CHAPTER 2

Karluk Sockeye Salmon Research History

Nature does not reveal all her secrets at once . . .
Of one of them this age will catch a glimpse,
of another, the age that will come after.—L. A. Seneca, AD 64

When the United States purchased Alaska from Russia in 1867, little had been written about any Karluk River salmon, especially concerning details of life history. Even the most basic biological facts remained mysteries to the scientific community. Yet, because Karluk River salmon had been important subsistence resources for the indigenous Alutiiq people of Kodiak Island for many thousand years, these early inhabitants must have accumulated considerable knowledge about the river and its different fish species.

Many Alutiiq were attracted to the Karluk River because of the abundant salmon runs that returned at predictable times each year. These fish were annually harvested, dried, and stored as a vital food source, rich in energy and nutrients, which sustained the early inhabitants for many months. Since their survival was directly linked to these salmon, the Alutiiq closely observed the kinds, abundance, and timing of fish migrations that entered the river each year. This accumulated wisdom was passed to succeeding generations by oral and cultural traditions.

Karluk River salmon also were important food resources for the Russian fur traders during 1784–1867. At least rudimentary knowledge about the fish species present and timing of the runs was needed to harvest the salmon, but little of this information was formally documented. Fragmentary insights about Karluk River salmon can be found in official reports of the Russian–American Company, but, in general, these only tallied the number of fish dried as food for local use or by sea otter hunting crews. Almost nothing was written about the salmon's biology. Often these early reports were based on brief visits to Karluk by company officials or from conversations with the employees who actually caught and dried the salmon. Naturalists aboard several Russian voyages of exploration and official visitors to Kodiak Island during 1784–1867 often mentioned the region's abundant fishery resources, but they seldom wrote specifically about Karluk's salmon.

Several individuals and companies commercially harvested and salted or dried salmon at the Karluk River during 1867–81 and sold their products in Kodiak Island and west coast markets. These initial commercial ventures, though of limited scale and success, required some knowledge about Karluk's salmon, but again little biological information was ever published.

The first commercial cannery began operations on Karluk Spit in 1882, initiating many decades of large harvests of its sockeye salmon. The huge runs and long harvest season made this an attractive resource to exploit, and the number of canneries that took fish from the Karluk River rapidly expanded. Sockeye salmon were harvested with beach seines that were made longer each year and more capable of catching many thousands of fish in a single haul. Soon, the federal government grew concerned that the ever-increasing harvests threatened the salmon's long-term survival. Consequently, early during this fishery, the federal government began to study these sockeye salmon to understand the biological processes sustaining abundant and healthy runs, though the inherent complexity of this species and its environment was not fathomed for many years. Most biological investigations of Karluk River sockeye salmon since 1882 have been focused on the long-term goal of assuring sustainable and healthy runs.

In this chapter, we trace the development of biological knowledge about Karluk River sockeye salmon from 1880, when essentially nothing was known about its life history, to 1970, when much was known.[1] Our chronological discussion is organized around the many biologists who successively studied sockeye salmon at Karluk (Table 2-1; Fig. 2-1). We ended the research history in 1970 because in that year the U.S. government

[1] The U.S. Senate hearing testimony of 1912 gives particularly revealing and detailed insights into the deficiencies of knowledge about sockeye salmon at Karluk and other locations in Alaska and the Pacific Coast (U.S. Senate, 1912).

Table 2-1

Historical outline of fisheries research in the Karluk River basin, 1880–1970.

U.S. Fish Commission

Tarleton H. Bean (1880, 1889)

- Descriptions of sockeye salmon runs and harvests in 1880, prior to any cannery operations.
- Descriptions of sockeye salmon runs and harvests in 1889, after eight years of cannery operations.
- Reconnaissance survey of the Karluk Lake spawning grounds (1889).
- Observations of sockeye salmon and other fishes in Karluk Lake and River.

Cloudsley L. Rutter (1896–97, 1903)

- Sockeye salmon egg and fry culture at Karluk River Hatchery (1896–97).
- Reconnaissance survey of Karluk Lake spawning grounds.
- Observations of sockeye salmon life history at Karluk Lake and River.
- Travel time of adult sockeye salmon from Karluk Lagoon to Karluk Lake.
- Dolly Varden food habits.
- Adult and juvenile sockeye salmon food habits in the ocean.
- Adult ripening period in Karluk Lake before spawning.
- Migratory behavior of adult and juvenile sockeye salmon.
- Detailed count of sockeye salmon spawning in Moraine Creek.
- Abundance and kinds of wounds received in the ocean by sockeye salmon adults.

U.S. Bureau of Fisheries

Charles H. Gilbert (1919–27)

- Reconnaissance of Karluk Lake spawning grounds (1919, 1921–22).
- Karluk River weir established in 1921.
- Escapement and total run of sockeye salmon.
- Seasonal distribution of sockeye salmon run.
- Freshwater and ocean ages of sockeye salmon determined by reading scales.
- Seasonal changes in age composition of the adult sockeye salmon run.
- Stock-recruitment relationship for sockeye salmon.

Willis H. Rich (1922, 1926–32)

- Sockeye salmon smolt-to-adult ocean survival and total outmigation numbers (1926–30).
- Smolt age and lengths of sockeye salmon.
- Karluk Lake bathymetric map (1926).
- Limnological sampling at Karluk Lake (1926–30).
- Influence of salmon carcass nutrients on Karluk Lake productivity.
- Spawning surveys of sockeye salmon in Karluk Lake and tributaries (1922, 1926–30).
- Tagging sockeye salmon to determine ocean migration routes along west coast of Kodiak Island (1927).

J. Thomas Barnaby (1930–38)

- Sockeye salmon smolt-to-adult ocean survival, by recovery of marked fish (1930–36).
- Smolt age and lengths of sockeye salmon.
- Relation between sockeye salmon growth and scale size.
- Limnological studies of Karluk Lake.
- Dolly Varden and Arctic charr food habits (1935–36).
- Dolly Varden and Arctic charr migrations, by tagging (1937–38).
- Spawning surveys of sockeye salmon in Karluk Lake and tributaries.

Allan C. DeLacy (1937–42)

- Dolly Varden and Arctic charr food habits (1939–41).
- Dolly Varden and Arctic charr migrations, by tagging (1937–42).
- Dolly Varden and Arctic charr taxonomy and life history (1939–41).
- Sockeye salmon subpopulation measurements (1939–42).
- Fecundity of sockeye salmon (1938–41).
- Limnological studies of Karluk Lake.
- Food habits of mergansers (1942).

William M. Morton (1939–42)

- Discovery that two species of charr were present in Karluk Lake—Dolly Varden and Arctic charr (1939).
- Morphological and meristic differences between Dolly Varden and Arctic charr (1939–41).
- Dolly Varden and Arctic charr food habits (1939–41).
- Dolly Varden and Arctic charr parasites (1939–41).
- Parasitological studies of many Karluk fishes, birds, and mammals.

U.S. Fish and Wildlife Service

Richard F. Shuman (1943–49)

- Fecundity of Karluk River sockeye salmon (1943).
- Travel time of adult sockeye salmon from Karluk Lagoon to Karluk Lake, by tagging (1945–46).
- Lake residence time and migration of adult sockeye salmon from Karluk River weir to spawning habitat, by tagging (1946–48).
- Bear predation on adult sockeye salmon in two Karluk Lake tributaries (Moraine and Halfway Creeks) (1947–48).
- Analysis of sockeye salmon escapements and returns, and factors causing decline of runs (1945–51).
- Limnological studies of Karluk Lake and preparation for lake fertilization (1947–49).
- Operation of weir at the Karluk River Portage (1943–44). Moved weir to Karluk Lake outlet (1945).
- Attempt to build permanent two-way weir on the Karluk River (1949).
- Spawning surveys of sockeye salmon in Karluk Lake and tributaries (1943–49).

Table 2-1 (cont.)
Historical outline of fisheries research in the Karluk River basin, 1880–1970.

Philip R. Nelson (1946–56)
- Travel time of adult sockeye salmon from Karluk Lagoon to Karluk Lake, by tagging (1946, 1953).
- Migration of adult sockeye salmon from Karluk River weir to spawning locations, by tagging (1946–48).
- Bear predation on adult sockeye salmon in two Karluk Lake tributaries (Moraine and Halfway Creeks) (1947–48).
- Limnological studies of Karluk Lake (1947–56).
- Limnological and fertilization studies of Bare Lake (1949–56).
- Stickleback life history in Karluk and Bare Lakes (with John T. Greenbank) (1948–56).
- Sockeye salmon egg studies – seeding density, mortality, and development (1947–54).
- Survival and spawning of gill-net marked sockeye salmon (with Carl E. Abegglen) (1953).
- Spawning surveys of sockeye salmon in Karluk Lake and tributaries (1946–56).

George A. Rounsefell (1951–58)
- Review and analysis of past FWS field research results and publication of paper on the decline of Karluk River sockeye salmon runs (1958).

U.S. Bureau of Commercial Fisheries

John B. Owen (1957–59)
- Review of Karluk River sockeye salmon research and discussion of the factors affecting production, emphasizing subpopulations and differences in spawning time and location (with Charles Y. Conkle and Robert F. Raleigh) (1962).
- Determination of spawning habitat types and seasonal use by sockeye adults.
- Diurnal spawning behavior of sockeye salmon in Karluk Lake tributary streams.
- Survival time of adult sockeye salmon in Karluk Lake tributary streams.
- Spawning pen studies of adult sockeye salmon.
- Sculpin life history study (with John T. Greenbank).
- Dolly Varden food habits study (with John T. Greenbank).
- Physical characteristics of Karluk Lake spawning habitats (substrates and gradients).
- Egg survival studies.
- Limnological studies of Karluk Lake and tributary streams.
- Operation of counting tower on Karluk River (1958–59).

Robert F. Raleigh (1956–61, 1965–66)
- Fertilization studies of Bare Lake (1956).
- Post-fertilization studies of zooplankton (1957), limnology, and sockeye and other fish populations (1957–61).
- Tributary homing of adult sockeye salmon in Karluk Lake, including tenacity of stream preference and effect of conditioning (1959–61).
- Determination of innate migration direction (upstream or downstream) in emergent sockeye salmon fry from the Karluk River and Karluk Lake tributaries (1958, 1965–66).
- Review of Karluk River sockeye salmon research and report on factors affecting production, emphasizing subpopulations and distinct differences in spawning time and location (with John B. Owen and Charles Y. Conkle) (1962, 1969).
- Total outmigration of sockeye salmon smolts determined (1961).
- Subpopulation differences of adult sockeye salmon in different spawning habitats was examined (1959–61).
- Spawning surveys of sockeye salmon in Karluk Lake and tributaries.

Richard Gard (1962–66)
- Travel time of adult sockeye salmon from Karluk River Portage to Karluk Lake (1963).
- Bear predation on adult sockeye salmon in a Karluk Lake tributary (Grassy Point Creek) (1964–65).
- Detailed spawning study and survival of sockeye salmon of Grassy Point Creek.
- Total freshwater and marine survival of Karluk River sockeye salmon.
- Subpopulation determination of sockeye salmon in Karluk Lake and its tributaries (1962–66).
- Relationships between fecundity and sockeye female size in many Karluk spawning habitats.
- Total outmigration of sockeye salmon smolts determined (1962–66).
- Merganser food habits at Karluk Lake (1965).
- Spawning surveys of sockeye salmon in Karluk Lake and tributaries.

Benson Drucker (1961–70)
- Coho salmon life history in the Karluk River system (1956, 1961–68).
- Detailed spawning study and survival of sockeye salmon of Grassy Point Creek.
- Subpopulation determination of sockeye salmon in Karluk Lake and its tributaries.
- Juvenile sockeye salmon age, size, abundance, and distribution in Karluk Lake (1961–63).
- Migratory behavior of sockeye salmon fry and smolts in Karluk Lake and River.
- Bear predation on adult sockeye salmon in two Karluk Lake tributaries (Grassy Point and Halfway Creeks) (1966–68).
- Total outmigration of sockeye salmon smolts determined (1961–69).
- Spawning surveys of sockeye salmon in Karluk Lake and tributaries.

Fisheries Research Institute, University of Washington

William F. Thompson (1948–58)
- Research emphasized that many independent subpopulations were present in the sockeye salmon run (1950).
- Reported that the midseason sockeye salmon at the Karluk River were depleted by the commercial fishery, causing the bimodal seasonal distribution of the run (1950).
- Claimed that counting weir may harm sockeye adults and fry by restricting their free movements.
- Changes proposed in the management of Karluk River sockeye salmon.

