The Challenge of Navigation to Hydrography on the British Columbia Coast, 1850-1930

William Glover

James Cook and George Vancouver are famous, among other things, for the accuracy and precision of their charts. Their less well-known successors employed to survey the British Columbia coast worked hard to maintain the same high standard. By comparison, the common practice of navigation was sadly lacking. In 1836, for example, the Select Committee on Shipwrecks found that masters' incompetence at navigation was responsible for most British shipwrecks.[1] At first glance, then, it would seem impossible that navigation practised so poorly could present a challenge to the work of the hydrographer, who had justly acquired an excellent reputation. Nonetheless, between about 1850 and 1930 this is exactly what occurred. The challenge is particularly evident in the coastal trade and hydrographie surveying of the pilotage waters along the BC coast.

The challenge had several related aspects, all products of new technology. First, improvements to the compass by Sir William Thomson (later Lord Kelvin) made possible an unprecedented level of accuracy in taking visual bearings to determine position and to steer a more precise course. Second, the change from sail to steam meant that trade routes changed since ships no longer had to favour the middle of the channel; the improved compass made it safer to shape the course closer to land. Third, on the BC coast the advent of steam was necessary for economic expansion and development of previously unsettled areas. To meet the changing needs of the navigator, charts suitable for sailing ships had to be replaced and new routes surveyed.

The task of the hydrographer is to produce charts, sailing directions and tidal information to satisfy the requirements of the navigator. To do so meant overcoming the adversities of geography and climate, both of which are constant factors on the BC coast. The mainland has a coastline of over 7000 kilometres, roughly equivalent to the distance from Halifax to Vancouver on Canada's main east-west highway. In nautical miles, it is roughly equivalent to one and one-half times across the Atlantic from Nova Scotia to Britain via the great circle. But those 7000 kilometres are only just over twenty-five percent of the total. The adjacent islands add more than 10,000 kilometres; the Vancouver Island coast is 3440 kilometres and the islands adjacent contain 2480; while the Queen Charlotte Islands (2320) and the islands adjacent (1200) bring the total to more than 26,000 kilometres (14,800 nautical miles) of coastline. The task of the surveyor is not only to chart the coast but also to plot the navigational hazards that lie off it. In many cases rocks rise suddenly from otherwise deep water. Finding them requires great patience

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and skill. They must be located while confronting currents in narrow channels, such as Cordero Channel or Seymour Narrows, where maximum rates of ten and twelve knots are common. And then there is the weather. On the BC coast fog and rain cause the loss of many working days. In addition to natural hazards, the surveyor must cope with the bureaucracy at headquarters, whether it be the Admiralty or Ottawa.

When in 1857 Captain George H. Richards, RN, received instructions to proceed to Vancouver's Island (as it was then called) to conduct the first detailed survey, George Vancouver's charts from the 1790s were still the best available. By the time the last of the RN survey ships, HMS *Egeria,* was paid off in 1910, steam had replaced sail, the compass binnacle had been materially improved, and the gyro compass was a subject of experimentation. These developments shortened the useful life of any given chart. Improving navigational standards required more frequent surveys. Even before *Egeria was* scrapped, the Canadian Hydrographic Service (CHS) had accepted responsibility for surveys on the coast. Until the introduction of electronic instruments and aerial photography in the early 1930s, hydrographic methods in the area remained largely unchanged from those passed on from Cook to Richards. In this seventy or eighty years, the challenge of the hydrographer to stay ahead of the navigator was at its greatest.

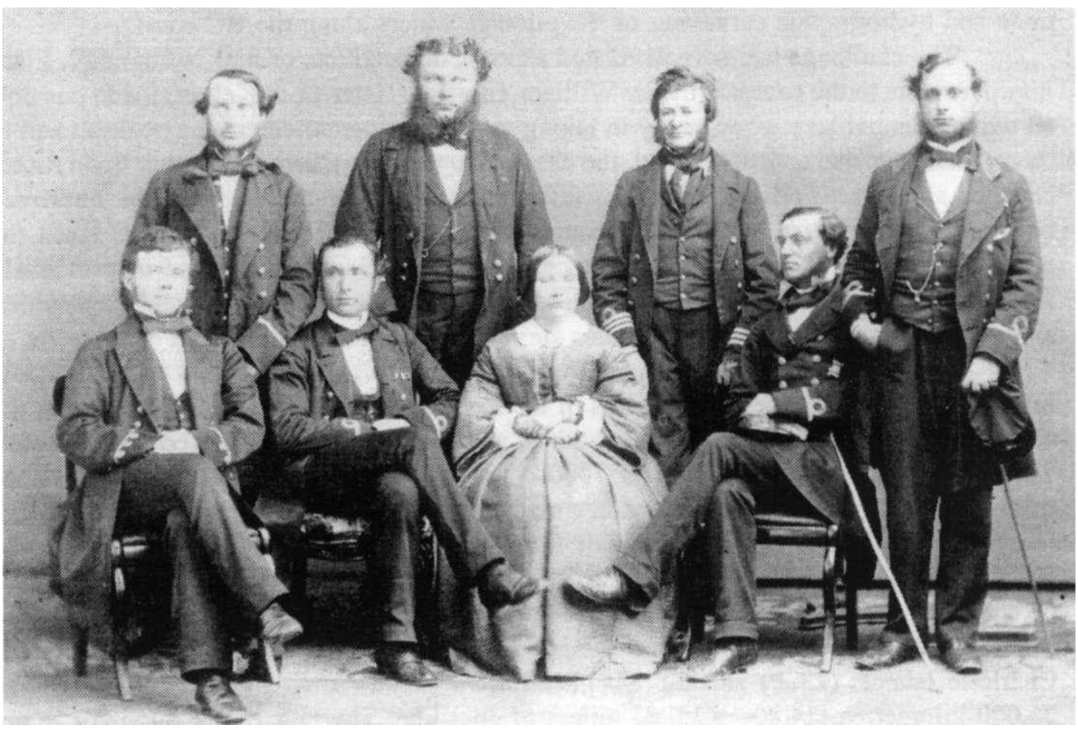

Figure 1: Officers of HMS ***Plumper*** about 1860. Seated (1-r): Sub-Lieut. E.P. Bedwell; 2nd Lieut. R.C. Mayne; Mrs. Richards; and 1st Lieut. William Moriarty. Standing (1-r): Dr. Lyall or Dr. Wood; W.H.J. Brown; Captain G.H. Richards; and Lieut. Daniel Pender.

