadian scientists to Pacific oceanography was small until the mid 1950s. T.W. Vaughan's *International aspects of oceanography,*[3] which surveyed international ocean science in 1937, contains no oceanographic information from Canadian sources, and Grier's bibliography[4] of North Pacific oceanography lists only a handful of chemical and hydrographic works, most of them very short, by Canadian authors. Although the whole Pacific was poorly known until the Second World War,[5] the Canadian contribution seems disproportionately small.

By the late 1950s, this situation had changed. Writing in 1957, J.P. Tully, Oceanographer-in-Charge of the Pacific Oceanographic Group (P.O.G.) at Nanaimo, British Columbia, expressed the organization and assurance of a scientist in a well-established discipline.

> ...in the past national oceanographic groups worked as individuals with very little coordination.
>
> The last few years have seen a revolution in oceanography - at least in Canada. The fisheries and navy have posed definite requirements for oceanographic information, and have provided the resources for work. The Canadian Joint Committee on Oceanography has brought close cooperation with the agencies representing hydrography, tides and meteorology. Furthermore, international coordination is reaching the level that has long been enjoyed by these surrounding disciplines.[6]

Earlier Tully had described the role of the P.O.G. as follows:

> ...the work of this group is directed toward providing an accurate

Revised from K.R. Benson + P.F. Rehbock (eds). 2002. Oceanographic History: the Pacific and Beyond. Seattle: Univ. of Washington Press, pp. 303-315

> description of the oceanographic conditions in the Pacific and Western Arctic approaches to Canada, in terms suitable for fisheries, naval, social and industrial use, and seeking means of predicting these conditions where possible.[7]

Less than twenty years after Vaughan's survey, an extensive program of oceanographic monitoring, regional surveys, cooperation with other research groups, open sea investigations and education was well established, centered in Nanaimo.

The background of Canadian marine science

In 1900, Canadian marine science was barely beyond the stage Suzanne Zeller has described as "inventory science," characteristic of an expanding, population-poor nation, extending its frontier across a huge land-mass which required description.[8] Before 1900, Canadian marine science was carried out *ad hoc* by university teachers working during their summer vacations, or by the occasional professional naturalist such as Andrew Halkett (1854-1939) of the Department of Marine and Fisheries, and John Macoun (1831-1920) and some of his colleagues at the Geological Survey of Canada.[9] Universities were small and not research oriented; graduate work was poorly developed, centered in Toronto and Montreal, where the pure sciences and engineering alone were taught.[10] No grants or subventions existed for research[11] and there were no marine research stations.

This situation began to change in 1898, when, under the Dominion Commissioner of Fisheries, Edward E. Prince (1858-1936), a board was established (later named the Biological Board of Canada) to supervise the establishment of a Canadian marine biological station. In 1908, two stations were opened, at St. Andrews, New Brunswick, and Nanaimo, British Columbia.[12] Small, isolated and poorly funded, they were staffed mainly during the summer when university teachers arrived to do their research or study problems of interest to the Board. Even the directors of the stations were only seasonal residents until the 1920s or later (1934 in the case of St. Andrews).

The state of early Canadian marine science is exemplified by the Canadian Fisheries Expedition of 1914-1915.[13] It originated in Prince's desire to expand the East Coast fishery and improve the economic lot of fishermen. He recruited the eminent Norwegian fisheries specialist Johan Hjort (1869-1948) to examine the East Coast herring fishery and other resources. Hjort conducted the expedition with all the marine scientific resources of Europe, tried and tested in the programmes of the International Council for the Exploration of the Sea (ICES) for more than a decade, and with the help of Canadian scientists such as A.G. Huntsman (1883-1972), director of the St. Andrews laboratory. The first extensive oceanographic survey of any part of North America, Hjort's expedition dealt with the plankton, fisheries and hydrography of the Scotian Shelf and Gulf of St. Lawrence. Its report not only summarized results, it served as a text for Canadian marine scientists for at least two generations.[14] But texts are only useful when groundwork has been prepared for their use. Sandström's lengthy chapter on dynamic calculations,[15] for example, fell into a void; it was regarded as abstruse by bureaucrats overseeing its publication in Ottawa and was ignored by Canadian scientists, either because of their inability to cope with mathematics or because of their concentration upon pure sciences such as physics, chemistry and biology.

Overall, the effect of the Expedition was limited; it served as an ideal, rather than as an example of objectives that Canadian marine scientists could achieve using their own resources. Even in 1931, the International Passamaquoddy Fisheries Commission, established to study the potential biological consequences of damming Passamaquoddy Bay for tidal power, had to recruit foreign specialists such as the Norwegians H.H. Gran (1870-1955) and Trygve Braarud (1903-1985), and Michael Graham (1898-1972) of England, among others, to assure scientific competence in such a wide-ranging study.[16] Examples of how internationally-sanctioned marine science should be conducted in Canada were beginning to accumulate by the early 1930s, but professional opportunities were few or non-existent, funding was sparse at best for anything but the most rudimentary field studies, and pure science was suspect in the Ottawa corridors of power and finance that scientists like Huntsman and his coequal at Nanaimo, W.A. Clemens (1887-1963), depended upon to support their tiny laboratories.

Physical oceanography in Europe and North America

In current usage, physical oceanography deals with the physics and circulation of the sea. As a designation of a discipline and a profession, the name was scarcely used before the 1920's; it came into most common use in North America during the 1950's. European usage, e.g. in Germany, designates physical oceanography as "oceanography"; related fields are marine chemistry, marine biology, and so on, united under the umbrella of *Meereskunde*, marine science.[17] The roots of European *Ozeanographie* lie in physical geography, not in physics or the marine sciences.[18]

Dynamic understanding of oceanic circulation increased rapidly afterVilhelm Bjerknes's theorem of baroclinic circulation in fluids, first devised for meteorology, was applied to the oceans by Johan Sandström and Bjørn Helland-Hansen in 1903 and 1905.[19] Dynamic calculations of ocean currents and a general increase in knowledge of the physics of the oceans were promoted by the scientific meetings of the International Council for the Exploration of the Sea (I.C.E.S.) and by courses on oceanography for technicians and scientists at Bergens Museum between 1903 and 1913. The Geophysical Institute in Bergen, founded in 1917 to induce Bjørn Helland-Hansen (1877-1957) to stay in his adopted city, became the center of instruction in mathematical oceanography, drawing students from Europe and North America until the Second World War.

