Property Rights, Salmon Husbandry, and Institutional Change Among Northwest Coast Tribes

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Abstract

This research investigates the hypothesis that prior to British sovereignty the native tribes of the Northwest Coast of North America established sophisticated property rights institutions to encourage efficient husbandry of the region's salmon fisheries. The hypothesis asserts that to the extent tribal property rights to salmon streams were clearly defined and enforced tribal leaders had the incentive to maximize the present value of expected returns to the streams under their exclusive control. As rational maximizers they would very likely have invested resources to accumulate private stream-specific knowledge of salmon husbandry. Husbandry could have included selection in favor of preferred biological characteristics such as larger average fish size, larger population size, reduced run variability, advantageous run timing, and home stream loyalty. In many cases, the resulting biological adaptations might have evolved unconsciously, but in other cases they would have had to be the result of counter-intuitive, and therefore purposeful, genetic selection by tribal leaders. The available evidence is broadly consistent with the salmon husbandry hypothesis. This research has important implications for the resolution of native land claims, the formulation of rational environmental policy, and understanding the evolution of customary law. It also sheds light on the conditions under which an early breakthrough in scientific knowledge might lead to dramatic and predictable institutional change.

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"Teach a man to catch a fish and you can feed him for a day. Teach a man to grow fish and you can feed him for a lifetime."[1]

I. Introduction

In the twenty-one years since North & Thomas published *The First Economic Revolution*,[2] the New Institutional Economics has made great strides and captured widespread attention. These developments are due largely to contributions from scholars in law, political science, sociology, and, most recently, evolutionary psychology. What has emerged is a synthetic body of theory capable of explaining institutions and institutional change over a wide range of circumstances of time and place. In what follows, I draw on this body of theory to examine institutional change along the Northwest Coast of North America prior to the assertion of British sovereignty in 1846.[3] My specific concern is with the extent to which Northwest Coast (NWC) tribal leaders accumulated the scientific knowledge to purposely husband their most important natural resource, the salmon fishery, and with the role of economic and cultural institutions in this process.[4] Among other things, this research has important implications for the

[1] Chinese proverb.

[2] North, Douglass C., and Robert Paul Thomas, *The First Economic Revolution*, THE ECONOMIC HISTORY REVIEW (Second Series), 30, no. 2 (1977).

[3] Treaty Between Her Majesty and The United Stated Of America, For the settlement Of The Oregon Boundary (Oregon Boundary Treaty, 1846), TS 120, cited in Delgamuukw v. British Columbia, 1997 Can. Sup. Ct. LEXIS 96, at ¶¶ 45, 62, 63, 64, and 145.

[4] Except where greater precision is warranted, I use the term "tribe" very loosely to refer to any of several levels of group affiliation found along the NWC, including phratry, clan, and sub-clan or local clan-house. My ultimate concern is with the resource exploiting unit (REU).

resolution of native land claims,[5] the formulation of rational environmental policy, the evolution of customary law, the marine biology and population dynamics of Pacific salmon, understanding the evolution of customary law,[6] the relationship between knowledge accumulation and the structure of property rights, and the role of scientific revolution in generating what is aptly characterized as *rational expectations institutional change*.

A recurring question in the study of institutions is whether technological change causes institutional change or whether technological change first requires the appropriate institutional foundation. The question is motivated by the real necessity of identifying an exogenous driver of institutional change. In contrast to the Schumpeterian view, which holds that technological change arises exogenously, with often dramatic institutional effects, North and others view technological change as largely endogenous and incremental, requiring an established institutional structure that fosters experimentation and trial-and-error adaptation.[7] In the context of man's emergence from several millennia as an egalitarian hunter-gatherer to settled agriculture with the arrival of the First Economic Revolution, this view suggests that institutional change preceded the

[5] See, e.g., Delgamuukw v. British Columbia, 1997 Can. Sup. Ct. LEXIS 96 (holding that aboriginal title had not been extinguished by the assumption of British sovereignty in 1846 nor by colonial legislation prior to 1871 and remanding the case to the trial court for further findings of fact). Being concerned with the settlement of an aboriginal title dispute between the Crown and various British Columbia tribes, Delgamuukw addresses, among other things, the requirement of native occupation of the lands to which title is being asserted at the time the Crown asserted sovereignty in 1846. As the Canadian Supreme Court stated, "[i]n considering whether occupation sufficient to ground title is established, 'one must take into account the group's size, manner of life, material resources and technological abilities, and the character of the lands claimed.'" *Supra*, at ¶ 149. This research is concerned specifically with sophisticated "technological abilities" the tribes may have possessed that have thus far gone unrecognized. It could therefore prove decisive in resolving the large number of pending claims. See discussion *infra*, at ??. Following the Delgamuukw decision, the B.C. First Nations Summit asserted aboriginal title to all of British Columbia. One reported effect of the decision has been a dramatic reduction in investment and a general province-wide recession in British Columbia. See Press Release by The Office of Preston Manning, M.P., Leader of the Opposition, at http://www. reform.ca/manningpress/080698.html.

[6] For two widely cited works on the evolution of customary law, see Ostrom, Elinor, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION (Cambridge: Cambridge University Press, 1990) and Ellickson, Robert. C., ORDER WITHOUT LAW: HOW NEIGHBORS SETTLE DISPUTES (Cambridge: Harvard University Press, 1991).

[7] North & Thomas, *supra* note ?. See, also, North, Douglass C., STRUCTURE AND CHANGE IN ECONOMIC HISTORY (New York: Norton, 1981) and Levi, Margaret, *A Logic of Institutional Change*, in THE LIMITS OF RATIONALITY, edited by Karen Schweers Cook and Margaret Levi (Chicago and London: University of Chicago Press, 1990).

innovations in cultivation and domestication that gave rise to settled agriculture. It also suggests that cultivation and domestication were primarily the result of unconscious adaptation rather than purposeful inventive activity.

I take a somewhat contrary view, at least insofar as the NWC tribes are concerned. Theirs appears to have been an economy in which the initial accumulation of scientific, or *Popperian*,[8] knowledge led to relatively purposeful and dramatic institutional change designed to reward further entrepreneurship. As emphasized by Brander & Taylor in their study of the fall of Easter Island civilization, a sufficient base of scientific knowledge can be critical to the process of efficient institutional reform.[9] For Easter Islanders, the antecedent knowledge was inaccessible, whereas for the NWC tribes it was apparently well within their grasp. This is due, in part, to the unique biological characteristics of Pacific salmon, which dominated their investment opportunities, and, in part, to the relatively noiseless relationship between capital investment and investment returns engendered by the prevailing property rights structure. Aided by customary law, the First Economic Revolution thus arrived on the NWC.

The NWC tribes have received a tremendous amount of attention from cultural anthropologists, who, unfortunately, have shown little interest in the tribes' economic organization.[10] Perhaps because economists have only recently become interested in non-market exchange and cultural norms as property rights institutions,[11] they have yet to fully discover the NWC tribes. This is unfortunate, because the tribes exhibited a rich and peculiar collection of institutions and considerable economic sophistication. Although within tribes they avoided reliance on prices and traditional market exchange,

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[8] I note that the U.S. Supreme Court relied on this view of scientific knowledge, citing Carl Popper, in *Daubert v. Merrell Dow Pharmaceuticals*, 509 U.S. 579 (1993).

[9] Brander, James A., and M. Scott Taylor, *The Simple Economics of Easter Island: A Ricardo-Malthus Model of Renewable Resource Use*, 88 A.E.R 119 (March 1998).

[10] But see Oberg, Kalervo, THE SOCIAL ECONOMY OF THE TLINGIT INDIANS (Seattle: University of Washington Press, 1973) and Donald, Leland, ABORIGINAL SLAVERY ON THE NORTHWEST COAST OF NORTH AMERICA (Berkeley, Los Angeles, London: University of California Press, 1997).

[11] *See, e.g.*, Ellickson, Robert, *Law and Economics Discovers Social Norms*, 27 J. LEGAL STUD. 537 (1998). *See, also*, Posner, Richard, *Social Norms, Social Meaning, and Economic Analysis of Law: A Comment*, 27 J. LEGAL STUD. 553 (1998) and Cooter, Robert, *Expressive Law and Economics*, 27 J. LEGAL STUD. 585 (1998).

between tribes they traded actively and aggressively and often successfully asserted exclusive rights over important trade routes, even against fortified Europeans. Prior to European contact, they had achieved a relatively high standard of living among North American natives, and they supported a relatively high population density until the rapid spread of contagious diseases led to severe population decline.[12]

The notable institutions found along the NWC included the following: exclusive communal, or "tribal," ownership of salmon streams; a form of corporate group structure that vested contingent resource control and residual claimancy in the hands of the clan-house leader; recognized title to these and other resources; intangible property similar to copyrights; stratified labor markets that relied on a systematic trade in slaves; clan-based capital markets to finance certain capital investments; and, most notably, a highly evolved and public system of reciprocal wealth transfers known as *potlatching*. To all this can be added a remarkably unabashed reverence for the accumulation of wealth, a shared system of cultural norms that elevated those who most actively redistributed wealth through potlatching, and the nearly complete absence of any kind of political or administrative hierarchy resembling what we know as the state. Consistent with the findings of Hoffman, McCabe, and Smith,[13] Reliance on public reciprocity through potlatching, and the trust it engendered, were sufficient to allow the NWC tribes to overcome the prisoners' dilemma and to achieve a cooperative and relatively stable system of exclusive property rights in the absence of Leviathan.[14]

In an earlier article, I argued that potlatching was a method of enforcing tribal ownership to salmon streams and the salmon fisheries they supported.[15] Salmon are born

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[12] *See* Johnsen, D. Bruce, *The Formation and Protection of Property Rights among the Southern Kwakiutl Indians*, 15 J. LEG. STUD. 41 (1986). The native's misfortune is the social scientist's bonanza, for such exogenous shocks provide an exogenous basis for testing hypotheses.

[13] Hoffman, Elizabeth, Kevin A. McCabe, and Vernon L. Smith, *Behavioral Foundations of Reciprocity: Experimental Economics and Evolutionary Psychology*, 36 ECON. INQ. 335 (1998).

[14] Reciprocity is increasingly being recognized as a common factor in the emergence of property rights. *See, e.g.*, Hoffman, Elizabeth, Kevin A. McCabe, and Vernon L. Smith, *Behavioral Foundations of Reciprocity: Experimental Economics and Evolutionary Psychology*, 36 ECON. INQ. 335 (1998).

[15] Johnsen, *supra* note ?.

in the upper reaches of a stream and return there to spawn and die after spending several years feeding at sea. As a result, compared to the open access resource rights characteristic of hunter-gatherers, exclusive tribal ownership of salmon streams served two important functions characteristic of settled agriculture. First, it ensured the capturability of returns from the tribal leader's husbandry investments. Second, it clarified the information feedback mechanism from trial-and-error husbandry experiments, thereby encouraging entrepreneurship and the purposeful accumulation of stream-specific knowledge by the tribal leader. Given the obvious benefits of exclusive ownership, potlatching evolved among the tribes as a mechanism for paying off would-be interlopers whose salmon runs were temporarily poor. Over time, the tribal leaders who accumulated superior knowledge of salmon husbandry and invested most wisely to husband their salmon fisheries were able to give superior potlatch gifts to forestall encroachment and to increase the security of their ownership claims. These leaders gradually ascended in the potlatch ranking and in social prestige, with their superior potlatch gifts compensating potential interlopers for respecting private property rights.[16]

In the remainder of this paper I investigate the hypothesis that tribal leaders actively engaged in salmon husbandry, going even so far as purposeful genetic selection. Examples of genetic selection include selection in favor of larger fish, larger population size, reduced population variability, advantageous run timing, and greater home-stream loyalty. Being in some cases counter-intuitive, the possibility of genetic selection, when recognized, would have represented a dramatic advance in the scientific understanding of salmon husbandry that revealed the manifest benefits of entrepreneurship and knowledge accumulation. Based on rational expectations, the prospects for further knowledge accumulation then would have led to a relatively rapid institutional transition from communal group ownership subject to fairly rigid egalitarian sharing to corporate ownership under the direction of a tribal leader acting as the group entrepreneur. Among

[16] The potlatch system appears strikingly similar to the "syndicate system" used by investment bankers to market initial public offerings of corporate stock. One of the notorious artifacts of the syndicate system is its reliance on so-called "reciprocal participations," in which the lead bank tends to invite participation from banks that extended the same privilege to it in prior offerings. See Barzel, Yoram, Michel A. Habib, and D. Bruce Johnsen, *IPO Syndicates, Private Foreknowledge, and the Economics of Excess Search* (unpublished working paper, 1999).

other things, the corporate form had the advantage of protecting the privacy of a leader's accumulated stream-specific knowledge from outside appropriation.

A simple example will illustrate the counter-intuitive nature of genetic selection in the context of salmon population dynamics. To this day, various streams along the NWC produce salmon of relatively large average size within a given species. Why would one stream produce larger fish than others if all the salmon feed in the same ocean? My hypothesis is that where tribal property rights were more secure tribal leaders invested more to develop relatively large species of salmon. To do this, the harvesting rule a tribal leader would have had to use early on in the process was to take the smallest salmon in the run and to leave the larger fish to spawn and reproduce. Since larger parents produce larger offspring, over the course of generations this rule would have produced larger fish. This rule is counter-intuitive because smaller salmon have less edible flesh and are more costly to harvest and process for given nutritional value. In the short run, a tribal leader with an acute interest in processing a sufficient inventory of preserved salmon for the long winter with minimum labor effort would naturally have tended to harvest the larger fish because of fixed costs in catching, cleaning, and preservation that were invariant to the *size* of the fish being harvested. Note that the investment returns from a small-fish harvesting rule would have taken many years to realize and would have required extremely secure property rights. Being counter-intuitive, it is my belief that a small-fish harvesting rule, or other rules leading to similar types of genetic selection, were the result of relatively sophisticated scientific understanding of salmon population dynamics arrived at by individual tribal leaders through purposeful trial-and-error experimentation.[17]

In Section II, I review the anthropological, archeological, and historical evidence on the NWC tribes and their cultural and economic institutions, paying special attention to the structure of property rights and the accumulation of knowledge. In Section III, I discuss the economics of salmon husbandry, differentiating between the strong and weak

[17] Being counter-intuitive, this type of knowledge seems unlikely to arise through incremental processes. This observation captures the essence of Kuhnian "scientific revolution" in a microcosm. Kuhn, T.S., THE STRUCTURE OF SCIENTIFIC REVOLUTIONS (Chicago: University of Chicago Press, 2nd ed., 1970). The progress of scientific knowledge is sometimes discontinuous, often allowing man to discover what was formerly completely outside their purview and to dramatically reorder their behavior in response thereto.

forms of the salmon husbandry hypothesis. According to the weak form, genetic selection was unconscious, while according to the strong form it was purposeful. Next, I review the relevant evidence from marine biology, anthropology, and archeology. The literature from marine biology reveals that Pacific salmon populations are extremely sensitive to genetic selection, whether induced by man or by nature. Moreover, the biological characteristics of Pacific salmon vary considerably across time and place and exhibit substantial unexplained variation that, subject to the availability of data, should provide ample opportunity to systematically test the salmon husbandry hypothesis.

In Section IV, I describe and discuss the evidence from preceding sections that is consistent with the salmon husbandry hypothesis. I also discuss the economics of institutional change on the NWC, relying both on the evidence from Sections II and III and on insights from the emerging field of evolutionary psychology. I argue that the institutional transition to corporate tribal ownership may have occurred relatively quickly in response to the early accumulation of knowledge regarding salmon biology and that this fostered the further scientific accumulation of stream specific knowledge by entrepreneurial tribal leaders. I should acknowledge that much work remains to be done collecting data and in systematic hypothesis testing. At this time, however, I view the preliminary evidence to be extremely supportive.

Finally, in Section V, I summarize, provide concluding comments, and discuss the many directions for future research on the NWC tribes. Even if institutional change on the NWC was in all events incremental and adaptive, plausible evidence that the tribes engaged in purposeful husbandry of their salmon populations has important implications for anthropology, archeology, evolutionary psychology, law, marine biology, and the study of institutional change. Moreover, this research should encourage law and economics scholars, game theorists, experimental economists, political scientists, and others concerned with cultural norms to recognize the NWC tribes as a rich source of opportunity for further research. In my view, a full program of research on the NWC tribes is warranted.

II. Northwest Coast Cultural and Economic Institutions[18]

The NWC tribes inhabited and exploited the many islands, fjords, and inland waterways of the rugged North Pacific Coast of North America, from Yakutat Bay at the northern end of the Alaska panhandle to as far south as northern California, with the mouth of the Columbia River on the Washington-Oregon boarder being considered by many as the effective southerly limit of the "culture area."[19] From roughly 60° to 46°N., the Tlingit, the Tsimsian, the Haida, the Nuxalk, the Kwakiutl, the Nootka, the Coast Salish, and the Chinook tribes, though diverse in background and linguistic origins, all relied heavily on salmon as a staple, recognized exclusive tribal ownership to salmon streams and other resources, and participated routinely in formalized reciprocity relations that have been broadly characterized as potlatching.