Source: British Columbia Archives and Record Services (BCARS), photo B-03617.

On arriving at the naval dockyard at Esquimalt in November 1857, the first task facing Captain Richards and his survey ship, HMS *Plumper,* was to assist the International Boundary Commission to find the exact location of the forty-ninth parallel on the mainland coast and the archipelagos of the Gulf and San Juan Islands. Richards was to conduct the accurate survey needed to resolve the dispute between the US and the British colonies. His instructions continued:

> As soon as the work connected with the Boundary Commission matter...is completed and Capt. Prévost [the Senior Naval Officer on the North Pacific station] shall have no longer occasion for your services you will proceed with the survey of the Gulf of Georgia and the harbours of Vancouver's Island according to their importance. Of this you will be a better judge on the spot than anyone here. You will of course be guided by the discovery of coal and the facilities for the supply of our ships.[2]

This work eventually took Richards around Vancouver Island, but not without distraction.

Gold was discovered in the Fraser River in 1858. The Governor, Sir James Douglas, asked the navy to assist in maintaining law and order. In response, Lieutenant Richard Mayne and some men from HMS *Plumper* were detached to Yale in the Fraser Canyon. Further, in January 1859, the ship was sent to Langley, above the delta at the river mouth, as a visible sign of force to the many American vessels proceeding upstream to the gold fields. This interruption concerned Richards, for the day he arrived at Langley he wrote Douglas "that the surveying duties I am employed on render it important that I should return to Vancouver Island with as little delay as possible."[3] Colonial duties diverting attention from the survey would always press on Richards. One comment is particularly revealing. Writing to the Hydrographer, Richards observed that "every vessel or Gun boat that has to move requires a person with some local knowledge, who must of course be got from the Surveying Ship."[4] This is neither a reflection of the abilities of the masters nor a slur on the institutional competence of the RN at pilotage, but rather a more general comment on the contemporary practice of navigation in coastal waters.

To navigate with confidence in unfamiliar waters, a pilot must be able to establish his position on the chart. Assuming an accurate chart, a position can be determined by visual observation with bearings or sextant angles. Today, with the gyro compass the standard in so many vessels, it may be difficult to appreciate the shortcomings of the magnetic compass. The properties of magnetism and how to correct for them were not properly understood until Thomson's studies, which culminated in his patent of a binnacle design in the 1870s.[5] Unfortunately, its expense prevented widespread adoption.[6] Before this, the compass could provide little more than direction, reliable perhaps to eleven degrees. In pilotage waters the navigator learned to rely on leading marks, or transits. Use of a line with a single object as a lead mark has only found acceptance with the widespread adoption of consistently accurate and reliable gyro compasses. In 1850, the reliability of compasses and knowledge of compass error meant that the sextant was more accurate. It was only just starting to be appreciated that compass errors were both correctable and different in the northern and southern hemispheres. Further, different positions in the same ship had distinctive magnetic influences, and therefore distinct corrections were necessary. Yet this assumes that ships had a suitable compass to take bearings. In 1851 regulations were adopted for swinging the steering compass of merchant steamers. But it was not necessarily well-suited for taking bearings, and they were not required to carry an azimuth compass. The other visual method for determining position is by horizontal sextant angles. The station pointer, used to plot them, was developed in 1774. Yet it was still largely unknown over 100 years later.[7]

The 1836 British Select Committee on Shipwrecks had found that "the incompetency of masters and officers" was "sometimes...from the want of skill and knowledge in seamanship, but more frequently from the want of an adequate knowledge of navigation." Some captains had "hardly known how to trace a ship's course on the chart, or how to ascertain the latitude by a meridian altitude of the sun; that many were unacquainted with the use of the chronometer."[8] The report ultimately led to the passage in 1850 of the Mercantile Marine Act, which required that from 1 January 1851 every master and mate of a vessel leaving Britain had to have a certificate of service or competency. The standard for certificates of competency was initially "kept as low as possible," although the intent was to raise it over time. As the exams were for foreign trade only, it is not surprising that the emphasis was on a day's work on the open sea. A master was expected to be familiar with the use of leading lights and an extra master had to be able "to deduce the set and rate of the current from the D.R. and observation."[9] Coastal navigation remained something to be learned from experience. In the RN the courts-martial following the loss of HMS *Impregnable* in 1799 established that in coastal and pilotage waters the captain was absolved of responsibility for the vessel; the master alone was accountable. Yet it was only in 1853 that RN masters were required to pass an examination in navigation.[10] Can it then be surprising that merchant captains and naval masters required assistance when their ships arrived in unfamiliar waters, if the practice of navigation "on the soundings" was by memory? The only challenge that standard presented to the surveyor was the interruption of which Richards complained.

Richards used a survey method of careful triangulation, a practice little changed today. The position of a station was established by astronomical observation and chronometer meridian distance. A base, preferably about a mile in length and across level ground, was measured by steel chain, and from this line a third station was established by sextant angle. The survey continued by adding triangles formed either with prominent geographic features or man-made stations of poles and flags. Sextant angles were taken between all prominent points and stations." Short distances between the stations were measured by timing the interval between seeing the survey ship fire a gun and hearing the sound. Ideally, every ten to fifteen miles a new triangulation base was established.[12] Soundings were taken by hand lead line from open boats. It is worth noting the emphasis on sextant angles, since the magnetic compass was too inaccurate for surveying, even after Thomson's improvements.