Table 2-1 (cont.)
Historical outline of fisheries research in the Karluk River basin, 1880–1970.

Donald E. Bevan (1948–58)

- Ocean migrations of sockeye salmon along west coast of Kodiak Island determined by tagging study.
- Length-frequency data of adult sockeye salmon collected from the fishery and spawning grounds to show the existence of subpopulations (1948–58).
- Spawning surveys of sockeye salmon in Karluk Lake and tributaries (1948–55).
- Spawning surveys of pink salmon of the Karluk River (1950–83).
- Limnological sampling of Karluk Lake (1951–54).
- Karluk River discharge rating curve (1954).
- Karluk Lake weather data (1950–54).
- Historical data gathered on sockeye salmon catches and cannery case packs.
- Karluk River explored for a counting tower location to replace the weir (1955).
- Reviewed past research results and published paper on decline of Karluk sockeye salmon runs (with Richard Van Cleve).

Charles E. Walker (1950–55)

- Juvenile sockeye salmon studies in Karluk Lake, River, and tributary streams (1950–55).
- Smolt age, size, run timing, and index of abundance in Karluk River (1954).
- Limnological sampling of Karluk Lake.
- Explored Karluk River for a counting tower location to replace the weir (1955).
- Spawning surveys of sockeye salmon in Karluk Lake and tributaries (1950–1955).

Richard Van Cleve

- Past research results reviewed and paper published on the decline of the Karluk sockeye salmon runs (with Donald E. Bevan).

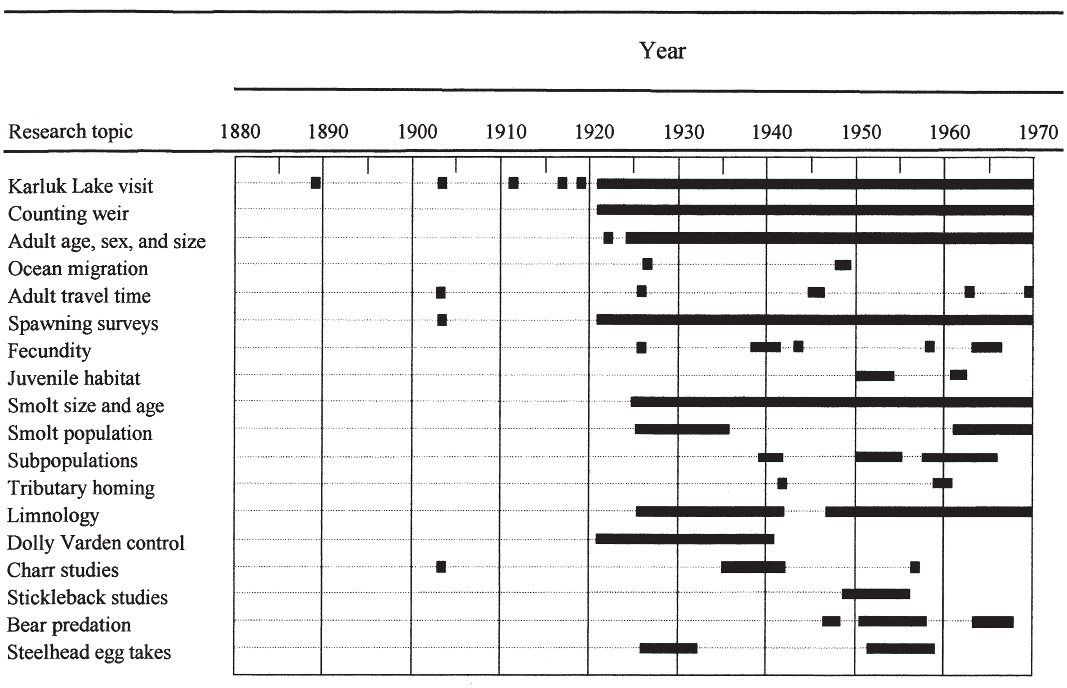


Figure 2-1. Summary of fisheries research at Karluk Lake and River, 1880–1970.

stopped its long-term research on Karluk's sockeye salmon, while the State of Alaska increasingly assumed research and management responsibilities for these fishery resources (Clark et al., 2006). This distinct change in governmental responsibilities gave a convenient endpoint for our historical discussion, though sockeye salmon studies at Karluk have continued to the present, and the recent era of biological research has produced numerous significant results, many being described in later chapters.

Tarleton H. Bean

1880

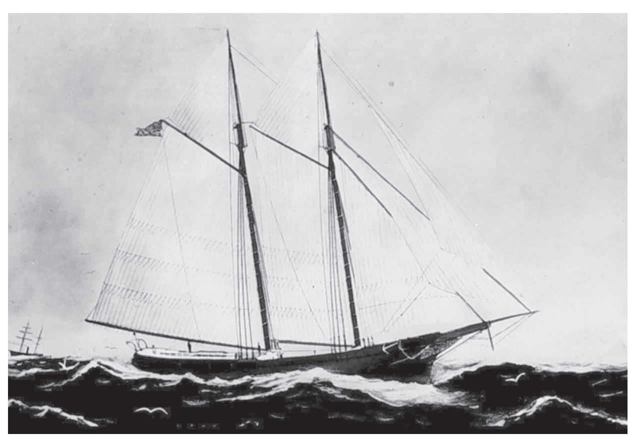
U.S. government involvement in Alaskan salmon research began in 1880 when the U.S. Census Bureau and the U.S. Commission of Fish and Fisheries (USFC) made plans to examine the fishery resources of its poorly known territories, which then included Alaska (Dunn, 1996; Pietsch and Dunn, 1997). Spencer Fullerton Baird, Commissioner of Fish and Fisheries, sent Tarleton

Tarleton Hoffman Bean (1846–1916). (Smithsonian Institution Archives, Record Unit 7177, George P. Merrill Collection, Negative #96-4529)

Hoffman Bean to Alaska in the summer of 1880 to investigate its fish and fisheries, and to collect biological specimens for the U.S. National Museum. Bean, then curator in the Division of Fishes and editor of the Proceedings of the U.S. National Museum, Washington, DC, was well qualified for the assignment. Although he earned an M.D. degree in 1876 from Columbian College, his real passion was the scientific study of fishes, and this was the career he pursued for his entire life.[2] He had first joined the Division of Fishes as an assistant ichthyologist in 1877.

Bean departed San Francisco on 13 May 1880 aboard the U.S. Coast Survey schooner *Yukon*, commanded by William Healey Dall, and for the next six months (May–October) traveled along the Alaska coast, exploring as far north as the Arctic Ocean.[3] On the outward voyage, they briefly stopped at Kodiak on 9–14 July and collected fishes in the immediate vicinity. Apparently Bean did not visit the Karluk River in 1880, but he learned of the river and its salmon resources and fishery by talking with several Kodiak residents: William J. Fisher, a U.S. Coast Survey tidal observer; Benjamin G. McIntyre, an agent of the Alaska Commercial Company; and two men involved in salting and drying Karluk River salmon, Captain H. R. Bowen of the Western Fur and Trading Company and Charles Hirsch of the Smith and Hirsch Company.

From the 1880 interviews at Kodiak and later correspondence, Bean learned that five species of Pacific salmon and Dolly Varden returned to the Karluk River each year. In 1880 Russian names were still used for these fishes, including "krasnoi riba" (sockeye salmon), "keezitch" (coho salmon), "chowichee" (Chinook salmon), "gorbuscha" (pink salmon), "hoikoh" (chum salmon), and "sumgah" (Dolly Varden). Bean learned that the Karluk River had a lagoon near the ocean and was fed by a large lake, reportedly 27 km upstream. Since two companies then salted and dried salmon at the river's mouth, he obtained data on their annual harvests, number of employees, and facilities used in the fishery (Bean, 1887). Sockeye salmon, caught in a 46 m beach seine, were the main species being harvested and salted, though other salmon species were being dried. Bean clearly described the bimodal seasonal pattern of Karluk's sockeye salmon runs, with the pink salmon run being interposed between the two sockeye peaks. The pink salmon run of 1880 was so large that he claimed it blocked other salmon species from entering the river. Once Bean learned that large salmon runs returned each year to the Karluk River, he realized this location had important fishery potential and stated that "there is perhaps no better place in Alaska for the establishment of a great salmon fishery" (Bean, 1887).



U.S. Coast and Geodetic Survey schooner *Yukon.* (National Oceanic and Atmospheric Administration Photo Library, NOAA Central Library, theb0372)

[2] Columbian College in Washington, DC is now known as George Washington University.

[3] Bean published part of his 1880 journal (11 August–17 September) that described the northernmost extent of the *Yukon* voyage to Alaska and Siberia (Bean, 1902). During the 1880 voyage, Bean collected 77 species of birds, 84 species of fish, and 110 species of lichen, some of them new to science.

Typical of naturalists from that period, Bean returned to Washington, DC, from Alaska with many specimens of plants, birds, and fishes for the U.S. National Museum collection. These travels and collections formed the basis for his later publications in the Proceedings of the U.S. National Museum and the popular magazine *Forest and Stream* (Bean, 1882, 1887, 1889).

In August 1881, Lucien M. Turner of the U.S. Army Signal Service briefly stopped at Karluk and observed its fishes, birds, and commercial fishing activities (Turner, 1886). Two companies then harvested its sockeye salmon and Dolly Varden, packing these fish into barrels with salt for eventual sale in San Francisco markets; over 3,000 barrels were prepared that year. He reported that 30–50 sharks (apparently, the spiny dogfish, *Squalus acanthias*) had gathered at the Karluk River mouth in mid-July to prey on the returning salmon and that village residents harpooned some of these large predatory fishes, which were prized for their liver oil.

1889

Bean's prediction of Karluk's great fishery potential was soon realized, starting in 1882 when Oliver Smith and Charles Hirsch built the first cannery on Karluk Spit. The cannery, eventually named the Karluk Packing Company, operated without competition for six years (1882–87), each year increasing its harvest and case pack production of sockeye salmon. Other entrepreneurs soon noticed the success of this commercial venture, and new canneries that took salmon from the Karluk River were built, four in 1888 and three more in 1889 (Fig. 2-2). Annual harvests of sockeye salmon rapidly grew from 1,000,000 fish in 1887, to more than 2,500,000 fish in 1888, and over 3,000,000 fish in 1889. To capture the 1888 salmon run, a wire fence was installed across the lower Karluk River, forming a complete barrier to upstream migration and concentrating the fish for easy capture.

News of the migration barrier and huge salmon harvests at Karluk soon reached federal authorities in Washington, DC. In January 1889 Marshall McDonald, U.S. Fish Commissioner, expressed concern about the sustainability of Alaska's salmon if river barricades were allowed and harvests increased even more. He presented his information about Alaska's fisheries to Poindexter Dunn, Chairman, House Committee on Fisheries, 50th Congress, and urgently recommended legislation to protect these fishery resources:

> [Karluk River salmon fisheries, 28 January 1889] This past season parties on the Karluk River, on Kodiak Island, conceived the idea of putting up a tight dam, merely using stakes and wire netting, intending no doubt to take what fish they required and allow the remainder to pass up to the lake, but no less than four other canneries started for the same place; consequently, to supply all, the river was closed from in May to October, the fish surging back and forward with the tide. The result was one company packed over 100,000 cases of salmon, and all the rest filled all their cans and made a perfect success. No care was taken of the surplus fish, and tens of thousands rotted on the banks . . . I beg to suggest to your honorable committee that prompt measures are necessary upon the part of the Government to place the salmon fisheries of the Alaskan region under such conditions as will insure their permanence. To prevent the ascent of the salmon to their spawning grounds will certainly result in a few years in the destruction of this valuable fishery. The erection of dams or barricades across the rivers, and the use of fixed contrivances for the capture of salmon in the rivers should be prohibited by law, under sufficient penalties actively and stringently enforced. (McDonald, 1889)

Congress responded on 2 March 1889, outlawing the use of river barriers to block salmon migrations and giving the Commissioner authority to investigate the conditions of Alaska's salmon and the methods used in the fisheries (Bean, 1891). Information gained from any inquiries would then be used to enact additional fisheries regulations.

