Charting Marine Pollution Science:

Oceanography on Canada's Pacific Coast, 1938-1970

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Arn Keeling

Abstract:
In drawing attention to how 'place' situates and configures scientific practice, recent scholarship examining historical geographies of science tends to overlook how natural places shape scientific ideas, practices and institutions. This paper suggests that environmental factors may be conceived in terms of the interplay of 'site and situation' in environmental science. It examines the pioneering marine pollution research program developed at the Fisheries Research Board of Canada's Pacific Biological Station in Nanaimo, British Columbia. Beginning with an analysis of pulp mill effluent in Alberni Inlet on Vancouver Island, oceanographers at the station undertook studies aimed at minimizing threats to commercial fisheries from aquatic pollution on the B.C. coast. As a key site of pollution research, Alberni Inlet was situated within a variety of environmental, institutional and social contexts: the politics of resource exploitation in B.C., institutions of fisheries research and regulation, and the disciplinary practices of marine pollution science on the Pacific coast. By the 1960s, the board's Pacific Oceanographic Group had developed a leading research program in marine pollution science, and the Alberni experience formed the basis for a coast-wide inventory of environments receiving industrial wastes. Oceanographers framed pollution control in terms of 'assimilative capacity,' or the ability of natural waters to dilute, disperse and absorb industrial wastes without harm to valuable commercial fish species. As subsequent pollution problems revealed, however, this instrumental approach to environmental management tended to ignore ecological complexity and variability, and the unforeseen consequences of engineering natural systems as waste sinks.

INTRODUCTION: SCIENCE, SITE AND SITUATION

In a 1962 reflection on the rapid growth of marine pollution studies on Canada's Pacific coast, Fisheries Research Board of Canada scientist Michael Waldichuk declared that 'our oceanographic approach to pollution problems has achieved our primary aim of finding means of pollution prevention.' Beginning with a study of pulp mill pollution at Alberni Inlet on Vancouver Island, oceanographers based at the board's Pacific Biological Station undertook a variety of surveys and assessments aimed at minimizing the threat to commercial fisheries from aquatic pollution on the B.C. coast. By the 1960s, the station's Pacific Oceanographic Group had developed a leading research program in marine pollution science. Studies of water circulation and waste diffusion, Waldichuk contended, helped companies and communities refine industrial and domestic waste disposal plans to ensure 'dilution and dispersion of the pollutant to safe levels.' Waldichuk considered this approach preferable to a 'biological attack' on the problem, which he felt would have become mired in political and scientific disputes over attributing changes in biological communities to pollution. After all, only in extreme cases was all life extirpated from polluted marine waters.[1]

Waldichuk's assertion framed oceanography as a natural and authoritative scientific response to aquatic pollution and the conflicts it generated. In fact, the development of the oceanographic pollution research program at the Pacific Biological Station reflected a constellation of social, geographical and environmental factors. The growth of the pulp and paper industry on the B.C. coast after the Depression posed grave new environmental threats to the province's valuable Pacific salmon fishery. The involvement of fisheries scientists, particularly oceanographers, in addressing these threats through research and regulation was conditioned by various local institutional and environmental circumstances. Drawing from the recent scholarly emphasis on 'locating' science within its geographical contexts, this paper examines how 'site and situation' shaped pollution control research on the B.C. coast, and suggests that historical-geographical factors influenced scientific approaches to environmental problems. The case of pollution oceanography indicates the need for historical geographies of science to attend not only to how the social, political and cultural aspects of 'place' shape scientific ideas and practices, but also to how these ideas and practices are influenced by the environmental conditions they encounter.

Geographers interested in the analysis of science as a socially and historically situated activity have advocated more sustained attention to how space and place configure scientific knowledge and practice at a variety of scales. As David Matless notes, 'geographical variation, in its most conventional senses of location, site and situation, has become a means for practitioners of a number of disciplines to exercise [a] more or less relativistic critique.'[2] Appealing to a range of theoretical perspectives from the sociology of scientific knowledge to actor network theory and constructivist epistemologies, David Livingstone suggests that 'place matters in the way scientific claims come to [be] regarded as true, in how theories are established and justified, in the means by which science exercises the power it does in the world.'[3] Livingstone goes on to outline at least three significant geographical factors that influence science, including site, region and circulation. In Livingstone's formulation — and that of much historical geography of science — the conception of 'place' is rooted in the social, cultural and even textual spaces of scientific endeavour.[4] Thus, while drawing attention to geographical influences on scientific production, communication and reception, he abjures the notion, advanced by the geographer Howard Dorn, that physical environmental factors condition or determine scientific enterprise.[5] Even in his discussion of the 'field' in science, Livingstone highlights the sociological characteristics of extra-laboratory endeavours, rather than their embeddedness in the natural world.

This emphasis on the cultural and social geographies of knowledge production privileges the representations and practices of scientists, devoting rather less attention to the natural spaces and phenomena which they study and engage. This may reflect, in part, the emergence of much of this literature from theoretical and philosophical debates around the social construction of nature and the production of scientific knowledge.[6] This paper, while acknowledging the force of these critiques, proposes a more modest goal: to explore how scientific efforts to understand and control the non-human world reflect historical, place-based interactions between humans and 'material nature.' As Simon Naylor has suggested, empirical, place-based studies (such as this one) can serve to ground theoretical ideas about knowledge creation and circulation by situating them within 'the spaces and times they are being used to unpack.'[7] For example, in their study of the intimate personal and scientific spaces of the ecologist and artist Marietta Pallis, David Matless and Laura Cameron illustrate how acts of scientific 'place-making' highlight the interaction of scientific networks, 'particular formulations of the natural' and specific landscapes — in this case the highly symbolic pool in east Norfolk that served Pallis as both a pleasure ground and fieldwork site.[8] This paper, in focusing on scientific activities conducted for public agencies and devoted to illuminating environmental or resource-use problems, will highlight the 'particularities of location,'[9] both in terms of local institutional and political contexts as well as physical environmental factors, in shaping scientific solutions to environmental conflicts.