In 1863 Richards was recalled to London. The BC coast survey continued under Daniel Pender, using the *Beaver,* chartered from the Hudson's Bay Company. The coasts and important routes were completed in 1870. While Richards was *en route* the Hydrographer, Rear Admiral Washington, died. On arriving in Britain, Richards found he had been nominated to succeed Washington. During his tenure as Hydrographer, he worked to improve the practice of pilotage and to broaden the base of navigational knowledge beyond the specialist navigating branch. "One of the first general improvements that Captain Richards brought about was the provision of an ample supply of charts, bound up in the form of atlases, to the officers of HM Ships...whose knowledge of charts up to this time was generally of the vaguest description." As a result of another of Richards' initiatives, navigation instruction was radically altered. The navigating branch, with its own rank structure, was amalgamated with the executive. Beginning in 1875, all executive branch officers were required as Sub-Lieutenants to qualify in pilotage before they could be promoted to Lieutenant. The syllabus included general navigation, pilotage, and compasses. Perhaps most important in terms of the evolving standard of coastal navigation, the exam was set by the Royal Naval College instead of Trinity House. "A universal knowledge of pilotage [was substituted] for the hitherto limited one of the English Channel." Although some knowledge of the Channel was still required, its weight in the exam was reduced from one-half to less than one-third of the total marks.[13]

Navigation methods evolved slowly in the late 1800s. Change could only be achieved by educating traditionally conservative sailors when new instruments, which made new methods possible, became available. Quick adoption of new techniques was rare. Thomson may have produced a compass capable of greater accuracy, but how well it was used (if it was used at all) depended on the compass card graduation. A suggestion in 1893 that points be removed from the compass card met stiff opposition, particularly from those who worked under sail.[14] To the modern, gyro-trained navigator, the division of a compass card into points seems cumbersome. One point, 111/4 degrees, was divided into quarter points, each approximately 2 3/4 degrees. Each quarter point was known by a name, such as North East by East 1/4 East, which today is 059°. Courses and visual bearings were also given by name. The lack of precision inherent in using such a large unit was compounded by a two-fold possibility for error: magnetic variation and deviation were normally provided in degrees. These had to be allowed for before using a chart. Even if the corrections were properly applied, the name of the heading could be mistaken. Bearings near the cardinal points might have a confusing name change from, for example, North 3/4 East to North ***Vi*** West, a change from approximately 008° to 354°.

Imprecise and awkward as this may seem, it was adequate for navigating sailing vessels, which could not steer an accurate course because of steerage and leeway. Steerage is the error which arises when a course is not steered accurately.

> In a wooden ship a good ordinary compass, with proper precautions to keep iron from its neighbourhood, may be safely trusted to within a half quarter point, but, reckoning the error of even very careful steering by compass, we cannot trust making a course which will be *certainly* within a quarter of a point of that desired.[15]

This represents a minimum margin of error of four degrees, or over one nautical mile, a possible lateral displacement of 400 feet. Leeway, the result of the strength of the wind, is "the angle between a ship's fore-and-aft-line and her wake," or the tendency for the vessel to move downwind slowly from the desired course.[16] Properly, both had to be allowed for in determining the ship's position, but at best they could only be estimated.

The danger of being caught on a lee shore, with the wind blowing a ship on the coast, meant that in a channel a sailing vessel by preference stayed near the middle, where precise fixing would not always be possible. For example, the Strait of Juan de Fuca is fifteen miles wide. From the middle some of the prominent features can be difficult to distinguish in anything but clear weather. In vessels without an azimuth compass, position in all likelihood was determined by hand bearings. The navigator would stand over the compass, swing his arm in the line of an object, and read the bearing off the card.[17] This method likely prevailed as long as sailing vessels were active. Using these methods even a well-trained navigator did not put excessive demands on the hydrographer. But steam introduced a higher standard and created new requirements for navigational information.

The new ships travelled at speeds that made allowance for leeway virtually unnecessary. Their steering mechanisms made accuracy in keeping an ordered course possible, thus removing steerage as a consideration. A compass card graduated in degrees (by quadrant) could take advantage of the improved steering. Hence, within five years of Thomson patenting his new binnacle, steamers frequently steered courses set in degrees rather than points.[18] This was duly reflected in navigational information provided the mariner. By 1888 the Hydrographer allowed new sailing directions to give courses and bearings in degrees magnetic rather than points.[19] The greater control over the ship's heading, and the certainty of steady power, had a major impact on surveying. As Rear Admiral Wharton, Hydrographer of the Navy, wrote in his manual:

> The necessity for these [detailed] surveys increases to an enormous extent every year, with the prodigious strides trade, more especially trade by means of steam vessels, is taking. A steamer works against time; her paying capabilities depend largely on her getting quickly from port to port, and captains will take every practicable short cut that offers, and shave round capes and corners in a manner much to be deprecated, but which will continue as long as utility is an object. A channel which a sailing vessel will work through in perfect safety, from the obvious necessity of keeping a certain distance off shore, for fear of failing wind, missing stays, &c, will be the scene of the wreck of many a steamer, from the inveterate love of shortening distances, and going too near to dangerous coasts only imperfectly surveyed.[20]

Thus, to meet the requirements of the steam navigator, coasts had to be resurveyed more carefully. The new charts which resulted were significantly better than those they replaced. Compass roses, which first appeared on charts in the 1840s, graduated in points magnetic, were changed. Wharton acknowledged the need for greater accuracy than a quarter point in the navigation of some ships, and of the mistakes that could result from having to convert from degrees to points. He therefore began to introduce charts in 1894 with magnetic degrees on the circumference of the compass rose. They followed comparatively quickly on BC charts in 1898.[21]