McDonald sent Bean to Alaska in the summer of 1889 to begin the salmon investigations. At that time, Bean served several professional roles in Washington, DC, including ichthyologist for the USFC, editor of reports and bulletins for the commission, and curator in the Division of Fishes, U.S. National Museum. After his previous trip to Alaska, he had earned his M.S. degree at Indiana University in 1883 while studying under David Starr Jordan (Jennings, 1997). Bean was selected for the Alaska studies because of his familiarity with the region gained in 1880 and for his fisheries expertise. McDonald instructed him to start the investigations on Kodiak Island and, if time permitted, to examine the salmon fisheries at Afognak Island, Bristol Bay, and Cook Inlet (Bean, 1891).

Bean departed Washington, DC, in mid-June and proceeded to Karluk with his assistant Robert E. Lewis, surveyor Franklin Booth, and fish culturist Livingston Stone. They reached Karluk on 2 August, well into the field season and after early-run sockeye had already ascended the river. They established headquarters in the Karluk Spit office of the Karluk Packing Company, and the cannery owners assisted their inquiry by providing them transportation, supplies, and shelter. Because of the limited time and poor transportation to other can-

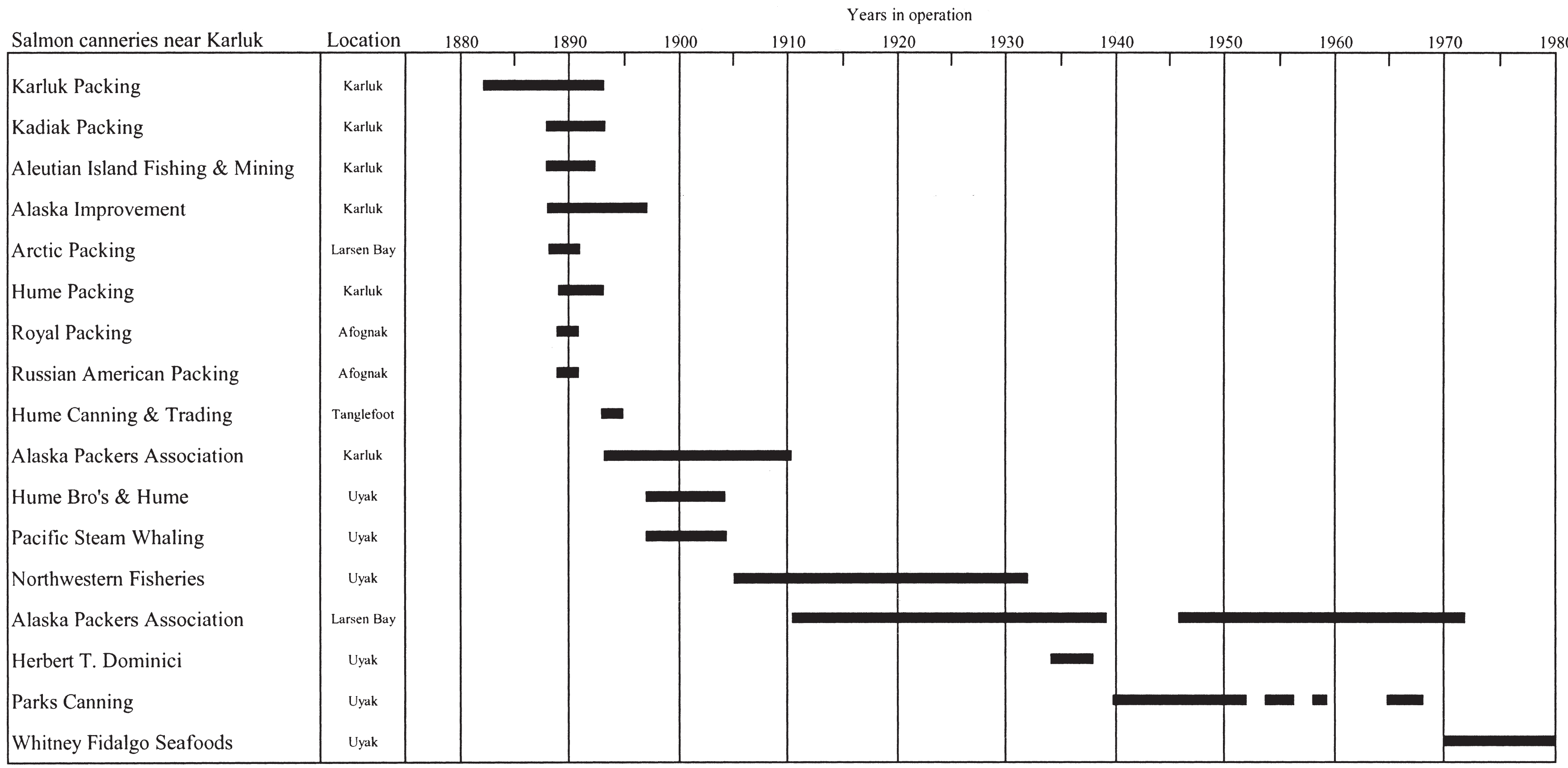
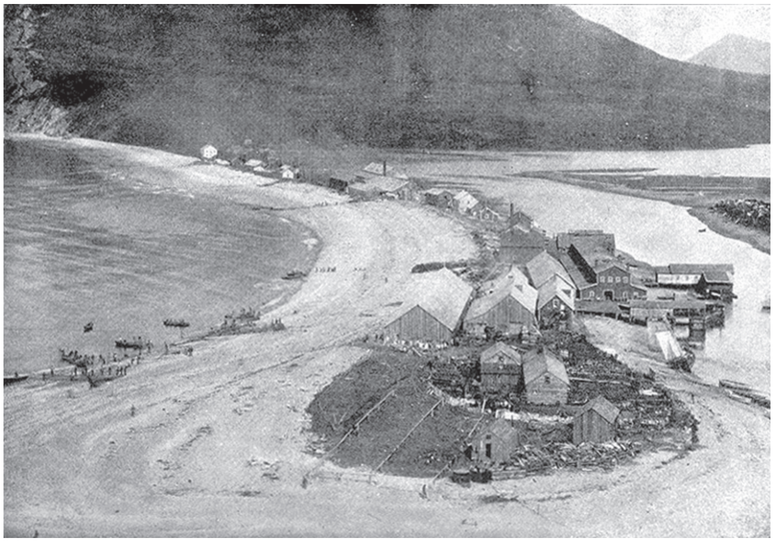


Figure 2-2. Summary of the salmon canneries that operated at or near Karluk, 1880–1980 (adapted from Roppel, 1986).



Karluk Spit salmon canneries (center), ocean beach seining (left), and Karluk River and Lagoon (right), 1889. (Tarleton H. Bean, from Bean, 1891)

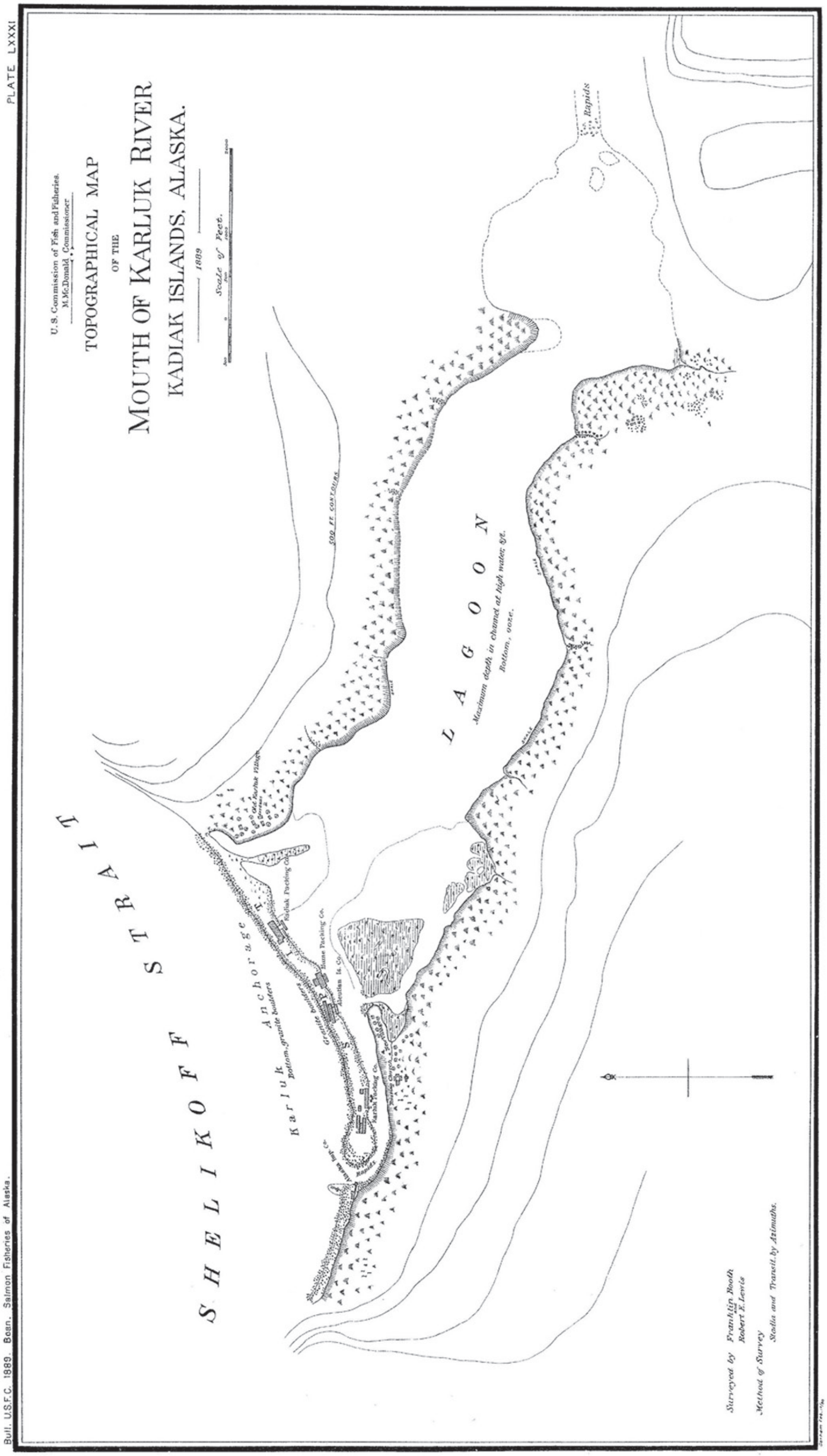
neries in the region, Bean focused his entire effort in 1889 on Karluk's salmon and fisheries, feeling justified in this decision because the Karluk River then supplied about half of Alaska's total salmon harvest. He stayed at Karluk for one month, departing 7 September for the return voyage to San Francisco. Despite this rather brief inquiry, he wrote the first detailed and published description of the Karluk River system, its salmon resources, and the fishery operations (Bean, 1891). His study marked the beginning of a long and concentrated effort to understand the biology of Karluk River sockeye salmon.

From his 1889 visit to Karluk, Bean described the region's physical geography, rugged coastline along Shelikof Strait, Karluk Anchorage, Karluk Spit, and Karluk Lagoon. He gathered data on tides, water temperatures, shoreline substrates, and regional vegetation. His map of Karluk Lagoon and Spit showed the locations of five canneries, old and new Karluk Village, and the newly constructed Russian Orthodox Church. Although a detailed Russian drawing of Karluk Lagoon already existed in 1867[4], and cruder versions had been present for several decades, Bean's was the first widely published map.