In the United States, early in the century, W.E. Ritter (1856-1944), founder in 1893 of the laboratory that became the Scripps Institution of Oceanography in La Jolla, California, saw the need for a "hydrographer" to link the physical environment to the lives of animals that were the subject of his laboratory's work.[20] He appointed George F. McEwen (1882-1972), a physicist from Stanford, to the laboratory staff in 1908. McEwen, who was an able mathematician, soon learned about, and mastered much of, European physical oceanography, but he regarded the dynamic method devised by Bjerknes, Helland-Hansen and Sandström, as only an expedient, lacking real physical meaning. He seldom used dynamical calculations and apparently taught them reluctantly, although he described them in a widely known monograph in 1932.[21]

On the East Coast of the U.S.A., H.B. Bigelow (1879-1967), a Harvard zoologist, began studying the biology, chemistry and physics of the Gulf of Maine in 1912.[22] He knew of dynamical methods quite early but had difficulty in applying them to his data. Help came in the person of Edward H. Smith (1889-1961), a U.S. Coast Guard Officer assigned to duty with the International Ice Patrol, who had the ability and the need to learn dynamic oceanography. In the course of his PhD study at Harvard with Bigelow, Smith spent 1924-1925 in Helland-Hansen's Geophysical Institute learning the technique and making calculations of current flow around the Grand Banks.[23] When he returned, he published a version of Helland-Hansen's lectures that became widely used as a primer of dynamic oceanography.[24]

In Canada, A.G. Huntsman's concern with the herring fishery of Passamaquoddy Bay, his opposition to the plans for a tidal dam there, the influence of Hjort and the Canadian Fisheries Expedition, and his long-standing correspondence with Bigelow about physical oceanography (among many other subjects)[25] led to the appointment of H.B. Hachey (1901-1985), a young physicist from the University of New Brunswick, as hydrographer at St. Andrews in 1928.[26] Among Hachey's first official tasks was the dynamic calculation of currents from data taken during the Hudson Bay Fisheries Expedition of 1930.[27] In so doing, he was the first Canadian to learn and apply these techniques, apparently using Sandström's monograph (1919) as a text.

Each application of the techniques of dynamical physical oceanography during the first four decades of the 20th century arose out of a specific scientific or practical need, ranging from animal ecology to the tracking of icebergs. When H.U. Sverdrup (1888-1957), a distinguished colleague of Helland-Hansen from Bergen, arrived in California in 1936 to direct the Scripps Institution of Oceanography, he quickly established a thorough training in dynamical oceanography for its students. Recognizing that the small and struggling institution needed a scientific raison d'être and powerful allies, he established liaisons with state and federal agencies to study the California Current, using physical oceanography to determine the parameters of a fisheries system.[28] This beginning, interrupted but ultimately fostered by the Second World War and its aftermath, led to the permanent establishment of mathematical physical oceanography, its growth and institutionalization, in North America by the 1950's.

Oceanography at the Pacific Biological Station

The Pacific Biological Station (P.B.S.) at Nanaimo was separated from its east coast counterpart by geography and by Pacific salmon, then Canada's most valuable marine resource.[29] As the laboratory's first director, W.A. Clemens, recalled:

> With the steady expansion of the fisheries, an increasing number of questions had arisen concerning the stocks of fishes and adequate conservation measures for them, and my appointment [in 1924] was expected to lead to the development of a program of fishery research and to the acquisition of basic information on the fish and fisheries.[30]

The reports of P.B.S. directors, year-by-year, invoke the importance of the salmon and other British Columbia marine resources.[31] In 1940, the new director R.E. Foerster (1899-1978) wrote that "the main objective of the work of the Pacific Biological Station is to undertake those scientific studies of the commercially important fishes of British Columbia which will provide the Department of Fisheries with accurate data for its guidance in establishing suitable regulatory and conservation measures for the continued safe exploitation of the fisheries." But how liberally would the directors of PBS construe the "scientific studies" undertaken at the station? Foerster continued:

> ...there are those [studies] that have reached the point where fundamental

factors governing the reactions of the fish are being investigated, such as those which control migration, those which produce variations in growth rate, abundance of fish, propagation, etc. All are definitely of what might be termed economic importance as well as of scientific value, but some naturally seem of more obvious significance than others. As research progresses, however, the fundamental phases become the primary concern of investigation and, in final analysis, they constitute the essential problem. They hold in so many cases the key to the explanation of the phenomena which, on the surface, are of importance in regulation and conservation.[32]

In Clemens's footsteps, Foerster and successive directors of PBS toed the fisheries line, but continued to support basic research that might eventually prove to be relevant to the fisheries.

Until a permanent staff was appointed, beginning in 1924, the work carried out at P.B.S. varied with the interests of its part-time director and visitors.[33] The second director 1912-1924, Charles McLean Fraser (1872-1946), began regular records of temperature and density in Departure Bay in 1914.[34] Visitors made occasional studies of the plankton,[35] or tried to relate the striking hydrographic variety of the Strait of Georgia to the distribution of marine plants and animals.[36] With R.E. Foerster's arrival in 1923 to work on sockeye salmon in Cultus Lake, the station's dominant line of research was established.[37] But work on the environment of the salmon, especially at sea, lay in the hands of visiting researchers for a few more years.

In 1926, Andrew H. Hutchinson (1888 - 1975), professor of Biology (later Botany) at the University of British Columbia, with the help of Colin C. Lucas (1903-1981), and Murchie McPhail (1907-1989) began a series of summer studies of the hydrography of the Strait of Georgia. Taking their inspiration from the work of H.W. Harvey and W.R.G. Atkins in Plymouth, they attempted to explain the fertility of the Strait (especially its diatom populations) by the mixture of Fraser River and ocean waters.[38] They concluded that the strait was dominated by freshwater from the Fraser, which formed a low salinity cap in mid-strait and provided most of the nutrients for plankton growth (and thus indirectly for fish nutrition). But the greatest abundance of phytoplankton was where the Fraser and ocean waters mixed, northwest and southwest of the river mouth; here some unknown factors (they referred to "mixing"), in addition to nutrients, were most favorable for phytoplankton blooms.[39]

According to Clemens, the work of Hutchinson and his colleagues "served to attract attention to oceanography and also helped me to organize ideas."[40] He set out to hire an oceanographer, first by trying to attract T.G. Thompson (1888-1961) of the University of Washington to Nanaimo. But Thompson's laboratory was about to be endowed by the Rockefeller Foundation; despite his interest in P.B.S., he stayed in Seattle. In his place, Clemens found Neal Carter (1902-1978), a young Canadian chemist on a post-doctoral fellowship in Germany in 1930. Later that year, Carter moved to Nanaimo as oceanographer and chemist. Within a few weeks, he began to carry on Hutchinson's survey of the Strait of Georgia,[41] and to study the hydrography of mainland fiords as habitats for fish.[42]

Carter's workload was heavy. To carry the burden of chemical analyses, an assistant was needed. A young chemist from Manitoba, John P. Tully (1906-1987) was recruited in 1931 (Figure 1). Even though he had lost a leg in an automobile accident during his youth, Tully was highly motivated, extroverted and expansionist in personality. When Carter left P.B.S. in 1933 to direct the