Still, the use of a magnetic compass for other than directional purposes remained suspect for some time. While it was recognized that compass bearings could be useful to determine position, provided three bearings were taken, the preferred way of fixing position, at least for naval vessels, was by horizontal sextant angles, plotted with a station pointer. It is difficult to determine when a magnetic compass three-point fix became more acceptable; it is easier to surmise the decline of the horizontal sextant angle. Before the First World War the three-point visual fix was treated with varying degrees of scepticism. While it was included in the Sub-Lieutenants' pilotage course at Greenwich, it was also the subject of "learned discussion" in professional navigation journals. During the war gyro compasses were introduced in RN capital ships. The ease and accuracy with which a visual fix could be taken and plotted in comparison with a sextant position was apparent, and became more so as the speed of ships increased. On the other hand, the accuracy of the sextant angle position had always suffered from the chart printing process. Up to 1913 charts were reproduced on paper which had first been specially dampened, and then mounted on linen. The drying of the paper caused some distortion. The result was that sextant angles when plotted on the chart would not always align properly. This distortion drew comment in official publications and was the subject of some discussion at the International Hydrographie Conference of 1929.[22]

How did these navigational developments affect hydrography on the BC coast? In 1871 Richards, in a supplement to a chapter on hydrography in the *Manual of Scientific Enquiry,* wrote that "we find that Vancouver Island has been accurately surveyed, and the whole of the coast line of British territory sufficiently examined for the purposes of navigation." Fourteen years later Wharton, newly appointed Hydrographer, writing an update to the same chapter, added that "the British possessions in Western America are with few exceptions well charted."[23] Yet in the same year, dramatic change was imminent. The Canadian Pacific Railroad was completed. Two years later the railroad company inaugurated a transpacific steamer service to Japan with three secondhand ships, which remained in CPR colours for only a few years until new custom-designed vessels were completed. One of them, SS *Parthia,* made a lasting contribution to hydrography. In 1890, navigating in that manner so deplored by Wharton, it ran aground in Vancouver harbour on the shoal that still bears its name. As a direct result of the grounding William Stewart, assistant surveyor for Georgian Bay and later Chief Hydrographer, was sent to the west coast for the 1891 survey season to examine the harbour. That completed, he returned to the Great Lakes, but the need for new surveys to meet the needs of steamers had been dramatically demonstrated.

By coincidence 1898, when magnetic compass roses first appeared on charts of the BC coast, was also the year that HMS *Egeria* arrived to commence a modern survey of the main steam routes around Vancouver Island. Between the completion of Pender's survey in 1870 and *Egeria's* appearance there had been no regular dedicated system to advance hydrography. For new information the Hydrographer relied on ship submissions. RN ships on station at Esquimalt forwarded hydrographie notes as circumstances permitted. Apart from that, one figure may be said to dominate the 1890s, Captain John Walbran. For twelve years, 1891-1903, he was master of the Canadian Government Steamer *Quadra* and is perhaps best remembered today as the author of *British Columbia Coast Names,* a volume still available in paperback. Wherever his work maintaining navigational aids and marks took him on the coast, if time allowed Walbran tried his hand at surveying. He became a regular correspondent of Admiral Wharton, the Hydrographer in Britain, and Colonel Anderson, the Chief Engineer of the Department of Marine and Fisheries in Ottawa. While his contributions were recognized by the addition of his name as one of the surveyors to a local chart, the quality of his work does not seem to have been consistent. It appears that Walbran taught himself the basics of hydrographie surveying by reading Wharton's book. But he either never had time for proper determination of positions or did not understand the importance of accurate triangulation as a basis for surveys. The sketches which accompanied his notes to the Hydrographer seldom included the sextant angles by which a position was determined. Nor did he always use an established observation station as a reference for his sketch. In some instances the lack of authority which accompanied his notes caused them to be treated with caution.[24] Notwithstanding these caveats, one can see in hindsight that Walbran's work made a significant contribution to the knowledge of navigational hazards on the BC coast.

When *Egeria* reached Esquimalt in 1898, it was already twenty-five years old. Its first task, after a brief refit, was to examine the east coast of Vancouver Island between Baynes Sound and Seymour Narrows. Cdr. Smyth, in his annual return, made clear the reason this area was selected. "Baynes Sound has become of some importance owing to its being the port of shipment for the coal mines situated at Cumberland, about six miles from the coast; it is also being used by Her Majesty's Ships for gun and musketry practice, the naval rifle range being situated at Port Augusta."[25] There were several requests for *Egeria* to survey channels of commercial benefit. The Hydrographer's policy was clear on this point: "*Egeria* is surveying for the requirements of H.M. Ships and that work for colonial requirements is for the consideration of the Dominion government."[26] On the other hand, Walbran, as an employee of the Dominion government, could respond to commercial requests. He forwarded a plan of Oyster Bay, saying it had been "made by order of the Department, at the request of Messers Dunsmuir, the large coal proprietors in this country and owners of new mines and wharves located there."[27]

Admiral Wharton recognized the importance of his department's work for commercial shipping. In 1900, after the immediate requirements of the Admiralty had been met, *Egeria* began to survey the main ship channels. Since Pender had completed the coastal survey started by Richards, commercial traffic had expanded considerably, in no small measure due to the arrival of the CPR. In addition to its transpacific service, the company also operated coastal steamers. Coastal traffic increased considerably as a result of the discovery of gold in the Klondike. In the early 1900s attention turned to the Prince Rupert area and the new Grand Trunk Pacific terminal with its associated shipping. Captain F.C. Learmonth, *Egeria's* commanding officer, noted in 1907 the need to improve the charts of the west coast of Vancouver Island because of the volume of shipping.[28]

The task facing the surveyors, even if limited to the main shipping routes, was revealed only gradually. The Admiralty contemplated paying off *Egeria* in 1900. Later, it was thought 1903 might be the last year, then 1909. As the work moved farther north it took longer because of the weather. Surveying could not be done when fog or heavy rain obscured the triangulation stations. Experience showed it unwise to count on more than three days work per week, and in some seasons even that was optimistic. *Egeria's* age began to tell as the survey extended to the exposed Queen Charlotte Sound. In 1909 Captain Parry reported that "this locality is noted for the very heavy swell that almost invariably sets from the Westward throughout the summer months, and it is a certainty that the ship would be subjected to a more severe strain than she is in a fit state to undergo."[29] Even so, that season the survey worked there and through Hecate Strait.