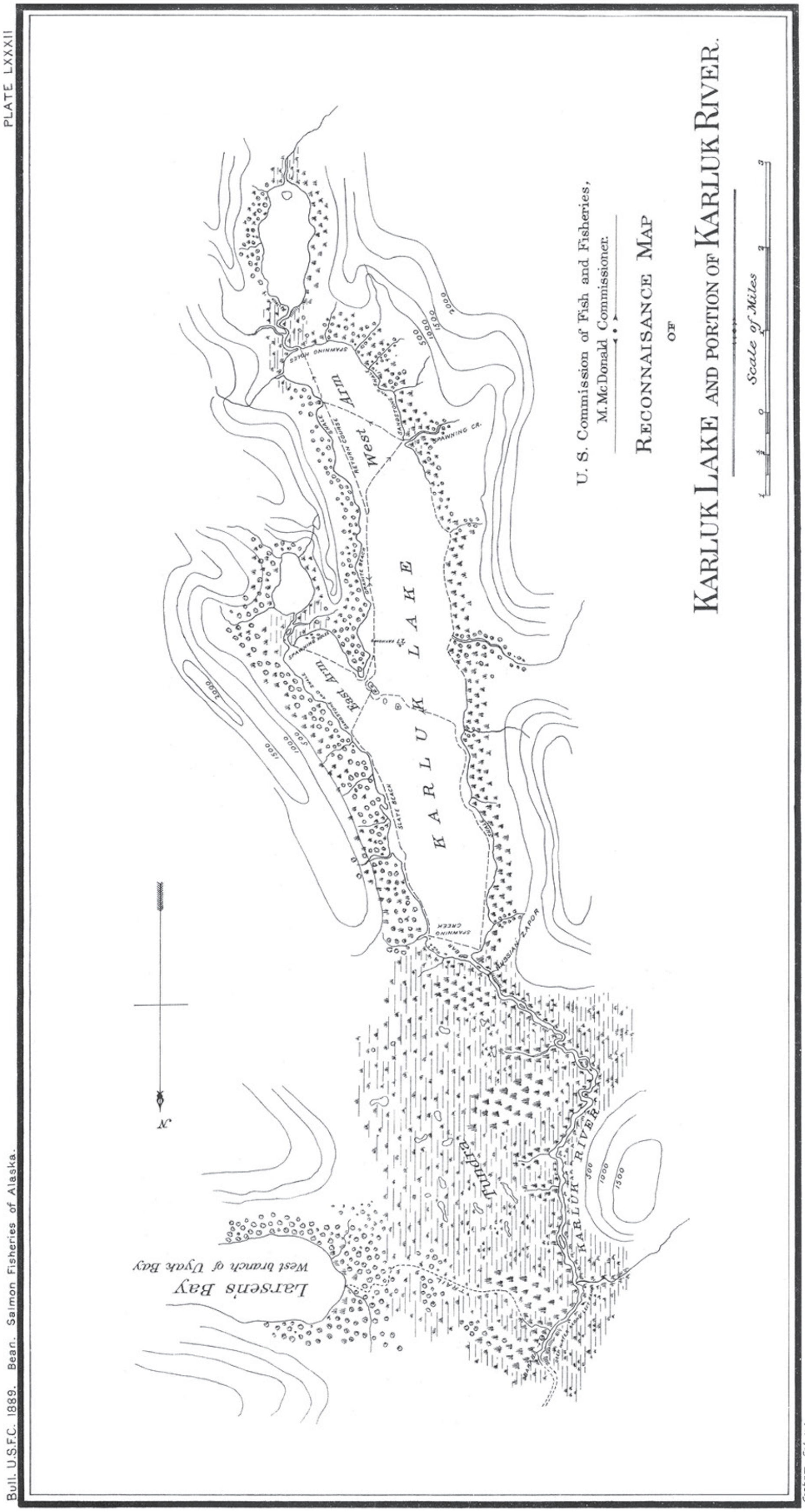
Likewise, he provided the first detailed map of Karluk Lake and the upper Karluk River between the Portage and lake, showing the location of many salmon spawning streams and lake beaches, tributary lakes, shoreline substrates, Portage barabara (native dwelling), and upper river zapor (weir-like salmon barrier). Considering his brief visit, these maps were reasonably accurate, being made with surveying instruments (theodolite transit, steel measuring tape, and aneroid barometer). Supplementing the descriptions and maps, Bean took many photographs of the Karluk Spit, River, and Lake, these first views of the region becoming important historical records. He had prepared for this task by being specially instructed in the new photographic methods at the U.S. National Museum in 1888 or early 1889 (Smithsonian Institution, 1891).

Karluk Spit, the narrow 1 km long bar at the mouth of the Karluk River, was the center of commercial salmon fishing and cannery operations in 1889. Here, Bean found that sockeye salmon were the most abundant and valuable commercial fish packed by the canneries, with about 13 sockeye needed for each case of canned salmon (one case = 48 1-lb. [0.45 kg] cans); whole sockeye salmon weighed about 3.2–3.6 kg each. For this early fishery, he described the harvest methods of beach seine crews and the steps needed to process and can the salmon, in addition to recording data on seine size and location, numbers and types of vessels, values of canning facilities, and employee nationality and wages. Beach seines had increased in length from 46 m in 1880 to 270–460 m in 1889, capturing vast numbers of sockeye salmon. Because of the keen competition for salmon in 1889, fishermen had shifted some beach seine sites from Karluk Lagoon and River to the ocean side of Karluk Spit. On the lower river, Bean saw the remains of the wire fence that had blocked the upstream salmon migration in 1888 and early 1889, but he was unconcerned that this illegal barrier might be reinstalled after his departure because competing canneries closely watched their rivals for unlawful fishing. Yet it alarmed him that nonstop

[4] Davidson, George. 1867. Plan reki Karluka = River Karluk, west coast Kodiak. Unpubl. map. Located at Bancroft Library (G4372.K3 1867 P5 Case XD), University of California, Berkeley, CA.



Map of Karluk Lagoon, Spit, and Village, 1889. The map identifies five salmon canneries located on Karluk Spit or immediately adjacent. The Karluk River enters the east end of Karluk Lagoon, flows though the lagoon, and enters the ocean at the west end of Karluk Spit. (Surveyed by Franklin Booth and Robert K. Lewis, from Bean, 1891)



Map of Karluk Lake and upper Karluk River, 1889. The map shows Bean's travel route around the lake and a Russian zapor in the upper Karluk River. (From Bean, 1891)

Native semi-subterranean dwelling (barabara) and dried sockeye salmon (ukali), Karluk, 1889. (Tarleton H. Bean, National Oceanic and Atmospheric Administration Photo Library, fish7461, from National Archives, Washington, DC)

Beach seining in the ocean for sockeye salmon, Karluk Spit, 1889. (Tarleton H. Bean, from Bean, 1891)

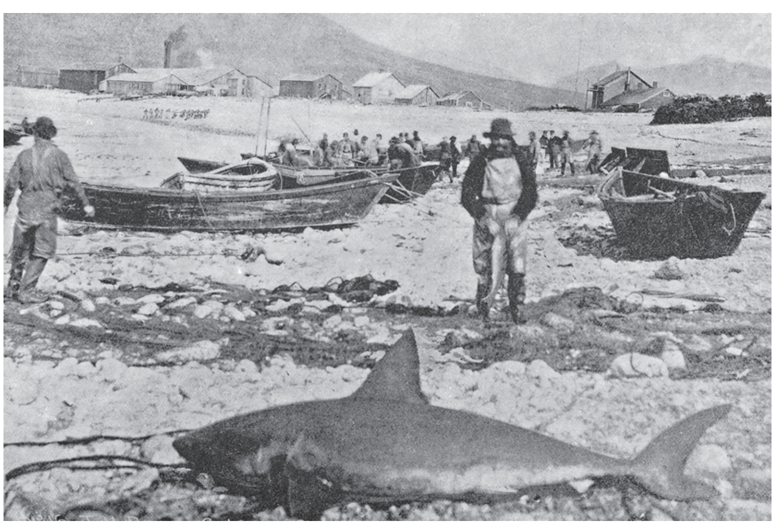
Beach seine crew, Karluk, 1889. (Tarleton H. Bean, National Oceanic and Atmospheric Administration Photo Library, fish7459, from National Archives, Washington, DC) seining at the river's mouth would, in effect, bar salmon from entering the river and reaching the spawning grounds. He believed that the large and rapidly increasing harvests of sockeye salmon were unsustainable, and he warned that these runs would soon decline.

While at Karluk Spit, Bean observed the migratory behavior of sockeye salmon and interviewed experienced cannery personnel about the salmon runs. Little was then known about the ocean life of any Pacific salmon, and there was no appreciation that these fish had traveled long distances from the Gulf of Alaska before they arrived at the Karluk River. Instead, most people thought that the salmon traveled only short distances from local ocean sources. Bean saw that the bull kelp, *Nereocystis luetkeana,* off Karluk Spit served as a salmon refuge from the seines, and he watched the sockeye enter the river on flood tides, only to re-enter saltwater on ebb tides. Small sockeye (jacks or grilse), usually males, were infrequently seen in the migrating schools. Bean photographed a salmon shark, *Lamna ditropis,* that was caught in a beach seine and added this species to a growing list of salmon predators. He learned from cannery workers about the seasonal run timing of Karluk's other salmon species (Chinook, coho, pink, and chum), steelhead, and Dolly Varden, and that many young salmon descended the river each spring. From his own experience, and that of others, Bean rightly concluded that sockeye only ascended rivers draining from a lake. He reported that the size of sockeye salmon adults varied by season and location, though it is unclear if this was a general comment for all of Alaska or for only the Karluk run. If the latter, his early statement hints at the presence of subpopulations in Karluk's sockeye salmon.

Bean was the first biologist to visit and describe the sockeye salmon's spawning grounds at Karluk Lake. After watching masses of sockeye being caught in the beach seines at Karluk Spit, he was eager to see firsthand the productive source of these huge salmon runs at Karluk Lake:

> After we had seen the fishing gangs of the canneries landing their tens of thousands of red salmon almost daily, and one particularly favorable Sunday running the catch up to about 150,000, we were all the more anxious to see the spawning grounds of these struggling myriads. The river would be considered a rather small creek at home, yet it yielded as many red salmon this summer as all the other streams of Alaska combined. It was evident that some explanation of the annual occurrence of such immense shoals of fish would be found in the lake out of which the Karluk starts on its devious course, and we determined to reach Karluk Lake if possible.

Bean visited Karluk Lake on 15–22 August, along with his assistant Lewis, surveyor Booth, and fish culturist Stone. Proceeding upstream from Karluk Spit was impracticable because the river was too low and a hike along its banks was too difficult. Consequently, they traveled 54 km by ocean on a cannery vessel to the head of Larsen Bay, hiked 4 km on the trail to the Karluk River, and then proceeded 14 km upriver to the lake, arriving there on 17 August. Bean hired seven native guides from Karluk to assist the field party. For the next 4–5 days, they traveled around Karluk Lake in two 3-hatch bidarkas, observing sockeye salmon at spawning sites in the lake's small tributaries and scattered along the shore zone. Bean and Stone expected the spawning grounds to teem with adult sockeye, but few live fish were seen, causing them to infer that the commercial fishery had already taken most of the present run in the lower river. They also examined Karluk Lake as a possible hatchery site, but felt it was too inaccessible and, if used, would need a road from Larsen Bay.



Salmon shark captured in a beach seine, Karluk Spit, 1889. (Tarleton H. Bean, from Bean, 1891)

During their August travels around Karluk Lake, numerous sockeye carcasses littered the spawning grounds, indicating that many adult salmon had reached the lake in June and July. These observations—abundant sockeye spawners in June–July, followed by mid-August scarcity—were particularly significant since they indicated that a bimodal run distribution existed in 1889, with a slack period between the spring and fall peaks. The many carcasses provided Bean with dramatic evidence that all sockeye salmon died after spawning, a fact not yet fully accepted by fish biologists. Though he did not link the salmon carcasses to the lake's productivity, he was the first biologist to see these abundant remains and the organically-modified shoreline sediments.

Bean's observations at Karluk Lake included a wide variety of the region's flora and fauna besides sockeye salmon. While traveling up the Karluk River, he noted abundant aquatic plants growing in slower reaches. He found that juvenile salmon (40 mm length) were abundant in the lake's littoral and assumed that they had been produced by the previous year's spawning. Being a keen observer, he noted small parasites in and on the salmon and Dolly Varden. Salmon predators drew his attention, especially the sculpins and Dolly Varden, which ate many salmon eggs. He saw many sticklebacks in the lake and believed they also ate salmon eggs. Upon shooting several terns and gulls at the lake, he found that they had eaten young salmon. Bears were seen feeding on adult salmon and Dolly Varden (Bean, 1894):

> The enemies of the salmon are numerous. Small fish called sculpins, or miller's thumbs, swarm in the nests and eat large quantities of the eggs. Trout devour great numbers of eggs and young salmon. Gulls, terns, loons, and other birds gorge themselves with the tender fry. When the young approach the sea they must run a cruel gauntlet of flounders, sculpins, and trout; and in the ocean a larger and greedier horde confronts them. There the adults are attacked by sharks, seals, and sea lions. Before they have fairly entered the rivers huge nets are hauling them to the shore almost every minute of the day, during six days in a week. When they reach their spawning-grounds, bears are waiting to snatch them from the water and devour them alive. The salmon, it appears, would have been better off had it never been born in fresh-water, where its dangers are cumulative and deadly.