For environmental scientists in particular, 'natural places are not just neutral stages for scientific activity, as laboratories are, but are themselves objects of study, part of the action,' as Robert Kohler observes.[10] Kohler's work reminds us that the spaces and places in which field science is practiced are dynamic natural ones, occupied and to a degree shaped by non-human forces and things. Environmental historians studying how science influences social reactions to environmental problems are keenly aware of the interplay between natural processes and scientific and social perceptions of nature. Scientific ideas and practices are important for environmental historians because, in the twentieth century, they became the main methods by which environmental conflicts were studied, debated and (possibly) resolved. Studies by Christopher Hamlin, Nancy Langston and Arthur McEvoy, for instance, have devoted particular attention to how scientific language and ideas formed a contested idiom of environmental politics and debates.[11] As Matthew Evenden has recently demonstrated, local social and ecological circumstances play a significant role in the scientific dimensions of environmental controversies. In a series of articles, as well as his book *Fish versus Power*, Evenden explores how scientific debates and prescriptions around salmon fisheries in British Columbia reflected important geographical and environmental influences, from the spawning behaviour of anadromous Pacific salmon to the complex and dispersed Native and commercial fisheries. Analysing fish-tagging experiments on the Fraser River, Evenden asserts that 'scientists not only frame nature according to dominant questions and concerns, but also that shifts in the natural world can affect the operation and implications of science. Scientific ideas are not simply discursive constructions; they also represent complex relationships between humans and the rest of nature.'[12] Human perceptions of nature, including scientific ideas, reflect not only cultural and social geographies, but the material circumstances of particular places and environments.

Integrating these perspectives from environmental history and historical geography, this paper provides an empirical exploration of 'site and situation' in environmental science. The 'environmental' qualifier is used to indicate explicitly the focus of this study on scientific activities undertaken primarily, though not necessarily exclusively, to address environmental problems or conflicts. The use of the geographical terms 'site and situation' captures the relational qualities of the idea of 'place' while maintaining a tight focus on material and discursive interactions within particular natural environments. For the purposes of this analysis, site is defined as a specific place or environment that is the object or location of scientific study; situation, in turn, is the social, political and environmental context of the site. As spatial categories, site and situation must be regarded as historical and mutually constitutive. A 'site' is not a pre-existing physical space or a mere statement of locational co-ordinates, but is defined in relation to its being externally framed and bounded, in rather the same way 'place' is. More than fixed locations, the geographer Trevor Barnes reminds us, places must be conceived as 'porous and incomplete, shifting in relation to the various changing associations out of which they are constituted.'[13] In this sense, the definition of a site depends critically on 'situational' elements, just as the 'field' as both an object and milieu of study is constituted through scientific discourse and practice. But situation, too, is determined in relation to the site(s) being situated; it is delineated through an analysis of the connections, orientations and interactions between particular sites and various individuals, institutions and processes. Thus, these concepts allow for the integration of 'networked' perspectives on scientific practices, by tracing how sites and their representations circulate and are transformed within various situational contexts. Site and situation can also integrate questions of scale, not only through the consideration of how site and situation are mutually constituted, but also since what is defined as a site at one scale may be regarded as situation at another, and vice versa. These terms thus help bring into focus both the natural spaces of scientific knowledge production, as well as the wider social and cultural contexts in which environmental knowledge is produced, deployed and circulated.

This article examines these questions through the analysis of a key 'site' — Alberni Inlet on the west coast of Vancouver Island, British Columbia — and its situation within a variety of social, environmental and scientific contexts: the politics and geography of resource exploitation in B.C.; the institutions of fisheries research and regulation; and the evolving practices of marine pollution science on the Pacific Coast. Situated at the nexus of forestry and fisheries resources, Alberni Inlet became a focus of regulatory and scientific concern over pollution from a proposed pulp mill. The potential impacts on commercial salmon fisheries influenced the prominent role of fisheries scientists in dealing with pulp mill pollution in B.C. coastal waters, as well as the specific recommendations and strategies they proposed. Using the analytical and representational methods of physical oceanography, fisheries scientists framed the physical characteristics of Alberni Inlet in terms of its 'assimilative capacity,' or the ability of ocean waters to absorb, dilute and disperse industrial wastes without harm to valuable fish species. The apparent success of this effort led to the establishment of a 'pollution investigation group' at the Pacific Biological Station and the development of a coast-wide inventory of environments receiving industrial wastes, based on the Alberni model. As the subsequent pollution problems at Alberni Inlet revealed, however, this instrumental approach to environmental management tended to ignore or elide ecological complexity and variability, and the unforeseen consequences of engineering natural systems as sinks for waste.

SITUATING OCEANOGRAPHY AND POLLUTION CONTROL IN BRITISH COLUMBIA

In 1938, the Bloedel, Stewart and Welch lumber company proposed to construct a sulphite pulp mill at the head of Alberni Inlet. The inlet is a 'true fjord' or estuarial seaway penetrating some 40 kilometres inland from Barkley Sound on the West Coast of Vancouver Island. (Fig. 1) The moderate-sized Somass River discharges to the head of the inlet, creating extensive tidal flats and marshlands. The inlet's physical geography is typical of the province's rugged Pacific coast, which is furrowed by long, narrow fjords surrounded by steep, mountainous and heavily wooded terrain. Like much of coastal B.C., Alberni Inlet boasts a long history of forestry and fishing activity. The Somass River supported a locally significant fishery based on substantial populations of anadromous Pacific salmon and sea-run trout. Alberni was also the birthplace of B.C.'s pulp and paper industry: a small, rag-pulp producing mill operated for a period during the 1890s before closing due to a lack of raw materials.[14] By the early twentieth century, the dense stands of hemlock and fir clothing the slopes of the Alberni Valley supported several large sawmills. The planned pulp mill development sought to capitalize on the recovery of continental newsprint markets and the emergence of new technology allowing for the use of wood waste from the company's Alberni sawmills in pulp and paper production.[15]

This proposal marked the resurgence on the Pacific coast of an industry noted for both profitability and pollution. Lured by generous pulpwood leases and booming export markets, before the 1930s three sulphite pulp mills had been built along the south coast of B.C. and on Vancouver Island.[16] Tidewater locations provided the dual advantage of deep-sea shipping access and easy disposal of effluent to the ocean. The province welcomed these developments, in spite of the notoriety of pulp mills in eastern Canada and the United States as major polluters.[17] The transformation of wood fibre into pulp is a multi-stage chemical process requiring large amounts of fresh water and noxious chemicals to disaggregate cellulose from its chemical binder, lignin. Before the 1960s, a typical pulp mill produced 80,000 gallons of wastewater per ton of pulp produced. The calcium-base sulphite pulping process, at the peak of its popularity in the early twentieth century, discharged an effluent laden with toxic compounds such as sulphides and mercaptans, high acidity and a tremendous volume of organic compounds that depressed oxygen levels in receiving waters. One estimate placed the biochemical oxygen demand (the amount of oxygen consumed due to bacterial action on organic compounds in the effluent) of a 500 ton per day sulphite mill as equivalent to the daily sewage output of nearly two million people.[18] In addition, since the process wasted nearly half the wood fibre processed, massive amounts of suspended and dissolved solids were discharged along with this effluent. After the 1940s, the sulph*ate*, or kraft pulping process spread rapidly, since the process chemicals used could be recovered and reused, whereas sulph*ite* cooking liquors were wasted each time. Still, effluent from kraft mills contained dissolved wood solids, lignin, trace process chemicals and a large volume of chlorine-laced waters used for bleaching the dark 'stock' of kraft pulp. Although mill owners improved plant processes to improve wood fibre recovery and chemical reuse, effluent treatment in the industry was virtually unknown in the industry before the 1960s. Wastewaters were simply disposed of in the nearest body of water.[19]