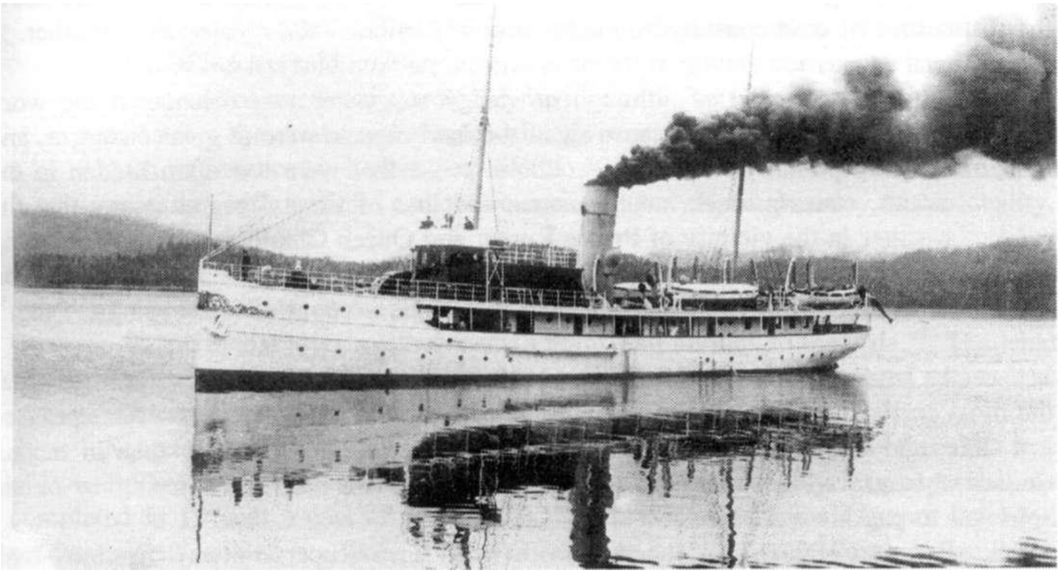

Figure 2: CGS ***Lillooet,*** shortly after building. ***Lillooet*** was one of the first ships purpose-built for the Canadian Hydrographic Service, and was the command of Captain Musgrave.

Source: BCARS, photo F-03551.

A subject of increasing importance during *Egeria's* period on the coast was the provision of accurate tidal information. In 1899 Captain Walbran had forwarded to Colonel Anderson "an amended tide table I have made from observations taken the last few years, showing, when used in conjunction with US Tide Tables for British Columbia, the approximate time of slack current at various places."[30] Using Port Townsend, Washington, or Sitka, Alaska, as primary reference ports, he had developed a rough guide for predicting times of slack water at such important commercial passages as Seymour Narrows and Active Pass. Anderson forwarded the information to Wharton, with a covering letter indicating severe misgivings about its reliability. It is probable that Walbran's observations were forwarded to *Egeria.* Two years later Cdr. Simpson, the new captain of *Egeria,* repeated some of the same information, with amendment, in his draft sailing directions.[31] The first tide tables for the coast were published in 1901, and current tables were added in 1908. Over time more reference ports were added.[32]

By 1908 the CHS had been established. In 1904 Britain had suggested that the dominions might organize their own surveys. Accordingly, Canada created the CHS by combining its existing surveys on the Great Lakes and the railways. Work on the west coast began in 1906 under P.C. Musgrave, a surveyor trained in the RN, who began at the entrance to Prince Rupert, using small boats. In 1908 Musgrave assumed command of the new steamer *Lillooet,* the first vessel built for the CHS, and expanded his survey.[33]

Several navigational challenges faced Musgrave and his new team of assistants. With limited resources they had to establish priorities among the requests for surveys. At the same time they had to fight for acceptance of their charts by coastal mariners. In addition, reporting to a new headquarters, Musgrave had to educate his superiors about the difficulties of west coast hydrography, and in particular those caused by weather.

> I have to report that although no dangerous water was discovered the work proved very difficult because all of the land objects were at great distances, and the only points visible were mountain peaks that were too often hidden in the clouds, causing much inconvenience and loss of time...I regret to say that the weather in the vicinity of Prince Rupert and Queen Charlotte islands is anything but favourable for economical surveying, as the parties are not able to work on an average of more than two days per week on account of wind, rain, and fog.[34]

In fact, the annual returns for the CHS show that in the early years the Pacific survey was the most costly. Larger vessels were required than on the St. Lawrence; weather caused lost time; and the local cost of living, and therefore wages, was higher than in eastern Canada. Musgrave repeatedly had to explain this to Stewart when trying to obtain approval to pay his crew the local wage.[35]

Before 1914, work connected with the Prince Rupert railway terminus took precedence. Slow, methodical hydrographie work revealed errors and filled in omissions from earlier surveys. Time also had to be found for other tasks, some of which were the result of cutting corners. At the end of the 1909 survey season, Musgrave was required to stop in Hiekish Narrows to locate a rock struck by a steamer that summer. It was found 350 feet offshore. In at least one instance it appeared that masters tried to hide from their owners exactly how close to shore they had passed by reporting the rocks they had struck as being in mid-channel. Such deceptions, and the resulting waste of time spent looking for the hazards, were carefully reported to the Dominion Hydrographer in Ottawa.[36]

A number of factors were taken into account when Musgrave planned work for the annual survey season. Experience showed that because of weather it was fruitless to start before early April, and little could be accomplished after the beginning of November. In the winter *Lillooet* was laid up in Esquimalt harbour, and the work moved ashore to drawing offices to make up fair charts and to complete other work. Was there an area of obvious importance, such as Prince Rupert because of the railway terminus, or another place because the survey was old, or charts poor? What facilities did he have available? Having decided on a primary site, what other work might be done? If, for example, he planned to work in the north where the weather was poor, was there an area in the south where he could open and close the season? What areas needed to be filled in so a new chart could be drawn? Did the department have a particular concern? Were local shipping firms asking for a survey? In contrast to Richards who was left on his own, Musgrave had to submit his plans to Ottawa for approval.