Recorded contact with the NWC tribes first occurred during the late eighteenth century, when Russian, Spanish, English, and American ships explored the coast trading with the tribes they encountered for sea otter pelts and other furs. Before long, intense competition for sea otter pelts developed between these flagships, a situation the natives are reported to have exploited to their distinct advantage. To take advantage of the lucrative fur trade, the Hudson's Bay Company eventually established permanent trading posts along the coast at Fort Langley (1827), Fort Simpson (1834), Fort McLoughlin (1834),[20] and Fort Rupert (1834).[21] Following construction of these forts the British succeeded in dominating European trade in the region.

During the prehistoric and early contact period the tribes were very warlike and possessive of their territories. In several cases they attacked and successfully destroyed trading vessels[22] and even fortified trading posts.[23] They also fought among themselves

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[18] Much of the discussion in this section can be found in Johnsen, *supra* note ?.

[19] Donald (1997), *supra* note ?, at 15,16.

[20] Drucker, Philip, INDIANS OF THE NORTHWEST COAST (New York: Natural History Press, 1955), at 19-23.

[21] Codere, Helen, *Fighting with Property*. AMERICAN ETHNOLOGICAL SOCIETY MONOGRAPHS, vol. 18, 1950.

[22] Jewitt, John R., WHITE SLAVES OF THE NOOTKA (Heritage House: 1987).

over trading rights and valuable natural resources. Wars were often waged to annihilate an entire group to gain possession of its fine salmon stream, to seek revenge for prior wrongs, or simply to pillage, plunder, and take slaves.[24] Donald estimates native population for the entire culture area at the time of contact at roughly 150,000, establishing a population density in the region well in excess of that found in other regions at the time.[25] This situation changed dramatically with the spread of smallpox, measles, and syphilis in the early- to mid-nineteenth century, with population declines from 80 to 90 percent being reported for specific regions.[26]

A. Production

With the exception of a limited subset of island-based tribes that relied more heavily on ocean fishing and sea mammal hunting, the primary source of production for the NWC tribes was salmon. Other produce included halibut, cod, seals and sea lions, whales, waterfowl, venison, mountain goat, elk, berries, and herring and salmon roe. The tribes harvested salmon with often elaborate fish weirs and traps, or with nets, harpoons, and spears during their summer and fall spawning migrations upstream. Fish weirs and traps involved substantial capital investment. Weirs were often built to span an entire stream, so that migrating salmon had to enter one of various holding traps from which they could be easily harvested or released to continue their migration to the upper reaches of the stream, where they would spawn and die.

Resource exploitation on the NWC was normally organized around the local clan-house, or sub-clan. During the leisure-oriented winter and spring, when most of the potlatching occurred, the individual houses of a clan assembled together in one of several

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[23] Ducker, *supra* note? and Drucker, Philip, CULTURES OF THE NORTH PACIFIC COAST (Scranton: Chandler, 1965).

[24] See Drucker, Philip, CULTURES OF THE NORTH PACIFIC COAST (Scranton: Chandler, 1965), at 19; Boas, Franz, KWAKIUTL ETHNOGRAPHY (Chicago: Univ. of Chicago Press, 1966); at 105-19; and Swadesh, Morris, *Motivations in Nootka Warfare*, 4 SOUTHWESTERN J. ANTHROPOLOGY 76-91 (1948).

[25] Donald, *supra* note ?, at 17.

[26] Codere, *supra* note ?, at 50; Donald, Leland, and Donald H. Mitchell, *Some Correlates of Local Group Rank Among the Southern Kwakiutl*, 14 ETHNOLOGY 325 (1975), at 333.

centralized villages, together with other houses of any number of other clans within the tribe. The members of each clan-house lived communally in a large cedar lodge that held up to forty people. The extended clan lineage might have several houses located at each of several different winter villages. The winter villages are said to have been judiciously located and heavily fortified in prehistoric and early contact times to minimize the likelihood of successful enemy attack.[27] In the event of attack on one house by members of another clan, the houses of other clans in the winter village would often remain neutral, thus leaving the members of the besieged clan-house to provide a common defense, which they were sworn to do. In the event of attack by an outside tribe, however, the entire winter village cooperated for their mutual defense.[28]

The male head of the clan-house typically held title to productive resources, which were manifested in his ceremonial privileges, names, and crests. The Coast Salish believed that these intangibles endowed their owner with supernatural powers that helped him succeed as a resource manager. According to Salish ideology, the more successful, wealthier titleholders possessed secret knowledge of "good" behavior, while the lesser chiefs were "without advice."[29]

The bulk of the year's production occurred during the late summer and fall when the weather was good and the salmon were running. At this time the local clan houses occupied and exploited their ancestral fishing and hunting territories, which were dispersed along the islands, inlets, rivers, and streams throughout each tribal region. According to Oberg, summer production occurred at a fairly leisurely pace, with September and October being preoccupied with catching and preserving — by drying and smoking — sufficient salmon to last through the winter.[30]

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[27] Drucker (1965), *supra* note ?, at 81.

[28] Oberg, *supra* note ?, at 61, 63.

[29] Suttles, Wayne, *Affinal Ties, Subsistence, and Prestige among the Coast Salish*, 62 AMERICAN ANTHROPOLOGIST 296 (1960), at 301, 303.

[30] Oberg, *supra* note ?. It is reasonable to assume that salmon preservation technology originated with the natives of the arid Fraser River interior, where salmon could be effectively dried in the warm unrelenting winds that kept the flies down. Salmon drying was no doubt gradually adapted to the moister coastal climate through the advent of smoking, thus allowing a gradual migration of the native population down the Fraser River valley or over the Coast Range and onto and up the coast. The anthropological record

Throughout the culture area, the tribes conducted the First Salmon Rite immediately following the first catch of the summer. The Kwakiutl, for example, believed the spirit of the salmon was immortal, and that it voluntarily sacrificed its body for the benefit of man. If the salmon spirit was offended, the salmon run might not return full force in following years. "Throughout the rite there was constant reference to the run and its continuance, and the first fish was usually placed with its head pointing upstream so the rest of the salmon would continue upstream and not turn back to the sea."[31] Following this ritual the group members began fishing, but not without restrictions by their leader on the number of salmon they could take and their allocation. Among other things, the substance of this rite confirms the natives understood that salmon populations in a given stream were intergenerationally related.

As titleholder, the house leader directed productive activity and allocated a customary share of the output to each member of the house group. He seldom engaged in menial tasks. His role was "to decide when it is best to go hunting, or to begin the salmon harvest, or to go to prepare oil."[32] Both gender and social strata determined the division of labor.[33] Women engaged in gathering, cleaning, preserving, and preparing food, while men performed the harvesting under the direction of their leader. Certain tasks were performed primarily by slaves, while ceremonial labor connected to the potlatch was the exclusive right of the clan-house leader. Commoners within the house performed the remaining tasks, which varied according to the situation and often involved cooperative effort directed by the clan-house leader.

The house leader not only supervised the more important productive tasks but also managed the collection of durable goods for potlatching, which he often accumulated by borrowing or calling in loans from other houses within the clan or from the houses of

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suggests that only the Tlingit, the northernmost tribe found on the NWC, had access to virgin territory in later times, which they took advantage of by gradually expanding northward to claim otherwise unoccupied areas. Oberg (1973), *supra* note ?, at 55, 56, 64.

[31] Drucker, *supra* note?, at 95.

[32] Oberg (1973), *supra* note ?, at 87.

[33] *Supra*, at 123 (possibly Donald).

other clans. The highest-ranking house leader in a clan may loosely be referred to as the clan "chief," although in no event did he have any formal political authority beyond the deference he could command based on his reputation as a wise resource manager and successful potlatch participant. Each clan-house was politically autonomous and could freely join or decline invitations to cooperate in various tasks with other houses in the same or other clans. At least in some tribes, the members of each clan-house were free to withdraw and join any of three other houses within their lineage.[34]

An important component of yearly production was the rendering of oil, which was taken from the fat of either sea mammals or eulachen fish during their spring migrations into the estuaries of larger rivers to spawn. Eulachen sometimes arrived in such large numbers during these migrations that they could be taken with dip nets. Eulachen fishing grounds, being found in relatively wide sections of the larger rivers, were treated as an open access resource within the tribe and possibly across different tribes. Eulachen oil was superior to the alternatives and was essential for preservation and storage of various foods through the winter months and for consumption on its own. In rendering the oil, timing and other attributes of the production process are said to have been critical. Such decisions, being of great importance, were left to the house leader.[35]

With the advent of trade, sea otter and other fur pelts became commercially important. Shortly after trade began, however, the once abundant sea otter was hunted nearly to extinction.[36] Oberg[37] and Garfield[38] note that what were once wider clan territories were soon subdivided by individual ownership to avoid over-harvesting, much along the lines reported by Demsetz for the eighteenth century Montagne of Quebec.[39]

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[34] Personal communication with Leland Donald, Department of Anthropology, University of Victoria, Canada.

[35] Oberg, *supra* note ?, at 87.

[36] Drucker (1955), *supra* note ?, at 95.

[37] Oberg, *supra* note ?, at 61.

[38] Garfield, Viola, *A Research Problem in Northwest Indian Economies*, 47 AMERICAN ANTHROPOLOGIST, 626 (1945).

[39] Demsetz, Harold, *Toward a Theory of Property Rights*, 57 A.E.R. 347 (1967).

Eulachen oil also became an important trade good. As European contact increased, salmon eventually became a commercial good, especially following construction of local canning factories starting around 1870.

B. Property Ownership

There is absolutely no doubt that NWC native notions of property ownership were extremely strong and well refined, extending to various resource sites and most forcefully to salmon streams. Among the Haida and Tlingit, for example, Garfield reported to the U.S. Department of Interior in 1944 that "smaller streams were divided between house groups, owned by single house groups or were the property of individuals."[40] Among the Southern Kwakiutl, ranking titleholders were often known by a name that translated roughly into "river owner."[41] According to Oberg's account of property rights among the Tlingit of southeast Alaska:

> The question of boundaries gave little trouble. The salmon streams when small were owned throughout their length, and when large . . . the question of ownership did not enter. The hunting grounds usually consisted of the watershed of the streams or valleys well enclosed by hills or high mountains. In Klukwan the clans divided the mountain slopes for goat hunting by the Ganaxtedi taking the valley above the village and the Kagwantan taking the valley below the village. The other two clans had valleys in the more distant tributaries of the main stream. Berry, root, and clover patches were small and often possessed by single houses. The same was true of rocks for sealing.[42]

The scale of salmon production was often determined by size of the stream held by the house leader. Larger houses were matched with larger streams, while smaller houses held smaller streams.[43] Optimal group size was no doubt determined by successive adaptation heavily influenced by the transactions costs of coordinating

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[40] Garfield, *supra* note ?, at 627.

[41] Drucker, Philip, and Robert F. Heizer, TO MAKE MY NAME GOOD (Berkeley and Los Angeles: University of California Press, 1967).

[42] Oberg, *supra* note ?, at 59.

[43] Oberg, *supra* note ?, at 56.

production and monitoring the allocation of output, within technological and environmental constraints. This is revealed in Oberg's account of recurrent attempts at cooperation between Tlingit clan-houses to build large fish weirs on the Chilkat River, presumably in a section that was unusually large in relation to the normal scale of fish weir operations. In his words: "The salmon trap would be built under the impulse of the initial enthusiasm of some intelligent person but, when constant repairs were needed, the question of dividing up the work proved too difficult to resolve. Dividing the catch also caused some altercation and after several years the weir would break down and the clans would go back to their former fishing enterprises."[44] Presumably, the "former fishing enterprises" of the separate houses involved the autonomous exploitation of smaller tributaries of the River in its upper reaches.

As already noted, a house's exclusive ownership rights to hunting, gathering, and fishing grounds were vested in its leader and manifested in his ceremonial privileges, names, and crests. Among the Haida and Tlingit, a titleholder's territorial claims included "both the custodianship of the major food-producing resources of his group and certain individual productive holdings from which he received all of the produce as personal wealth."[45] Ownership of clan crests and the rights they represented was, in any event, contingent. The leader's rights, and indirectly the group's rights, could be divested by any number of actions on the part of inside or outside rivals, including warfare, debt foreclosure, and conclusive demonstration by a competing claimant of his superior productivity through potlatching.

Among the Coast Salish, according to Wayne Suttles, wealth came from the possession of hereditary rights, . . . but even then, the man not only owned the right to [exploit] a certain place but also usually possessed the special practical and ritual knowledge necessary for [success]."[46] The presumption was that great names and the "advice" they carried would be inherited by primogeniture, although the bequest often

[44] Oberg, *supra* note ?, at 62.

[45] Garfield, *supra* note ?, at 629.

[46] Suttles, Wayne, *Private Knowledge, Morality, and Social Classes among the Coast Salish*, 60 AMERICAN ANTHROPOLOGIST 497 (1958).

went to the child judged most likely to succeed, which often meant the child with the best memory who could later use the associated knowledge to best advantage. The Coast Salish regarded "moral training as private property" available only to upper-class people, who thereby possessed "secret knowledge on the gaining of wealth and the maintenance of status."[47] All along the NWC, wealthy titleholders belonged to so-called "secret societies" in which membership was restricted to those with sufficient means to adopt and validate mythic family names through the distribution of gifts.[48]

In addition to salmon streams and private knowledge about how to exploit them, slaves were apparently an important capital asset on the NWC, especially in the more northerly regions. Slavery has been a long neglected topic in the anthropological literature based on the widespread misperception that the main use of slaves was as status items. In a recent treatise on the subject, however, Donald persuasively demonstrates that slaves were essential sources of labor in the NWC economy.[49] He shows that there was an active trade in slaves along the coast and with the interior, and that slaves were viewed as important items of wealth in both productive activity and in potlatching. More importantly, he shows that in the face of possible defections by coalitions of kin-based labor, a clan-house leader had resort to slaves as an alternative source of labor available in a reasonably liquid market.

The interior native tribes of the Fraser River Plateau and the Great Columbia Basin on the eastern boarder of the culture area also relied heavily on salmon production and engaged in sharing and reciprocity — if somewhat less formally, but their sense of property ownership was far weaker than that found along the coast. This is remarkable because the coastal tribes are generally believed to have descended from the interior tribes. As Boas observed:

> [T]he feeling of attachment to the home is strong all along the Pacific coast, far south into California, under the most diverse conditions of

[47] *Supra*.

[48] Donald, *supra* note ?, at 1997.

[49] *Supra*.

> geographical environment and of food supply. In contrast to these, the tribes of the interior are much less firmly attached to the soil, each band having its own habitat; but the attachment of the individual to his band and also that of the band to its location was rather loose and liable to change, without particular reference to the more or less favorable food supply found in a central location.[50]

An example of this is found in Canon (1992),[51] who describes repeated incursions by one tribe on another's traditional territory in the upper Fraser River drainage, often amounting to sustained or repeated seasonal occupation by the aggressors. And yet violent retaliation was seldom forthcoming. This kind of encroachment simply would not have been tolerated on the coast. Moreover, even during normal times the "owners" of fishing cites along the Fraser River were merely accorded preferential use and were expected to share access once having taken sufficient fish for their own needs.[52]

C. Potlatching

The word potlatch is said to derive from the Nootka language and means to give with the expectation of a return gift. Though some authorities dispute whether potlatch gifts created an obligation to reciprocate (Barnett (1938)),[53] reciprocation was nevertheless the norm. Any failure to reciprocate, or any shortfall in the amount of the return gift, raised the social prestige of the more generous party. The potlatch itself consisted of a ceremony arranged by a clan or sub-clan of the tribe, with its leader acting as host, for one or more guest groups from the same or a different winter village. The host provided guests with a lavish feast during which they were expected to bear witness to a ceremony in which the host asserted various privileges and other claims. At the

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[50] Boas, Franz, KWAKIUTL ETHNOGRAPHY (Chicago: Univ. of Chicago Press, 1966).

[51] Cannon, Aubrey, *Conflict and Salmon on the Interior Plateau of British Columbia*, in A COMPLEX CULTURE OF THE BRITISH COLUMBIA PLATEAU, edited by Brian Hayden (Vancouver: UBC Press, 1992).

[52] Romanoff, Steven, *Fraser Lillooet Salmon Fishing*, in A COMPLEX CULTURE OF THE BRITISH COLUMBIA PLATEAU, edited by Brian Hayden (Vancouver: UBC Press, 1992).

[53] Barnett, H.G., *The Nature of the Potlatch*, 40 AMERICAN ANTHROPOLOGIST (New Series) 349 (July-Sept., 1938).

conclusion of the ceremony, the host distributed gifts whose value varied according to the recipient's social prestige.