Like other industrializing societies, British Columbians had long considered the ocean to be an almost limitless 'sink' for wastes; that is, the sheer volume of water and the effect of the tides were assumed to adequately absorb and neutralize almost any amount of waste.[20] As a 'company province,' government resource policies favoured industrial development with little consideration for environmental impacts. The pulp and paper industry represented the cornerstone of the emerging industrial economy on Canada's west coast. The lifting of American tariff restrictions on Canadian pulpwood and newsprint in 1911 had precipitated an industrial boom, and by the Second World War the pulp and paper sector led the national economy in the value of production and employment. Eager to replicate the rapid development of the industry in eastern Canada, provincial governments in B.C. offered massive timber leases and promoted foreign capital investment in the industry.[21] As historian Margaret Ormsby noted in the epilogue to her 1958 *British Columbia: A history*, in spite of the 'despoliation of nature' most British Columbians 'counted as gain' the mines and mills that sprang up in the province's wilderness.[22] With the growth of the pulp and paper industry in the early twentieth century, however, commercial fishing interests grew concerned that, in coastal bays, estuaries and inlets, industrial pollution could affect the migration of valuable Pacific salmon. As they had in cases of the pollution of salmon streams by sawdust and mine tailings, fishermen and salmon packers alerted government fisheries officials about the impending (or existing) threats to commercial fisheries.[23]

Facing environmental damage and resource conflicts from uncontrolled waste disposal, Canadian fisheries officials turned to science for a solution. The involvement of federal government scientists reflected the legal and political context of environmental regulation in Canada. Under the British North America Act of 1867, most direct regulatory responsibility for environmental and resource management, with the exception of commercial fisheries, was vested in provincial governments.[24] Provincial and federal officials frequently clashed over perceived federal intrusions in the sphere of natural resource management, including pollution control. Before the 1960s, effective local government pollution controls were limited to provincial public health regulations, and municipal smoke and sanitation bylaws. Beyond these limited circumstances, industrial pollution was virtually unregulated by provincial governments before the late 1950s.[25] For most of the twentieth century, the most potent statutory control of industrial water pollution in Canada was vested in the federal Fisheries Act, which contained sections prohibiting the deposit of 'deleterious substances' into fish-bearing waters. Administration of the act was somewhat confusingly divided between federal and provincial fisheries departments, based on local arrangements and conditions. In B.C., provincial officials regulated and policed sport fisheries in the interior of the province, while federal fisheries officers promoted and regulated pelagic and anadromous commercial fisheries.[26] There was no other federal legislation for environmental protection, which was legally considered provincial jurisdiction; thus, 'pollution of fish … became the surrogate in Canada for federal protection of the environment.'[27]

The situation of the proposed mill site at Alberni Inlet within the legal, economic and political context of resource and environmental regulation did not in itself ensure effective pollution control. While federal fisheries officials were empowered to prosecute industry for waste discharges that harmed fish, they were reluctant to hamper industrial development. For instance, when a fishery inspector investigated complaints against a Howe Sound pulp mill in 1912, the mill insisted its 'strongly acidic' wastes were amply diluted with wastewaters before discharge, and federal officials relented.[28] In the 1930s, fisheries officials in B.C. appeared to have little definite knowledge of the impact of pulp mill wastes, but generally assumed that ocean currents would disperse wastes before they caused harm. In response to an industry inquiry in 1937 regarding pulp mill development, the federal fisheries minister, J.E. Michaud, wrote that while the Fisheries Act was intended to 'prevent injury to fish life due to pollution of waters ... my Department seeks to place no unnecessary impediment to development of any industry.'[29] In this pro-development era, and in the absence of scientific certainty, research and negotiation, rather than strict enforcement of the Fisheries Act, became the hallmark of the Department of Fisheries pollution policy. Nevertheless, the anticipated expansion of the industry following the Depression prompted closer examination of subsequent developments, beginning with the mill at Alberni Inlet.

Unusually for the period, Bloedel, Stewart and Welch sent an inquiry to fisheries officials in advance of mill construction, seeking advice on pollution control and regulations. The Alberni file was handed to John P. Tully, a chemist recently appointed as the oceanographer at the Fisheries Research Board's Pacific Biological Station (PBS). As the main site of oceanographic and marine pollution science on Canada's Pacific coast, the Nanaimo station (Fig. 2) reflected important aspects of the institutional situation of fisheries science in British Columbia and Canada. Early in the twentieth century, the federal government had established the Fisheries Research Board (FRB), with research stations on the Atlantic and Pacific coasts, in order to bolster the authority of its regulations and to promote 'rational' fishery management. Originally called the Biological Board of Canada, it operated a mobile laboratory beginning in 1889 before establishing its coastal marine biological stations in 1908.[30] Government scientists and visiting university researchers based at the PBS conducted studies of west coast marine biology, the life-history and behaviour of commercial species, and ocean conditions and climatic factors affecting the fishery. They also investigated 'fish cultural' problems such as stream obstructions, spawning conditions and artificial propagation. Similar to American marine laboratories established around the turn of the twentieth century, such as the Marine Biological Laboratory at Woods Hole in Massachusetts, the Scripps Institution in California or the Puget Sound Biological Station in Washington State, the PBS combined both mandated and basic scientific research by both visiting and staff researchers (although the institutional origin and patronage of each differed).[31]