The requests had to be considered carefully. How many would benefit, and how far would it take the team from the primary work area? Local decisions always had to be justified to Stewart. As an example, Musgrave wrote the following to his superior about a Kyoquot Sound survey suggestion:

> As the *Macquinna* is the only steamship operating on the west coast of Vancouver island such a survey would not be warranted when so much important work on the main route has not yet been surveyed...Captain Gillam, the captain of the *Macquinna* has told me that the charts are all relatively correct, he has from time to time discovered rocks, and the positions given by him are sufficiently accurate to correct the charts, and this has always been done; there is no one who has had such experience as he has had of the west coast, and if he would furnish the necessary information I can see no necessity for a special survey of the locality.[37]

On another occasion Musgrave quoted the same Captain Gillam that "all the West coast charts by Captain Richards are absolutely accurate, the only drawback to the chart of Quatsino Sound is that it is on rather a small scale, half an inch to the mile."[38] The length of coastline and volume of work meant that many charts of less-frequented areas, in use in the 1950s and later, were on a similar scale.

Sometimes Musgrave was called upon to solve commercial problems. The town of Powell River, with its pulp and paper industries, expanded quickly. The paper mill was completed in 1912 at a cost of $4,000,000 and employed 600 men. It was capable of producing 250 tons of newsprint a day. Yet despite its commercial importance, Powell River was not called a "port" by Lloyd's and therefore ships were unable to proceed directly to or from it. Musgrave was asked by the town to complete a survey and draft a modern description that could be included in a new edition of sailing directions.[39] This would provide port recognition and reduce insurance premiums.

The first west coast chart published by CHS grew from Musgrave's 1906-1907 surveys of the Prince Rupert area. Indirectly this led to an unusual navigational challenge for the new service — acceptance of its product by local mariners, many of whom had been trained in Britain and raised on Admiralty charts. These men would replace the new Canadian charts as soon as they were republished with the Admiralty crest. The Admiralty Hydrographie service, with its world-wide catalogue and regular system of correcting charts through weekly notices to mariners, was respected; CHS was new and therefore suspect. When offered the choice of a small-scale Admiralty chart or a larger-scale chart published by CHS, the former was often preferred.[40] During World War I, Musgrave found that the chart depots at the two naval ports, Halifax and Esquimalt, knew nothing officially about Canadian charts. Indeed, it was suggested that if a warship were to run aground while using a Canadian chart, the navigator would be held responsible.[41] That this situation could have developed is the more extraordinary because CHS was part of the Department of Naval Service. Clearly, the first step was to ensure that the depots were supplied with Canadian charts for issue to naval and merchant ships.

While Musgrave was establishing his office on the Pacific coast, another major development in navigational instruments was unfolding slowly. In 1908 the German navy (followed in 1910 by the RN) began experimenting with the gyro compass. But the first British trials were not for navigation, but for gunnery.[42] The idea of a gyro had obvious appeal for target indication. A master compass was able to drive several repeats in different parts of the ship which would all show the same bearing without need for independent correction. Navigational use followed. By 1918 gyros had been fitted in RN capital ships, but its adoption for navigation outside the service was not widespread.

Figure 3: Pulp and paper mill at Powell River, 1911. Built at a capital cost of $4 million, this was a large commercial enterprise.

Source: BCARS, photo G-06698.

Figure 4: "Beautiful downtown Powell River," 1911. The town dramatically emphasizes the low population on the coast. Today, the highway to Powell River still uses ferry crossings. BC commercial development was dependent on maritime communication.

Source: BCARS, photo G-06688.

The Hydrographer had started to introduce true bearings on the outer ring of the compass rose in 1911. The motive does not appear to have been a wish to stay ahead of navigators, but rather to remove a source of confusion. With the correction for ship's deviation, and annual change in variation, there was considerable room for error when working in magnetic bearings. True bearings solved that problem. Following the introduction of the true compass rose, sailing directions were published using true bearings only. Again there was a time lag before the true compass rose showed up on Canadian charts; the first appeared on west coast charts about 1916-1917.[43] The reason was probably that Pacific coast charts were a low priority for Admiralty printers.

During the First World War an interesting distinction developed between gyro and magnetic compasses in use by the RN. The war had ended the comparative trials between the German Anschutz and American Sperry gyros, and the US became the sole source of supply. Sperry compass cards were graduated from 0° to 359°, while British magnetic compass cards remained in degrees by quadrant, another source of confusion. It is an example of conservative resistance to change not overcome until wartime pressure from the RCN prompted adoption of the 07359° marking after the Second World War.[44]

The increasing pressures of the First World War forced Musgrave to confine his surveys for 1918 to Victoria and Esquimalt harbours. With the cessation of hostilities, the west coast survey resumed full operations. During the 1920s the major impetus was the expansion of the coasting trade. If any reminder was needed of the incomplete knowledge of the coast, it was provided by the almost regular monthly discovery of a new rock when a ship struck it.[45]

The work continued throughout the 1920s. The 1930s, however, introduced further technical change to the CHS. In 1928 CGS *Acadia* was fitted with a gyro compass and echo sounder for work in Hudson's Bay. This experiment was highly successful: the gyro simplified observations for magnetic deviation and "was found...most satisfactory and a valuable acquisition to this vessel's charting and navigation equipment."[46] The echo sounder was to have results little short of revolutionary. Automation of a laborious manual task meant that the daily area of soundings could be almost doubled. As a result, similar equipment was fitted in CGS *Lillooet* in 1930.[47] Widespread use of aerial photography on the BC coast resulted in a thirty to forty percent reduction in the time required to produce finished charts and, in 1933, the fitting of radio acoustic ranging was confidently forecast as another technological innovation.[48] With the introduction of this equipment for surveying, and with aerial photography and Radio Acoustic Ranging to follow, the hydrographer enjoyed a technical superiority over the navigator, which enabled the surveys to progress faster and to better meet the expanding needs of commerce.