Potlatches were held primarily during the leisure-oriented winter and early summer months for any of a variety of reasons, including important marriages, the birth of an heir to group titles, or the actual inheritance of those titles. They were also held to ransom war captives, to pay off would-be attackers, and to resolve title disputes to fishing and hunting territories. The term potlatch has been used to describe so many different events in NWC tribal life that, according to some cultural anthropologists, it has become almost meaningless.[54] There is no doubt that for most NWC tribes sharing and reciprocity were the prevailing norm in nearly all aspects of daily life and were carried out on virtually all occasions, from those that were strictly local and informal to those that occurred between distant clans or sub-clans on formal and very profound occasions.

Oberg describes an occasion on which a high-ranking member of Tlingit society would want to host a small feast for local guests.[55] The occasion might arise if the important man were to slip and fall on the beach. Such an event would undermine the man's dignity and subject him to gossip and ridicule. To restore his reputation, he invited those who witnessed the event and others in the community to be his guests at a feast in which he gave them gifts in proportion to their social prestige. As Oberg puts it: "In every case ridicule could be heaped upon him but the important man prevented this by giving a feast, inviting all the individuals who had seen him. This saved his honor, for it was a great shame to ridicule one's host."[56]

Perhaps one of the most important functions of the potlatch was as a public spectacle, in which guests served as outside witnesses to any of various claims made by the host group. As Barnett writes: "[The members of the host group] speak, sing, dance,

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[54] Donald, *supra* note ?.

[55] Oberg, Kalervo, *Crime and Punishment in Tlingit Society*, 36 AMERICAN ANTHROPOLOGIST 145 (1934).

[56] Oberg, *supra*, at 153. In this setting, the witnesses to the event gained the right to ridicule the man for his clumsiness. By accepting gifts from the man at a feast in which he declared his sure-footedness, they would be seen as having transferred this right back to him. It is doubtful that a truly clumsy man would be willing to pay enough to redeem the right, since his clumsiness would eventually become clear to all. Only the man for whom a reputation as being clumsy was inaccurate would be willing to make a sufficiently large payment to redeem the right.

or otherwise put themselves before the public eye at the same time that some claim to social distinction is expressed or implied with reference to them. Claims are commonly embodied in family names, so that the assumption of the latter customarily signifies a claim to certain distinctions and privileges."[57] These privileges and claims of right were often embodied in family or clan crests and ceremonial songs and performances that were zealously guarded as the exclusive property of the group asserting the claim. According to Drucker, when title to land and fishing rights was in dispute, the competing claimants held a "rivalry" potlatch, which he describes in the following passage:

> When two chiefs claimed the same place, the first one would give a potlatch, stating his claim; then the second would try to outdo him. Finally, one or the other gave away or destroyed more property than his opponent could possibly equal. The one who had been surpassed had no recourse. He could no longer contest his claim, for, in the native mind, it came to be regarded as ridiculous that an individual of few resources (and of course this involved not only the man, but his entire local group) should attempt to make a claim against someone who had demonstrated power and wealth.[58]

The level of formality and the extent to which the NWC tribes kept track of the balance of potlatch gift distributions no doubt varied from tribe to tribe. Within the potlatch system of the Southern Kwakiutl, for example, there are said to have been exactly 658 named and numbered potlatch positions, with the number of the position indicating its holder's rank in Kwakiutl society. This ranking was subject to change according to the participants' recent potlatch performance. Each position holder was matched with one or more closely ranked rivals from other clans or clan-houses with whom he competed in the distribution of potlatch gifts.

The ethnographic record leaves little doubt that potlatching was a substitute for violence in enforcing a group's territorial claims against interlopers. As Oberg reports, "If a Tlingit wants to bring a potential enemy to terms, he invites him to a feast. When

[57] Barnett, *supra* note?, at 351. There seems little doubt that feasting and ceremonial gift giving in front of a large audience was a substitute for a written record.

[58] Drucker, (1965), *supra* note ?, at 128.

hunters or fishermen encroached upon the property of another clan, the clansmen could often bring about a settlement by inviting the poachers to a feast after which the visitor would feel ashamed and leave the territory of the hosts in peace."[59] The following passage, recorded during a winter dance ceremony in 1895, indicates that the Kwakiutl, themselves, explicitly viewed potlatching as an alternative to violence: "We used to fight with bows and arrows, with spears and guns. We robbed each other's blood. But now we fight with this here (pointing at the copper which he was holding in his hand), and if we have no coppers, we fight with canoes or blankets. . . . This time of fighting has passed. The fool dancer represents the warriors but we do not fight now with weapons: we fight with property."[60]

According to the war records, when encroachment occurred it was often met with violence by the incumbent group and in many cases, of course, the encroachers came with the intent to annihilate the incumbents.[61] Apparently, on these occasions the transaction costs of negotiating and enforcing a simple agreement between clans to recognize private property rights were prohibitive in the absence of third-party enforcement by the state. The alternative was for the incumbent group to offer protection payments to the group whose marginal productivity was relatively low due to a poor salmon run. By doing so it increased the outsider's opportunity cost of encroaching. The size of the necessary protection payment would have been roughly equal to the net gain anticipated by the would-be encroacher. Since the alternative method of enforcing exclusivity was violence — which used the real resources of both the encroacher and the incumbent — and since a system of violent enforcement would have reduced the willingness of the clans to make wealth-increasing investments for fear of being unable to capture the full investment return, the incumbent group normally would have been able to make the necessary protection payment and still come out with greater wealth than otherwise.

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[59] Oberg, *supra* note ?, at 99.

[60] Codere, *supra* note ?, at 118-19.

[61] See Jewitt, *supra* note ?, at 91-93.

Given that all clan groups faced the possibility of a poor salmon run at one time or another due to exogenous events, the encroachment problem was reciprocal.[62] Consequently, the tribes established potlatching as a reciprocal exchange system between rival groups to enforce private property rights by smoothing intertemporal variations in the opportunity cost of encroachment. Unless those groups whose productivity was relatively low were paid off through the potlatch system by those groups whose productivity was relatively high, the system of reciprocally recognized private property rights would undoubtedly have broken down.[63] Abstracting from differences in managerial talent, over the long run the wealth transfers through the potlatch system would have approximately balanced, but all groups would have experienced absolute increases in wealth due to their increased willingness to invest in husbanding their salmon populations.

III. The Economics and Biology of Salmon Husbandry

The preceding section showed that resource ownership, especially the ownership of salmon streams, routinely carried with it accumulated private knowledge about resource use handed down from generation to generation. In this section I develop the hypothesis that this knowledge could have included an implicit or explicit scientific understanding of salmon husbandry. I first describe the economics of property rights and knowledge accumulation as they apply to salmon stream management to provide a general guide to the husbandry techniques tribal leaders might have found worthwhile. I

[62] Even in the absence of productivity variations, there would always have been an incentive for the members of one clan to encroach on another's private fishing territory. This is because in optimally exploiting their territories all groups would have continued to supply fishing effort until the marginal product of labor was equal to its opportunity cost. But the marginal product of labor to an encroacher would have equaled the average product of labor to the incumbent and been greater than the marginal product of labor to either the incumbent or to the encroacher in his own territory. This is because the encroacher would not have had to bear the reduction in catch — an uncompensated external cost — experienced by the incumbent as a result of his actions. Cheung, Steven N.S., *The Structure of a Contract and the Theory of a Nonexclusive Resource*, 13 J. LAW & ECON. 49 (1970).

[63] Potlatching may have served the added function of providing an incentive for the clans within the potlatch system to assist in defending the territories of other clans from outside aggressors.

then review the basic biology of Pacific salmon to identify the husbandry techniques that were available given the peculiarities of salmon biology, including population dynamics.

A. The Economics of Salmon Husbandry

There are two forms of the salmon husbandry hypothesis, the weak form and the strong form. The weak form of the hypothesis is that tribal leaders had little scientific knowledge of salmon biology, and that any husbandry they engaged in was rudimentary and the result of successive adaptations. As weak as this hypothesis is, it nevertheless suggests that tribal leaders behaved *as if* they understood at least some of the relevant scientific knowledge. Certain biological characteristics of salmon should have been favored in the evolutionary selection process as a result. Some of these characteristics might have persisted for years following the effective abandonment of the native fishery around 1840 and the advent of commercial ocean fishing around 1870. The implications of the weak form of the salmon husbandry hypothesis for institutional change are, themselves, weak; institutions would have adapted incrementally and fitfully following incremental technological change.

The strong form of the hypothesis is that tribal leaders developed a scientific understanding of salmon biology early on and that they consciously selected in favor of the characteristics in salmon that maximized the rents to the fisheries under their control. Here also, some of these characteristics might have persisted for years following the abandonment of the native fishery and the advent of commercial ocean fishing. The implications of the strong form of the salmon husbandry hypothesis for institutional change are strong. The rapid accumulation of knowledge, or even the manifest prospect of its rapid accumulation, following a fundamental entrepreneurial insight would have created an "institutional vacuum" likely to have resulted in purposeful and dramatic institutional change.

According to Langdon, up until about 1960 the extensive work done on the NWC tribes by cultural anthropologists assumed they inhabited an environment superabundant with salmon.[64] From this environment they harvested an ample food supply with the

[64] Langdon, Steve, *Comparative Tlingit and Haida Adaptations to the West Coast of Prince of Whales Archipelago*, 18 ETHNOLOGY 101 (1979).

sacrifice of only modest labor effort. Early anthropologists focused their attention on the role property ownership, warfare and, most of all, potlatching played in Marxian class struggle and the "limitless pursuit of . . . social prestige" by tribal "elites."[65] According to this view, the superabundance of salmon freed the tribes from the bounds of scarcity that economists have found so powerful in explaining man's behavior and institutions in virtually every other setting from Pleistocene hunter-gatherers to Wall Street investment bankers. This is a difficult view for most economists to accept, presumably because people would not bother to create private property rights, accumulate private knowledge, or systematically kill one another in a world unbounded by scarcity.

In a series of articles beginning in 1960, Wayne Suttles proposed what came to be known as the "functional" approach to potlatching.[66] This theory asserts that although the NWC was generally rich in salmon and other resources, due to natural resource variability people occasionally starved to death, or at least went hungry. Suttles's work brought a wave of investigations by cultural anthropologists and archeologists, in several cases relying on biological evidence, to determine whether there was any systematic relationship on the NWC between local resource variability and potlatch ranking or other cultural artifacts.[67] From the standpoint of scientific inquiry, the functional approach to potlatching has proven to be a distinct improvement over earlier work. Yet, aside from

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[65] Codere, *supra* note ?, at 118.

[66] Suttles(1960), *supra* note ?; Suttles, Wayne, *Variation in Habitat and Culture on the Northwest Coast*, PROCEEDINGS OF THE 34TH INTERNATIONAL CONGRESS OF AMERICANISTS (Vienna, 1962), at 522-537; Suttles, Wayne, *Coping with Abundance*: SUBSISTENCE ON THE NORTHWEST COAST, IN MAN THE HUNTER, edited by Richard B. Lee and Irvin DeVore (Chicago: Aldine, 1968), at 56-68.

[67] Shaulk, Randall, *The Structure of an Anadromous Fish Resource*, in FOR THEORY BUILDING IN ARCHEOLOGY: ESSAYS ON FAUNAL REMAINS, AQUATIC RESOURCES, SPATIAL ANALYSIS, AND SYSTEMATIC MODELING, edited by Lewis R. Binford, (Academic Press, 1977); Kew, Michael, *Salmon Availability, Technology, and Cultural Adaptation in the Fraser River Watershed*, in A COMPLEX CULTURE OF THE BRITISH COLUMBIA PLATEAU, edited by Brian Hayden (Vancouver: UBC Press, 1992); Donald and Mitchell (1975), *supra* note ?; Donald, Leland, and Donald H. Mitchell, *Nature and Culture on the Northwest Coast of North America: The Case of Wakashan Salmon Resources*, in KEY ISSUES IN HUNTER-GATHERER RESEARCH, edited by Ernest S. Burch, Jr. and Linda J. Ellanna (Oxford, Providence: Berg, 1994); and Donald (1997), *supra* note ?. This literature uniformly treats observed resource variability as exogenous. I discuss some of it *infra* at ?.

Oberg[68] and Donald,[69] the functionalists have devoted little attention to the important role property ownership undoubtedly played in resource management.

Private property rights do not simply happen. Nor, it can be plausibly shown, are they likely to arise purely to protect one party's slice of an otherwise fixed pie from encroachment. Private property rights are costly to define and enforce. As economists, legal scholars, political scientists, and others have shown over and over again, wealth maximizing actors will incur these transaction costs only for the prospect of compensating benefits. What might these benefits have been on the NWC?

Under the strong form of the salmon husbandry hypothesis, the reputed abundance of salmon along the NWC must be viewed as the outcome of privately efficient — and perhaps socially efficient — resource management within existing institutional constraints. Similarly, the observed variability in salmon abundance must be viewed as the residuum after each resource manager undertook all economically feasible efforts to reduce variability. At a time in human pre-history when man's brain was fully developed, and where private or small-group ownership to salmon stocks was clearly defined and enforced, its seems plausible that individual resource managers could have accumulated the knowledge necessary to bring about this outcome. In any event, the hypothesis is logically sound and must therefore be judged by the consistency of its implications with observed patterns of behavior or their lingering manifestations.

Assume that each of two tribal leaders in a given locality manages a salmon stream to which he asserts exclusive ownership on behalf of his clan-house. I begin with the basic proposition from financial economics that, as resource managers, they will optimize over both risk and return in making investment decisions, with returns being measured by the value of output net of production and transaction costs. Streams are subject to variability depending on the stream-specific effects of nature and the proficiency of stream management, neither of which is observable either ex ante or ex post. "Management" involves prospecting for the knowledge to identify investment projects and undertaking all projects that increase the net present value of expected

[68] Oberg, *supra* note ?.

[69] Donald, *supra* note ?.

returns. With costlessly enforced private ownership, each manager would bear the full variability, or risk, to which his stream is subject, but he would also capture the full return free of transaction costs. Where ownership is costly to enforce, each manager would suffer diminished returns due to any transaction costs he incurred in enforcement. In contrast, with open access to all streams each manager would distribute his labor in such a way that he would receive the average product of all streams with no variance.[70] Under these circumstances, private property rights will arise only if they make all managers better off than under open access.[71]

With costly property rights enforcement, stream managers will have an incentive to reduce stream-specific resource variability even if they are risk neutral. This is because, as maximizers, they are averse to systematic losses. Consider a hypothetical in which there are three possible states of the world for each of two streams — good, neutral, and bad — with the states being uniformly distributed but independent across streams. When Manager A's productivity is good and Manager B's productivity is bad (or, for that matter, neutral), Manager B will be able to successfully encroach on Manager A's stream. This is because A must give up more at the margin in forgone production to repel B than B gives up encroaching.[72] Manager A can either allow B to fish on his stream until their marginal products are equalized, or he can do the fishing himself and pay B the appropriate amount to leave his stream in peace. Note that all else equal the parties should prefer the former solution since B's opportunity costs are relatively low; the cost to A in forgone labor product from paying B exceeds the cost to B of catching the same number of fish himself. But either way, as long as negotiating, monitoring, and enforcing a solution is costly Manager A's good-state returns will fall by more than Manager B's bad-state returns will rise, net of transaction costs. The situation is both

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[70] I assume that the average product of all streams is fixed through time. Thus, there is no periodic variation in the "market portfolio." Obviously, any variations in resource productivity due to market-wide shocks could be verified ex post by the participants.

[71] Smith, Vernon L., The Primitive Hunter Culture, Pleistocene Extinction, and the Rise of Agriculture, 83 J.P.E. 727 (1975) and North & Thomas, *supra* note ?.

[72] Johnsen, *supra* note ?.

symmetrical and reciprocal. The prospect of stream-specific variability therefore imposes systematic expected losses on both managers, and even if they are risk neutral they will have an incentive to invest resources, ex ante, to accumulate the knowledge necessary to reduce variability.

The one remaining question to be answered is why Manager A would prefer to devote his labor effort to catching salmon that he will end up transferring to B rather than simply allowing B, who faces lower labor costs, to do his own fishing on A's stream. The answer must be that there are offsetting benefits to A, and in my view these benefits very likely took the form of superior knowledge accumulation. Manager A cannot perfectly observe or control Manager B's fishing effort, and B's encroachment therefore introduces noise into the information feedback mechanism A observes from prospecting for superior knowledge of salmon husbandry. Because net returns are concave in the state of the world, A's expected returns from prospecting will fall from allowing B to encroach. Of course, where the returns from prospecting for knowledge are lower, encroachment as a response to differential resource productivity should be more likely, thereby reducing the social costs of catching a given number of fish.