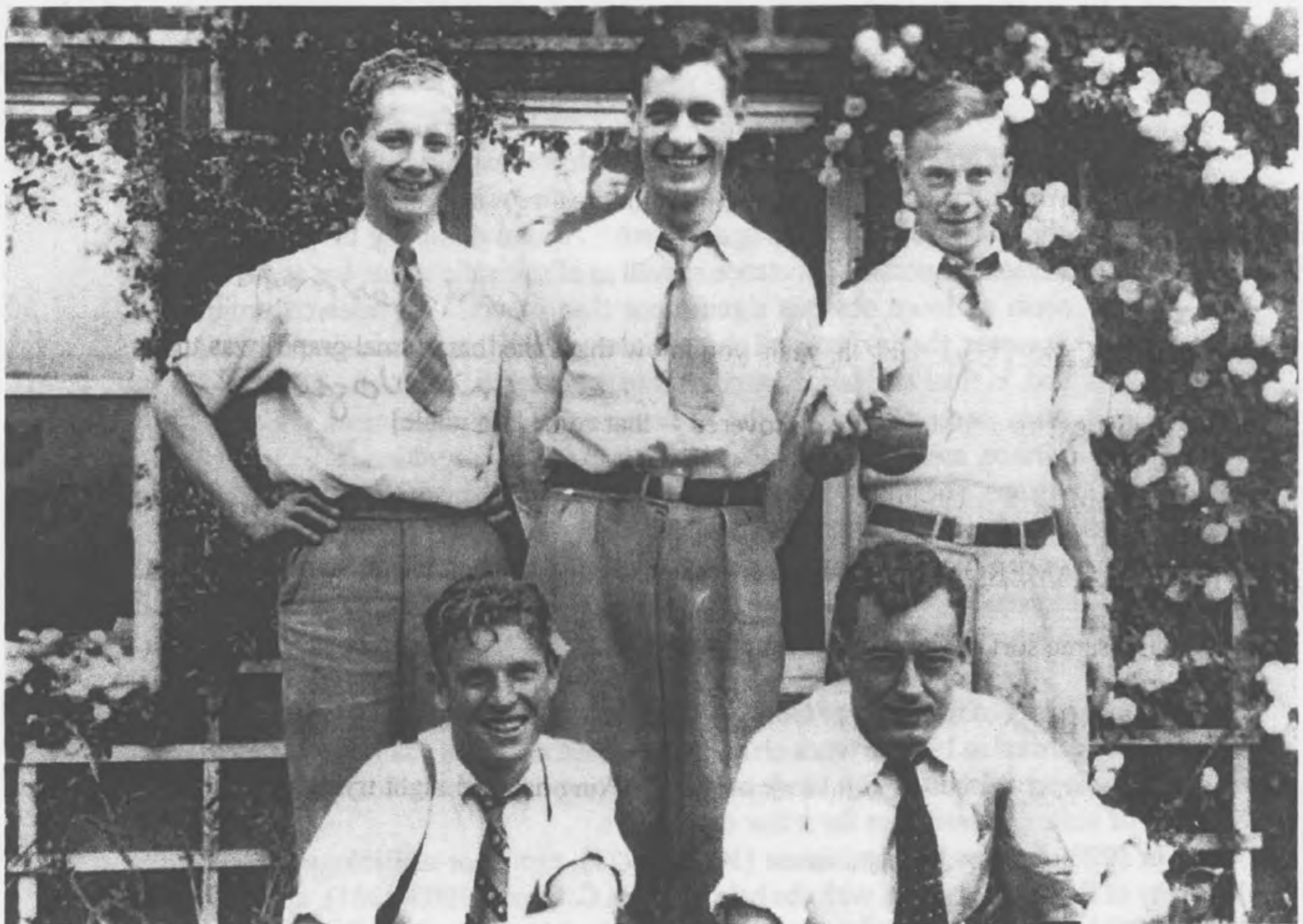

FIGURE 1

Board's Experimental Station in Prince Rupert, B.C., Tully stepped into his place. Unencumbered by any preconceptions about marine science, he set about learning oceanography and applying it in the context set by Clemens and the purposes of the station.

Sea-temperature records had been kept since 1914 in Departure Bay, and since 1917 at William Head, near Victoria. In 1932, Tully arranged to have lighthouse keepers at five locations record daily sea temperature and meteorological variables. As he said later:

> ...the direct object of this program is the preparation of continuous charts of the hydrospheric and atmospheric variations to show their geographical daily, seasonal and annual variations and their inter-relations with a view to determining the meteorological factors that affect the movements of the various commercial fishes. It is well known that the sea and the air affect each other and that the behavior of one cannot be entirely separated from the other.[43]

Furthermore, the lighthouse observation program, which expanded to more than twenty stations later, was a proxy for work at sea, for, although the Strait of Georgia could be studied from P.B.S.'s small boats,[44] the open ocean could not. Its characteristics and variations off the British Columbia coast were totally unknown in 1932. Tully's solution, along with the lighthouses, was to use ships of convenience. Viewing red-tape as a way to pull oneself along, not as an impediment,[45] he began hitching rides on hydrographic surveying vessels to study the west coast of Vancouver Island and the open Pacific. Aboard the Canadian Hydrographic Service's vessel *William J. Stewart*, he spent a few days studying the currents of Nootka Sound in July 1933,[46] several weeks between Cape Flattery and Esperanza Inlet in 1934, and three months in the area of the Queen Charlotte Islands in 1935. These experiences were valuable, but frustrating; oceanographic work took second place to charting and to the whims of the chief hydrographer, and was hindered by the unsuitability of the vessel.[47] The solution was to find a better vessel that could be devoted, at least part time, to oceanography. Such a vessel was HMCS *Armentières*, loaned for a few months each year by the Royal Canadian Navy for oceanographic surveys from 1936 to 1938.

Between February and September of the first year of his offshore surveys, Tully and colleagues occupied 100 oceanographic stations between the entrance to the Strait of Juan de Fuca and Queen Charlotte Sound. In the next two years, he concentrated on Swiftsure and Lapérouse Banks at the entrance to the Strait of Juan de Fuca,[48] showing the variability of water properties, the presence of rapidly-changing eddies, and the existence of areas of cold water just offshore, bounded by even cooler coastal and offshore waters, a situation quite contrary to expectations that a warm "Japanese Current" extended across the Pacific to British Columbia.