During the brief visit to Karluk Lake, Bean circumnavigated the entire lake and spent at least one night in the Camp Island barabara before proceeding down river on 21–22 August. Soon after returning to Karluk Spit, the 1889 field party departed on their return voyage south. Bean returned to Washington, DC, with specimens of Karluk's fishes, plants, and birds for the U.S. National Museum.

Viewed by present day standards of fisheries research, Bean's 1889 investigations at Karluk would be classed as a reconnaissance survey. He did not conduct detailed studies of sockeye salmon biology or life history, but he did make many natural history observations of sockeye and other fish species. Bean was the first biologist to visit and describe the sockeye's spawning grounds at Karluk Lake, and his biological observations continue to be relevant and of interest. He provided a unique view of the sockeye salmon runs as they existed in the early fishery, possibly before they were greatly modified by many more years of large harvests. Yet, it is prescient that Bean, the first biologist to study Karluk's sockeye salmon, predicted their coming decline in abundance. While many of his observations would now be considered to be well-known facts, he was the first biologist to investigate and publish them. At the time, these field observations gave new scientific information about Karluk's sockeye salmon. We are indebted to Bean for providing a clear and detailed view of conditions at the Karluk Spit canneries and Karluk Lake spawning grounds in 1889.

Cloudsley L. Rutter

1896–97

In the years following Bean's 1889 investigation, special agents of the U.S. Treasury Department made brief summer visits to Karluk's salmon canneries to collect statistics on the sockeye harvests and fishery

Cloudsley Louis Rutter (1867–1903). (G. S. Myers/A. E. Leviton Portrait File in the Natural Sciences, Archives, California Academy of Sciences, San Francisco, CA)

Karluk Lagoon (left), Karluk Spit canneries (center), ocean (right), viewed from east hill, Karluk, 1897. (Harry C. Fassett papers, Box 4 Book II, California Academy of Sciences Archives, San Francisco, CA)

Fish bins full of salmon at Hume Cannery, Karluk Spit, 1897. (Harry C. Fassett papers, Box 4 Book II, California Academy of Sciences Archives, San Francisco, CA)

Beach seining for sockeye salmon, Karluk Spit, 3 August 1897. U.S.S. *Albatross* anchored offshore. (Harry C. Fassett papers, Box 4 Book II, California Academy of Sciences Archives, San Francisco, CA)

Beach seining in the ocean for sockeye salmon, Karluk Spit, 1901. Photograph entitled "An 80,000 haul, Karluk, 1901." (Alaska State Library, Wickersham State Historical Sites Photograph Collection, P277-008-065)

Karluk village and River (near), Karluk Spit buildings (center), Shelikof Strait and ships (far), 27 September 1900. Photograph entitled "Ship *Indiana* leaving Karluk." (W. C. Fitchie, William J. Aspe Collection, Anchorage Museum, Gift of Mary Rolston, B1990.13.5)

Alaska Improvement Co. dock and cannery on west bank of Karluk River, Karluk, 1900–01. Karluk River at entry to ocean. (W. C. Fitchie, William J. Aspe Collection, Anchorage Museum, Gift of Mary Rolston, B1990.13.6) operations. Apparently, the first such inspection occurred in 1892 (Pracht, 1898). Though these special agents only visited Karluk for 1–2 days each year, they tried to enforce the fisheries regulations, received complaints from rival cannery superintendents, and observed the canning and fishing activities. Since their enforcement areas in Alaska were extremely large and travel between canneries was difficult, these agents had no time for biological studies of salmon. Thus, little biological information was gained about Karluk's sockeye salmon and the spawning grounds during this period.

George R. Tingle (1897), U.S. Inspector of Salmon Fisheries, visited Karluk Lake on 15 August 1896 and found it "well stocked with red salmon." He noted the presence of the new APA hatchery on Karluk Lagoon, a modern facility of fish culture intended to boost sockeye salmon runs by incubating thousands of eggs and releasing fry back to the river. James A. Richardson was the hatchery's superintendent.

One employee at the Karluk Lagoon hatchery in 1896–97 was the young zoologist, Cloudsley Louis Rutter, who had just taken his Bachelor and Master of Arts degrees in zoology (1896) while studying under Charles Henry Gilbert at Stanford University, then renowned for its ichthyology and fisheries biology faculty (Brittan, 1997; Dunn, 1997).[5] In addition to his fish culture work at the hatchery, Rutter pursued wider scientific interests by collecting fishes, birds, mammals, and plants in the Karluk area; these specimens were eventually added to the Stanford University Museum (later transferred to the California Academy of Sciences), University of California Museum of Vertebrate Zoology, and U.S. National Museum (Seale, 1898; Grinnell, 1901; McGregor, 1901; Friedmann, 1935b; see also the Appendix). He collected and published information on the tide-pool fishes of Karluk (Rutter, 1899); this paper also contained data on two freshwater fishes, the coastrange sculpin, *Cottus aleuticus,* and threespine stickleback, *Gasterosteus aculeatus.* Beyond his work at the hatchery, there is little indication that Rutter did biological studies of Karluk's sockeye salmon in 1896–97, though he did travel to Karluk Lake and the upper river and saw the decayed salmon carcasses along the shorelines (Rutter, 1903a). Nevertheless, his fish culture work and time at Karluk prepared him for his later studies of its sockeye salmon.

1903

Between 1897 and 1902, special agents of the U.S. Treasury Department annually visited Karluk's canneries and hatchery to report on the salmon fisheries. Also in 1897 and 1900, Jefferson F. Moser, U.S. Navy Commander of the steamer *Albatross,* and several assistants visited Karluk to collect information on the salmon fisheries for the U.S. Fish Commission (Moser, 1899, 1902). On both visits, they focused on the commercial fishing and cannery operations at Karluk Spit (facilities, seine lengths and catches, case packs, employees, and vessels) and spent little time investigating sockeye salmon biology. During the 1897 visit, Alvin Burton Alexander, a fishery expert of the commission, spent a few weeks (18 July–6 Aug.) gathering fishery statistics and visiting the new hatchery at Karluk Lagoon. In the process, he learned from cannery personnel that adult sockeye salmon migrated to Karluk in two distinct runs, one in the spring of smaller fish and another in the fall of larger fish. As commonly happened, their 1897 visit coincided with the slack period between the spring and fall runs. Shortly after departing Karluk in 1897, Moser and Alexander unsuccessfully tried to reach Karluk Lake via Larsen Bay to view the spawning grounds. They claimed that few people, especially cannery personnel, had ever seen the spawning salmon at the lake. Surprisingly, they declared that Karluk Lake froze to the bottom in extreme winters and theorized that this event might explain the recent smaller runs of salmon. Their 1900 visit to Karluk lasted only three days (7–9 August), when Harry Clifford Fassett of the U.S. Fish Commission inspected the sockeye salmon hatchery and found it to be a model plant. His report focused on the hatchery facilities and operations, and he also gave some biological data on egg development times, fry predators, and the distinctness of the spring and fall runs. In 1900 the pink salmon run at Karluk was so large at its peak that beach seining for sockeye was temporarily halted.

By 1897–1900 it was well established in the scientific community that all salmon died after they spawned

[5] 1) Fisheries historian Mark R. Jennings, Davis, CA, personal commun. with Richard L. Bottorff, 1996.
2) One record of fish specimens in the U.S. National Museum (*Gymnelus*—USNM 00126717) indicates that Rutter visited Karluk in July 1894 and collected these fishes aboard the *Grampus.* Yet, the information on this museum record is difficult to interpret. We believe that the USFC schooner *Grampus* was primarily used along the east coast of North America and never sailed to Alaska. Possibly, these fish specimens were collected by another biologist and USFC vessel and mislabeled (or incorrectly dated). A second possibility is that Rutter was aboard the Pacific Steam Whaling Company steamer *Grampus,* which did operate in Alaskan waters during this period. The Pacific Steam Whaling Company did not have a salmon cannery near Karluk until 1897 (at Uyak).

and that adult sockeye only ascended rivers with headwater lakes, but it was still controversial whether or not adult sockeye salmon returned to their birth stream to spawn (the home-stream theory). This controversy continued even though fishermen around Kodiak Island already recognized unique characters in the sockeye they caught from different river systems. Sockeye salmon catches remained high during this period, but, even so, it was feared that the fishery was declining and that future large harvests were unsustainable because of overfishing. Seine hauls at Karluk Spit often captured 25,000–30,000 sockeye salmon at the peak of the run, while in previous years 100,000 fish were reportedly taken in a single haul (Moser, 1899; Rutter, 1903c). Moser expressed concern for the salmon's future and recommended new regulations and stronger enforcement of the commercial fishery. To manage this bountiful fishery, much greater scientific information was needed about its sockeye salmon.

In November 1902 President Theodore Roosevelt directed George M. Bowers, U.S. Fish Commissioner, to establish the Alaska Salmon Commission to study the condition of these fisheries (Roosevelt, 1904). Headed by David Starr Jordan and Barton Warren Evermann, this special commission included 12 other members selected mainly from the U.S. Fish Commission and Stanford University for their fisheries expertise (Jordan and Evermann, 1904). To do the salmon studies, members were stationed in 1903 at the most important salmon fisheries along Alaska's coast, from Southeastern Alaska to Bristol Bay. Cloudsley Rutter, a USFC employee since 1897 (U.S. Government Printing Office, 1897), and his assistant Milo H. Spaulding were chosen to study Karluk's sockeye salmon.[6] At the time, Rutter was one of the most knowledgeable Pacific salmon biologists, having earned this distinction for his recently completed landmark study of Sacramento River Chinook salmon in California (Rutter, 1903a).

Frederic Morton Chamberlain (1867–1921). (From Jennings 1987, courtesy of *Fisheries,* American Fisheries Society)

Rutter and Spaulding spent about four months studying sockeye salmon at Karluk in 1903, from early May to late August or early September (Chamberlain, 1907). They maintained two bases of operations that summer, one at Karluk Spit and Lagoon by Rutter, and another at the north end of Karluk Lake by Spaulding, but with regular visits by Rutter.[7] From these two locations, they studied the adult sockeye salmon from the time when these fish first entered the river from the ocean until they reached their spawning sites at Karluk Lake. Similarly, they gathered data on the sizes, foods, and migrations of juvenile sockeye.

Although their 1903 field work was the first sustained biological study of Karluk's sockeye salmon, Rutter never directly published this information. Shortly after returning to California from Alaska, Rutter died on 29 November 1903 before completing a full report of the Karluk field work (Van Arsdale and Gerber, 1904; Jennings, 1987). Instead, many of his Karluk results were included in the 1907 paper by Frederic M. Chamberlain, another member of the Alaska Salmon Commission stationed in southeastern Alaska (Jennings, 1987). Chamberlain extracted and summarized data about Karluk's sockeye from the field notes and fish collections of Rutter and Spaulding.

Rutter's 1903 field studies at Karluk were extraordinary in that they focused on sockeye salmon biology,

[6] By 1903 Rutter held the position of naturalist on the USFC steamer *Albatross* (Jordan and Evermann, 1904).

[7] 1) Fisheries historian Mark R. Jennings, Davis, CA, personal commun. with Richard L. Bottorff, 1996.
2) Letter (19 July 1903) from Spaulding, Karluk Lake, to Rutter [at Karluk Spit]. Located in Box 130, Barton Warren Evermann papers, Library Special Collections, California Academy of Sciences, San Francisco, CA.
3) Rutter, Cloudsley L. 1903. Memo notebook for 1903 (16 June–14 July), Karluk Spit, Portage, River, and Lake. Located in Box 130, Barton Warren Evermann papers, Library Special Collections, California Academy of Sciences, San Francisco, CA.

while all previous efforts had centered on the commercial fishing and cannery operations. At the time, many basic biological facts about sockeye salmon remained unknown, such as: 1) multi-year rearing of juveniles in a freshwater lake, 2) planktonic food habits of juvenile salmon, 3) multi-year aged smolts that migrate downstream each spring to the ocean, 4) ocean residence in the Gulf of Alaska and Bering Sea far from the Karluk River, 5) many combinations of freshwater and ocean ages of returning adult salmon (ages not yet determined by scale analysis), 6) fidelity of adults in returning to their home stream, and 7) uniqueness of the sockeye's life history from that of other salmon species. Rutter's investigations included scientific collections, natural history observations, and, for the first time, field experiments designed to answer specific biological questions. Significantly, since his study lasted four months and included most of the sockeye's spawning period, he observed the seasonal changes in this dynamic river-lake ecosystem.