Over the course of time, failure to respect private property rights reduces the rate at which private knowledge accumulates and limits the opportunities for positive net present value projects. This situation constitutes a stylized example of why private property rights might arise along with a system of reciprocal sidepayments similar to potlatching. The potlatch system allowed participating tribes to diversify the exogenous stream-specific variability they inevitably realized from the choice of private ownership rather than open access. With the potlatching secure as an institution for defining and enforcing property rights, steam managers quite properly would have invested fewer resources to reduce stream-specific variability and more resources to increase expected returns.[73]

[73] Even if the potlatch system succeeded in completely diversifying local stream-specific resource variability, all resource managers would nevertheless have had an incentive to reduce variability that might affect all streams in the entire region identically. This variability is known in financial theory as "market risk." Brealey, Richard, and Stuart Myers, PRINCIPLES OF CORPORATE FINANCE (? Ed, 199?), at ??.

This system could suffer from shirking on the accumulation of knowledge by resource managers. This is because prospecting is costly. It requires trial-and-error experimentation and the current sacrifice of known opportunities for uncertain future returns. But the benefits in term of reduced variability or increased returns are subject to sharing. With management proficiency being unobservable, what mechanism could be used to encourage all managers to engage in prospecting up to the point where the social benefits just equaled the social costs? There were two possibilities. First, at least among the Kwakiutl, potlatch ranking was highly formalized, and participants potlatched only with those groups whose ranking was close to their own. Over time, resource managers who excelled at accumulating knowledge of salmon husbandry no doubt ascended in the potlatch ranking, and the value of the gifts they received in return increased. If, as Oberg reports for the Tlingit, potlatch goods consisted exclusively of durables that were supposed to remain unused until given away in a subsequent potlatch, there was little immediate benefit in the receipt of more valuable potlatch gifts.[74] Also, since one had to give more to get more the net material benefit from ascending through the ranks may have been small.

Second, and more convincing, social prestige accompanied one's ascent in the potlatch rankings. The norm of giving was highly revered and could easily have provided the incentive for zealous prospecting to accumulate knowledge and wealth. It is perhaps instructive that high-ranking titleholders were said to possess "secret" knowledge of good behavior in the management of resources. Greater social prestige was the residual payoff for superior knowledge of salmon husbandry by the resource manager who achieved the good state more often than his rivals. It was therefore unnecessary for members of tribal society to attempt to monitor their leaders' inputs; outputs conveyed the important story. Indeed, privacy regarding inputs was necessary to inhibit knowledge appropriation.[75]

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[74] Oberg, supra note ?, at ?. I have a difficult time believing Oberg's the assertion that potlatch gifts were never used. This may well have been the prevailing norm, but in times of hardship I suspect the norm gave way to necessity. Of course, the custodian of these goods would have to account for any obvious wear and tear the next time he hosted a potlatch and gave them away.

[75] Donald (1997), *supra* note ?, at ?, reports that one reason for taking a titleholder captive in war was make him tell his knowledge. In many cases a leader's clan would offer a ransom for his safe return, while in

B. The Basics of Pacific Salmon Biology

It has long been recognized that the biological characteristics of salmon are extremely sensitive to environmental factors. As George P. Marsh reported in 1874, "[f]ish are more affected than quadrupeds by slight and even imperceptible differences in their breeding places and feeding grounds. Every river, every brook, every lake stamps a special character upon its salmon, its shad, and its trout, which is at once recognized by those who deal in or consume them."[76] Pacific salmon are considered by ecologists to the model of an "*r*-selected" species.[77] In contrast to "*K*-selected" species, such as most mammals, salmon are born in large numbers, grow quickly, suffer high mortality, live fairly short lives, reproduce only once, and are extremely fecund. Like insects, the time between generations is short enough, and the struggle to reproduce keen enough, that over the course of a man's lifetime the characteristics of a given salmon stock can evolve dramatically in response to even minor changes in environment. To this can be added the anadromous character of salmon, which brings them home to their natal streams to spawn and die after spending several years feeding and growing in the open ocean. The homing instinct in Pacific salmon is strong, so that even a small tributary of a larger river leaves its unique imprint on the salmon populations that originate in its waters.

1. Nomenclature

Pacific salmon enter their natal streams from the ocean to spawn in what marine biologists call a "run."[78] A run can occur over the course of many months or as quickly as one or two hours. In larger rivers, a run might consist of many populations of a given

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other cases they would refuse. No doubt those leaders with a greater accumulated stock of secret knowledge were the ones most likely to be ransomed.

[76] Marsh, George P., THE EARTH AS MODIFIED BY HUMAN ACTION (New York: Scribner, Armstrong & Co., 1874), at 108.

[77] Hayden, Brian, *Research and Development in the Stone Age: Technological Transitions among Hunter-Gatherers*, 22 CURRENT ANTHROPLOGY 519 (Oct. 1981), at 525.

[78] The source for terms that follow is Ricker, W.E., *Cycles of Abundance among Fraser River Sockeye Salmon (Oncorhynchus nerka)*, 54 CAN. J. FISH. AQUAT. SCI. 950 (1997).

species entering the river together, with the separate populations having originated in different spawning habitats within the drainage — the headwaters, tributaries, or lakes — and perhaps at different times. Each population can be seen as a separate race, although that term is also used to describe unique characteristics of a species genetically selected for factors other than spawning habitat. In very small rivers with an essentially homogenous spawning habitat, the species run and population are synonymous. Since each population reflects idiosyncrasies of spawning habit and other factors that uniquely affect the number and size of fish it contains in a given year, the aggregate run in larger rivers will tend to be more stable through time than in smaller rivers due to the effects of diversification. Larger rivers tend to contain more species than smaller rivers, in addition to more populations within each species, and the diversifying effects on the number and size of fish entering the river in a given year also lead to greater temporal stability.[79]

Pacific salmon belong to any of several "lines" in a "cycle." The cycle refers to the number of years between the generations, or cohorts, of a given population, and the lines refer to the separate generations within the cycle.[80] The term "stock," as I use it, refers to the indefinite sequence of cycles in a particular line. As with cattle, the stock represents both current and future biologically related generations.[81] "Parents" consist of those fish that reach the spawning grounds and succeed in mating, and "recruits" consist

[79] Shaulk, Randall, *The Structure of an Anadromous Fish Resource*, in FOR THEORY BUILDING IN ARCHEOLOGY: ESSAYS ON FAUNAL REMAINS, AQUATIC RESOURCES, SPATIAL ANALYSIS, AND SYSTEMATIC MODELING, edited by Lewis R. Binford, (Academic Press, 1977). The obvious question is "diversification" as to whom. If all fish are taken in the privately owned tributaries and headwaters of a river, then the relative stability of total fish entering the river in a given year is meaningless as far as humans are concerned. In aboriginal times, larger rivers like the Fraser were heavily fished in their downstream trunk sections. Thus, these natives faced less natural variability due to diversification than those whose territories were confined to the tributaries and headwaters.

[80] Consider the cycle of days of the week in a sequence of weeks. The Mondays comprise one line, the Tuesdays another, and so on. At the beginning of each week the cycle repeats itself. It is unclear to me whether each line of a cycle can develop distinct characteristics that would allow a careful observer to distinguish between two lines if he could observe them simultaneously at identical stages of progression. In the case of pink salmon, the answer is clearly yes. What about other species? The answer is important, because even if the NWC natives knew that the salmon in a given stream were in some way intergenerationally connected, which I believe they surely did, they did not necessarily know the exact pattern of interconnection. If each line in a cycle is identifiable by visual inspection, the exact pattern of interconnection would have been easier to identify because the effect of harvesting actions taken at Time 1 would be more easily observed at Time 2.

[81] *See, e.g.*, Ostrom, *supra* note ?, at 30.

of those that reach sexual maturity and are either caught in the commercial fishery or enter the river to begin their spawning migration. The number of river entrants is referred to as "escapements." For the pre-contact native fishery, where ocean fishing was nil, recruits and escapements are synonymous.

Salmon spawn in the moderate currents of the upper reaches of the stream (or connecting lakes) in gravel beds that allow subsurface water flow to deliver oxygen to the eggs. The female salmon uses her tail to dig a nest, or redd, in the gravel with her tail and deposits her eggs, which are fertilized by the male. The female then covers the fertilized eggs with gravel and defends the nest against intruders until exhaustion or death prevail. Competition in spawning due to crowding and other factors affect the success rate of fertilization. Once having hatched, the alevin remain below the surface of the gravel stream bed until their yolk sack is consumed. On emerging from the gravel, the fry, or smolt — distinguished by ascending order of age — eventually make their way to sea. Depending on the species and population, the young fish may remain in freshwater for anywhere from a few days or weeks to several years.

The "life-history type" of a line of Pacific salmon is denoted as i/j, where i refers to the number of years the young salmon remains in freshwater and j refers to the number of years of ocean residence before spawning. Thus, 1/3 indicates a line that repeats on a four-year cycle and remains one year in freshwater after birth and three years in the ocean. Pacific salmon life histories can range from 0/2 to 3/4 to 1/6, and all but one species exhibit multiple life histories.[82]

A male salmon that has quickly reached sexual maturity and skips a line to spawn with an earlier line of its population is known as a "jack." Jacks are far more common than their female counterparts, known as "jills." Because of their small size and quickness, jacks may have a stealth-based spawning advantage over medium sized males, who are easily dominated by larger males. Although jacks are smaller than their spawning cohorts, they are also exhibit relatively fast growth and sexual maturation, so that their effect from successful spawning on the average size of recruits is ambiguous. If

[82] Marine biologists determine life histories from anomalies appearing on the rings of the salmon's scales. A magnified view of the scale looks surprisingly like a fingerprint (Burgner (1991), at 86).

their offspring also tend to be fast growing but live out their full cycle before spawning, the effect of jacks on the average size of recruits in the adopted line should be positive. If their offspring tend to mature quickly and at a smaller size than the average of the adopted line (that is, if the offspring of jacks also become jacks), their effect will be to reduce the average size of recruits over time. In any event, the intergenerational mixing that jacks provide allows rapid recovery of any line that might happen to suffer catastrophic population decline due to land slides or other disasters.

2. Five Species of Pacific Salmon

There are seven species of Pacific salmon, only five of which spawn in North American waters. They are the pink, the chum, the coho, the sockeye, and the chinook. Each species exhibits obvious differences in average size, color, markings, spawning habits and habitat, and life history, with these characteristics varying considerably across time and place even within each species. In North America, Pacific salmon range from Northern California along the Pacific coast to the Bering Sea, north into the arctic ocean, and at least 1000 miles east along the northern coast of Alaska and Canada. In the most southerly portion of the range, only coho and chinook occur in noticeable numbers, while in the far northerly portion of the range only chum and pink salmon occur. Within the NWC culture area all five species occur in substantial numbers.[83]

Pink salmon (or humpacks) are by far the most abundant of the Pacific salmon species in terms of both numbers and weight currently harvested.[84] They are found all along the NWC coast but proliferate in southeastern Alaska, where they normally spawn in a very short but dense run[85] in the lower reaches of rivers and streams from August to late October. Black bear predation during the spawning migration is a heavy cause of mortality in migrating pinks, especially in unspawned females, and they have evolved a specific flight response to black bear odors as a result. Pinks migrate to sea immediately

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[83] Shaulk, *supra* note ?.

[84] Heard, William R., *Life History of Pink Salmon (Oncorhyncus goruscha)*, in PACIFIC SALMON LIFE HISTORIES, edited by C. Groot and L. Margolis (Vancouver; UBC Press, 1991).

[85] Langdon, *supra* note ?.

after birth and follow a uniform two-year cycle; thus, their life history is expressed as 0/2. Alternating line-dominance between years in the two-year cycle of pinks is fairly common and often results in huge differences in numbers and up to 50% differences in average size, which, overall, is close to five pounds.[86] Heard reports that repeated large-scale attempts to transplant pinks along the Pacific coast in an effort to reduce the pattern of alternating line-dominance have largely failed.[87]

Chum (or dog salmon) are evenly distributed in large and small rivers along the NWC. They may have been the natives' favorite for winter preservation through drying or smoking because of their relatively low fat content, which inhibits spoilage and lends itself to preservation. Chum average close to 12 pounds, with a life history that ranges anywhere from 1/2 to 1/6, with 1/3, 1/4, and 1/5 being the most common. They tend to spawn during a fairly short run[88] in September, October, or November, and even into winter, which makes them the latest-spawning of the five species.[89] Newborn chum salmon tend to spend only a few days or weeks in freshwater before migrating to the sea.

Coho (or silvers) may be the most ancient species of Pacific salmon. They average slightly over seven pounds and exhibit a predominant 1/1 or 2/1 life history. Their spawning migration normally occurs over an extended period in September and October, normally during daylight hours. In many cases, coho have been transplanted with remarkable success, most notably in Lake Michigan. There are two distinct types of coho based on ocean residence. The "ocean" type and the "inshore" type. The inshore type typically remain in localized inland waterways during their ocean phase, while the ocean type range much more widely in outer coastal waters.[90]

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[86] Donald, Leland, and Donald H. Mitchell, *Nature and Culture on the Northwest Coast of North America: The Case of Wakashan Salmon Resources*, in KEY ISSUES IN HUNTER-GATHERER RESEARCH, edited by Ernest S. Burch, Jr. and Linda J. Ellanna (Oxford, Providence: Berg, 1994).

[87] Heard, supra note ?, at 127-129.

[88] Langdon, *supra* note ?, at 102.

[89] Donald & Mitchell (1994), *supra*.

[90] Sandercock, F.K., *Life History of Coho Salmon (Oncorhyncus kisutch)*, in PACIFIC SALMON LIFE HISTORIES, edited by C. Groot and L. Margolis (Vancouver; UBC Press, 1991).

Sockeye are the only Pacific salmon that requires a lake environment for reproduction. Recruits average over six pounds and spawn both in lakes and in tributaries connected to lakes, but either way their offspring generally spend the first two years of their lives in a lake environment. Sockeye are said to be the most "plastic" of the Pacific salmon species, because they exhibit 1/2, 1/3, 1/4, 2/2, 2/3, 3/1 and 3/2 life histories. Moreover, given their relatively stable spawning environments in or near lakes, their populations deviate least from expected numbers.[91] Where nighttime bear predation has been a factor in their reproductive survival, sockeye have adapted by spawning during the daytime, and where daytime egg predation by char has been a factor they have adapted by spawning at night.[92] Along the NWC, sockeye spawn over a very long run primarily in August, September, and October, although this varies considerably across the region.

Chinook salmon (also known as spring, king, and tyee) are by far the largest of the five species, averaging close to 13 pounds but often growing to more than 100 pounds. The largest chinook are found in the Columbia and Fraser Rivers, although Ricker reports that northern British Columbia chinook are also unusually large.[93] Chinook follow a life cycle of three to seven years and return to spawn any time during the year, although later summer and early fall runs are most prolific in northern regions. Chinook salmon occur in two behavioral forms or races, "ocean-type" and "stream-type." Stream-type chinook remain in the river for one or more years following birth and on returning may spend several months in the river before spawning; their life histories range from 1/2 to 3/4. They are most prolific in the upper tributaries of larger rivers like the Columbia and Fraser and in northern rivers well north into Alaska and west into Asia.[94] Healey

[91] Langdon, at 102.

[92] Burgner, Robert L., *Life History of Sockeye Salmon (Oncorhyncus nerka)*, in PACIFIC SALMON LIFE HISTORIES, edited by C. Groot and L. Margolis (Vancouver; UBC Press, 1991).

[93] Ricker, W.E., *Trends in the Average Size of Pacific Salmon in Canadian Catches*, 212 CAN. SPEC. PUBL. FISH. AQUAT. SCI., 593 (1995), at 596. Within the Columbia and Fraser River systems, the size of chinook is highly related to the distance they travel to spawn, with the largest fish often traveling hundreds of miles to the headwaters of the river.

[94] Healey, M.C., *Life Histories of Chinook Salmon (Oncorhychus twhawytscha)*, in PACIFIC SALMON LIFE HISTORIES, edited by C. Groot and L. Margolis (Vancouver; UBC Press, 1991).

reports that ocean-type chinook have shown themselves to be more adaptable to diverse river environments than stream-type chinook and notes that the reasons for these behaviorally distinct types of chinook have yet to be understood.[95] Ocean-type chinook make their way into the ocean within a few months of birth and spawn within a few weeks of returning to the river; their life histories range from 0/2 to 0/6. They are better adapted to small streams than stream-type chinook, although they also occur in the lower tributaries of larger rivers. Their northernmost distribution occurs at around 56°N., slightly south of the northernmost limit of the NWC culture area. Reports indicate that ocean-type chinook have a much stronger fidelity to their release site on transplantation than stream-type chinook. This makes them much more attractive for transplantation, which has generally been successful.[96]

3. Heritability

The effect of man's behavior on genetic selection of Pacific salmon is a subject over which marine biologists have been, and continue to be, intensely concerned. This is because various species and populations of salmon demonstrate disturbing cyclical patterns and other dynamic trends in size and numbers that affect commercial profits and have yet to be fully understood, let alone optimized. In the words of perhaps the most notable living scholar in marine biology:

> From data available up to 1975, I suggested that a change in the genetic constitution of salmon stocks was mainly responsible for the observed decreases in size. After all, if you are raising beef cattle, for example, you select breeding stock with a proven history of fast growth. Our fisheries have been doing exactly the opposite. Our breeding stocks, on the whole, contain more of the smaller individuals in any population. Experiments have shown that both rate of growth and age at maturity are determined, in part, by hereditary factors and, to some extent at least, independently so. Also, both average rate of growth and average age of maturity in a population can be modified by selection.[97]

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[95] Healey, s*upra*, at 382.