Oceanographic research based at the PBS dated from the 1920s, when visiting University of British Columbia biologist A.H. Hutchinson led a series of 'bio-hydrographic' studies in the Strait of Georgia, an important waterway for transportation, human settlements and fisheries resources.[32] This biological oceanography approach, closely related to Northern European 'fisheries hydrography,' sought to relate environmental conditions in the oceans — their salinity, temperature, tides, and other characteristics — with their biological productivity, particularly of plankton.[33] After 1930, physical and chemical oceanographic research flourished at the Nanaimo station. Physical oceanography emphasized the study of ocean characteristics as they related to the fluid dynamics of ocean waves, water-mass movements, current circulation and meteorological conditions. In addition to these factors, chemical oceanographers focused on aspects of marine chemistry, such as salinity. Like biological oceanography, 'dynamical' physical oceanography was strongly quantitative, and oriented to the mathematical modelling of ocean conditions.[34] As Eric Mills notes, 'each application of the techniques of dynamical physical oceanography during the first four decades of the twentieth century arose out of a specific scientific or practical need'; the primary goal of oceanographers at the PBS remained the determination of ocean conditions as they related to commercial fisheries.[35] The station hired its first full-time oceanographic researcher, chemist N.M. Carter, in 1930. J.P. Tully, a chemist with a B.Sc. from the University of Manitoba, was hired as Carter's assistant shortly thereafter, becoming the lead oceanographer when Carter moved to the FRB's Pacific Experimental Station in Prince Rupert.[36] Wartime innovations in oceanographic instrumentation and methods, along with the many outstanding research questions about the Pacific Ocean, subsequently boosted the growth of Pacific hydrographic and physical oceanographic research in both the U.S. and Canada.[37] Links were strong among Pacific coast oceanographers and fisheries scientists: in fact, the two foremost Canadian Pacific oceanographers, Tully and Michael Waldichuk (a native of Romania), received their PhDs from the University of Washington's Department of Oceanography in Seattle, studying under prominent oceanographer and chemist T.G. Thompson, who was also the director of the Puget Sound research station.[38] Tully formed the nucleus of the FRB's Pacific Oceanographic Group (created in 1943). After the war, this group was linked to multi-agency national and international research efforts through the Canadian Joint Committee on Oceanography. By the 1950s, one observer noted, ‘the best oceanography in Canada, and some of the best in the world, was being done at [the Pacific Biological Station’s] west coast complex.’[39]

Defining pollution at Alberni Inlet

This disciplinary training and institutional setting provided the situation within which the Alberni Inlet site was constituted as a field and object of study by FRB oceanographers. Tully’s investigations of the potential impact of pulp mill effluent on the inlet’s salmon fishery combined traditional physical oceanographic survey practices with his growing interest in mathematical and physical modelling of ocean hydrodynamics.[40] The physical surveys consisted of several water-sampling cruises between 1939 and 1943, conducted aboard a converted fishing trawler contracted for the purpose and later, the station’s own research vessel, the *A.P. Knight*. These cruises yielded data on salinity, dissolved oxygen, pH, temperature and other physico-chemical characteristics, as well as measurements of tidal flows, currents and the effects of the Somass River on water mixing and flushing. These data were plotted on numerous charts and elevations to illustrate the distribution of these key characteristics through the three-dimensional inlet system. Tully also constructed scale models of the inlet for conducting dye tests to determine the behaviour of mill effluent in the environment. Housed in the station’s chemistry building, Tully’s first model, made with ‘plaster of Paris, buckets, pulleys, hoses, an electric fan and parts of alarm clocks,’ measured six feet by four feet and attempted to replicate the effects of winds, tides and river flows on dyes in the water representing the effluent.[41] Tully’s makeshift inlet was the first of several attempts at hydraulic modelling at the station, reflecting his larger interest in ‘experimental approaches to oceanographic circulation.’[42] Tully’s studies (which also formed the basis of his doctoral dissertation) and the eventual publication of his results were delayed by his assignment to the Royal Canadian Navy as a hydrographer in 1943; upon his release from the Navy in 1946, he completed the Alberni study (and his dissertation) in 1948.

While relating estimated water quality conditions to those required to sustain fish life, the Alberni study did not include biological surveys. Rather, Tully's goal was to create a quantitative, mechanistic picture of the inlet's fluid dynamics in order to predict the impact of mill effluent on fisheries and to recommend the location of mill waste outfalls. As he asserted in a report to the Seventh Pacific Science Congress in 1952, 'This research is unique in that it undertakes to evaluate quantitatively the characteristics of an estuarial seaway in terms of river discharge.… It provides a quantitative measure of pollution and shows how it may be evaluated from a knowledge of the properties of the pollutant, and the oceanography of the system.'[43] Based on his oceanographic observations and the chemical characteristics and volume of mill effluent, Tully derived a numerical estimate of pollution (dubbed 'Pmax'), based on the percentage of the minimum dissolved oxygen level in water required to sustain fish life which would be removed due to the biochemical oxygen demand of the effluent. Thus, if 100% of 'Pmax' occurred anywhere in the inlet, the dissolved oxygen level in the water would be depressed below the critical value of 5 parts per million.[44] From these calculations, Tully concluded that oceanographic conditions precluded the establishment of a sulphite mill at the head of the inlet, due to the extreme biochemical oxygen demand of the effluent. Several options were proposed for mitigating the impact of the sulphite waste liquor; after the war, the company, partly in response to these recommendations and partly for economic reasons, chose instead to construct a less-polluting kraft pulp mill near the town of Port Alberni in 1947 (Fig. 3).[45]

Reviewing the initial performance of the mill in 1948, Tully concluded that his research had 'established a workable measure of pollution, defined the tolerable limits, and shown how they can be determined, either before or after pollution occurs, in inlets and rivers.'[46] Tully's researches intersected with contemporary efforts by engineers, chemists and other scientists to model and predict the environmental fate and behaviour of pollutants in the aquatic environment. His work both reflected and informed the technical concept of 'assimilative capacity,' a measure of the ability of natural waters to absorb, dilute and disperse wastes without causing environmental degradation. [47] Beginning in the early twentieth century, sanitary engineers, chemists and pollution-control officials around North America applied this concept to a wide range of river and in-shore pollution problems from domestic and industrial wastes. Rather than blind reliance on the dilution of wastes, these experts promoted reliable, quantifiable measures of water quality and better scientific understanding of the aquatic environment to guide 'safe' industrial and waste-disposal siting. As Hugh Gorman has documented with regard to the U.S. oil industry, pollution-control science, technology and regulation were guided by an 'efficiency ethic' rather than by the explicit goal of environmental protection.[48] Increasingly, the scientific management of waste disposal and assimilative capacity was regarded as central to the efficient and economic utilization of aquatic resources. Indeed, as California's top pollution-control official, sanitary engineer A.M. Rawn, declared in 1959, "Because it can act as a natural treatment system, [the ocean] should be used for this purpose with respect to sewage."[49]