Shortly after Rutter and Spaulding reached the Karluk region in 1903, they began their sockeye salmon studies at the lake. By late May they had installed a fish trap at the outlet to capture adult sockeye moving upstream (Chamberlain, 1907). To measure the sockeye smolt migration from Karluk Lake, they made five overnight sets of a fyke net at the outlet on 5–30 June, but it is unclear what was caught because Chamberlain reported that "salmon parr" and "salmon fry" were trapped, without identifying the species or giving their size. Chamberlain defined "parr" as being juveniles of any size so long as they had parr marks, while Rutter used this same term for young salmon of 100–200 mm length (Rutter. 1903c).[8] Using Rutter's definition, the fyke nets likely caught about 200 sockeye smolts in June. At Karluk Spit, Rutter collected many large juvenile sockeye that had been incidentally brought ashore in the commercial beach seines in June and July, though it is unclear if he realized that these were the recent smolt migrants from Karluk Lake (Chamberlain, 1907). Often as many as 1,000 salmon smolts, most likely sockeye, were caught in each beach seine early in the fishing season. Chamberlain (1907) remarked that Karluk's sockeye smolts were much larger than those produced in other lake systems of Alaska and Canada, but the reasons for this size difference were unknown.

In 1903 it was difficult for biologists to identify the young stages of all salmon species. To remedy this problem, Rutter preserved juvenile fish of many sizes and all species from a wide range of habitats: freshwaters of the lake, its tributary creeks, and river; estuarine waters of Karluk Lagoon; and the ocean at Karluk Spit. Further, he photographed and fully described the colors and marks of living specimens of all species.[9] Chamberlain later used Rutter's specimens and field notes to illustrate and taxonomically separate these juvenile salmon. At least some of Rutter's preserved sockeye specimens were also examined for their food habits; the young had fed on crustaceans and insect larvae in the lake's tributaries and upper river (May–July) and on planktonic crustaceans in the ocean.

Typical of most fish biologists who visited Karluk Lake, Rutter and Spaulding examined the spawning habitats and behaviors of adult sockeye salmon. They found many spawning redds in the lake's lateral and terminal streams and along its lakeshore, but their observations went beyond general surveys. In addition, they described the areas and substrates of spawning sites, the development of secondary sexual characters in adult salmon, the adult behaviors in digging and defending the redds, the male–female spawning behavior, and the eventual decline, death, and decay of adults.

To measure the number of spawning sockeye and their egg production, Rutter selected Moraine Creek for intensive study.[10] Here, all dead sockeye were periodically counted, checked for spawning condition, and removed from 5 August to 5 September, a total of 21,756 carcasses closely divided between males and females (Chamberlain, 1907). About 80% of females had completely deposited their eggs and 20% retained 100 eggs on average. By digging into spawning redds and using spawning baskets,[11] they concluded that

[8] Rutter, Cloudsley Louis. 1903. Field observations by Cloudsley Rutter on his Karluk work of 1903. Unpubl. notes. 48 p. Copy provided courtesy of Mark R. Jennings (Davis, CA) and located in Box 130, Barton Warren Evermann papers, Library Special Collections, California Academy of Sciences, San Francisco, CA.

[9] See footnote 7 (3).

[10] Rutter and Spaulding identified Karluk Lake's tributaries by number, not name; Moraine Creek was first formally named in 1921 by Charles H. Gilbert. The creek they intensively studied, apparently Moraine Creek, was identified as the second stream from the outlet on the east side of Karluk Lake. Most of Rutter and Spaulding's salmon spawning studies were confined to the northern end of the lake in the vicinity of Spring, Moraine, and Cottonwood creeks.

[11] A 1906 APA map shows the 1903 locations of Rutter's spawning baskets. APA 1906 reconnaissance map located at Alaska State Library, Historical Collection, Juneau, AK, and a copy at NARA, Anchorage, AK.

eggs buried deep in the gravel remained in good condition. From the number of females counted and an assumed fecundity of 3,500 eggs per female, Rutter estimated that the Karluk system produced 400,000,000 sockeye salmon eggs in 1903.

Rutter and Spaulding were the first biologists to study the migration speed and behavior of adult sockeye at Karluk. They tagged 400 spring-run sockeye and released them off Karluk Spit, finding that most entered the river within a day and few remained after a week. Rutter next attached copper jaw tags to hundreds of adult sockeye in Karluk Lagoon in June and released them for Spaulding to record their arrival at the lake, finding that they needed about 10 days to ascend the river (Chamberlain, 1907). A few tagged sockeye were later recovered off Karluk Spit, showing that some fish returned to the ocean after entering Karluk Lagoon. One tagged fish was recovered near the mouth of the Ayakulik River, over 60 km from Karluk, suggesting that sockeye salmon might ascend two different streams, a possible refutation of the home-stream theory (Jordan, 1903; Kutchin, 1904; Chamberlain, 1907).[12] While doing this tagging work, Rutter observed many details of the migratory behavior of adult salmon, including how they reacted to tides, winds, and river currents.

After completing the tagging work on the lower river in late June, Rutter and Spaulding next tagged 255 adult sockeye as they entered Karluk Lake on 3–25 July (Chamberlain, 1907). Most tagged fish were later recovered on the spawning grounds, but unexpectedly three were caught in seines at Karluk Spit, indicating that a few adult sockeye had descended the entire river and re-entered the ocean. Their tagging work at Karluk Lake, plus observations at the spawning streams, showed that adult sockeye had a 1-month maturation period between their June–July arrival at the lake and July–August spawning. Thus, Rutter and Spaulding obtained a remarkably accurate understanding of the entire upstream migration of adult sockeye between ocean, lagoon, river, lake, and specific spawning sites.

Based on his 1896–97 hatchery work and 1903 studies, Rutter declared that adult sockeye salmon returned to Karluk in two distinct and intergrading runs, the first peaking in late June and the second peaking in early August (Chamberlain, 1907).[13] The spring run was abundant in 1903 and Rutter stated that "apparently there was a considerable run of salmon during June, for there was certainly an enormous number reached the lake."[14] In fact, he estimated that "at least two millions reached the lake," a surprising number since this horde of salmon had passed by the Karluk Spit canneries unnoticed, the strong northeast winds keeping fishermen from setting their nets. And yet, for some reason, he claimed that the 1903 sockeye run was rather poor, the two runs not being observed. Since Rutter departed Karluk in late August, he possibly missed seeing the fall sockeye run.

When at Karluk Spit, Rutter often watched the frenzied beach seining activities and frequently examined fish samples from the catch. The adult sockeye hauled ashore had only eaten small crustaceans and fishes, foods he considered appropriate for their fine gill rakers (Chamberlain, 1907). These simple ocean foods suggested to him that it would be unnecessary for sockeye to migrate far from the Karluk River to be adequately nourished. Further, while observing these adult sockeye, Rutter noticed that many had body scars, and he carefully examined 500 individuals for wounds received in the ocean.[15] Over 10% had suffered some damage, mostly posterior body injuries. On the gill covers and posterior bodies of five adult sockeye, he found the characteristic circular mark made by lamprey (Rutter, 1903a).

Although Rutter and Spaulding focused their 1903 field studies on sockeye salmon, much of the region's flora and fauna interested them. Whenever possible, they collected fishes, birds and their eggs, and plants to deposit in several museum collections, such as Stanford University and the U.S. National Museum (see Appendix). In 1903 Rutter added to his previous collections of tide-pool fishes and was fascinated by the mass migration of threespine sticklebacks into Karluk's tributary lakes.[16]

Whenever at Karluk Lake, he kept notes on its numerous bald eagles, *Haliaeetus leucocephalus,* and often examined their nests for eggs and eaglets. Fifteen pairs of bald eagles nested at the lake in 1903 (Rutter, 1903b). Rutter and Spaulding also collected 230 plant specimens in the Karluk region (Hulten, 1940), but found it difficult to dry the pressed samples in the

[12] See footnote 8.

[13] See footnote 8.

[14] See footnote 8.

[15] See footnote 8.

[16] Rutter, Cloudsley Louis. 1903. Notes made by Mr. Cloudsley Rutter at Karluk, season of 1903. Unpubl. notes. 7 p. Copy provided courtesy of Mark R. Jennings (Davis, CA) and located in Box 130, Barton Warren Evermann papers, Library Special Collections, California Academy of Sciences, San Francisco, CA.

damp rustic conditions of the lake field camp.[17] To further document the region's biota, Rutter photographed its fishes and plants.[18] Beyond these wide-ranging biological interests, Rutter wanted to prepare an accurate map of the Karluk region and took compass bearings of prominent landmarks from good vantage points during his travels.[19] In 1903, during Rutter's time at Karluk, the U.S. Bureau of Fisheries (USBF) was created within the Department of Commerce and Labor.

Rutter's 1903 field observations provide many interesting insights into then prevailing ideas about the life history of sockeye salmon.[20] For example, where did sockeye salmon spend their ocean residence, close to the Karluk River mouth or far away? When salmon returned to the Karluk River, did they home to that specific river as a distinct stock or did they only return to it because it just happened to be the closest river? No one could unequivocally answer these questions in 1903.

There had been reports of salmon being washed aboard vessels in the mid North Pacific Ocean, hinting of a distant marine residence, but Rutter believed that the salmon remained fairly close to their spawning streams (Rutter, 1903c). He felt that long distance migrations were unnecessary since ample foods were readily available locally. Thus, he concluded that salmon did not home to a specific river, but only returned because it was the first river that attracted them. He believed that the salmon of Shelikof Strait, Chignik, and Cook Inlet had a common feeding ground where they intermixed, forming a common pool from which future runs were drawn, but not as distinct stocks returning to specific home streams. This theory seemed to explain why the millions of sockeye fry that had been released from Karluk's hatchery had provided few benefits to its runs; that is, the hatchery output was being absorbed by other regions.

By 1903, after 20 years of commercial fishing at different sites around Kodiak Island and Shelikof Strait, it was obvious that the size of adult sockeye varied between locations and that the Karluk River fish were smaller than at some other sites. Rutter believed that the ocean food supply of juveniles explained these size variations. He reasoned that juveniles spent their first ocean year near the mouth of their natal river and that their growth depended upon the habitat's food abundance. Furthermore, he thought the abundance and variety of juvenile foods were directly proportional to the size of the ocean bay at the river's mouth. In other words, rivers discharging into large ocean bays would have abundant food and rapid juvenile growth, while rivers discharging into small bays would have sparse food and slow juvenile growth. Thus, larger adult sockeye would be expected at Uganik and Chignik with large bays, while smaller fish would occur at Karluk and Little River with little or no ocean bays.

The large diversity of age compositions in Karluk's sockeye salmon runs remained unknown in 1903 because scale-aging methods had yet to be used on Pacific salmon. Biologists then had little idea that returning sockeye adults had many combinations of freshwater and ocean ages. When Rutter examined the sockeye catch statistics for Karluk, he noticed a 5-year cycle between good catches and concluded that adults were five years old, but he believed that the only accurate way to measure salmon ages was to mark juveniles and observe the later return of marked adults. This method was tried on several thousand sockeye fry released from Karluk's hatchery in 1897 and 1902, but the results were unclear because few marked adults were ever recovered (Chamberlain, 1907; Roppel, 1982).

Biologists realized by 1903 that most sockeye salmon returned to spawn in river systems having lakes, but the reason for this behavior was unknown. Rutter speculated that adult fish used the lakes while their reproductive products matured before spawning (Rutter, 1903c). He rightly contrasted the dramatically different salmon runs of the Karluk and Sturgeon rivers, these two adjacent watersheds discharging into Shelikof Strait only 8 km apart.[21] The Sturgeon River lacked a headwater lake and sockeye salmon, while the Karluk River flowed from a large lake and had a huge sockeye run. But how did returning adult sockeye recognize which rivers had lakes?

Rutter theorized they might be attracted to a lake-bearing river by seeing or smelling the juveniles present in the river or clustered around its mouth. Or possibly, returning adults could smell the adult carcasses that remained from the previous year's spawning. Clearly, he failed to understand the lake's importance as a multi-year nursery for juvenile sockeye; instead, he believed that once the egg-sac had been absorbed and fry could swim, they started on a slow migration downriver to the ocean. Thus, he claimed that juveniles spent little time in Karluk Lake and reported seeing few along its shores in 1903. Holding such views, he had no reason to collect limnological data at Karluk Lake. Never-

[17] See footnote 7 (2).
[18] See footnote 7 (2) and footnote 7 (3).
[19] See footnote 7 (3).
[20] See footnote 8.
[21] See footnote 8.

theless, only a short time later, Chamberlain (1907) began to reveal the unique life history of sockeye salmon and document that most juveniles reared for at least one year in a lake before they entered the ocean.