[96] Healey, *supra*, at 380.

[97] Ricker (1991), *supra*, note ?, at 600-01.

Ricker arrived at this observation after over 50 years of studying Pacific salmon. Two of his many major contributions to the field are his analysis of the persistent pattern of four-year line-dominance in Fraser River sockeye, first noticed at the turn of the century, and his study of the apparent downward trend in the average size of all species of commercially harvested Pacific salmon between 1951 and 1975.[98] The one trait identified by Ricker necessary to preserve the cyclical dominance of one line of Fraser River sockeye is that they mature and reproduce only once at roughly the same age. Spillover effects between lines could be a contributing factor as well. Given this, a dominant cohort could arise and persist due to cycles of cannibalism of smolt by incoming recruits, cycles of food supply available to fry, cycles of predation by trout and other predators on eggs, alevin, and fry, or the cyclical incidence of parasites. Ricker found only modest support for any of these explanations and concluded that the longstanding pattern of four-year line-dominance may have "developed gradually during prehistoric time . . . assisted by . . . intensive fishing by the large indigenous human populations that existed in the region before western contacts brought a succession of virulent epidemic diseases, starting with smallpox in the 1790s."[99] Not only does this passage suggest that the behavior of the interior natives could have influenced the sockeye fishery, but it gives plausible support to the notion that the effects of genetic selection on salmon population dynamics can persist for decades or even centuries.

Fisheries biologists define "heritability" as the propensity of recruits to adopt a *selection differential* reflected in their parents.[100] Heritability is a measure of the intergenerational elasticity of the population to genetic factors that are over- or under-represented in parents relative to the mean of the population from which the parents were

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[98] Ricker (1997), *supra*, note ?.

[99] Ricker (1997), *supra* note ?, at 963.

[100] Ricker, W.E, *Changes in the Average Size and Average Age of Pacific Salmon*, 38 CAN. J. FISH. AQUAT. SCI. 1636 (1981).

selected.[101] Heritability increases in genetic variance and decreases in environmental variability, which essentially introduces noise into the selection process.

In examining the downward trend in Pacific salmon size from 1951 to 1975, Ricker suggests that modern commercial fishing methods could have caused the trend through genetic selection. One possible mechanism arose from a change in the constraints faced by commercial fishermen. Until 1945, Pacific coast canaries uniformly paid for all species of Pacific salmon except chinook by the piece, regardless of weight; 1935 prices were 5 cents for pinks, 10 cents for cohos, and 25 cents for sockeye. Thereafter, the canneries switched to paying by the pound for all salmon. This gave commercial fishermen an incentive to target larger fish in their choice of equipment. They shifted to gill nets with larger mesh size than before. They shifted way from purse seining — which catches salmon independent of size — and toward gill-netting. And they shifted away from purse seining and toward trolling, which also, apparently, catches larger fish.[102]

Ricker found modest support for the proposition that size selectivity in the commercial fishery caused or contributed to the reported decline in salmon size. The reason the evidence was not stronger may have been that size selectivity can have offsetting effects on heritability factors. If the commercial ocean fishery could select exclusively from a given cycle line, in which there was no mixing of lines or interpopulation straying, then commercial fishing methods that suddenly bias the catch in favor of larger and faster growing fish would very likely result in genetic selection toward smaller average size. But with the mixing of lines and populations in commercial ocean fisheries, size-biased fishing methods can impose a selection differential on both

[101] Intuitively, one can think of the heritability of a given genetic factor as the shift in the statistical population distribution of Generation 2 as a result of spawning by a biased subset of recruits in Generation 1. To get a true picture of heritability, my view is that one must assume that in long-run steady state all genetic factors will generate measured heritability of zero. For example, there is no doubt that from a given steady-state population of salmon larger recruits will have greater success in achieving parenthood by spawning. The average size of parents will therefore exceed the population mean. But given the assumption of steady state this will not increase the population mean of recruits. Thus, a true measure of heritability requires an analysis of the *deviation* of the selection differential for a given genetic factor from its steady state value.

[102] Ricker, *supra* note ?, at 1638.

growth rate and age at maturity. Greater age at maturity is associated with slow growth. The net effect is ambiguous, but it leaves open the possibility that the NWC natives used size selection as a basis for affecting returns to the fishery.[103]

More recently, Bigler, Welch, and Helle (1996) suggest that the observed size trends might be the effect of "density dependent growth" caused by environmental factors.[104] Density dependent growth refers to the relationship between population numbers and the average size of the fish in the population. One of the most likely causes of such a relationship is the existence of a finite food supply on which the population feeds. When external factors affect either population numbers or average size the new equilibrium tends to hold total biomass constant. Although the direction of causality is ambiguous, empirically there is nevertheless a negative relationship between numbers and size through some range of population dynamics. Based on a study of cannery records, one researcher discovered that smaller fish and greater numbers were a periodic feature of the commercial salmon fishery prior to the period Ricker studied.[105] This suggests that long-term ocean environmental factors may be responsible for the observed trends in size and numbers, although it does not necessarily refute Ricker's hypothesis because the two explanations are not mutually exclusive.

Another important heritability factor appears to be run timing. In an unfortunate experiment during one fishing season, Alaska regulators allowed only the first 10,000 fish in a particular run to be harvested. Virtually none of these recruits succeeded in spawning, thus truncating the line and imposing a timing-based selection differential on parents. When the next generation in the line returned, the run occurred noticeably later in time. Since late arriving parents give birth to late arriving recruits, run timing is

[103] A private stream-based fishery that used a stream-width weir for harvesting would have provided exactly the conditions necessary to eliminate noise if the native operators were able to differentiate jacks and other strays.

[104] Bigler, Brian S., David W. Welch, and John H. Helle, *A Review of Size Trends among North Pacific Salmon (Oncorhynchus spp.)* 53 CAN. J. FISH. AQUAT. SCI. 455 (1996).

[105] Attributed to Welch (19??). Personal communication with Gordon Miller, Pacific Biological Station, Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada. Get cite.

heritable and is therefore another genetic factor on which the NWC tribes could have husbanded their fisheries.[106]

4. Variability and Other Factors

Aside from ocean-based environmental factors, there are many stream-specific environmental factors that can affect the biological characteristics of salmon. Being variable, many of these factors introduce variability into stream returns. Of these, I have already noted cycles of predation, cannibalism, freshwater food supply, and parasites. I have yet to discuss the effects of overcrowding in the spawning beds. If a run of salmon is exceedingly large, parents naturally adjust at the margin by reducing the size of the redd. But in total this can lead to a large cohort of fry for which the freshwater food supply is wholly inadequate, thereby subjecting the entire cohort to starvation and disease. This factor would seem to be less troublesome for pinks than for other species, because they tend to spawn closer to salt water and in any event make their way to sea much sooner in their life cycle. In many cases, overcrowding will also lead to the destruction of successfully completed redds by later arrivals, thereby uncovering already fertilized eggs and subjecting them to predation and disease. The effects of overcrowding appear to be greater within species because different species have different spawning habitats and freshwater food sources.[107] As a result, the NWC tribes could have exploited species complementarities to increase overall stream productivity by undertaking appropriate stocking programs. Scattered evidence suggests that the tribes were aware of, and routinely took advantage of, opportunities for transplantation. As Sproat notes, "[i]t is common practice among the few tribes whose hunters go far inland, at certain seasons, to transport the ova of the salmon in boxes filled with damp mosses, from the rivers to the lakes, or to other streams."[108]

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[106] Personal communication with Dr. Richard Beemish, PBO, DFO, Canada. Get cite.

[107] Heard, *supra* note ?, at 154.

[108] Sproat, Gilbert Malcom, SCENES AND STUDIES OF SAVAGE LIFE (London: Smith, Elder and Co., 1868), at 220. Also, personal communication with Gordon Miller, PBO, DFO, Canada. Consider the following report: "In fact, after deglaciation, the Columbia River appears to have been the principal source for the repopulation of Fraser River fish fauna in general (McPhail and Lindsey 1986) and chinook salmon in particular (Utter et al. 1989)." Waknitz, F. William, Gene M. Matthews, Thomas Wainwright, and Gary A.

Two important variable environmental conditions affecting stream returns are water temperature and runoff, or stream flow.[109] My concern is with their effects on stream-specific variability.[110] Depending on topography, soil content, vegetation, and other factors within the stream drainage, regional weather patterns can affect the water temperature and runoff of streams in a given locality quite differently.

Salmon are extremely sensitive to temperature, and this is especially true for fertilized eggs and the young alevin and fry. Among other things, lower temperature increases the oxygen carrying capacity of the stream, which can dramatically influence mortality and hence the number of subsequent recruits. Rapid water velocity from excessive runoff can reduce the rate of spawning success and, once spawning has occurred, it can scour a stream bed and expose fertilized eggs and the already hatched but otherwise protected alevin to predation and disease. It can also deposit silt on the spawning beds, thereby depriving eggs and alevin of oxygen. Low stream flow due to drought can expose spawning beds to air, resulting in high mortality.

One response by NWC tribal leaders to these environmental influences could have been the engineering or re-engineering of spawning beds to regulate stream flow, siltation, and perhaps temperature. But absent this kind of active management, they could also have reacted to environmental shocks to a population by taking steps to minimize the negative effects in later years. For example, by introducing multiple species with different life histories into their streams, and by adjusting the run timing of species to avoid concurrent migration, the natives could have diversified much of the associated risk. Moreover, by accumulating the knowledge to predict the effects of environmental shocks on the next generation of recruits, they could have taken mitigating action. For example, if the fry of Year 1 of a line that is known to be on a four-year cycle

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Winans, *Tech. Memo-22: Status Review for Mid-Columbia River Summer Chinook Salmon* (Seattle: U.S. Dept. Commerce/NOAA/NMFS/NWFSC/Publications, 1995).

[109] Shaulk, *supra* note ?, at 1977.

[110] Shaulk provides a careful analysis of "macro" factors affecting stream variability, most of which are correlated with latitude. Because these factors have an identical influence on streams over a wide region, they are irrelevant to the hypothesis that the NWC tribes used potlatching to diversify relative stream-specific variability, which is by definition localized.

is hit hard by runoff, the predicted effect would be low returns of that species in Year 4. Thus, in Year 2 a tribal leader could adjust his harvest of pinks, which are on a fixed two-year cycle, to increase their returns in Year 4. This adjustment would result in overcrowding under ordinary harvesting of the returning pinks in Year 4. But with the knowledge of reduced returns of the other species in Year 4, the leader would be confident of the need to make an unusually large harvest of pinks.

This kind of adjustment is characterized by fisheries biologists as a "compensatory" effect on mortality in the sense that the rate of harvest increases (decreases) when population size is above (below) its long-run mean; the high rate of harvest reduces the deviation from the mean in the subsequent cycle. "Depensatory" effects on mortality are those that increase (decrease) the rate of harvest when population size is below (above) the long-run mean; the high rate of harvest increases the deviation from the mean in the subsequent cycle.[111] Of course, compensatory and depensatory fishing effort, as with heritability, must be evaluated relative to a steady-state equilibrium. Out of equilibrium, it is clear that through some range in a private fishery an increase in sustained fishing effort will increase the population mean and the sustainable harvest.[112]

IV. Property Rights, Salmon Husbandry, and Institutional Change

A. Evidence Consistent with Salmon Husbandry

1. Evolutionary Psychology and Archeological Dating

Throughout much of the world, including the North American continent, man emerged from millennia as a nomadic hunter-gatherer to take up animal domestication and sedentary agriculture between 12,000 and 8,000 before present (BP).[113] Evolutionary

[111] Burgner, Robert L., *Life History of Sockeye Salmon (Oncorhyncus nerka)*, in PACIFIC SALMON LIFE HISTORIES, edited by C. Groot and L. Margolis (Vancouver; UBC Press, 1991).

[112] *See, e.g.*, Rostlund, E., FRESHWATER FISH AND FISHING IN NATIVE NORTH AMERICA (1952) and Kew, *supra* note ?, at 179, 180.

[113] Smith, *supra* note ?, at 733; Hayden (1981), *supra* note?, at 521.

biologists and psychologists largely agree that man's brain was fully developed at this time. That development was patterned on the complex and subtle demands of hunting cooperatively in social groups.[114] Success in the hunt required routine reliance on what Stinchcombe defines as "reason," "a socially established method of calculating what should be authoritative in a particular case."[115] There is little doubt that the scientific method, consisting of simple empirical hypothesis testing, played a prominent role in such reasoning.[116] The scientific method as a basis for accumulating knowledge is both flexible and powerful. It can be applied privately by an individual, but unlike other methods of gaining private knowledge it also can be applied socially to gather data from, and to reason with, the participants in a coordinated effort in which the shrewd investment of scarce group resources is essential. The accumulation of scientific knowledge yields a premium to careful observation, memory, and the ability to analogize between events that are disconnected in time and place.[117] In my view there is little doubt that the very structure of language evolved to accommodate the power of the scientific method.

It is in this stage of evolution that man turned their attention to animal domestication and sedentary agriculture, both of which rely on husbandry in one form or another. North & Thomas argue that this transition resulted from a gradual institutional evolution to private communal ownership in place of open access.[118] Smith makes a

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[114] *See, e.g.*, Tooby, John, and Leda Cosmides, *The Psychological Foundation of Culture*, in THE ADAPTED MIND, edited by Jerome H. Barkow, Leda Cosmide, and John Tooby (Oxford: Oxford University Press, 1992); Kaplan, Stephen, *Environmental Preference in a Knowledge-Seeking, Knowledge-Using Organism*, in THE ADAPTED MIND, edited by Jerome H. Barkow, Leda Cosmide, and John Tooby (Oxford: Oxford University Press, 1992); and Hoffman, McCabe, and Smith, *supra*.

[115] Stinchcombe, Arthur L., *Reason and Rationality*, in THE LIMITS OF RATIONALITY, edited by Karen Schweers Cook and Margaret Levi (Chicago and London: University of Chicago Press, 1990), at 289.

[116] At its most basic level, the scientific method is nothing more an empirical application of the following simple logical syllogism: if A logically implies B, then the absence or negation of B refutes A, where B is an observable event, interaction, or relationship.

[117] Memory and analogical reasoning perform an important role in economizing on the costs of processing data into information because they allow the reasoning process to be applied to incremental bits of data relative to what was encountered in otherwise identical past experiences. The ability of participants to focus on marginal information is an important attribute of sophisticated institutions such as the common law and modern securities markets.

[118] North & Thomas, *supra* note ?.

plausible argument that in North American the transition was hastened by Paleolithic man's overexploitation of various mega-fauna, which were hunted to extinction under an open access property rights structure.[119] With the disappearance of mega-fauna, North American man turned to sedentary agriculture and abandoned open access in favor of some form of private communal ownership. Whatever the exact nature of cause and effect, animal domestication and sedentary agriculture, both of which rely on husbandry, appear to have been causally related to private ownership. According to anthropologists and archeologists, however, salmon were superabundant on the NWC, and the inability of the tribes to overexploit them led to the rise of sedentary *complex* hunter-gatherer societies and not to sedentary agriculture.[120]

Man apparently arrived on the southern portion of the NWC in significant numbers starting around 9500 BP, perhaps from the Columbia River and Fraser River drainages. From these points of entry, man appears to have moved gradually northward, arriving at the northern limit of the culture area as late as 5000 BP. Nevertheless, on arriving man apparently did not immediately take advantage of superabundant salmon. The archeological evidence indicates that early on the native diet consisted largely of shellfish and large mammals. It was only after a few thousand years that salmon became the major component of the native diet.[121] Why would the natives have declined to take advantage of a superabundance of salmon? One explanation is that preservation technology was limited. Carlson places the advent of salmon preservation at about 7000 BP, which is roughly consistent with dietary evidence of increased salmon consumption. The alternative explanation is that salmon were not always so abundant. In fact, Carlson

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[119] Smith, *supra* note ?. Some might contend that open access property rights are no property rights at all. Relative to alternative property rights structures, however, open access must be considered one possible structure. Moreover, although open access treats the wild stock of, say, fauna (*farae naturae*) as unowned, private ownership applies to the members of the wild stock that have been captured and reduced to exclusive individual possession through consumption. Oberg makes this perceptive point in relation to individual versus common group ownership among the Tlingit. Oberg, Kalervo, *A Comparison of Three Systems of Primitive Economic Organization*, 45 AMERICAN ANTHROPOLOGIST, 572 (1943), at 582.