Oceanographic research played a key role in the analysis and exploitation of the ocean's assimilative capacity, especially after the Second World War. Growing pollution problems plagued North American estuaries and shorelines, and Tully's Alberni study was cited as an early model for the application of oceanographic techniques to the practical problem of pollution control.[50] Beginning in the late 1940s, similar hydrographic studies of estuarine dynamics and the effects of pollution on microbial life were conducted in east coast waters by Bostwick Ketchum of the Woods Hole institute.[51] In the 1950s, oceanographers at the Scripps Institution engaged in a wide range of studies relating to radiation in the aquatic environment as part of the American military's nuclear testing program in the South Pacific — studies that, like Tully's, produced both applied knowledge and basic research on ocean circulation.[52] Facing increasing pollution in Puget Sound (a semi-enclosed ocean inlet system near Seattle), in the 1960s oceanographers from the University of Washington joined state and federal pollution control officials in attempting to document the extent and severity of the problem using physical oceanographic techniques. These studies documented the severe oxygen depletion and effluent toxicity in parts of the sound, which was ringed by mainly older, heavily-polluting sulphite pulp mills.[53] Oceanographers' embrace of pollution control as a practical application of their expertise was evidenced in the proceedings of the First International Conference on Waste Disposal in the Marine Environment, held in 1959 at Berkeley, California. Roger Revelle, oceanographer and director of the Scripps Institution, opened the conference by declaring that 'one of the resources of the sea, both actual and potential, is its availability for the disposal of waste products of our civilization.' Revelle and others argued that the scientific planning, not restrictive regulation, was the key to avoiding pollution of the oceans.[54] Notably, the conference volume included a theoretical paper by Tully on estuarine circulation, derived from his observations at Alberni Inlet.[55]

The quantitative methods of physical and chemical oceanography informed this managerial approach to pollution control. Tully's research provided fisheries officials with what David Demeritt calls an 'enframing device,' a formulation that characterized the complex environment of Alberni Inlet in terms of a few key parameters related to pollution control. In his study of the development of quantitative forest measurements around the turn of the twentieth century, Demeritt links statistical methods with the growing influence of scientifically trained foresters and state bureaucracies over forest-conservation practices. He describes how quantitative and cartographic representations of forests advanced particular views of forests as 'objective' truths about natural conditions.[56] Scientific representations allowed foresters across North America to 're-engineer' forest landscapes for the maximization of production under the slogan of 'sustained-yield management.'[57] Analogously, Arthur McEvoy notes that the quantitative methods and sustained-yield theory developed by fisheries scientists at the Scripps Institution and elsewhere in North America appealed to fisheries managers, on the basis that these data appeared to simplify the complex and uncertain conditions of fisheries ecology and seemed '"objective," intuitive, and politically inoffensive' to their constituents in the industry.[58] The main goal in the quantification and modeling of natural systems was control, whether of river flow, forest growth or animal populations; as Martin Reuss has suggested in relation to river research, this managerial imperative brought the 'art' of engineering together with the theoretical world of science.[59] Similarly, by measuring and modeling oceanographic conditions and developing a numerical estimate of pollution ('Pmax'), Tully's study facilitated the mobilization of natural processes for industrial use. In the terms used by James C. Scott, this approach 'simplified' natural phenomena in Alberni Inlet, making the inlet 'legible' and therefore available for bureaucratic control. As Scott's study of 'how certain schemes to improve the human condition have failed' demonstrates, quantitative measures of natural (or social) phenomena glossed the policies of the managerial state with the patina of scientific authority.[60] Nominally undertaken in service of fish protection, the oceanographic surveys of Alberni Inlet provided a scientific rationale for the exploitation of the aquatic environment in service of waste disposal.

In this sense, research at the Alberni Inlet site reflected its situation within politics of resource exploitation and pollution regulation in British Columbia, as well as the ideas and practices of government oceanographers. This research reflected the applied emphasis of oceanography at the Pacific Biological Station, which 'faced the task of describing the sea as an environment for fisheries, as a physical medium for the navy, as a sink for sewage for social purposes, and as a source of raw materials for industry.'[61] Although it both drew from and informed 'basic' scientific questions and methods in oceanography, from estuarine circulation to hydraulic modeling, Tully's studies were geared principally towards solving site-specific engineering and regulatory problems. Similar connections between research sites and the development of scientific concepts are illustrated by the emergence of the idea of the 'carrying capacity' of a wildlife range. As Christopher Young has shown, the celebrated studies of wildlife problems on Arizona's Kaibab Plateau in the 1920s and 1930s pioneered this concept long in advance of its theoretical deployment by ecologists in the 1950s. Young suggests the Kaibab case illustrates how 'practice and theory are part of a dynamic interaction,' and that attention to the field practices of early wildlife biologists reveals the complex social, political and — I would suggest — geographical contexts in which such ideas were worked out.[62] Amidst jurisdictional conflicts and the conflicting demands of local resource users, agencies such as the National Parks Service and the Forest Service sought to strengthen and deploy the 'scientific' idea of carrying capacity to justify their at-times divergent management strategies. As at Alberni Inlet, the situation of the Kaibab Plateau site (bisected as it was by a national forest/national park boundary) in geographies of resource management shaped biologists' approaches to its particular environmental conditions and problems.

Marine pollution science at the Pacific Biological Station

Thus far, I have examined how the natural environment of the Alberni site was enframed and defined by its situation within a variety of institutional, regulatory and disciplinary contexts. But this influence was not unidirectional, and this site, in turn, also reshaped situational factors. The scientific and regulatory strategies worked out at Alberni Inlet formed the blueprint for subsequent approaches to pollution control research and regulation by fisheries officials. The threat of widespread pollution from the expanding pulp and paper industry, and the perceived success of the Alberni project, stimulated the creation of a 'pollution investigation group' within the Pacific Oceanographic Group in 1954, headed by physical oceanographer Michael Waldichuk, the first fisheries scientist in Canada specifically designated as a water pollution researcher. Under Waldichuk, pollution research grew into a major aspect of the FRB's oceanographic program in the Pacific in the 1950s and 1960s.[63] Using the methods and principles developed by Tully at Alberni Inlet, Waldichuk launched an 'oceanographic inventory of B.C. coastal waters receiving industrial wastes.' This project addressed the practical need to evaluate the growing number of mill developments along the coast; by the end of the 1950s, the number of coastal pulp mills in B.C. reached ten, double the number at the end of the Second World War. All ten locations of existing or proposed mills were surveyed between 1954 and 1961, in order to assess current conditions and forecast the effects of pulp mill wastes. These 'synoptic surveys' generally involved oceanographic studies and the annual or biennial sampling of physical and chemical conditions at each location. This information was used to advise industry on the location of mills and their outfalls so that 'pollution would not create a serious hazard for the fisheries.'[64] It was also intended to provide baseline data to detect and monitor future degradation of the marine environment.