Tully summarized the rationale for his work in 1937, stating that:

> ...the hydrographical investigations...have been primarily directed towards the discovery and measurement of the factors affecting the physical environment of the food fishes. Primary consideration has been given to discovery of the elements of the problem so that it would be possible to reduce the observed phenomena to their primary causative forces and to determine their cyclic nature with a view to forming a firm basis for the predictions of the physical conditions in

the fishing areas which might be used in fisheries prediction.[49]

But the years of the *Armentières* cruises, ending just before the Second World War, were ones in which Tully's capabilities and orientation as an oceanographer changed rapidly. A BSc. in chemistry had not prepared him for the complexity of current analysis. Initially Tully used conventional methods of analysis presented by the tidal expert H.A. Marmer,[50] in which hydrodynamic forces were responsible for the difference between total currents measured by current meters and those that could be resolved as tidal by mathematical analysis. Rapidly, however, Tully began to teach himself the dynamic methods based on Bjerknes's theorem, adapted for routine oceanographic surveys by Sandström and Helland-Hansen.[51] His first text was Sandström's (1919) classic monograph. Only a year later, in 1937, he referred to a variety of works by Bjerknes, V.W. Ekman, G.F. McEwen, and E.H. Smith on dynamic methods of analysis.[52] Never a very skillful mathematical oceanographer, Tully knew his limitations and, in 1936-1937, corresponded with Bjørn Helland-Hansen about the possibility of doing a PhD in Bergen. This came to nothing; instead, Tully began work toward a PhD in T.G. Thompson's Oceanographical Laboratories at the University of Washington where, probably for the first time, he encountered the full range of oceanographic literature.[53] The war interrupted his doctoral research on the oceanography of Alberni Inlet, where in 1939 he had begun work to assess the impact of a sulfite pulp mill being planned for Port Alberni.[54]

Research at P.B.S. was frozen for a time by the onset of the war. Work on the open ocean became impossible. Redirecting himself to Alberni Inlet, Tully completed his surveys in 1942. In 1940 he had begun to construct a small hydraulic model of the inlet to simulate and simplify estimations of the effect of the pulp mill. He quickly developed an interest in experimental approaches to oceanographic circulation that complemented his energetic surveys of coastal waters. Oceanographic surveys, long time-series of measurements (the lighthouse observations) and hydraulic modeling began to loom larger in Tully's view of ocean science. But it was the war that allowed them to coalesce.

Origins of the P.O.G.: evolution of a research program

Canadian physical oceanography entered the Second World War as small-scale, fragmented science carried out independently on the two coasts. It left the war with new organizations, resources and raisons d'être.

Submarines precipitated the entry of oceanographers into the war. The early sonic detection of submarines by ASDIC (precursor of SONAR) was often hindered by vertical changes of temperature and salinity. To study these problems on the West Coast, Tully was assigned to duty with the Royal Canadian Navy (R.C.N.) in Nanaimo in 1943. On the East Coast, H.B. Hachey returned to St. Andrews from service with the Canadian Army in England for similar work. Tully's group at P.B.S. became known as the Pacific Oceanographic Group (P.O.G.), Hachey's at St. Andrews the Atlantic Oceanographic Group (A.O.G.). Each worked in close contact with the R.C.N. and especially the National Research Council (N.R.C.) and reported directly to the N.R.C. acoustician G.S. Field in Ottawa.[55] When Tully was formally released from the R.C.N. in 1946, the P.O.G. survived and prospered in the postwar environment at P.B.S.. Tully, who had been termed "scientific assistant in hydrography" for years, now found himself in 1949 senior oceanographer and officer-in-charge of the P.O.G., a semi-autonomous and growing research group within P.B.S.. The secret of Tully's success and the growth of P.O.G. was the series of projects and alliances that united the P.O.G.'s scientists and technicians; these could always be linked to the primary aims of the laboratory, the study of factors governing the marine resources of British Columbia waters.

The autonomy and effectiveness of P.O.G. and A.O.G. were increased by their inclusion within the Canadian Joint Committee on Oceanography (J.C.O.) when it was established in April 1946. Intended to coordinate and promote Canadian Oceanographic research, the J.C.O. was made up of senior members of the Fisheries Research Board of Canada (F.R.B.) (successor to the Biological Board in 1937), the R.C.N., the N.R.C., and later the Canadian Hydrographic Service, the Meteorological Service and the Defence Research Board (D.R.B.) (founded in 1946, and eventually including the Pacific Naval Laboratory (P.N.L.) and other laboratories[56]). The J.C.O.'s members were in close contact with research, had influence with their chiefs or directors, and did not hesitate to find resources for oceanographic work ranging from ships to money.[57]

Tully completed the work for his PhD in Seattle during the academic year 1946-1947. When he returned to Nanaimo, a ship had been assigned for oceanographic work on the West Coast: CNAV *Ehkoli*, an 84-foot converted seiner, ideal for inshore studies. The next year, HMCS *Cedarwood*, 165 feet and capable of offshore work, became available.[58] Ships made the expansion of the P.O.G.'s programs feasible, beginning in 1948 with a physical study by Tully, W.M. Cameron, and G.L. Pickard, of the effect of Skeena and Nass River waters on Chatham Sound, near Prince Rupert, traversed by sockeye on their way to and from the rivers.[59] Nearby was Nodales Channel, well-mixed and isothermal, and thus ideal for studying the SONAR signatures of submarine-like objects (and submarines themselves). In what was described as "probably the largest joint oceanographic research operation undertaken in Canadian waters," P.O.G. and United States Naval Electronics Laboratory (USNEL) personnel, including Tully and Cameron, in four ships and two smaller craft, studied the acoustic signatures of iron spheres, a triplane target and a submarine (Figure 2).[60]

Tully and Cameron's collaboration with USNEL expanded far beyond Nodales Channel in 1949, when the P.O.G. in *Cedarwood* and USNEL scientists began oceanographic work, much of it security-classified, in the Bering and Chukchi Seas. This was only a first step in yearly Arctic cruises between 1950 and 1954, involving P.O.G., D.R.B. and USNEL scientists, culminating in 1954, when HMCS *Labrador* joined a group of American vessels in the Western Arctic after negotiating the Northwest Passage.[61]

Closer to home, the availability of *Cedarwood* made studies in the open Pacific, begun in HMCS *Armentières* between 1936 and 1938, possible once again. Tully's colleague L.A.E. Doe (b.1916) was put in charge of an extensive dynamic survey of offshore waters between Cape Flattery to the south and Dixon Entrance in the north, extending to 141°W. "Project Offshore" under Doe amplified and extended Tully's early conclusions about the current regime west of Vancouver Island, verifying that the warm water not far offshore was of local, seasonal origin, not the result of the North Pacific Current. When J.L. Reid of the Scripps Institution of Oceanography visited Nanaimo in 1953, he suggested amalgamating data from Project Offshore with that taken by the Marine Life Research Group off the U.S. West Coast. As a result, Doe's publication of the results was the first synoptic account of currents off the North American West Coast, showing the divergence of the North Pacific Current at the latitude of British Columbia, its variations, and the source of the Alaska and California Currents.[62] As a logical extension of this work, Tully and the P.O.G., using HMCS *Ste Thérèse*,