[120] Hayden (1981), *supra* note ?.

[121] Mitchell, Donald, and Leland Donald, *Archeology and the Study of Northwest Coast Economies*, RESEARCH IN ECONOMIC ANTHROPOLOGY, Supplement 3, 293-351 (1988), at 336-341.

also reports that salmon appeared in abundance almost 1500 years prior to the advent of preservation technology, around 8000 BP. It wasn't until 5000 BP that tribal leadership emerged, and formalized potlatching began only as late as 2000 BP.[122]

2. Cross Sectional Variations

To directly test the salmon husbandry hypothesis, it would be ideal to have data on salmon stocks over a wide cross section of streams and to compare the characteristics of the stocks as the structure of property rights varied. Thus far, however, the data have proven elusive. There are nevertheless several ways of getting at the question of cross-sectional variation in resource use based on variations in the structure of property rights.

Donald & Mitchell made one of the early systematic attempts to use biological evidence to determine the relationship between exogenous stream-specific productivity, resource variability, and NWC cultural institutions.[123] The authors first established a hierarchy of 16 Southern Kwakiutl "local groups" based on their potlatch rankings from the historical record. They determine each local group's population in 1830 and 1880, their private territories, and the separate streams within each territory. Based on estimates of salmon escapements in these streams from 1950 to 1967 made by Canadian Department of Fisheries protection officers, the authors then determine the relationship between local group potlatch ranking, median salmon productivity during the 17-year period, yearly productivity variation around the median, population in 1830 and 1880, and distance from Fort Rupert.[124] They find that median productivity and 1830s population are the best unconditional predictors of group rank, but conditional on 1830s population their measure of productivity variation is able to explain 36% of variation in

[122] Carlson, Roy L., *The Later Prehistory of British Columbia*, in EARLY HUMAN OCCUPATION IN BRITISH COLUMBIA, edited by Roy L. Carlson and Luke Dalla Bona (Vancouver: UBC Press, 1996).

[123] Donald, Leland, and Donald H. Mitchell, *Some Correlates of Local Group Rank Among the Southern Kwakiutl* 14 ETHNOLOGY 325 (1975).

[124] The authors construct a "coefficient of relative variation" for each tribe as their measure of productivity variation. It consists of the sum of the absolute values of each year's percentage difference between actual escapements and median escapements for the entire 17-year period for each tribal territory, all divided by the number of years in the sample, 17. The authors then ranked each tribe according to productivity variation, with the tribe whose territory had the least variable productivity receiving the highest ranking.

local group rank. The authors' hypothesis is that those local groups with the least variable resource base should have had the highest ranking, where they implicitly assume that resource variability is exogenous. The salmon husbandry hypothesis predicts that a local group's ability to *reduce* resource variability from what naturally occurred would have resulted from more secure property rights and would have lead to higher potlatch ranking. This hypothesis treats resource variability as endogenous, that is, at least to some extent under the control of the participants.[125] The data therefore appear equally consistent with the salmon husbandry hypothesis.[126]

This test of the salmon husbandry hypothesis suffers from the criticism that the data were gathered many years after the virtual abandonment of the native fishery with the advent of commercial fishing. To expect the effects of salmon husbandry to persist for over 100 years may seem implausible, however it becomes more plausible when one considers that salmon husbandry may have persisted for over 5000 years on the NWC, in which case the salmon fishery might have yet to fully adjust to a new equilibrium. This is consistent with Ricker's suggestion that native population decline may have been the cause of cyclical dominance in the Fraser River sockeye fishery. It is also consistent with fisheries biologists' more general suspicion that some kind of long-run equilibrating process appears to be slowly working itself out for the entire Pacific Coast salmon fishery.

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[125] A more complete analysis of the effects of resource variability on group rank would use the capital asset pricing model from financial theory. See Brealey, Richard A., and Stewart C. Myers, *Principles of Corporate Finance* (New York: McGraw-Hill, 1996), at 141-204. According to this model, it would have been socially wasteful to invest resources in reducing stream-specific variability because, by definition, it would have been uncorrelated with other tribes' productivity. This is exactly the kind of variability for which potlatching served to compensate. In this view, each tribe's incentive would have been to increase expected returns and, if possible, to reduce the "systematic" variability — extent to which its productivity increased or decreased with increases and decreases in the system-wide trend, or "market portfolio." Any tribe whose productivity was negatively correlated with the market portfolio would have commanded the highest ranking because of its ability to share its surplus with other tribes when their productivity was low and to require a share of other tribes' surpluses only when those tribes' productivity was relatively good.

[126] It is easy enough to show theoretically that, under plausible assumptions, in an initial allocation of resources between groups with equal population, clearly defined property rights, and no system of wealth transfers, each group will command an identical allocation, and that, all else equal, after years of husbandry the group with the least variable resource will be the one that best succeeded in reducing variability. This inference requires the additional assumption that in the initial allocation all groups received natural resources with the same risk and return. In theory, a group should have been willing to accept a stream with greater exogenous variability if it also exhibited greater expected returns.

Another source of cross-sectional variation in property rights and resource use comes from the coastal eulachen fishery, which suffered from occasional localized failure.[127] Recall that eulachen were harvested by multiple tribes under open access in the estuaries and lower trunks of the larger rivers and inlets where exclusive ownership over the entire fishery was virtually impossible. With multiple tribes fishing in common on the fishing grounds, no tribe had the incentive to consider the social consequences of depensatory fishing effort. Even if they had the incentive, they lacked the wherewithal given that information regarding the number of other tribes fishing and their level of fishing effort was difficult to assess.

Perhaps the most powerful example of cross-sectional differences in resource productivity and the structure of property rights comes from comparing the Fraser River fishery to the coastal fishery. I start by comparing tribes in the upper reaches of the Fraser River drainage to their counterparts on the coast whose streams were roughly identical in size and productive capacity. In either setting, the costs of identifying and policing the limits of the drainage would have been roughly identical, but the costs of establishing ownership over the fish stocks themselves would have been much higher in the interior. This is because upriver stocks were subject to downriver fishing by many tribes, thus requiring the fish to "run the gauntlet" to reach the spawning beds.[128] The benefits of ownership differed tremendously as a result. I showed above that coastal stream managers had an incentive to invest in reducing the variability of their stocks and in increasing returns. On the upper Fraser, the benefits from such investments by upriver tribes would have been substantially shared with downriver tribes and, under certain plausible assumptions, with neighboring upriver tribes. Perhaps more importantly, although downriver fishing of the trunk stream was probably not systematically discriminatory against different tribes an equal distance upriver, it nevertheless would have introduced substantial noise into the information feedback mechanism from any trial-and-error husbandry investments made by upriver tribes. Being a huge river, moreover, the distance between upriver and downriver tribes on the Fraser probably

[127] Get cite.

[128] Shaulk, *supra* note ?, at 240.

prevented any formalized payoffs to forestall overfishing by downriver tribes. As the salmon husbandry hypothesis predicts, reciprocity, although practiced, fell far short of the systematic and sustained sidepayments characteristic of potlatching by coastal tribes.

The reports leave little doubt that although the tribes of the Fraser River drainage had a loose sense of ownership to fishing stations and manageable tributaries, these rights seldom amounted to more than acknowledged claims to priority of use that were routinely relinquished when the "owner" had ceased fishing (Romanoff (1992a)).[129] Even then, claims of privilege invariably arose as a result of "improvement in the productivity of procurement sites by dint of labour investment in site facilities or special knowledge."[130] As a result, the interior tribes appear to have evolved a shared cultural norm of "stewardship" in the use of common property resources as the next best alternative to exclusive ownership of salmon stocks. In contrast, the Coast Salish at the mouth of the Fraser had much more refined notions of ownership vested in the individual with superior ability. As Romanoff writes regarding exclusive ownership rights among the Coast Salish, "there is the facility for certain hunter/fishermen to evince a productive competence which fellow producers will recognize as importantly superior; these people attract a close stable following and thereby expand the territory which they, as individuals, control."[131]

In Section III-A, I argued that the main source of benefits from private ownership arise from reducing noise in the information feedback from trial-and-error husbandry experiments, which, in turn encouraged appropriate investment based on the associated accumulation of knowledge. This explains why a resource owner on the coast

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[129] Romanoff, Steven, *Fraser Lillooet Salmon Fishing*, in A COMPLEX CULTURE OF THE BRITISH COLUMBIA PLATEAU, edited by Brian Hayden (Vancouver: UBC Press, 1992). An important exception may have been chinook fishing stations Cannon, Aubrey, *Conflict and Salmon on the Interior Plateau of British Columbia*, in A COMPLEX CULTURE OF THE BRITISH COLUMBIA PLATEAU, edited by Brian Hayden (Vancouver: UBC Press, 1992), at 518.

[130] Hayden, Brian, *Conclusions: Ecology and Complex Hunter/Gatherers*, in A COMPLEX CULTURE OF THE BRITISH COLUMBIA PLATEAU, edited by Brian Hayden (Vancouver: UBC Press, 1992), at 544.

[131] Romanoff, Steven, *The Cultural Ecology of Hunting and Potlatches among Lillooet Indians*, in A COMPLEX CULTURE OF THE BRITISH COLUMBIA PLATEAU, edited by Brian Hayden (Vancouver: UBC Press, 1992), at 498.

experiencing the good state would not simply allow a neighboring resource owner experiencing the bad state to encroach for the time it took to catch the allotted salmon. Consistent with the salmon husbandry hypothesis, in the Fraser River interior such encroachment was routine and often systematic, no doubt because the costs of defending exclusive ownership claims was prohibitive given the meager benefits from accurate information feedback that resulted from downriver fishing. Canon reports that the Thompson tribe engaged in yearly raids of the downriver Lower Lillooet for over 70 years, with no retaliation by the latter. Canon further reports that raiding was generally directed downriver, normally against nonadjacent tribes (for whom the cost to upriver tribes of achieving cooperative settlements would have been relatively high). In some cases it also occurred between tribes asserting claims to equally-positioned tributaries, but never upriver. Moreover, the purpose of raiding was most often to procure either salmon or slaves.[132]

The systematic tendency to raid downriver was no doubt the result of depensatory fishing of the trunk stream by downriver tribes.[133] In terms of basic financial economics, with optimal coordination between upriver and downriver tribes, downriver tribes held something like a diversified "market" portfolio in which the assets consisted of all lines of all runs of all species that entered the river in a given year.[134] The variability of their portfolio would have been very low, consisting purely of what can be loosely described as "market risk." But in the absence of some kind of mechanism by which upriver tribes could influence the harvesting done by downriver tribes of the lines destined for upriver tributaries, downriver tribes would have had very little incentive to consider the full social costs of their harvesting decisions. Coordination between them must have been imperfect at best. As the market portfolio varied around its steady-state mean the

[132] Canon, *supra* note ?.

[133] Compensatory fishing effort would have required a tribe to harvest more fish than necessary for consumption during the good state, with the cost of such effort coming in the form of other valuable labor opportunities or leisure forgone. Early ethnographic reports of salmon so abundant that much of the harvest went to waste could be an artifact of compensatory fishing effort in the good states by the tribes. It could also have mislead the observers into concluding that salmon were routinely superabundant.

[134] Brealey & Myers, *supra* note ?, at 141-204.

downriver tribes would have tended to hold their total harvest constant, taking a relatively small share of large runs and a relatively large share of small runs.[135] In this sense, from the perspective of upriver tribes, downriver tribes look more like debtholders in the salmon fishery, while each upriver tribe would regard itself as an equity holder in an undiversified enterprises. Depensatory fishing by downriver tribes therefore would have left upriver tribes to bear the residual and, to achieve socially compensatory management, upriver tribes would have had to dramatically increase their fishing effort when the run was large (to avoid overcrowding) and to dramatically reduce their fishing effort when the run was meager.[136]

To the extent that variability in the downriver tribes' portfolio is disproportionately the result of variability in one particular line, the distribution of depensatory burden would fall on both lines but less so on the more stable line. Table 1 shows the results across the good, neutral, and bad states. It shows total recruits entering the river in a given year, which are split between two lines destined for two separate tributaries claimed by Tribes 1 and 2, respectively. Both lines yield the same number of recruits in the neutral state, but Line 1 is subject to variability that depends on the state. Downriver tribes engage in depensatory fishing and will harvest ten percent of expected, or neutral-state, recruits pro rata across both lines, regardless of the state. This amounts to 20 fish in all states. As a result of depensatory fishing by downriver tribes, however, Tribe 1 must dramatically reduce its harvest in the bad state and dramatically increase its harvest in the good state to achieve overall compensatory fishing of the line. Thus, Tribe 1 must hold constant the total *percentage* of Line 1 harvested (upriver and downriver) equal to the total percentage harvest in the neutral state. That is, to avoid reduced future

[135] This is probably not strictly true. If labor was scarce, a smaller run would have caused the marginal cost of harvesting fish to rise and somewhat fewer fish would be taken, but not by enough to avoid depensatory spillovers on upstream tribes.

[136] The standard view in finance theory is that the residual claimants to a levered firm have an incentive to engage in "asset substitution" by taking excessively risky actions. But that is in the case where debtholders have a call option on the entire remaining stock value of the firm. Here, an upriver tribe that experiences a very bad state due to asset substitution is left to bear the burden year after year, while the downriver tribe suffers a proportionate share of the short-term burden in relation to the upriver tribe, but also has a portfolio of N assets on which to rely (and to shift to). Compared to a coastal stream owner, my impression is that an upstream Fraser manager had relatively less incentive to invest in increasing returns and more incentive to invest in reducing systematic variability, but I have yet to formalize this proposition.

returns Tribe 1 will have to adjust its harvest to compensate for most (but not all) of the downriver tribes' depensatory fishing, and its harvest will be 2.8, 9, or 16.5. Notice that Tribe 2 must also compensate for the variability in Line 1, with a harvest of 5.7, 9, or 11, even though Line 2 does not vary with the state. This is because the variability in Line 1 causes downriver tribes unknowingly to vary their proportionate harvest of Line 2 to maintain a constant absolute harvest. Given depensatory fishing downriver, the variability in Line 1 therefore imposes a spillover on Tribe 2. Holding all else equal, it is also appropriate to say that the variability in Line 1 imposes a spillover on downriver tribes that declines as the share of Line 1 in the downriver harvest declines.

Table 1

Effect of Variability in One of Two Lines on Upstream Fishing with Depensatory Downriver Fishing

	Bad State	*Neutral State*	*Good State*
Total Recruits	150	**200**	250
# Harvested Downriver	20	**20**	20
DR Harvest as % of Total	13.3%	**10%**	8%
Line 1			
Total Recruits	50	100	150
# Harvested Downriver	6.7	10	12
DR Harvest as % of Recruits	13.3%	10%	8%
Residual # Arriving in Stream 1	43.3	90	138
UR + DR Harvest as % of Residual		10%	
# Harvested Upriver	2.8	9	16.5
UR Harvest as % of Recruits	19%	19%	19%
% of Recruits Spawning	81%	81%	81%
Number Spawning	40.5	81	121.5
Line 2			
Total Recruits	100	100	100
# Harvested Downriver	13.3	10	8
DR Harvest as % of Recruits	13.3%	10%	8%
Residual # Arriving in	86.7	90	92

Stream 2			
UR + DR Harvest as % of Residual		10%	
# Harvested Upriver	5.7	9	11
UR Harvest as % of Recruits	19%	19%	19%
% of Recruits Spawning	81%	81%	81%
Number Spawning	81	81	81

Who "causes" harm to whom in this kind of setting, as Coase made clear, is a meaningless question.[137] More important, the parties will attempt to mitigate the social wealth losses within the constraints of transaction costs. One possible response by either upriver tribe is to influence the downriver tribes to discriminate in their harvest. This would have been much easier to do between two species of salmon than between two lines of the same species because different species are much more easily identified at a glance.[138] It would also have been much easier and more beneficial to arrange between adjacent tribes than between nonadjacent tribes. The observed pattern of downriver raiding by upriver tribes on nonadjacent downriver tribes therefore makes sense in light of transaction costs. Sustained occupation by one tribe of a nonadjacent downriver tribe's fishing grounds also makes sense. One problem left unaddressed above is how the upriver tribes would have been able to gather the information to make the proper adjustments in response to the downriver tribes' depensatory tendencies. By occupying downriver territories they would have been able both to take salmon and to gather information as to whether the poor run they were experiencing upriver was the result of the downriver tribes' depensatory fishing, a downturn in the "market," or both.