Based on these studies, Waldichuk developed an oceanographic classification system for the evaluation of pollution threats from marine effluent disposal. This systematic approach, promoted widely in Waldichuk's many publications on pollution oceanography in the 1960s, underlined the spatial and geographical strategy of waste disposal and pollution control based on the scientific measurement and exploitation of assimilative capacity. He divided B.C. coastal waters into four types: fjord-type inlets with fresh-water inflow (such as Alberni Inlet); inlets without significant fresh-water inflow (such as Neroutsos Inlet on northern Vancouver Island); partially-enclosed embayments (such as Wainwright Basin at Prince Rupert); and tide-swept channels (such as Discovery Passage near Campbell River). Each of these idealized coastal environments exhibited characteristic features, from tidal effects and water circulation to water temperature, salinity and fresh-water runoff. (Fig. 4) These environments were appraised for their assimilative capacity and their physical ability to disperse wastes. As in the case of Alberni Inlet, Waldichuk's systematic approach made these environments 'legible' for the purposes of waste disposal planning. While he recognized that each specific mill location posed unique geographical problems, Waldichuk intended his classification system to offer at least a preliminary basis for recommending waste disposal practices.[65] As Waldichuk told industry representatives in 1960, the pollution oceanography project sought to provide a 'reasonable threshold' of water quality protection through 'rational' engineering of waste disposal.[66]

While Waldichuk's studies yielded concrete suggestions for mill siting and outfall design, they also uncovered serious pollution problems already existing on the coast. Surveys documented significant environmental deterioration at two locations: Neroutsos Inlet and Wainwright Basin. Waldichuk surveyed Neroutsos Inlet on north-western Vancouver Island, site of the remote Port Alice sulphite mill, in advance of a mill expansion in 1956-57. A previous study of the inlet in 1927 by FRB biologists had dismissed local fishers' pollution complaints, but the 1956 survey revealed long-term degradation of the marine environment from 40 years of uncontrolled sulphite waste disposal. The effects included low dissolved oxygen levels in parts of the inlet and the obliteration of the pink salmon run (although other species of salmon continued to migrate through the inlet).[67] At Wainwright Basin near the town of Prince Rupert on the central mainland coast, fisheries officials had approved the construction of a sulphite pulp mill some years previous, believing that ocean currents would disperse the effluent. However, a 1961 survey revealed 'an advanced state of pollution' in the basin. For more than a decade, the mill had discharged untreated wastes to semi-enclosed bays connected to each other and to open water via narrow, shallow channels. Poor circulation in these waters meant waste sulphite liquor remained trapped, depressing dissolved oxygen levels to near zero in some areas. Biological surveys indicated that a stressed and possibly simplified biotic community remained in the bay. Although a productive in-shore herring fishery had recently begun in the area, Waldichuk suggested that degenerating aquatic conditions would ultimately threaten this fishery, as well as the Skeena River salmon runs passing through these waters.[68] Despite these conclusions, pollution continued unabated at Prince Rupert and Port Alice for years while fisheries officials negotiated process improvements with reluctant mill owners. Political and economic considerations in these remote, industry-dependent communities ensured that although its own scientists documented pulp mill pollution at various locations, the Department of Fisheries appeared no more likely than before to prosecute industry for the discharge of 'deleterious substances.'

Still, the oceanographic research remained an important practical response to the growing number of pollution problems threatening the B.C. coast. By 1965, the pollution investigation group numbered four full-time staff and one seasonal assistant. Pollution research at the station expanded to include studies of the chemical constituents of pulp mill wastes and biological studies of the toxicity of effluent to fish.[69] Research into environmental conditions also contributed to the development and evaluation of technical waste disposal methods, such as mill outfall location and the use of submarine effluent diffusers. In addition, FRB oceanographers applied the techniques and approaches to ocean effluent disposal pioneered at Alberni Inlet to investigations of sewage disposal plans for the coastal cities of Nanaimo, Vancouver and Victoria. As with pulp mill research, this information was used to redesign sewerage and drainage systems to more effectively exploit ocean waters as a sink for domestic wastes.[70] While the pollution group continued to respond to problems as they arose with 'synoptic surveys,' it also undertook longer-term projects, such as the Fraser River Estuary Monitoring Program, which conducted annual surveys of water quality in the rapidly urbanizing Strait of Georgia/Fraser Estuary region near Vancouver.

Developed in response to local environmental problems, the expanding pollution program at the Pacific Biological Station came to influence marine pollution research both nationally and internationally. By the time pollution became a focus of national public concern and government policy in the mid-1960s, oceanographers and other scientists at the west coast complex had already established a leading pollution-control research program.[71] As historian Frances Anderson chronicles, pollution became a national priority for the FRB only after 1966, the year of a highly publicized Canadian Council of Resource Ministers conference on pollution. Notably, it was J.P. Tully, in his capacity as oceanographic consultant to the chairman of the FRB, who called for the expansion of research into complex industrial and agricultural chemicals and the effects of pollution on plants and fish, as well as how to reduce these effects by waste treatment.

In 1969, the federal Minister of Fisheries Jack Davis explicitly mandated pollution study as a major priority of the FRB.[72] The experience gained by Waldichuk in the 1950s and 1960s helped launch his subsequent career as national and global marine pollution expert. In one instance in the early 1960s, Waldichuk was called upon to consult on the location of a tidewater pulp mill in Scotland. A prodigious publisher of scientific papers and reports, in 1971 he was appointed the head of the newly established Pacific Environmental Institute in Vancouver, a marine environmental research laboratory. In the 1970s, he also advised or served on a number of national and international marine pollution working groups and technical committees, including the United Nations Joint Group of Experts on Scientific Aspects of Marine Pollution and the London Convention on Marine Dumping.[73]