FIGURE 2.

became involved in an even more ambitious survey, NORPAC, the study of the remaining unknown central regions of the North Pacific, north of 20°N into the Bering Sea, during the summer of 1955. This joint project of Japan, the United States, and Canada provided baseline studies of the Subtropical and Subarctic North Pacific, upon which all subsequent work has been grounded.[63] The Canadian contribution was modest - one ship in more than twenty involved in the project - but it indicated the ability of Tully and his P.O.G. oceanographers to make significant contributions to international oceanography only a decade after the changes initiated by the war. Their contribution continued when the P.O.G. was designated in 1955 to contribute to the oceanographic program of the International North Pacific Fisheries Commission (INPFC) in the Northeast Pacific.[64]

International programmes were a measure of the ability of the P.O.G. to undertake significant tasks as a group, but they were not its only activities at the time of NORPAC. When the Institute of Oceanography at the University of British Columbia was founded in 1949, Tully commuted to Vancouver to teach chemical oceanography to its first graduate students, and its students frequently worked with the P.O.G. in Nanaimo.[65] The P.O.G. supported the Institute's first studies of B.C. fiords, an extension of Neal Carter's early work.[66] Renewed studies of the Strait of Georgia began in 1949 under R.J. Waldie,[67] and the Group was also pressed into service to study the Fraser River outflow and Vancouver's sewage disposal problems. Modeling, dear to Tully's heart, was not neglected. A large scale model of Alberni Harbor was the first project, followed by an ambitious (ultimately unsuccessful) model of Hecate Strait arising from the P.O.G. hydrographic survey in that area (which was important for groundfish), beginning in 1954.[68] Under R.H. Herlinveaux, Tully's early studies of the Strait of Juan de Fuca were greatly enlarged in 1950-1951,[69] and bathythermograph data from the ocean weather ship at Station "P" (50°N, 145°W) were compiled and interpreted by H.J. Hollister beginning in 1952.[70] Tully's remark in 1949 that "this has been a busy year" applied in spades to the 1950s, when the P.O.G.'s activities were steadily accelerating, and its organization was tightening.[71]

The evolution of a research group: fisheries and physical science:

How could a research group like the Pacific Oceanographic Group develop so successfully in a laboratory devoted to research on commercial fisheries? There are four elements in the success of Tully and the P.O.G.[72]

1. The ability of Tully to persuade successive directors of P.B.S. of the importance of his work.
2. The opportunity, brought about by World War II, for physical oceanographers to practice their profession independently of biology.
3. The ability of Tully and his group to provide services to other groups such as USNEL, the P.N.L. and the INPFC.[73] The variety of hydrographic conditions on the British Columbia coast made it a natural laboratory for physical study, attractive to collaborators.
4. Tully's eclecticism and wish for independence. Although he never gave up the attempt to relate environmental factors to fish distribution and abundance, Tully built his empire opportunistically, regarding shifts of the scientific climate as new opportunities, not as disadvantages. The division between applied and basic science was not a fundamental issue. What mattered was the opportunity to conduct his own work as effectively and broadly as possible.

Early indications of the independent line that Tully envisioned may be found in the mid-1930s, when his first surveys off the West Coast of Vancouver Island began. In 1937 he wrote of physical oceanographic research on circulation as "classic in its field and scope," though of great importance commercially.

> A program is required that will observe all the significant factors affecting the sea in this area, and reduce them by correlation in the fewest possible factors affecting the fisheries directly.
>
> Fisheries investigations cannot possibly be conclusive unless the physical factors of environment are fully considered. Since these factors have not been observed in the past, it is impossible to expect conclusive results from the previous investigations until the physical effects on the observed biological phenomena have been established. This program should have been started in 1900, but as it was not, the fisheries information since that time cannot be related to physical factors in the sea unless these can now be related to meteorological characters that have been observed since that time.[74]

This was his justification for the lighthouse observations of temperature and salinity that began in 1932. These could be related to physical variation in the open ocean.[75] Many special problems in fisheries biology would benefit from physical oceanographic information - but the same data could give information on ocean dynamics, turbulence, geostrophic, wind-driven and estuarine circulation, upwelling and meteorology.

> Thus it follows that in these oceanographic investigations that are primarily designed to discuss the factors directly affecting the fisheries, it is necessary to make a rather thorough study of the factors contributing to those conditions, and as a result, not only are data available for conclusions affecting fisheries research, but also for many fundamental and applied studies in physical geography, physical and chemical oceanography, meteorology, and navigation.[76]

After the War, with the establishment of the P.O.G., the lines became more firmly drawn around the proper function of physical oceanography - and of the group that conducted it. What Tully called the greatly increased "horizon and capabilities of Canadian oceanographic research," were evident soon after the war.[77] Making studies was the proper stuff of oceanography; providing information (to biologists, the R.C.N. and so on) was the outcome of this function, not its cause.[78]

With the increasing autonomy of the P.O.G., Tully set forth its aims increasingly programmatically during the 1950's. Stating that "the overall programme of this group is to describe and predict the oceanographic state in the coastal and offshore waters of British Columbia, and present the information in suitable terms for fisheries, military and industrial use," he made its operations explicit and separate from other work at P.B.S.. Projects would be carried out annually in selected areas; daily observations would be maintained at the lighthouses, ocean models would be constructed if simple observation would not suffice, and oceanographic atlases would eventually be compiled.[79] This was not new (the elements date to the 1930's); what was new was the confidence with which these goals were expressed.

It may have been irksome to his director at P.B.S. to read Tully's remark that "the personnel