The navigator, on the other hand, does not seem to have embraced the new technology as rapidly. In particular, it took considerable time for the gyro compass to penetrate coastal shipping. Even after 1945 the Union Steamship Company, one of the larger west coast shipping firms, removed the fitted gyros when converting three surplus RCN corvettes to commercial use. No one in the company had any experience with gyros, the equipment was bulky, and the power requirements were awkward. There was no perceived need to fit more modern units.[49] One possible reason may be that the improved accuracy of the gyro was not justified by the expense. After all, the unit of measurement remained the degree.

The early 1930s, then, marked a watershed in the challenging relationship between the navigator and hydrographer. In the late nineteenth century, navigators led hydrographers, and the expansion of trade severely tested the latter's resources. In the 1930s, the hydrographer had found the necessary new tools to meet the demands of trade, while the navigator, essentially conservative, stood still. What may one deduce from this relationship during the period from Richard's survey to the early 1930s? The dominant force was surely commerce. Sailors went to new coastlines in search of trade, an expansion of maritime activity that required new charts. Trade was limited until the charts and other information had been provided by the hydrographer. Without the surveys, commercial risks were much higher.

The adoption of steam also played a vital role. Without the fundamental changes forced by new technology, the navigator would never have overcome tradition and accepted the Thomson binnacle and compass cards in degrees. Steam put a value on time that brought the shipping routes inshore and created a need for greater accuracy by both the navigator and the hydrographer. The gyro, developed at a time when there was no powerful incentive for change, was ignored by the navigator for much longer. It was the hydrographer, seeking the means to meet the requirements of the navigator, who accepted the new electronic equipment.

The period 1850-1930 was a time of challenge for the hydrographer. The practice of navigation demanded more accurate charts and better information. The expansion of trade along the BC coast required charts of areas never surveyed and better charts where the surveys were old. The hydrographers of both the RN and the new CHS succeeded in meeting the challenge presented by the requirements of navigation.

NOTES

* William Glover is a Lieutenant Commander in the Royal Canadian Navy in command of HMCS ***Prévost*** and a Vice-President of the Canadian Nautical Research Society. He has first-hand knowledge of the BC coast from navigating HMCS ***Mackenzie.*** Previous versions of this essay were presented to the annual conference of the Canadian Nautical Research Society on Galliano Island in 1986 and at the Second International Congress of Maritime History in Amsterdam in June 1996.

1. "Report of the Select Committee on Shipwrecks," ***Nautical Magazine,*** V (1836), 592.

2. British Columbia Archives and Record Services (BCARS), GR 284, "Hydrographie Instructions for Captain George Richards to Proceed to Vancouver's Island," 10 March 1857.

3. Great Britain, Public Record Office (PRO), Admiralty (ADM) 1/5714, Richards to Sir James Douglas, 12 January 1859.

4. Ministry of Defence, Taunton (MOD), Hydrographie Department (HD), Captains' Letters, SL 39, Richards to John Washington, 18 March 1861.

5. Thomson determined that the directional capability of a magnet was a function not of its mass but of its surface area. Further, he found that the steadiness of the compass card was dependent not on its weight but on the period of its movement. Accordingly, he developed a card that was as light as possible, and attached to the underside four thin magnets. This reduction in weight, combined with more effective magnets, meant that the card was steadier and more accurate. He also made considerable advances in the practical method of correcting a compass for the deviation caused by a vessel's magnetic field. Finally, his binnacle was self-contained and lockable, so only the individual holding the key could adjust the correcting magnets. He also invented an azimuth circle fitted with a mirror that greatly facilitated taking the bearings.

6. Captain S.T.S. Lecky, ***Wrinkles in Practical Navigation*** (20th ed., London, 1920), 11.

7. A.E. Fanning, ***Steady As She Goes: A History of the Compass Department of the Admiralty*** (London, 1986), 25; A.H.W. Robinson, ***Marine Cartography in Britain*** (Leicester, 1962), 64; and Lecky, ***Wrinkles,*** 137.

8. ***Nautical Magazine,*** V (1836), 592.

9. ***Nautical Magazine,*** XX (1851), 37-41.

10. Vice Admiral B.B. Schofield, ***The Story of HMS Dryad*** (Havant, Hamps., 1977), 12 and 14.

11. It is worth noting the stress laid on sextant angles for survey work. The magnetic compass was too inaccurate for surveying, even after Thomson's improvements. Commander Edward Belcher, ***A Treatise on Nautical Surveying*** (London, 1835), 3; and Sir Robert Ball (ed.), ***The Admiralty Manual of Scientific Enquiry*** (5th ed., London, 1886), 24. By 1898 the theodolite had generally replaced the sextant for measuring angles from shore stations. But "it must be understood that, ***with care,*** an excellent triangulation may be obtained with that valuable instrument, the sextant." Rear Admiral Sir William Wharton, ***Hydrographical Surveying: A Description of the Means and Methods Employed in Constructing Marine Charts*** (2nd rev. ed., London, 1898), 75.

12. Hydrographie Office, Admiralty, ***General Instructions for the Hydrographie Surveyors of the Admiralty*** (London, 1877), 18; and Henri Delpe Parizeau, "The Development of Hydrography on the Pacific Coast of Canada Since the Earliest Discoveries," ***Proceedings of the Fifth Pacific Science Congress*** (Toronto, 1933), 1262.

13. Commander L.S. Dawson, RN, ***Memoirs of Hydrography*** (Eastbourne, 1885), Part II, 136; and PRO, ADM 13/238, passing certificates in accordance with Circular W., No. 54,24 December 1868, and Circular No. 11, 19 March 1885.

14. Lieutenant J.F. Stuart, RN, "The Advisability of Adopting a Mariner's Compass Card Marked in Degrees Only, in Place of the One Now In Use," ***RUSI Journal,*** XXXVII (1893), esp. 1303-1308.