Mastering the aquatic environment

But while the model of waste disposal planning pioneered by oceanographers at Alberni Inlet informed institutional and scientific directions at the Pacific Biological Station, the physical environmental conditions of the site proved difficult to master. Ongoing monitoring of the inlet revealed that the goal of forecasting pollution had proven elusive, as already by the mid-1950s, water quality problems emerged. Initially, mill waste was discharged via an open channel across the swampy tidal flats at the mouth of the Somass River, a situation which threatened to create intermittent toxic concentrations of effluent, particularly during periods of low river flow.[74] Twice the company was prevailed upon to relocate the outfall to where the effluent would mix more effectively with receiving waters. Although annual follow-up surveys of Alberni Inlet found ample dissolved oxygen levels in the water, a proposed mill expansion in the mid-1950s that would double pulp production and add a newsprint mill raised concerns about the dilution and dispersion of increased volumes of effluent, particularly during periods of low river discharge. To combat this problem, a dam and storage reservoir was constructed on the Somass River to ensure a consistent freshwater flush for the inlet.[75]

While this solution appeared to solve the problem of maintaining oxygen levels in the surface waters and estuary of Alberni Inlet, new problems soon appeared on the inlet floor. At this time, even the more-efficient kraft pulp mills wasted 10-25% of the wood fibres they consumed.[76] Massive accumulations of sludge and waste fibres from the Alberni pulp mill and neighbouring sawmill coated the bottom of the inlet and harbour near the outfall. In his initial study, Tully had anticipated these deposits but dismissed them as inconsequential. Instead, they proved to be damaging. In September 1956, a dredging operation in Alberni harbour stirred bottom sediments, which released toxic hydrogen sulphide from the decomposing fibre beds, killing thousands of fish in the vicinity.[77] Of still greater concern than this episode, however, was the discovery that decomposing wood fibre on the sea floor gradually reduced in oxygen levels at depth, leaving an increasingly thick bottom layer of deoxygenated water in which fish could not survive. In his 1960 pollution report, Waldichuk speculated that a peculiar set of environmental conditions — such as a long dry spell (which reduced river-replenished oxygen levels in the surface layer), combined with the disturbance of this bottom layer — could result in a catastrophic fish kill or block fish migration.[78] Indeed, annual surveys at Alberni began to reveal that, even with the control of the river's discharge, the considerable interannual variation in climatic conditions had a major impact on the ability of the inlet to absorb wastes. Warm, dry summers resulted in poor conditions at all depths in the inlet; cool, damp summers ensured ample runoff and adequate replenishment of oxygen levels. The long-term deposit of organic wastes on the inlet floor, interacting with climatic factors, had resulted in the overall degradation of fish habitat. Alarmed by these conditions, in the late 1960s fisheries officials pressured the mill's new owner, Macmillan Bloedel, to install clarifyers and screens to recover more of the solids from the effluent. Ironically, this process may have resulted in increased air pollution, as the recovered waste fibres were used as hog fuel in boilers that spewed fly ash into the atmosphere, infuriating Port Alberni residents. By 1970, 25 tons per day of wood solids were being recovered, and the mill owners announced further plans to install an aerated lagoon effluent treatment system to reduce biological oxygen demand — a first for tidewater mills in B.C.[79]

At Alberni Inlet, oceanographic research aimed at preventing pollution became implicated in the re-engineering of nature as a sink for industrial wastes. Tully's reductionist, quantitative representations of inlet waters contributed to the notion that the ocean's natural biophysical processes could be managed and exploited as 'assimilative capacity.' His narrow definition of pollution was based on the maintenance of acceptable oxygen levels to sustain fish; other biological or physical effects were not considered. The aquatic spaces of the inlet and estuary were reconfigured through a spatial strategy of effluent dispersal and circulation. This extended to the engineering of estuarine hydrology through the control of the Somass River. At other sites along the coast, waste disposal recommendations based on oceanographic conditions appeared to adequately protect marine waters from degradation. However, as subsequent developments at Alberni Inlet revealed, this approach failed to reflect the problems of natural variability and unintended consequences. Instead of a model instance of waste disposal design, Waldichuk himself noted, perhaps ruefully, that 'Alberni Inlet has continued to serve as a field laboratory for the study of industrial pollution and its effects on the marine environment.'[80] Indeed, a temporary shutdown of the mill in 1964 offered FRB researchers the opportunity to contrast the unpolluted harbour with conditions after the resumption of waste discharges.[81] When pollution problems resurfaced in the late 1980s, Waldichuk reflected that natural variability in climatic conditions and the unpredicted effects of long-term environmental degradation had complicated efforts to re-engineer Alberni Inlet. 'Perhaps some luck has been involved, as well as good pollution control, in that no major disaster has occurred with respect to the mass destruction of salmon by low dissolved oxygen due to pulpmill pollution in Alberni Harbour,' he concluded.[82] In the early 1990s, the mill was made subject to special federal Department of Environment regulations designed to protect the commercial, native and sport fisheries of the inlet.[83]

Marine pollution science at the Pacific Biological Station aimed to dispel both environmental and regulatory uncertainty. To reduce environmental uncertainty, oceanographers proposed relatively simple parameters for diagnosing pollution, determining the capacity of waters to receive wastes and devising waste disposal strategies. Although these techniques were developed at a particular site, their abstraction into Waldichuk's oceanographic classification scheme exhibited what Kohler (in the context of natural experiments in field biology) calls the 'logic of placelessness,' which sought to 'use the very particularity of nature to create knowledge that is true of nature generally.'[84] The imperative was to establish quantitative representations of predictable natural conditions that could be applied to diverse environments in coastal B.C. By examining the currents, tides, and the physical and chemical characteristics of marine waters, pollution oceanography attempted to determine their assimilative capacity. To a certain degree, this concept represented a new version of long-standing ideas about the self-purifying properties of flowing or circulating water. But it also reflected physical oceanographic emphasis on chemical properties and fluid dynamics, as opposed to marine biology or ecology. Based on these factors, waste disposal studies proposed the location of outfalls and recommended technological solutions to potential pollution problems, such as the use of submarine diffusers to ensure the adequate dispersal of effluent into the aquatic environment.[85]

Fisheries scientists also sought to eliminate regulatory uncertainty by generating scientific and political consensus around the use of certain parameters as a guide to waste disposal. The development of the PBS pollution oceanography program the fraught relationship between science and the institutions and practices of environmental governance, particularly in the period preceding the formal incorporation of science into regulatory practices that characterized what Samuel Hays calls the 'environmental era.'[86] Before the wave of pollution concern in the late 1960s that spurred the promulgation of formal standards for pulp mill effluent in Canada, government officials concerned with mitigating the impact of pollution often relied on ad hoc procedures and informal negotiations with polluters to achieve environmental protection. Yet the ambiguities inherent in the vague definition of pollutants as 'deleterious substances' made the statutory prohibitions of the Fisheries Act difficult, if not impossible, to enforce. As Stephen Bocking notes in his recent overview of science and environmental policy, "In the absence of definitive proof of harm the imposition of environmental regulations must instead be grounded in confidence in expertise."[87] For the FRB, this meant that "attention has thus been directed toward procuring full information on the effects of any pollutant on fish and reaching a mutually acceptable compromise, rather than dictating a complete prohibition" on waste disposal.[88] Thus, in addition to disciplinary practices, quantitative representations of nature such as those developed at Alberni Inlet reflected the political necessity for an authoritative basis for regulation in the absence of formal standards and scientific certainties. As Ted Porter has argued, 'quantification is a way of making decisions without seeming to decide. Objectivity lends authority to officials who have very little of their own.'[89] In place of political or scientific disputes over environmental effects or waste treatment, pollution oceanography offered a practical yet authoritative answer to the question, 'how much waste should be allowed in the environment?'