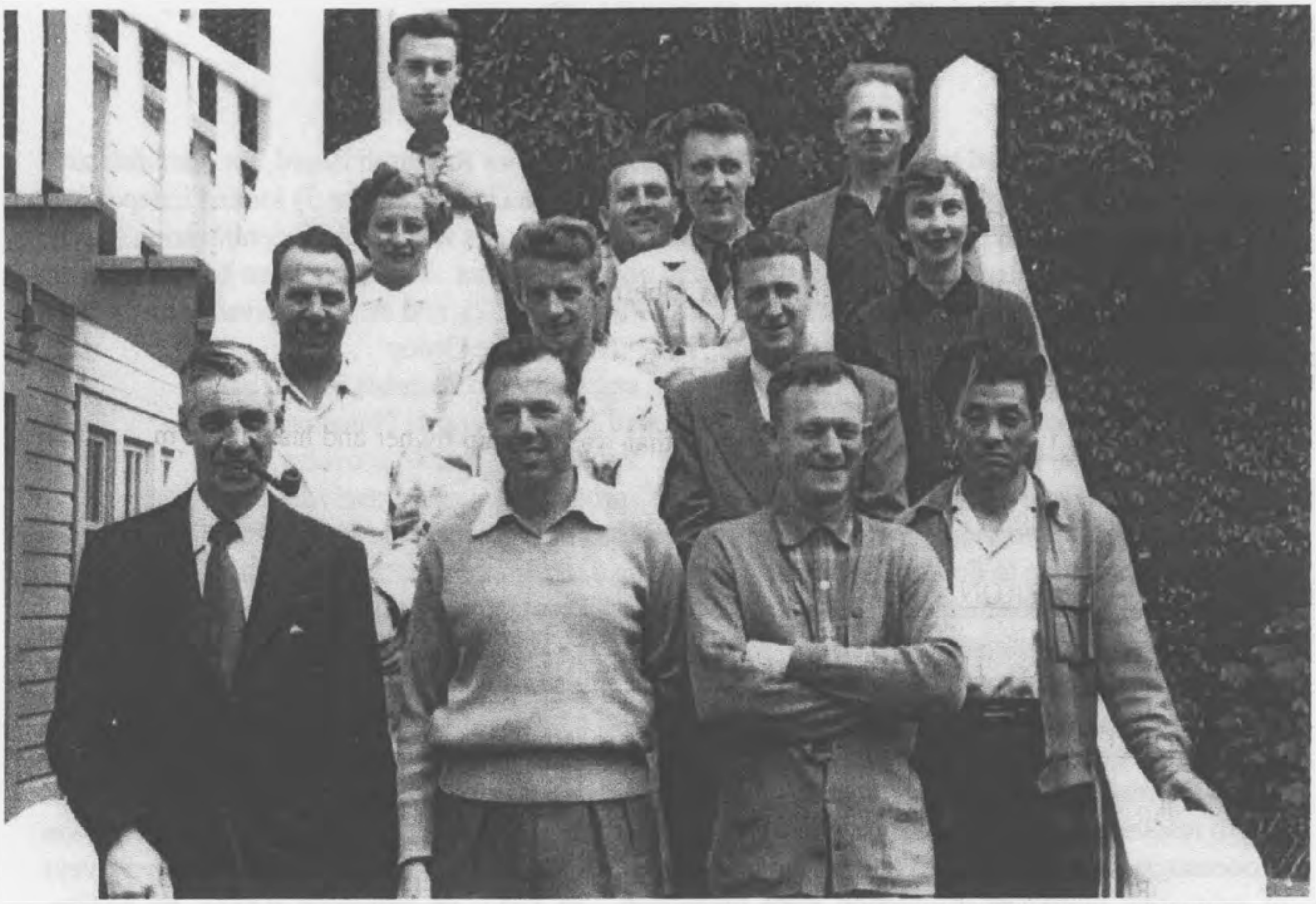

FIGURE 3

of the Group are attached to this branch [P.B.S.] of the Fisheries Research Board, for administrative purposes," which was correct but diplomatically inept.[80] The Group (Figure 3) looked independent and acted independently, gaining strength from the usefulness of its work and its identification (by the mid 1950's) with an international group of physical oceanographers. The P.O.G. ran its own show at P.B.S., having its own office staff, personnel (11 full-time in 1952), and seminar series.[81] Its esprit de corps was evidently high. With fatherly pride, Tully wrote of the Group:

> We have an association of physicists, engineers and chemists served by a competent clerical and technical staff in the Group at Nanaimo and the Institute of Oceanography at Vancouver, which provides for efficient planning, observation, processing and analysis of oceanographic research. Our Group has high morale, the ability and desire to do good work, and is building a tradition of accomplishment. I am fortunate in having capable associates, and I am proud to represent this company.[82]

It would not be correct to conclude with a picture of the P.O.G. as an inflexibly independent research group by the end of the 1950's. It had achieved a high degree of independence and a modest, but important, degree of international recognition by and after the time of NORPAC,[83] but it existed within the framework of a governmental organization, the Fisheries Research Board, whose activities had to respond to events within a broader context of Canadian science and politics.[84] The "revolution in oceanography"[85] that Tully discerned late in the 1950's had further to turn, especially when new ways of estimating biological production were developed. In 1957, he expanded P.O.G. by adding, nominally, a marine chemistry group under J.D.H. Strickland (1920-1970), which was "to experimentally examine the conditions affecting productivity...With the addition of this work, the oceanographic program will be considering all factors affecting climate and productivity of the region of interest in Canada."[86]

In a further turn, when the Federal Department of Mines and Technical Surveys began to expand into physical oceanography late in the 1950's, Tully was sufficiently sure of himself and of the capabilities of the P.O.G. (especially after its successful venture into production studies) to advise the Chairman of the F.R.B., J.L.Kask, to "seize the opportunity that is offered in fisheries oceanography and, on the basis of [the F.R.B.'s] considerable experience, define and guide the development of environmental oceanography elsewhere."[87] Not a counsel of despair in a changing political environment, Tully's advice was the direct outcome of the career he began as a young chemist from the Canadian prairies in Nanaimo in 1931. The P.O.G., securely established in its science, could afford to redirect its work and take on the challenge of uniting the marine sciences.

What Tully could not foresee in the 1960's, the decade with which my paper ends, was the dissolution in the next decade of the whole structure upon which the P.O.G. depended - the Fisheries Research Board, the Canadian Committee on Oceanography, and the near autonomy of his and other government research groups - in the cause of increased accountability to government managers. Physical oceanography had rooted itself on the West Coast of Canada as a result of Tully's and the P.O.G.'s efforts during a 30 year period. At the end of Tully's career it was about to take a new direction. That black box too needs to be opened, to lead us into the recent history of Canadian Oceanography.

NOTES

1. Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1 and History of Science & Technology Programme, Dalhousie University and University of King's College, Halifax.

   My research was supported by grants from the Social Sciences and Humanities Research Council of Canada.

   This paper is a slightly edited version of one printed in P.F. Rebock and K.R. Benson (eds.) 2001. *Oceanographic History: The Pacific and Beyond.* (Proceedings of the Fifth International Congress on the History of Oceanography, La Jolla, California). Seattle: University of Washington Press, and is reprinted with permission of the University of Washington Press.