15. Sir William Thomson, ***Navigation*** (Glasgow, 1876), 62.

16. ***Admiralty Manual of Navigation 1914*** (London, 1915), 39.

17. Joseph James Curling, ***Coastal Navigation: or Notes on the Use of Charts*** (2nd ed., Portsmouth, 1893), 18.

18. Lecky, ***Wrinkles,!.***

19. ***General Instructions for Hydrographie Surveyors*** (London, 1888), 21.

20. Wharton, ***Hydrographical Surveying,*** 52.

21. Vice Admiral Sir Archibald Day, ***The Admiralty Hydrographie Service 1795-1919*** (London, 1967), 126. For Wharton's comments, see Stuart, "Advisability," 1303.1 am indebted to M.D. Cope for his search of the chart collection in the BC Archives, for the date the new compass rose appears on charts of that coastline.

22. ***Notes Bearing On The Navigation of H.M. Ships*** (London, 1891), 8 and 10-12; ***Handbook for the Pilotage Course 1908*** (London, 1908), 19; Admiralty, Hydrographie Department, "Remarks on Position Fixing by Three Cross Bearings," ***Half-Yearly Report On Subjects Connected With Navigation of H.M. Ships,*** No. 1 (July 1910), 9; ***Manual of Navigation,*** 238; Admiralty, Hydrographie Department, ***Pilotage Handbook*** (rev. ed., London, 1917), 7 and 133; and Commodore G.P. Reinius, "Some Results of Experiments in Chart-Printing From Copper-Plates," ***Report of the Proceedings of the First Supplementary International Hydrographie Conference*** (Monaco, 1929), 403-412.

23. ***A Manual of Scientific Enquiry*** (London, 1886), 45 and 49.

24. MOD, HD, "The Pads," BC(A), 1876-1898, and BC(B), 1899-1907, contain all the hydrographie notes and supporting letters for the period. For comments on the weaknesses of Walbran's work, see William P. Anderson to Wharton, 8 May 1895; Anderson to Wharton, 17 May 1899 (with Wharton's minute of 1 June 1899); Anderson to Wharton, 27 December 1899; Anderson to Arthur Mostyn Field, 26 April 1906.

25. Report on Admiralty Surveys for the Year 1898 (London, 1899), 7.

26. MOD, HD, Surveyors' Letters, Morris Henry Smyth to Wharton, 30 September 1898; and Wharton minute, 17 October 1898.

27. MOD, HD, "The Pads," BC(B), Walbran to Stanley, 1 August 1899.

28. MOD, "Annual Return of Survey of North America, West Coast British Columbia and Alaska for the Year 1907."

29. MOD, "Annual Return of Survey of North America, West Coast British Columbia & Alaska for the Year 1906;" National Archives of Canada (NAC), RG 89/404/2140/1, "Hydrographie Survey Report to the Deputy Minister, Dept. of Marine and Fisheries, for the Period 1909-10," 26 July 1910; Surveyors' Letters, John Henry Parry to Field, 11 September 1909.

30. MOD, "The Pads," BC(B), Walbran to Anderson, 29 April 1899.

31. MOD, OD 122, "Discovery Passage and Johnstone Strait." This is a draft set of sailing directions, which includes tidal information for Seymour Narrows (of Ripple Rock fame). Using Sitka, Alaska, as a reference point, Walbran gave a local time for slack water in the narrows as four hours fifty-three minutes after high water. Cortland Herbert Simpson gives the correction as four hours fifty minutes after a high water following the larger range, and 6-6 *Vi* hours after a smaller range at neaps. I have checked both calculations against modern tidal predictions. As a general rule, they seem accurate within half an hour, although Simpson's figures provide a better estimate.

32. R.W. Sandilands, "Hydrographie Charting and Oceanography on the West Coast of Canada from the Eighteenth Century to the Present Day," ***Proceedings of the Royal Society of Edinburgh*** (1971/72), 80.

33. NAC, RG 89/404/2140/1.

34. ***Ibid.***

35. NAC, RG 89/24A/71-72, P.C. Musgrave to William Stewart, 28 June 1917; RG 89/24A/102, 8 November 1916; RG 89/24A/107,15 August 1917; RG 89/24B/107, 17 August 1917; RG 89/24B/149-151, 17 October 1917; RG 89/24B/217, 12 February 1918.

36. "Hydrographie Report 1909-10," 5-6; NAC, RG 89/24B/248, Musgrave to Stewart, 18 March 1918.

37. NAC, RG 89/24B/92, Musgrave to Stewart, 8 August 1917.

38. NAC, RG 89/24C/40, Musgrave to Stewart, 14 February 1919.

39. NAC, RG 89/24C/92, Musgrave to Stewart, 3 March 1919; Henry Taylor (ed.), ***Powell River's First 50 Years*** (NP, I960?).

40. NAC, RG 89/24B/237, Musgrave to Stewart, 6 March 1918. Prejudice against CHS charts continued in British circles into the late 1950s; W.A.B. Douglas to Glover, personal communication, April 1987.

41. NAC, RG 89/24A/332-333, Musgrave to Stewart, 21 December 1916.

42. Captain H.L. Hitchin and Cdr. W.E. May, ***From Lodestone to Gyro Compass*** (rev. ed., London, 1955), 111.

43. Day, ***Admiralty Hydrographie Service,*** 259. For the Canadian information 1 am again indebted to M.D. Cope.

44. PRO, ADM 1/18425.

45. NAC, RG 89/404/2140/3, "Annual Report for the Fiscal Year 1922-23," 13.

46. NAC, RG 89/404/2140/4, "Annual Report for the Fiscal Year 1929-30," 4.

47. NAC, RG 89/404/2140/4, "Annual Report for the Fiscal Year 1928-29," 4; RG 89/404/2140/5, "Annual Report for the Fiscal Year 1930-31," 1-2.

48. NAC, RG 89/404/2140/6, "Annual Report for the Fiscal Year 1932-33."

49. Captain C.G. Mcintosh (retired Master on the BC Coast), Interview, 20 July 1986.