Ricker's suggestion that native fishing pressure interrupted by severe population declines could have set in motion the cycle of four-year line dominance observed over 60 years later in Fraser River sockeye can now be evaluated. I offer one of several possibilities. In spite of the many property rights problems that prevailed along the

[137] Coase, Ronald H., *The Problem of Social Cost*, 3 J. LAW & ECON. 1 (1960).

[138] To the extent that upriver tribes could influence the behavior of downriver tribes, they therefore might have tended to specialize in a single species.

Fraser, the tribes may have achieved a reasonably stable institutional equilibrium by the time native population decline occurred. Quite possibly by that time upriver Fraser sockeye had evolved genetically to rely on dramatic compensatory management by upstream tribes. With the sudden demise of native institutions and husbandry, it would be unsurprising to see a dramatic increase in the variability of salmon populations whose natural equilibrating mechanisms had been disfavored until then in the native selection process. Moreover, native population decline probably proceeded from the Coast to the interior, with the likely result that downriver tribes were the first to fall victim, thereby suddenly reducing the level of downriver depensatory fishing.[139] Seen in this light, there seems little doubt that the observed line-dominance of various populations of Fraser River sockeye could have been set in motion by native population declines.

3. Salmon Husbandry Techniques

Compelling support for the salmon husbandry hypothesis comes from native use of fish weirs, whose advent Hayden (1988) places at the beginning of the Mesolithic/Archaic era (8000 BP).[140] I have already noted several biological characteristics of salmon that tribal leaders might have found advantageous, such as average fish size, number of fish permitted to spawn, stability in the number of spawning parents, adjustments in run timing, and adjustments in run duration. The fish weir would have allowed favorable selection of such characteristics. Fish weirs involved a substantial capital investment and in many cases were built to span an entire stream. The only way for salmon to pass was to enter a holding trap,[141] which gave the attendants complete selectivity over which salmon were allowed to pass. In fact, this kind of weir demanded the exercise of selectivity. Various reports have suggested that the natives would erect a fish weir, take their harvest, and then open the weir or tear it down entirely to allow the rest of the run to pass. Since run timing is a heritable factor in salmon, this

[139] Check this.

[140] Hayden, Brian, *Nimrods, Piscators, Pluckers, and Planters: The Emergence of Food Production*, 9 JOURNAL OF ANTHROPOLOGICAL ARCHEOLOGY 31 (1988).

[141] Stewart, Hilary, Indian Fishing: Early Methods on the Northwest Coast (Seattle: University of Washington Press, 1977), at 103.

decision necessarily would have had an effect on the timing of subsequent runs. This kind of effect very likely would have been noticed and could have been taken advantage of to substantially delay or even advance the timing of a run within the course of a few generations. Moreover, in any stream small enough to erect a bank-to-bank fish weir, the extra capital investment necessary to build the weir would have had to promise a distinct economic advantage over the use of harpoons, spears, and nets. If salmon were naturally superabundant the advantage in terms of reduced labor effort must have been small. My view is that selectivity provided that advantage. Compared to modern commercial fishing, the use of fish weirs in privately controlled streams would have allowed the tribal leader to minimize noise in the information feedback mechanism and rapidly to accumulate knowledge of salmon population dynamics. Of course, the selective use of fish weirs would have required the operators to be able to recognize different species, different lines, jacks, strays, etc. But as Marsh so aptly put it, "[e]very river . . . stamps a special character upon its salmon . . . which is at once recognized by those who deal in . . . them."[142]

It may be that the "natural" duration of most salmon runs is much longer or shorter than under native husbandry, which might have tended to concentrate runs strategically during warm weather months as preservation technology progressed. Carlson reports the appearance of salmon abundance, which could have been an artifact of man-made concentration of runs.[143] As to run timing, it seems more than coincidental that along the coast chum were the preferred fish for winter preservation and that in many coastal streams they tend to run over a short duration fairly late in the season. Late-season arrival minimizes storage time, and would have been a valuable characteristic in the native portfolio. Economists have long known that under certain circumstances batching of production runs, in this case for the preservation of a winter supply, can substantially reduce costs. Sockeye, and to some extent chinook, can be seen as the low-risk assets in the native portfolio. Recall that sockeye, being reared in relatively stable

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[142] Marsh, *supra* note ?.

[143] Carlson, *supra* note ?.

lake environments, show the least natural variability and that they, and chinook, run over an extended period. Being able to depend on these runs, a tribal leader would be much more inclined to aggressively manage the other assets in his portfolio.

I have already noted that one response by tribal leaders to the risk of exogenous environmental influences such as excessive or inadequate runoff that could damage spawning beds might have been to engineer or re-engineer them out of stone walls or levees. The hydro-dynamics of a given stream does not seem to be an exceedingly complicated body of knowledge to accumulate over the course of a few thousand years. Stewart reports that "[s]tone traps were widespread along the whole coast, with the Kwagiutl [sic] people making the most extensive use of this effective method of catching fish. In their central coast area, almost every creek or stream contained some kind of stone trap. Many and often elaborate were the stonewalled structures that relied on 'tidal drift' for their success."[144] If the natives were able to master the use of stone traps in tidal areas, they could surely have used the same technology to engineer controlled spawning beds.[145]

One hypothesis to explain the archeological evidence on the timing of man's arrival, salmon abundance, the emergence of tribal leadership, and the beginning of formalized potlatching is that salmon spread with the hand of man along NWC and that only when the region's human population increased substantially were the institutions of tribal leadership and potlatching necessary. There is no doubt that as the glaciers receded between 15,000 and 13,000, B.P. salmon appeared first in the Columbia River and then in the Fraser River. Being further south and occurring at lower elevation, the Columbia was the first of these two great river systems to develop prolific salmon populations, including the huge stream-type chinook that spawn in the very upper reaches of both rivers. The headwaters of the Columbia River and Fraser Rivers are separated by a distance of less than five miles in many locations in what is now south central British Columbia. The evidence suggests that after deglaciation, the Columbia River was "the principal source

[144] Stewart, *supra* note ?, at 121-23.

[145] Intricate intertidal stone traps are still visible from the air. The same could be true of any upriver spawning beds engineered of stone.

for the repopulation of Fraser River fish fauna in general and chinook salmon in particular.[146]

How did salmon transmigrate between drainages? Given the scattered evidence that NWC natives had the wherewithal to transplant salmon stocks, I hypothesize that early natives transplanted salmon from the Columbia River drainage to the Fraser River drainage, and the knowledge of transplantation followed or even assisted the natives in their gradual migration down the Fraser and northward along the NWC.

There is substantial evidence consistent with this hypothesis. First, the homing instinct of salmon is thought to be based largely on the olfactory sense.[147] Odors from the tributaries of two different river systems that originate in the same vicinity, with the same climate, the same glacial runoff, and the same soil composition, should be nearly identical and the probability of success in transplantation between the rivers correspondingly high.

Second, the homing instinct of salmon is very strong, and although salmon are known to stray from stream to stream, straying is much more likely between streams whose mouths are close together. It is very unlikely that chinook salmon, naturally established in the Columbia, could have strayed 200 miles to the Fraser in a single ocean migration of a misguided population. Repopulation of the Fraser would have required incremental straying northward from stream to stream, perhaps made possible by evolution of the more adaptable ocean-type chinook. Once having arrived in the Fraser, however, the ocean-type chinook then would have had to evolve back into a race of stream-type chinook, gradually reaching the headwaters of the Fraser. But contrary evidence indicates that the Fraser was first populated by stream-type chinook in its upper reaches. The more plausible story is that stream-type chinook were transplanted (or in some other way transmigrated) from the Columbia to the Fraser. Thereafter, in both rivers, ocean-type chinook gradually adapted from stream-type chinook to take advantage of smaller tributaries and other small-stream spawning environments, and that they were therefore naturally adapted to transplantation.

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[146] Waknitz, *et al*., *supra* note ?.

[147] Healy, *supra* note ?, at 379-80.

Third, the northern limit of ocean-type chinook occurs at 56°N., only 300 miles inside the northern margin of the NWC culture area, which the evidence suggests was settled fairly late in prehistory, possibly by the Tlingit, for whom salmon transplantation may have been a relative mystery. Chinook salmon, although not as prolific in numbers or in total biomass as the other species, have the advantage of being very large, having a very high fat content, and exhibiting an extended spawning migration lasting as long as nine months. Leaving aside for the moment the possibility that the duration of its spawning migration is man-made rather than "natural," this would have provided the natives with a steady source of nourishment over much of the year with relatively low labor costs per pound of edible harvest. The natives could very well have learned early to catch a number of migrating salmon that were ready for spawning in their home stream, to partially fill a large cedar canoe with fresh water, to put the salmon in the canoe, to paddle to a barren stream, and to artificially spawn the salmon in a suitable habitat (which, in my understanding, is a fairly simple procedure with ripe salmon). Although spawning by straying salmon in other than their home stream occurs naturally, the spread of salmon populations from barren stream to barren stream would have been a relatively slow process as the late receding glaciers along the coast gradually permitted.

B. Implications for Institutional Change

Whether salmon were abundant, scarce, or nonexistent when the early natives settled along the coast is unimportant. Quite possibly, salmon were superabundant when the natives arrived and, after initially overfishing the stocks under open access, they gradually learned the secrets of salmon husbandry and succeeded in rebuilding the fishery. Or perhaps salmon were fairly scarce when the natives arrived and their early fishing efforts led to increasing stocks and the fitful shift to a higher sustained equilibrium under open access, followed by further increases as the structure of property rights as salmon husbandry techniques advanced. The evidence reported by Carlson that salmon abundance occurred 1500 years after the appearance of man is consistent with the latter story. For the salmon husbandry hypothesis to have implications for the evolution

or design of native institutions, however, it is necessary only that salmon abundance ultimately came to depend on native institutions. The available evidence is sufficient to suggest the empirical validity of the salmon husbandry hypothesis. Given its logical plausibility, in this section I derive the implications of the hypothesis for the structure and change of native institutions. I focus on two questions. The first is whether the structure of NWC tribal institutions specifically served to encourage the accumulation of knowledge of salmon husbandry by tribal leaders. In my view, the answer is clearly that they did. The second question is whether NWC institutions changed incrementally or dramatically to accommodate this accumulation of knowledge.

Before proceeding, I should make clear that as I use the term an "institution" is a generally accepted set of complex and durable behavioral algorithms that economize on the social costs of accumulating, gathering, and acting on valuable information.[148] Evolutionary psychologists tell us that man's brain was essentially hard-wired for specific patterns of social behavior in hunter-gatherer society.[149] In that setting, they would have needed either no institutions at all or what can properly be considered simple default institutions. There would have been few, if any, social decisions to be made or behaviors to be constrained in long-run steady state. It is only in man's departure from the default institutions that the study of institutional structure and change becomes interesting. I start out by asserting that any transformation away from the default institutions would have involved both up-front and ongoing transaction costs. It takes effort for humans to depart from, and avoid regressing back to, their natural instincts, and the costs of that effort are minimized by establishing and maintaining relatively complex

[148] By "accepted" I have in mind something different than "consented to." It may be that there are members of the group that would prefer to, and realistically believe they have a right to, live under an institutional form different than the one being imposed on them. Nevertheless, once having suffered the "income effect" of having been dispossessed they will equilibrate with respect to the "price effect," thereby *accepting* the new institutional form. For example, a person taken as a slave in NWC society did not consent to his status, but given that he could cooperate more or less in performing tasks assigned to him, he could extract concessions from his master that allowed him to earn a surplus above the alternative. Within the constraints of the unconsented relationship, the slave and the master established terms of trade (prices) for their mutual betterment. See Barzel, Yoram, *An Economic Analysis of Slavery*, 20 J. LAW & ECON. 87 (1977).

[149] Rubin, Paul, *The State of Nature and the Origins of Legal Institutions* (unpublished working paper, Emory University, 1998).

institutions. Thus, whether incremental or dramatic, institutional change is a prospective, forward-looking process in which the present value of expected (net) returns must exceed the up front costs. If we can identify situations in which the expected returns would have been relatively large, we have a basis for predicting that institutional change *might* have been relatively dramatic.

1. The Resource Exploiting Unit

In this section I abstract from distinctions between tribal, clan, clan-house, and individual resource ownership and focus on what can be characterized as the Resource Exploiting Unit (REU). The evidence strongly suggests that there was a close congruence between the REU, resource ownership, and the basic unit of potlatch gift giving, although there were surely many variations on the basic theme. The REU in hunter-gathering society was staunchly egalitarian,[150] with all members having equal access to the resource stock and sharing in the resulting output. But this institutional form could not have been conducive over the long term to accumulating knowledge of salmon husbandry, including the complexities of heritability and population dynamics. Sometime between the arrival of man on the NWC and European contact, the natives made the transition to what I will call a "corporate" form of REU.[151] The corporate form was specifically suited to the accumulation of knowledge through trial-and-error experimentation because it placed responsibility for these functions with one person, and yet it preserved the long-standing norm of output sharing and reciprocity.

The post-transition REU form was *corporate* in the following sense. First, the members of the unit delegated exclusive control over salmon stream management to a single person, who was also the unit "leader" for the purposes of household organization, direction of labor resources, and potlatching. Along with the delegation of resource control came the assignment of residual claimancy. At least immediately, the leader received the direct material profits and losses from effective management and was

[150] Rubin, *supra* note?.

[151] For the sake of simplicity, I assume the optimal size of the REU remained the same before and after the transition, although it would be surprising to find that this was actually the case.

thereby recognized as the resource "owner."[152] Consistent with the established norm of reciprocity, the leader was expected to transfer to the other members of the unit a share of output, with the share being subject to his discretion depending on the particular circumstances. Economic theory suggests that in equilibrium these sidepayments must have been no less than the group members' alternative wage, and they appear to have included a share of the material profits as well. To the extent the leader was able to accumulate a substantial surplus and distribute it advantageously to other REUs through the potlatch system, the leader received a large share of the resulting social prestige, although the entire REU also benefited from this public (nonrivalrous) good. Sidepayments served as compensation to the members of the unit for accepting the corporate form as opposed to the former egalitarian institutional form. Sidepayments occurred both within the REU and between REUs through the potlatch system.

What superior knowledge the leader possessed was passed on to a younger member of the REU, or perhaps to a younger kinsman outside the unit. Thus, the stock of knowledge that reposed in the leader had the potential for unlimited life, which is an attribute associated with the modern corporate form. If the leader was able to accumulate a stock of knowledge superior to others, he was somewhat free to pick his successor and to pass the stock of knowledge along. Unless the leader could produce a surplus above the next best alternative, however, he could be divested of authority, reflected in his title to resources. There were several methods by which "contingent consent" to a leader's authority could be revoked.[153] First, the members of the REU were generally free to quit the unit and join any one of three other REUs in the kinship line.[154] As already noted, Donald suggests that the existence of a liquid market for slaves was important in preventing effective opportunism by the leader's traditional REU labor force.[155] Indeed,

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[152] The leader's ownership rights did not include the power to transfer title to those outside the REU.

[153] Levi, Margaret, *A Logic of Institutional Change*, in THE LIMITS OF RATIONALITY, edited by Karen Schweers Cook and Margaret Levi (Chicago and London: University of Chicago Press, 1990).

[154] A weaker explanation for labor mobility is as a response to resource variability. But this ignores the use of labor rental between REU leaders as an alternative method for handling resource variability with immobile labor.

[155] Donald, (1997), *supra* note ?.

he tells the story of one leader whose entire labor force consisted of slaves. Second, the leader's title to salmon streams could be divested through a so-called "rivalry" potlatch, in which a competing claimant with colorable claim who offered greater potlatch goods to the incumbent than the incumbent offered in return could successfully depose him. Unless the incumbent could use his salmon fishery to generate a flow of net returns whose discounted present value was higher than the next most proficient resource manager, he could — quite appropriately in the native mind — lose the right to control the fishery to the superior man.

At stake were the stream-specific quasi-rents (surplus) the owner could produce through exclusive control over the fishery compared to the next best alternative. It is therefore not surprising that to finance potlatches REU leaders often borrowed extensively from members of their units and the members of other REUs related by kin. Default on these debts was one method by which a leader's title to a stream could be divested. Since default by the leader gave the lender the right to claim the leader's resources, the maximum loan an outsider would make was equal to the lender's assessment of what the next most proficient resource manager could generate with the same resources, with that manager quite possibly being the lender himself. Note that to the extent the leader's superior productivity arose from private stream-specific knowledge, he could increase the amount others would lend by divulging part or all of that knowledge, though it would appear to be wise to closely guard private knowledge to forestall outside appropriation.

Under some circumstances the leader could be divested of title through the withdrawal of military support by his unit members. Military force was vested in the group as a whole and therefore remained under egalitarian control. Although the leader was often very influential in the decision to use military force, he had no constituted authority in that regard. The evidence clearly indicates that any member of the unit could choose not to participate in a given military action. If the existence of the state requires a professional army outside the control of constituents, the absence of the state along the entire NWC may have been due, in part, to groups' refusal to grant unilateral military force to their leaders. In any event, outside groups could and did use military force to divest REU leaders, and their REU members, of ownership.