   For providing their recollections and analyses I am grateful to A.J. Dodimead, W.N. English, George S. Field, W.M. Cameron, the late R.H. Herlinveaux, T.R. Parsons, G.L. Pickard, R.W. Trites, Mrs. Lorraine Tully and the late Michael Waldichuk. Gordon Miller and Pam Olson of the Pacific Biological Station Library, Nanaimo, B.C., Marilynn Rudi, then of the Biological Station Library, St. Andrews, N.B., Sharon Thomson and Susan Johnson of the Institute of Ocean Sciences Library, Sidney, B.C., Graeme Durkin, then of the Library, Dept. of Fisheries and Oceans, Ottawa, and archivists at the National Archives of Canada, University of Toronto Archives, and Harvard University Archives helped in many ways.
2. B. Latour, *Science in Action. How to Follow Scientists and Engineers Through Society.* (Cambridge, Massachusetts: Harvard University Press, 1987), 274 pp. Latour likens science, as seen from the present, as black boxes in which the events of the past have been hidden. Historical and sociological analysis, which open black boxes, reveal a different picture - "Uncertainty, people at work, decisions, competition, controversies are what one gets when making a flashback from certain cold, unproblematic black boxes to their recent past."
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4. M.C. Grier, *Oceanography of the North Pacific Ocean, Bering Sea and Bering Strait: a Contribution toward a Bibliography* (University of Washington, Public Library Series, 2, 1941), xxii + 290 pp.
5. E.L. Mills, "The Oceanography of the Pacific: George F. McEwen, H.U. Sverdrup and the Origin of Physical Oceanography on the West Coast of North America," *Ann. Sci.*, 1991, 48: 241-266.
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9. J. Hubbard, *An Independent Progress: The Development of Marine Biology on the Atlantic Coast of Canada, 1898-1939*. PhD thesis, University of Toronto, 1993, v + 446 pp.
10. See, for example, B.N. Smallman, H.M. Good and A.S. West, *Queen's Biology. An Academic*

History of Innocence Lost and Fame Gained (Kingston, Ontario: Department of Biology, Queen's University, 1991), 215 pp.

11. The Honorary Advisory Council on Scientific and Industrial Research (precursor of the National Research Council) was founded in 1916. It soon began to award very small subventions for the support of research in universities, nearly all going to physics and chemistry at first.
12. H.B. Hachey, "History of the Fisheries Research Board of Canada", *Fish. Res. Bd. Can., Manuscript Report Series (Biological)*, 1965, No. 843, Ch. 3-8; Hubbard, "Independent Progress," Ch. 1; K. Johnstone, *The Aquatic Explorers: A History of the Fisheries Research Board of Canada* (Toronto: University of Toronto Press, 1977), Ch. 2-6.
13. E.L. Mills, "Canadian Fisheries Expedition," in *The Canadian Encyclopedia, Second Edition*, 1: 341-342; Hubbard, "Independent progress," Ch. 3.
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    As late as 1950, Sandström's chapter of the report, dealing with dynamic calculations of currents, was still being used at St. Andrews, according to Dr. R.W. Trites, who joined the Atlantic Oceanographic Group there. My thanks to Dr. Trites for this information.
15. J.W. Sandström, "The Hydrodynamics of Canadian Atlantic Waters", in *Canadian Fisheries Expedition 1914-1915* (Ottawa: Department of the Naval Service, 1919), pp.221-346.
16. Hubbard, "Independent Progress," pp.329-343.
17. E.L.Mills, "From Marine Ecology to Biological Oceanography," *Helgoländer Meeresuntersuchungen*, 1995, 49(1-4):29-44.
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21. G.F. McEwen, "A Summary of Basic Principles Underlying Modern Methods of Dynamical Oceanography," Washington, D.C., *Bull. Nat. Res. Council*, 1932, No. 85, pp.310-357.
22. J.P. Brosco, "Henry Bryant Bigelow, the U.S. Bureau of Fisheries, and Intensive Area Study," *Soc. Stud. Sci.*, 1989, 19: 239-264.
23. Extensive correspondence and some of Smith's hand-drawn current charts are in the Henry Bryant Bigelow papers, Harvard University Archives.
24. E.F. Smith, *A Practical Method for Determining Ocean Currents* (Washington, D.C., U.S.

Coast Guard Bulletin, 1926, No. 14), vi + 50 pp.

25. Documented *in extenso* in A.G. Huntsman papers, University of Toronto Archives; and Henry Bryant Bigelow papers, Harvard University Archives.

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Fisheries and Oceanography No. 66. Pacific Biological Station Summary Reports, 1933, 1p; J.P. Tully, "Oceanography of Nootka Sound," *J. Biol. Bd. Can.*, 1937, 3(1): 43-69.

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52. Tully, "Oceanographic Program 1937."

53. Bjørn Helland-Hansen correspondence, Geophysical Institute, University of Bergen. I thank Professor Odd H. Saelen for his help in allowing me to work with this correspondence. Financial problems probably prevented Tully from going to Bergen. T.G. Thompson had a close relation with Clemens and P.B.S., so Seattle must have seemed an attractive alternative. Perhaps too, Tully's marriage in 1938 affected his choice of a graduate school.

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The D.R.B. was established as such in 1946/1947, bringing under one administrative roof the Naval Research Establishment in Halifax and other defence laboratories. The Pacific Naval Laboratory was established by D.R.B. in Esquimalt, B.C. in 1948.

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Little formal documentation of this work exists, though brief accounts are found in P.O.G. and P.B.S. reports during the early 1950s and in contemporary newspapers. Collin and Dunbar used some of the data in their survey of Arctic oceanography.

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70. S. Tabata, "Characteristics of Water and Variations of Salinity, Temperature and Dissolved Oxygen Content of the Water at Ocean Weather Station "P" in the Northeast Pacific," *J. Fish. Res. Bd Can.*, 1960, 17: 353-370.

71. J.P. Tully, "Annual Report," *Fish. Res. Bd Can., Ann. Rpt. Pac. Oceanogr. Group*, 1949, p.1. H.B. Hachey, who had been appointed Chief Oceanographer of Canada under the J.O.C. in 1946, attempted to apply the brakes, or at least to focus the attention of P.O.G.; the Group's report for 1951 states that "priorities assigned by the Chief Oceanographer" were to be Georgia Strait, the offshore Pacific, daily observations (the lighthouse programme) and, finally, incidental studies. Relations between Hachey and Tully were frequently strained. Both had powerful personalities and short tempers. Hachey viewed Tully as attempting more than he could accomplish (interview, Dr. R.W. Trites, 2 June 1993). See J.P. Tully, "Annual Report," *Fish. Res. Bd Can., Ann. Rpt Pacific Oceanogr. Group, 1951*, 1951, p.1.