CONCLUSION: PLACE AND ENVIRONMENTAL SCIENCE

Marine pollution remains a significant environmental problem, despite over thirty years of international scientific and regulatory concern since the 1972 United Nations Environment Conference in Stockholm and the London Convention on Marine Dumping of the same year. As a 2001 United Nations scientific report noted,

> The state of the world's seas and oceans is deteriorating. Most of the problems identified decades ago have not been resolved, and many are worsening. New threats keep emerging. The traditional uses of the seas and coasts — and the benefits that humanity gets from them — have been widely undermined.[90]

Although the problem of pollution is widely acknowledged, scientific debate persists over the most appropriate scale and approach to its regulation. After the Second World War, scientists and regulators developed new perspectives on the traditional use of the ocean for waste disposal, based on the assimilative capacity of natural waters. This capacity was constructed as a kind of natural resource that could be scientifically measured and rationally exploited for the benefit of urban-industrial society, while avoiding pollution and damage to other aquatic resources. By the 1980s and 1990s, marine scientists were debating whether the ocean's assimilative capacity could be safely exploited, or whether to adopt a 'precautionary' approach to environmental contamination, perhaps even eliminating harmful waste discharges altogether.[91] At the heart of these questions are social and political attitudes and values that shape how society regards the aquatic environment: as a resource amenable to rational exploitation, or as a complex and fragile ecosystem subject to stresses and abuse. In scientific or policy disputes over marine pollution, politics is never far below the surface.

An historical-geographical approach to these debates provides an illuminating view into the complex role of science in environmental regulation. Christopher Hamlin notes that, while appealing to scientific authority, environmental projects are 'forged from a peculiar assortment of ideology, institutions, political circumstance, and perceptions of nature.'[92] This paper suggests that these various influences may be analysed through the interplay of 'site and situation' in environmental science. In confronting the threat to fisheries from pulp mill pollution, research at the Pacific Biological Station reflected both the social and institutional contexts of environmental regulation, as well as the site-specific problems posed by marine waste disposal. Environmental circumstances — particularly the clash between forestry and fisheries — triggered important regulatory and scientific reactions to the prospect of pulp and paper industry expansion along the coast. As a site for oceanographic research, Alberni Inlet provided researchers like Tully and Waldichuk the opportunity to develop methodological and theoretical approaches to the prediction of the assimilative capacity of ocean waters. In turn, oceanographic methods framed both perceptions of pollution and prescriptions for its abatement at Alberni Inlet and beyond. The Alberni model ultimately formed the basis for a coast-wide survey project of domestic and industrial pollution in B.C. and technical recommendations for industrial siting and waste-disposal practices.

Thinking about site and situation helps illuminate how individuals and institutions developed scientific approaches to environmental problems that reflected both local circumstances and wider influences. In his history of ecological science and politics, Stephen Bocking has shown how local institutional and environmental contexts shape the ideas and practices of scientists. Focusing on how environmental politics have influenced ecologists and scientific institutions, Bocking asserts that 'many contemporary environmental controversies originate in concern about a specific local issue or place,' which in turn influences the direction of scientific research on the environment.[93] Similarly, while becoming an object of institutional concern, the Alberni Inlet site transformed its institutional situation, stimulating the pioneering program of pollution oceanography at the PBS. But the kinds of research undertaken at the station also reflected its setting within the central institution of Canadian Pacific fisheries science, the Fisheries Research Board. Oriented mainly towards research supporting commercial fisheries management after the 1920s, the FRB exhibited a shifting tension between 'basic' and 'applied' research. As chief oceanographer, Tully noted that even basic research into oceanographic conditions in the Pacific sought to 'present the information in suitable terms for fisheries, military and industrial use.'[94] Oceanographic pollution studies reflected this mixture of mandated and basic research: Tully's Alberni work, for instance, combined 'practical' solutions to pulp mill effluent disposal with basic research into the mathematical modeling of estuarine circulation. At yet another scale, pollution oceanography also reflected the situation of the FRB within transnational networks of fisheries and oceanographic research, as it bore the stamp of the west-coast physical and dynamical methods imbibed by Tully and Waldichuk at the University of Washington. Thus, while considering the importance of place and of local environmental contexts, understanding the politics and practices of environmental science also requires attention to how research sites are situated within a variety of institutional and disciplinary contexts.[95]

By considering factors of site and situation, this study underscores the importance, highlighted by a number of historical geographers, of 'placing' science within a complex of local factors, including political, economic and legal circumstances. While exerting their influence on local scientific practices, these circumstances may be the product of processes or factors operating at a variety of geographical and temporal scales, some apparently remote from the site in question. But while stressing the influence of place and other geographical factors on scientific ideas and practices, historical geographers have been less eager to grapple with physical environmental factors. This research suggests that an historical geography of environmental science, in particular, must account for the circumstances of both place *and* nature. This is not to suggest that environmental conditions influence scientific practice in any simplistically deterministic manner. Rather, environmental factors exert their influence as part of a series of historical and geographical elements in scientific endeavour. The recent suggestion by Karen Bakker and Gavin Bridge that '"things" (commodities, bodies, biophysical processes) … are themselves historical products of material, representational and symbolic practices' applies here. They contend that an emphasis the 'materiality' of the non-human world brings into focus its 'unpredictability, unruliness and, in some cases, resistance to human intentions.'[96] Similarly, as 'part of the action' of scientific activity, natural places are more than structural features or passive participants, but rather provide dynamic and unpredictable challenges to the construction and application of scientific knowledge. Historical geographers may overcome their reticence to consider these material factors by incorporating approaches developed by environmental historians and others studying how scientific knowledge about the natural world is generated, circulated and deployed within specific ecological and historical contexts.

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