When Bean visited Karluk Lake in 1889, the idea that Pacific salmon died after spawning was just gaining acceptance among biologists, but by 1903 it was a known fact. Rutter discussed reasons for this phenomenon and realized that death after spawning was determined by a long evolutionary process on the salmon's life cycle.[22]

Rutter was the first Karluk biologist to examine the food habits of hundreds of charr collected from the lake, lagoon, and ocean. He wanted to test the widespread belief that charr intensely preyed on salmon eggs and young. No distinction was made in 1903 between the two charr species present at Karluk. Rutter referred to these fishes as "Dolly Varden trout,"[23] while Chamberlain called them charr. Despite examining many stomach samples, Rutter found little evidence of charr predation on sockeye fry, except at the unnatural habitat inside hatchery corrals. Though schools of salmon fry inhabited the upper river in June–July, charr stomachs lacked young salmon (Chamberlain, 1907). Nevertheless, charr ate many sockeye eggs and these were found in more than 50% of the charr examined from a creek with spawning sockeye.

Although the main purpose of the Alaska Salmon Commission was the biological study of Pacific salmon, members were also asked to evaluate the potential of hatcheries to enhance salmon production. Rutter outlined several advantages of locating a hatchery at Moraine Creek, a Karluk Lake tributary, including 1) an abundant supply of adult sockeye that could not be completely blocked by commercial fishing, 2) ripening ponds would be unnecessary for holding brood stock, 3) catching spawners would be easy, 4) a good water supply existed, 5) a good building site existed, and 6) Karluk Lake had almost no Dolly Varden to prey on sockeye fry.[24] His claim that few charr occurred at the lake was unusual; most biologists, before and after, reported them to be common. The main disadvantage of a Karluk Lake hatchery was the site's inaccessibility, which would require that a railway be constructed from Larsen Bay. Rutter criticized the low efficiency of the Karluk Lagoon hatchery, stating that many adult sockeye held in ripening ponds died before spawning. He concluded that "I think this hatchery has been of very little value."

In summary, Rutter's 1903 investigations at Karluk comprised a wide range of biological topics on sockeye salmon and the region's biota. Atypical for biologists of this era, his methods went beyond natural history observations, descriptions, and museum collections, and included for the first time field experiments to answer specific biological questions. Considering the relatively short field season spent at Karluk, the rustic living conditions, poor transportation, and limited field assistance, the scope of his studies and scientific accomplishments were remarkable. Rutter revealed many life history aspects of Karluk's sockeye salmon and his findings remain pertinent today. It is noteworthy that many of the topics he studied and methods he used fall within the discipline of fishery biology, which was then in its infancy. It is unfortunate that the full details of his pioneering research at Karluk were curtailed by his untimely death.

Following Rutter's 1903 studies, no further comprehensive investigations were done on Karluk's sockeye salmon for 15 years. Although sockeye salmon harvests were declining during these years, the yields still remained relatively high and apparently there was little urgency within the government or canneries to obtain basic biological data on this species. The APA discounted the need for a federal biological station in Alaska devoted to the scientific study of its salmon, but they did want the government to study fish processing technology:

> I do not think that the canners believe particularly that we should have a biological station, which I suppose would be perfectly proper for the fisheries to utilize. We do not care particularly about knowing how many scales there are to the square inch or whether the lateral line runs up or down or how big the peduncle is, or anything of that kind, but we do want to know how to utilize our products. (U.S. Senate, 1912)

Several USBF biologists briefly visited Karluk after 1903, most often to evaluate the operations and effectiveness of the sockeye salmon hatchery located on the lagoon. The APA first built this hatchery in 1896 as a private volunteer effort to help augment the runs at Karluk, but shortly thereafter this facility let them satisfy the 1900 and 1902 federal mandates that canneries must release 4–10 fry for every adult salmon caught. This requirement became less onerous in 1906 when the federal government began to rebate case pack taxes to those canneries that operated a hatchery (40 cent rebate for every 1,000 fry released).

[22] See footnote 8.
[23] See footnote 8.
[24] See footnote 8.

Despite the notable efforts of the APA to enhance the sockeye salmon runs at Karluk, the hatchery received increased criticism over the years because a large portion of the sockeye brood stock died before they spawned and the fry were released into the estuary, an unnatural rearing environment for these young fish. It was during this period (1903–07) that biologists first discovered that young sockeye reared for one or more years in a freshwater lake before they migrated to the ocean. This new fact immediately cast doubt on the hatchery practice of releasing fry into an estuary. To remedy the serious defects of the existing hatchery, the APA considered building a new facility at Karluk Lake or transporting the hatchery fry to the lake, but these ideas were never completed.

Fassett made a detailed inspection of the Karluk hatchery on 1–8 September 1910 and provided information on the spring and fall sockeye runs, egg size and fecundity, and fry biology.[25] Ward T. Bower of the USBF Division of Alaska Fisheries examined the hatchery in 1910 and 1911 (Bower, 1912). He explored Karluk Lake on 29 July–1 August 1911 to find a new hatchery site to replace the inefficient facility at Karluk Lagoon and noted huge numbers of sockeye salmon spawning in the lake's tributaries and in the shallow waters along its shorelines.[26] Chamberlain next inspected the hatchery in September 1911 and spoke favorably of its operations.[27]

When the U.S. Senate held hearings in 1912 on a bill (S 5856) to amend the laws that regulated Alaska's salmon fisheries and governed its federal taxation, the Karluk Lagoon hatchery came under intense scrutiny (U.S. Senate, 1912). Jefferson F. Moser, then an APA official, argued that the hatchery had benefited the sockeye returns at Chignik, a cannery located 160 km away on the Alaska Peninsula, but that Karluk's runs had not been helped. The consensus reached at the hearings by Moser, Bower, and Evermann (Chief, USBF Division of Alaska Fisheries) was that Karluk Lake would have been a much better hatchery site than Karluk Lagoon. It was also clear from the testimony that federal biologists and cannery officials did not know the ultimate fate of hatchery fry released into the lagoon, though various opinions were offered on their survivability. James Wickersham, Alaska's delegate to Congress, reported that an informant "had seen those little fish at the Karluk hatchery in windrows dead on the beach," but this evidence was discounted (U.S. Senate, 1912).

The U.S. Senate hearings of 1912 also focused attention on the APA commercial fishing and canning activities, which appeared to have few benefits for Alaskans. The use of fish traps by the large canneries had long angered Alaska residents because these ensnaring devices, erected each year at select locations along the state's coastline, appeared to give non-resident companies an exclusive fishing right (U.S. Senate, 1912). Moreover, in the pursuit of their commercial ventures, the early canneries bought few supplies and hired few employees from Alaska. Instead, they came to Alaska each spring on their own vessels that were already fully loaded with the necessary materials and laborers to harvest and process salmon for the full canning season. At the end of each season, they returned to San Francisco, Seattle, or other west coast ports with their laborers and salmon case pack, leaving a single watchman to guard the cannery buildings over the winter. Although

Alaska Packers Association ship *Star of Alaska,* ca. 1920. (Gabriel Moulin, National Park Service, San Francisco Maritime National Historical Park, San Francisco, CA, SAFR P80–084.1NL)

[25] Fassett, H. C. 1910. Report on the salmon hatchery operated by the Alaska Packers Association on Karluk Lagoon, Kadiak Island, Alaska. Unpubl. USBF Report. 25 p. Located at Alaska Historical Collections, Alaska State Library, Juneau, AK.

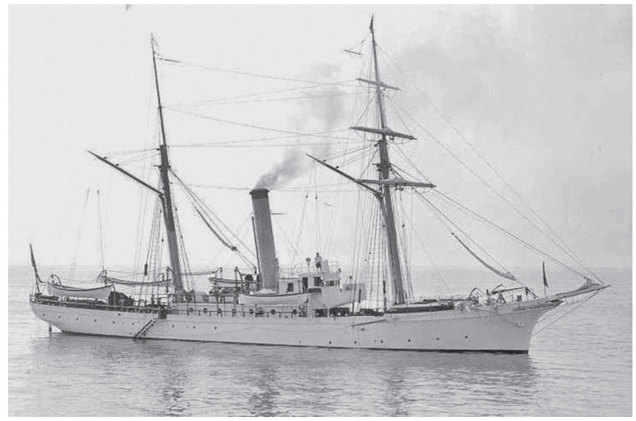
[26] 1) In 1910 he visited the hatchery on 7 May. Memo (7 October 1910) from Ward T. Bower, Department of Commerce and Labor, USBF, Washington, DC. Located at NARA, Anchorage, AK.
2) Apparently, Bower prepared a special report of his 1911 visit to Karluk Lake, but the details of this trip are unknown because the special report was not located. Letter (31 January 1927) from Ward T. Bower to Willis H. Rich, Stanford University, CA. Located at NARA, Anchorage, AK.
3) Bower related some of the information about his visits to Karluk Lake during his testimony at the Senate hearings of 1912 on Alaska's fisheries (U.S. Senate, 1912).

[27] Memo (16 April 1916) from Ward T. Bower, USBF, Washington, DC, to Commissioner of Fisheries, Washington, DC. Located at Alaska Historical Collections, Alaska State Library, Juneau, AK.

the canneries paid a tax on their case pack production (4 cents per case in the early years), little of this money went to improve Alaska's infrastructure, especially from companies that received tax rebates for operating a sockeye salmon hatchery. No other levies, including property taxes, were imposed on the early canneries in Alaska. All of these long-festering grievances were tersely voiced by Wickersham at the 1912 hearings, well before statehood, but anticipating that future change in governance (U.S. Senate, 1912).

Just prior to permanent closure of the Karluk Lagoon hatchery in 1916, USBF biologist E. M. Ball examined the facility in April and July and on the later date traveled upstream to the Karluk River Portage. Then, in 1917, Ball surveyed the spawning grounds at Karluk Lake on 12–14 September and saw sockeye salmon spawning in the upper Karluk River. He believed that artificial propagation of sockeye was unnecessary, declaring that "nature has made wonderful provision for the salmon of Karluk by supplying them with ideal spawning grounds and other favorable conditions." In fact, he wanted this productive system protected and suggested that "it would be a splendid thing to set apart by Presidential Proclamation Karluk Lake and its catchment basin as a National Fisheries Reservation in which salmon would be allowed to live out their lives in the reproduction of their kind . . ."[28]

Besides the biologists that briefly investigated the sockeye salmon, federal agents continued to visit Karluk for a few days each year during 1892–1915 to enforce the fisheries laws and gather information on the commercial fishing and cannery operations. But the task of monitoring and regulating the Karluk fishery was nearly impossible because these agents were spread across extensive enforcement areas and lacked suitable vessels for independent travel in the Kodiak region. Most agents did not live in Alaska near their enforcement areas, traveling to the region each summer from the coterminous United States. Their brief annual visits to Karluk were typically made on U.S. Treasury Department revenue cutters (*Grant, Perry, Rush,* and *Walcott*), and, at times, the agents depended on cannery vessels for transportation to the canneries inspected, completely removing the possibility of surprise visits. As a consequence, Karluk's salmon fishery in the early years was largely unregulated for most of the harvest season, and the enforcement agents relied on the honesty of the fishermen and canneries to abide by the laws. This resulted in many infractions of the fishery laws, but few violations were brought to the attention of the enforcement agents and, during this era, it was difficult to get convictions and significant penalties for fishing crimes. In fact, the lack of governmental oversight caused the competing canneries at Karluk to self-regulate the salmon fishing in 1890, though many conflicts still occurred between the different beach seine crews:



U.S. Revenue Cutter, *Commodore Perry,* Alaska service 1894–1910. (U.S. Coast Guard Historian's Office, Historic Image Gallery of Revenue Cutters)