72. Tully's numerous reports and reviews are the basis of this analysis. See especially Tully, "Oceanographic Program, 1937"; J.P. Tully, "The Program in Oceanography," *Fish. Res. Bd Can., Summary Reports of the Pacific Biological Station for 1939*, 1939, No. 75, 3 pp.; J.P. Tully, "LIGHTHOUSE Project," *Fish. Res. Bd Can., Ann. Rpt of the Pacific Biol. Sta. for 1947*, 1947, Appendix No. 125, p.155; J.P. Tully, "Pacific Oceanographic Group," *Fish. Res. Bd Can., Ann. Rpt of the Pacific Biol. Sta. for 1947*, 1947, Appendix No. 124, p.154; Tully, "Annual Report, 1949"; J.P. Tully, "Review of Canadian Pacific Oceanography since 1938," *Trans. Amer. Geophys. Union*, 1949, 30(6): 891-893; Tully, "Annual Report, 1951"; J.P. Tully, "Oceanography," *Fish. Res. Bd Can., Ann. Rpt for 1951 of the Pacific Biol. Sta*, 1951, pp.181-184; Tully, "Oceanography on the Pacific Coast, 1951"; Tully, "Annual Report, 1952"; J.P. Tully, "Review of Canadian Pacific Oceanography since 1938," *Proc. Seventh Pacific Sci. Congress,* 1953, 3: 1-8, figure; Tully, "Oceanography on Canada's Pacific Coast"; J.P. Tully, "Oceanography along the Canadian Pacific Coast," *Int. North Pacific Fish. Comm. Bull.*, 1955, No. 1, pp.131-138; J.P. Tully, "Oceanography," *Ann. Rpt Fish. Res. Bd Can. 1955*, 1955, pp.115-126; Tully, "Review of the Oceanographic Program"; Tully, "Canadian Pacific Oceanography since 1953"; J.P. Tully, "Fisheries Oceanography on the Pacific coast of Canada," *Fish. Res. Bd Can.*, Pacific Oceanographic Group, Nanaimo, B.C. Memorandum. POG File N6-28-2(3), 5 December 62, 1962, 5 pp + appendix, pp i-iv.

73. Tully's brief introduction to the work of P.O.G. in 1947 (Note 72), includes a diagram of the P.O.G.'s oceanographic program in which oceanography (above) provided information for fisheries, naval, industrial and meteorological research (below).

74. Tully, "Oceanographic Program, 1937," pp.17-18.

75. Tully, "LIGHTHOUSE Project".

76. Tully, "The Program in Oceanography".

77. Tully, "Review of Canadian Pacific Oceanography since 1938," p.891.

78. Tully, "Pacific Oceanographic Group, 1947," p.154.

79. J.P. Tully, "General," *Fish. Res. Bd Can., Ann. Rpt of the Pacific Oceanogr. Group, 1950,* 1950, p.3; Tully, "Annual Report, 1952," pp.1-3; Tully, "Oceanography along the Canadian Pacific Coast," p.131.

80. Tully, "Oceanography on Canada's Pacific Coast," p.10.
According to an early J.C.O. document, "an Oceanographic Group is, in fact, independent of the Director of a Biological Station, but will be expected to conform to the general administrative arrangements of the Biological Station concerned. Administrative facilities of Biological Stations will be made available to the respective Oceanographic Groups" (Appendix "F", p.3. A directive on *The Joint Committee on Oceanography*. In *Minutes of meeting of Executive Committee of the Fisheries Research Board of Canada*, November 18-19, 1948). Personnel of the P.O.G.., depending on their duties, were paid by money from the R.C.N., the N.R.C., or the F.R.B., although it was agreed that the N.R.C. had the responsibility for providing salaries for what was termed "the technical secretariat of each scientific group" (i.e. of P.O.G. and A.O.G.).

81. In 1953-1954, the P.O.G..'s seminar series included "the classical oceanographic subjects with lectures on other interesting scientific topics" ranging from dynamic calculations to music and

diving (P.O.G. Scrapbook - *Pacific Oceanographic Group Seminar Schedule*).

82. Tully, "Annual Report of the P.O.G., 1950," p.7.
Tully or other staff members of the P.O.G. contributed significantly to the teaching program of the U.B.C. Institute of Oceanography until the late 1950's, and the Institute's early research depended heavily on cooperation with the P.O.G. (see Note 65).

83. Tully became the Secretary of the Canadian Committee on Oceanography and a Fellow of the Royal Society of Canada in 1964, and was awarded the Manley-Bendall Prize (the medal of Albert 1er de Monaco) by the Société océanographique de France in 1967. Conventional biographical details are in S. Tabata, "John Patrick Tully 1906-1987," *Atmosphere-Ocean*, 1987, 25(4): 355-357; S. Tabata, "Obituary. John Patrick Tully, 1906-1987," *Can. J. Fish. Aqu. Sci.*, 1987, 44: 1674-1675; and J.H. Tully, "John Patrick Tully, 1906-1987," *Trans. Roy. Soc. Can.*, 1988, Series V, 3: 206-208.

84. Outlined by F. Anderson, "The Demise of the Fisheries Research Board of Canada: a Case Study of Canadian Research Policy," *Scientia Canadensis*, 1984, 8: 151-156; and F.R. Hayes, *The Chaining of Prometheus: Evolution of a Power Structure for Canadian Science* (Toronto: University of Toronto Press, 1973), xix + 217 pp.

85. Tully, "Review of the Oceanographic Program," p.1.

86. Tully, "Review of the Oceanographic Program," p.11; J.D.H. Strickland, "The Primary Productivity and Fertility of the Northeast Pacific and the British Columbia Coastal Waters," *Fish. Res. Bd Can. Progr. Rpts of Pacific Coast Sta.*, 1959, No. 113, pp.13-15.

87. Tully, "Fisheries Oceanography on the Pacific Coast of Canada," p.5.
Some participants (and historians, including myself) see this as the first step in the loss of power by the Fisheries Research Board and its eventual dissolution between 1972 and 1979. The A.O.G. and P.O.G. did not long survive the demise of the F.R.B.; their staff members were incorporated into other federal government scientific groups.

FIGURE CAPTIONS

Figure 1. J. P. Tully (back row, center) and colleagues at the Pacific Biological Station, Nanaimo, British Columbia in 1935. The others include H.J. Hollister (front left) and J.L. McHugh (front right) (from J.P. Tully retirement scrapbook, Pacific Biological Station, Nanaimo, B.C.).

Figure 2. CNAV *Ehkoli* towing an acoustic target in Nodales Channel, British Columbia, in 1949 (from J.P. Tully retirement scrapbook, Pacific Biological Station, Nanaimo, B.C.).

Figure 3. Personnel of the Pacific Oceanographic Group in the 1950's. Included are J.P. Tully (from row left), A.J. Dodimead (front row, second from left), S. Tabata (front row right), H.J. Hollister (back row center), R.H. Herlinveaux (back row, second from right) and L.D.B. Terhune (back row right) (from J.P. Tully retirement scrapbook, Pacific Biological Station, Nanaimo, B.C.).