The corporate form of REU organization offered a distinct advantage over the egalitarian form in vesting accumulated knowledge in the mind of one man. Efficient biological selection dictated that a single party be able to conduct trial-and-error experiments free from noise created by others making concurrent harvesting decisions. This allowed the most rapid accumulation of knowledge, and the associated residual claim vested in the resource manager accurately rewarded entrepreneurship on his part. What is more, groups are notoriously bad at keeping secrets. A single stream manager was much better able to keep stream-specific knowledge secret. Under egalitarian access to the fishery, any accumulated knowledge would have been much more likely to become widely known. With its stream-specific knowledge being public, the REU would then have been open to the threat of outside appropriation. Recognizing this ex ante, REU members would have been less likely to make the investments in knowledge accumulation.[156]

The REU was similar to the firm. It was headed by a leader with the right to direct labor and it did not rely on explicit prices for internal allocation. Demsetz (1988) persuasively argues that the firm is characterized by a specialized stock of knowledge that allows the entrepreneur to coordinate team members without the necessity of having them learn one another's specialty.[157] Demsetz's view of the firm is less than compelling in the context of NWC tribal management, however, because the division of labor within the REU was extremely limited. An alternative rationale for the corporate form of REU that complements Demsetz's view of the firm is that it served to prevent appropriation of the leader's accumulated stream-specific knowledge. By analogy, within the firm the entrepreneur has discretion to set up tasks and rewards in any number of ways. This gives him much greater discretion than he would have if all inputs had to be purchased in

[156] The superiority of a single mind in testing hypotheses and accumulating knowledge can be seen as a transaction cost problem. In theory, there is no reason why knowledge accumulation cannot occur among the members of a coordinated group. The clear benefit of coordination within a single mind is that it reduces the likelihood of outside appropriation. Quite possibly, the human mind evolved to coordinate internally due to the benefits of privacy.

[157] Demsetz, Harold, *The Theory of the Firm Revisited*, 4 J. LAW, ECON., AND ORGANIZATION 141 (1988).

the market through the payment of prices for metered outputs.[158] In part, this discretion can be used to assign tasks in such a way that the underlying knowledge is difficult or costly to identify and appropriate and can therefore be kept private. Even where the labor force is unspecialized, privacy provides a rationale for the firm.[159] In any event, by protecting privacy, the corporate form of REU organization further rewarded the accumulation of private knowledge of salmon husbandry techniques.

It appears from the evidence that tribal leadership arose fairly suddenly about 5000 BP.[160] Formalized potlatching began about 3000 years later. My interpretation is that formalized potlatching marked the transition from the reciprocal transfer of salmon and other foodstuffs to the reciprocal transfer of durable goods. As time and affluence progressed, the tribes devoted increasing resources to the creation of tangible and performance art, both of which are a form of public (nonrivalrous) good that benefits the entire group. To the extent sidepayments within the REU and between REUs took the form of nonconsumables, the effect, whether intended or not, would have been to limit population growth. Thus, under the corporate form of REU the leader had this additional instrument to maximize returns net of labor costs.

2. The Rate of Institutional Change

The weak form of the salmon husbandry hypothesis implies that the transition from the egalitarian form of REU to the corporate form was a slow and incremental process. The 3000 year span reported by Carlson between the appearance of "abundant

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[158] See Barzel, Yoram, Measurement Costs and the Organization of Markets, 25 J. LAW & ECON. 27 (1982).

[159] This view of the firm rationalizes a common method for transferring ownership of a closely-held corporation. The old entrepreneur often accepts stock options that cannot be sold for a specific period of time after the transfer. He also agrees to act as a consultant to the new owner for that time. The consulting fee compensates him for his time, but the real impetus to zealously ensure an effective transfer of private knowledge is that unless he does so his stock options will not be worth exercising. In some cases, the transfer of private knowledge can be done easily, as with a printed list of customers, but in other cases it requires the subtle communication of complex processes. I propose that the latter cases will give rise to the transfer mechanism described above. Retaining privacy would also seem to explain why entrepreneurs of high-tech startup firms tend to seek financing from reputable venture capitalists whose reputation will be lost if they are caught appropriating the entrepreneur's private knowledge. *See also* Barzel (1992), *supra* note ?.

[160] Carlson, *supra* note ?.

salmon" around 8000 BP and the emergence of tribal leaders around 5000 BP, with the beginning of formalized potlatching around 2000 BP,[161] is consistent with an incremental pace of institutional change.

As a formalized manifestation of reciprocity between autonomous groups, potlatching no doubt evolved incrementally. Reciprocity had been part of man's social consciousness for millennia, in this case adapted to a situation in which the returns to private ownership were overwhelming. But the transition to the corporate form may have been much more dramatic.[162] In theory, the discrete emergence of tribal leadership and the corporate form relies on the strong form of the salmon husbandry hypothesis. Much of the knowledge of salmon husbandry outlined above could easily have been accumulated over a long course of noisy observations by the members of the REU or even multiple REUs working in common. This would require, first, the recognition that salmon return to their natal streams and that successive lines are biologically related. Second, it would have required the recognition of population cycles and the identification of specific lines. After that, it might have included recognition of density dependent growth (the negative relationship between size and numbers), the transplantability of salmon, and the positive effects of harvesting (through some range) on the population size of the next generation of recruits. These are fairly gross and obvious effects, which could have been discerned with little or no purposeful investment in experimentation, or that could even have been exploited for the most part unconsciously.

Other knowledge of salmon husbandry, especially knowledge of genetic selection of heritable traits in the context of salmon population dynamics, seems much more likely to have required purposeful experimentation under the control of an entrepreneur. This is

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[161] Carlson, *supra* note ?.

[162] North (1990), *supra* note ?, might view the REU as an "organization" rather than as an institution, and he allows that organizations are much more likely to change through the purposeful actions of entrepreneurs than are the meta-institutions with which he is concerned. An organization is, of course, an institution, but it occurs at a conceptually lower (more immediate) layer of abstraction than the institutional change with which North is concerned. As we ascend through the layers, our ability to identify exogenous bases for change decline and institutional change appears increasingly noisy and incremental. My claim is that the transformation to the corporate form was a relatively monumental change for the NWC tribes akin to a transition to representative democracy, constitutional government, etc.

because the associated population dynamics are, and no doubt were, both nonobvious and counter-intuitive. As I noted at the outset of the paper, if one perceives a distinct benefit in harvesting bigger fish, the natural inclination is to harvest them now. Even in a relatively noiseless environment such as private stream management with the use of fish weirs for harvesting, recognition that harvesting smaller fish would ultimately lead to a population of larger recruits would take substantial experimentation. The same is true of run timing, run duration, and no doubt other factors unknown to me. In fact, the heritability of various characteristics of Pacific salmon are so nonobvious that modern fisheries biologists have yet to fully understand the relevant population dynamics, being confined as they are to a much noisier laboratory for hypothesis testing than what was available to the NWC tribes.

If and when an entrepreneurially minded REU members working in common with others under egalitarian open access recognized the prospect of genetic selection, it could have created something akin to an incipient Kuhnian scientific revolution.[163] The fundamental entrepreneurial insight regarding heritability would have run contrary to the reigning state of the art and would have raised the manifest prospect of rapid knowledge accumulation through purposeful experimentation. The prospect of dramatic investment returns from institutional change would have been equally manifest. In the context of the established egalitarian form of REU, this would have created an institutional vacuum. Egalitarian resource exploitation quickly would have been recognized as incapable of uncovering the further secrets of genetic selection because it lacked "high powered incentives"[164] and because it distorted information feedback. Either constructively, or in fact, this could easily have led a hopeful entrepreneur to "cut a deal" with his unit members wherein they agreed to accord him exclusive but contingent control over a particular stream in exchange for a promise of future rewards.[165] In this sense, the yet-to-materialize prospect of dramatic investment returns leads to the rapid transformation of

[163] Kuhn, *supra* note ?.

[164] Williamson, Oliver, The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting (New York: The Free Press, 1985).

[165] Anderson, Terry L., and P.J. Hill, *Institutional Entrepreneurship in the not so Wild West* (unpublished working paper, Political Economy Research Center, 1998).

the institution to create the residual claimancy and establish the control over labor resources necessary to actually generate and capture the returns. Virtually all visible "technological change" and observable know-how would then occur after the transformation of the institution, even though the institutional reform was designed around and motivated by the ex ante prospect of reward arising from the initial scientific insight. Hence the term "rational expectations institutional change."

V. Summary, Conclusions, and Directions for Future Research

This paper proposes what is the plausible but untested hypothesis that, rather than being hunter-gatherers, the NWC tribes engaged in active salmon husbandry. At this time there is little direct evidence available to systematically test this hypothesis. The indirect evidence, as follows, seems strongly in its favor. Evolutionary psychologists tell us that when the natives arrived on the NWC 9500 years ago, man's brain had fully evolved and was specifically suited to hypothesis testing. On man's arrival, according to archeologists, salmon apparently were less abundant than in later times. The evidence from fisheries biology shows that salmon are extremely sensitive to influences affecting their heritable factors and suggests that a private stream fishery using native fish weir technology for harvesting would have reduced the noise from trial-and-error experimentation to an extremely low level. Throughout the culture area, the NWC tribes established private property rights in salmon streams. Economists know that private ownership is costly to define and enforce and will not arise in the absence of compensating benefits. We know that there was and is substantial variation along the NWC in both the structure of native property rights and the characteristics of salmon populations. Property rights appear to have varied in ways that are consistent with known variations in salmon populations. The NWC tribes uniformly revered the private accumulation of wealth and they associated a resource manager's ability to succeed in that pursuit with the accumulation and possession of secret knowledge of resource management. The process of knowledge accumulation would have occurred over no less

than 2000 years, but possibly as many as 8000 years. I could go on, but this should be enough to convince most skeptics that both the weak and strong forms of the salmon husbandry hypothesis are plausible and warrant further investigation.

Layered over the salmon husbandry hypothesis are its broader implications for the structure and change of economic institutions. According to the weak form of the salmon husbandry hypothesis, institutional change would likely have been incremental. The strong form of the salmon husbandry hypothesis suggests that the transformation from egalitarian group structure to corporate group structure might have been rather sudden due to an incipient scientific revolution set in motion by entrepreneurial insights regarding salmon heritability and opportunities for genetic selection. Searching for such dramatic institutional change may seem excessively pedantic. On the other hand, incremental institutional change has problems of its own. When change occurs slowly along multiple dimensions, it can be difficult to identify unambiguous testable implications due to noise from the aggregation of confounding events. It is therefore worthwhile, at the margin, to search for the rare occasions when institutional change is driven by discrete exogenous events. Because they are more easily observed, they show greater promise for building a general theory of institutions capable of penetrating the more subtle cases of incremental institutional change. I suggest that scientific revolutions, being by their nature unexpected, are a likely starting point in this search.

I have by no means uncovered a large share of the existing evidence that might be brought to bear on the salmon husbandry hypothesis or its implications for institutional change. Much work therefore needs to be done before any clear hypothesis testing can occur. In my view, the salmon husbandry hypothesis is methodologically similar to the kind of theorizing done by archeologists. Moreover, it stands in stark substantive contrast to the theories that have guided archeological digs in the past. Further archeological evidence, either extant but currently unknown to me, or that which has yet to be dug up, should prove helpful in testing the salmon husbandry hypothesis. The increasing use of sub-marine excavation of “wet” sites is promising in this regard.

This paper suggest any number of directions for future research that are more or less closely related to a full-scale research program on NWC tribal institutions. I now list these briefly. For those economists interested in cultural norms and other manifestations

of cooperation and conflict, the anthropological literature on the NWC tribes provides a wealth of unique material that has yet to be subjected to economic scrutiny. The tribes exhibited many variations in culture and ideology that appear systematically related to their environment or other exogenous factors. Not the least interesting attribute of the NWC tribes is their fairly frequent resort to violence and warfare. In my earlier work on the Southern Kwakiutl, I argued that potlatching was a substitute for warfare in the enforcement of property rights and that a tribe's comparative advantage in violence served as the relevant constraint in setting the direction and magnitude of wealth transfers. This explains the use of sidepayments at the margin to forestall encroachment and conflict. But it does not explain why actual violence, as wasteful as it is, regularly occurred in certain settings, one of which was the occasional, and sometimes successful, attempt by one tribe to completely annihilate another.

I have already noted the peculiar absence of any kind of political hierarchy on the NWC resembling what we could call the state. This may be in part a result of the unwillingness of the group to grant its leader control over a professional army. It could also have something to do with the fairly one-dimensional nature of the tribes' resource stocks (salmon) and the peculiarities of property rights enforcement in such a setting. In any event, anthropologists have spilled a lot of ink trying to decipher whether the NWC tribes were or were not "class"-based societies. Little attention has been devoted, however, to the resulting implications for tribal institutions. This might be the result of mainstream cultural anthropologists' refusal to take seriously, as Marx did, economic institutions. My naïve view of Marxian "class struggle" is that it is one manifestation of a two-sided bargaining game whose antagonists, in general, could be divided along class lines or any other lines of broad social coalitions such as age, race, sex, religious affiliation, education level, productive or consumptive activity, etc. There is no doubt that noncooperative outcomes arise, and they may well be the result of one coalition's opportunistic behavior in mobilizing the power of the state to change or preserve institutions in a way that allows them to capture rents. The role of institutions, or "mechanism design" as it is known to some economists, in such processes deserves to be understood, and a close look at NWC tribal institutions is a fruitful context for study.

That labor was somewhat mobile in the NWC resource exploiting unit suggests that opportunism by the leader was easily avoided. What about opportunism by labor? One way to prevent this would be for the leader to borrow from his labor force. Any subsequent attempt by labor to appropriate the rents from a salmon harvest by holding out for higher wages could then be followed by the leader's refusal to honor the debt. The prospect of default could serve, ex ante, to deter the strike. Economists have only recently begun to recognize the incentive effects that debt financing can have.[166] New work suggest that, in general, borrowing by a ruler should be limited by the value to the next most proficient ruler of the durable institutions the first ruler puts in place. Thus, his constituents will finance a level of debt only up to the redeployment value of the ruler's institutions in the event he must be deposed. The ruler will be required to finance the investment in any assets that are specific to him in the sense that their value disappears in his absence.[167] As I already showed, this confronts the ruler with a tradeoff between the ability to finance investments in durable institutions and rendering himself expendable. Obviously, as with the knowledge of stream-specific husbandry techniques on the NWC a constituency has no particular reason to perpetuate the office of a ruler whose knowledge is widely known. A thorough integration of the advancing knowledge on debt finance could prove extremely helpful in explaining institutional change along the NWC and the financial and institutional structure of the state, more generally.

If sufficiently supported by the evidence, the salmon husbandry hypothesis would have striking implications for our understanding of native environmental use, as well as the many lingering legal claims natives continue to press that rely, in part, on the extent to which they made efficient use of their resources and territories. That the NWC tribes recognized exclusive property rights appears to run contrary to the conventional lore of native Americans as egalitarian hunter-gatherers. It is not, however, contrary to the notion that native Americans sometimes succeeded remarkably in managing their environment. In my view, the salmon husbandry hypothesis, if correct, has tremendous

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[166] Jensen, Michael, and William Meckling, *Theory of the Firm: Managerial Behavior, Agency Costs, and Capital Structure*, 3 J. FINANCIAL ECON. 305 (1976).

[167] Habib, Michel A., and D. Bruce Johnsen, *The Financing and Redeployment of Specific Assets*, 59 JOURNAL OF FINANCE 693 (1999).

implications for the settlement of native land claims and the proper public policy toward the Pacific salmon fishery.

For this and other reasons, the salmon husbandry hypothesis should provide a special challenge to marine biologists. In my view, they have been somewhat puzzled by the dynamic trends in Pacific salmon populations witnessed over the past one-hundred and fifty years. Although a few lone voices have hinted that the native fishery might have had an influence, until now no one has recognized the strikingly powerful incentives for productivity that private ownership of the Pacific salmon fishery could have had or the devastation that the abandonment of with native population decline could have wrought. I suggest that fisheries biologists pose the following thought problem: Assume that at the time of European contact the natives had succeeded in managing their salmon stocks to maximize the present value of economic rents accruing to the Pacific salmon fishery, which was therefore in long-run steady state. That is, over the course of the preceding 5000 years they had undertaken all positive net present value projects given their relatively advanced technology. What, then, would we expect to have been the long-run dynamic effect on the Pacific salmon fishery from its effective abandonment by natives and its subsequent open-access exploitation with the advent of commercial ocean fishing? Could the dynamic effects have persisted to this day? These questions, and others posed above, are just a few that now await further research.

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