> [Karluk Spit, 1890] That fishing at Karluk had interested a lot of cannerymen. There was twenty-seven seines in on that one seining ground there in 1890. And there wasn't a single law enforcement official. Later I read that Congress passed the first legislation limiting the methods of fishing in the Territory in 1888–89. They had a few revenue cutters around up there, coming and going, trying to figger out about it all. But we never heard of no laws. We didn't have no one to tell us what to do. There we was, out of touch with everyone, all trying to fish at the same time in the same place. It's a wonder there wasn't more shooting than there was. Why, so many fellows waited to fish, that as quick as the end of one seine was pulled up on shore, another outfit would throw in. . . . Finally, the cannery representatives called a meeting . . . The law we agreed on was this: no one could fish on Saturday. . . . The next law was that the cannery representatives would meet every Saturday night and shake dice to see who would get the first haul . . . The year after that the government took over. The boys said it was all right as long as the revenue cutters was there, but as soon as a cutter was

[28] 1) Ball, E. M. 1916. Report of operations, July 21, 1916. Unpubl. report. 1 p. Located at NARA, Anchorage, AK.
2) Memo reports (27 April and 23 July 1916) from E. M. Ball, Assistant Agent, Alaska Fisheries Service, USBF, Washington, DC, to Commissioner of Fisheries, Washington, DC. Located at Alaska Historical Collections, Alaska State Library, Juneau, AK.
3) Ball, E. M. 1917. Extract semi-monthly report of Mr. E. M. Ball, season of 1917. Unpubl. report. 1 p. Located at NARA, Anchorage, AK.
4) Ball, E. M. 1919. Extract from report of Mr. E. M. Ball, season of 1919. Unpubl. report. 3 p. Located at NARA, Anchorage, AK.

gone, one of the canneries would anchor a boat on the seining grounds. (McKeown, 1960)

In 1891 the eight canneries taking sockeye salmon at Karluk formed the Karluk River Fisheries, a cooperative agreement that controlled the fishing and apportioned the resulting case pack (Roppel, 1986). J. K. Luttrell, special agent of the U.S. Treasury Department, recommended in 1893 that a federal officer be posted at Karluk during the fishing season to enforce the laws, but this was not done (Luttrell, 1898). In the summer of 1914, E. Lester Jones, USBF Deputy Commissioner of Fisheries, toured coastal Alaska and was appalled by the lack of governmental regulation of the salmon fisheries, a shortcoming previously noted in 1897 by David Starr Jordan and C. L. Hooper (Jordan and Evermann, 1904). In particular, these men stressed the critical need for a fleet of federal patrol vessels to help fishery regulatory agents perform their enforcement duties:

[Alaska, 1914] A fundamental necessity in the protection of the fisheries of coastal waters is a fleet of vessels of a type fitted for the requirements of the region concerned. . . . It is absolutely necessary to have more boats and funds to carry out the instructions of Congress in regard to the enforcement of the fishery laws of Alaska . . . Without more vessels and men it is almost .. useless to make laws to protect this great fishing industry . . . The waters to-day in western Alaska, including the fishing districts of . . . Kodiak Island .., are practically without any protection, and fishermen operate in any way they care to, without, I may say, even the slightest semblance of investigation or restriction. This is entirely due to the fact that there are no Government vessels to look after these vast and important fields. We have one man stationed at Afognak Island, not only an isolated place, but with the waters surrounding it and Kodiak Island treacherous and dangerous a greater part of the time, and all we have available for his use is an 18-foot skiff. In this he is supposed to investigate fishery violations and follow fast-moving tugs and fishing boats. As a result, this Government official has been forced to jeopardize his life by going out in this skiff, or resort to the unfortunate and inexcusable practice of asking a cannery to furnish passage on a boat so that he may investigate the company's own fishery operations. This is the only safe means he has of getting there. The necessity of such a practice is ludicrous and absurd in the performance of official inspection work. To cite one instance which reflects discredit on the Government: One of our chief officials in Alaska requested that a cannery tug take him to a certain fishing ground so that he might see if the law was being violated. The company's superintendent readily acquiesced, and when he was nearing the fishing grounds blew five long blasts. The Government official naturally inquired why this was done, and the answer came back: "I am very sorry, but my instructions from the boss are to warn all the fishermen by five whistles when any of our boats are carrying a United States fisheries official." In other words, they were in the habit of violating the law and this was a warning that they must desist for the time being. (Jones, 1915)

U.S. Bureau of Fisheries patrol vessel, *Blue Wing,* 1947. (E. P. Haddon, National Oceanic and Atmospheric Administration Photo Library, ship0313)

His recommendation of seaworthy patrol vessels eventually was fulfilled by the USBF in the 1920s. Thereafter, several USBF vessels—*Blue Wing, Brant, Crane, Eider, Penquin, Red Wing,* and *Teal*—patrolled the coastal waters of Kodiak Island to monitor the fishery or passed through the region en route to the Aleutian and Pribilof islands.

During the early fishery, the number and location of canneries that harvested sockeye salmon from the Karluk system varied substantially (Fig. 2-2). After the initial proliferation of five canneries on or near Karluk Spit in 1882–89—from west to east: 1) Alaska Improvement Company, 2) Karluk Packing Company, 3) Aleutian Island Fishing and Mining Company, 4) Hume Packing Company, and 5) Kadiak Packing Company—all of these were consolidated into the APA facilities or closed by 1897 (Roppel, 1986). In addition to the five Karluk Spit canneries, another three canneries located further from Karluk also took sockeye salmon from this system—Arctic Packing Company on Larsen Bay and Royal Packing Company and Russian–American Packing Company on Afognak Island. When Afognak Island was set aside as a Forest and Fish Culture Reserve in 1892, its two canneries were closed.

The APA continued to operate several Karluk Spit canneries during 1897–1910, but closed them all after

Wreck of the Alaska Packers Association ship *Servia,* Karluk, 6 November 1907. (John N. Cobb, University of Washington Libraries, Special Collections, UW 14295)

they built a new cannery at Larsen Bay in 1911. Karluk Spit, the main site where fishermen caught sockeye salmon with beach seines, had major disadvantages for cannery operations, including an unprotected anchorage and lack of deep-water access for large vessels. These physical limitations had plagued the APA for many years and greatly complicated their work. Since large vessels drawing more than 1.2 m of water could not dock at the Karluk Spit canneries, it was often difficult to transfer supplies and passengers, and the entire case pack of salmon had to be lightered in small boats to the ships lying offshore in Shelikof Strait, fully exposed to sudden storms and rough seas that threatened to drive them onto the nearby rocky coastline.

During the early era when sailing vessels supplied the Karluk Spit canneries and received their output, the exposed anchorage resulted in a succession of disastrous shipwrecks—schooner *Pauline Collins* (6 October 1881), bark *Julia Foard* (27 May 1888),[29] ship *Raphael* (7 July 1895), bark *Merom,* (6 October 1900), and ship *Servia* (6 November 1907). Additionally, several smaller launches were wrecked at Karluk (U.S. Senate, 1912)—*Annie May* (1895), *Karluk* (1899), and *Delphine* (1903). Between 1888 and 1907, shipwrecks at Karluk and around Kodiak Island cost the APA about $658,000. These losses and other problems with the Karluk Spit site finally convinced the APA to replace the existing facilities with a single, large, new cannery at Larsen Bay, a protected location for vessels on the west side of Uyak Bay and 29 km east of Karluk. Work on the new cannery began in 1909 and was completed in time to process the 1911 salmon harvest (Marsh and Cobb, 1911). Commercial fishermen continued to beach seine for sockeye salmon at Karluk Spit for many years, but the harvested salmon were then transported 47 km by sea to the new cannery.

Charles H. Gilbert

1917–27

Charles Henry Gilbert began his studies of Karluk's sockeye salmon about 1917, during the last 10 years of his distinguished career as a descriptive ichthyologist,

Charles Henry Gilbert (1859–1928). (From William W. Gilbert, deceased)

[29] Some references say the *Julia Foard* (or *Ford*) was wrecked at Karluk on 27 April 1888.

pioneering fishery biologist, and educator (Dunn, 1996, 1997). From 1891 until his retirement in 1925, Gilbert was Professor and Chairman in the Department of Zoology, Stanford University. Prior to 1909 he collected and described hundreds of freshwater and marine fishes, mainly from the American west and Pacific Ocean. Several early collecting trips brought him to Alaska, where, in 1903, he served as a member of the Alaska Salmon Commission, being stationed at Bristol Bay. Gilbert, an authority on Pacific salmon, was appointed Scientist-In-Charge of USBF Pacific Coast fisheries in 1909, and thereafter focused much of his attention on the biology of salmonid fishes (Dunn, 1996). In about 1909–12, he first began using fish scales to age Pacific salmon and study their racial composition.

Because of Gilbert's extensive knowledge of Pacific salmon, his previous travels in Alaska, and his contacts with other salmon biologists, he undoubtedly knew about Karluk's abundant runs of sockeye salmon and intense commercial fishery well before he began studies there. Yet, it remains unclear just when Gilbert first visited Karluk. He analyzed a few hundred scales of Karluk's adult sockeye salmon collected in 1914, 1916, and 1917, most likely by various USBF workers (Gilbert and Rich, 1927).[30]

Gilbert annually visited Alaska to study salmon during 1917–27 (Dunn, 1996) and in 1919 he spent two days (25–26 July) at Karluk Lake with Henry O'Malley, then USBF field agent in charge of Pacific Coast operations. They limited their explorations to the north end of Karluk Lake. From this brief survey, they concluded that Spring, Moraine, and Cottonwood creeks were rather poor spawning habitats for sockeye and suggested that a hatchery at the lake may be beneficial (Gilbert and O'Malley, 1920). Their report to Commissioner of Fisheries Hugh M. Smith warned about overfishing of sockeye salmon and urged greater governmental protection for the Karluk River and other salmon streams in central and western Alaska. Further, they called for increased scientific studies of Alaska's salmon and emphasized the vital importance of collecting escapement and other fisheries data. Gilbert understood in 1919 that Pacific salmon returned to a home stream and that proper management and conservation must be based on fisheries data collected at each river system.

To obtain these fisheries data, the USBF, at Gilbert's direction, operated a counting weir on the lower Karluk River in 1921 and for the first time accurately measured the escapement of adult sockeye salmon to the spawning grounds. This first counting weir in Alaska came from Gilbert's recognition that escapement and other statistical data were urgently needed to understand the life cycle and population dynamics of sockeye salmon.[31] By combining the escapement and catch data, the total run of sockeye salmon was correctly determined for the first time at Karluk in 1921. Without a doubt, the weir operations provided vitally important data on Karluk's sockeye run and 1921 marked the beginning of a sustained program of biological studies on this salmon species.

Besides the actual counts of escaping sockeye, other fishery data were collected at the weir. Although few scales were collected from adult sockeye salmon in 1921, hundreds of samples were soon taken each year and analyzed to learn the abundance and age composition of the run. Information was also recorded on fish size and sex. With these new data Gilbert began exploring the stock-recruitment relationship of Karluk's

Henry O'Malley (1876–1936). (From 1922 *Pacific Fisherman* 20(6):16)

[30] USBF. 1914. Karluk River scales. Unpubl. data. 7 p. Located at NARA, Anchorage, AK.

[31] USBF officials Henry O'Malley, Field Agent; Ward T. Bower, Chief Agent, Alaska Service; and Hugh M. Smith, Commissioner of Fisheries, were also instrumental in establishing the Karluk River weir.

sockeye salmon, though answers were still years away because of the complex and long life cycle. He felt that management of sockeye salmon would be improved once the relationship between escapements and returns was known. Apparently these new data collections and research ideas were initially viewed with skepticism or humorous derision by some governmental and cannery workers. For the next 15 years, Karluk's research biologists were affectionately called "the Bug Hunters," possibly in reference to the hordes of mosquitoes and flies they had to endure to collect the fisheries data.[32] Nevertheless, collection of escapement and run composition data is now a routine annual task for fishery biologists; these data monitor natural population fluctuations, guide management policies, and check rehabilitation efforts.

Following his 2-day incomplete visit of 1919, Gilbert made a second short reconnaissance of Karluk Lake on 8–12 August 1921 with O'Malley, Fred Lucas (USBF fish culturist at Afognak Hatchery), and "Mose," a resident of either Larsen Bay or Karluk Village.[33] Departing from Larsen Bay cannery, they traveled to Dreadnaught City (a few cabins) at the head of the bay, packed across the portage trail, and then continued upriver by boat to Karluk Lake, camping the first night at Tent Point. Over the next four days, they circumnavigated Karluk Lake by boat, proceeding first along the west shore to the lake's southern end and into O'Malley Lake. They stopped at tributaries entering the lake and explored upstream, noting the abundance and condition of spawning sockeye and the creek's physical features (water depths, substrates, and water temperatures). Salmon were also seen spawning at several locations along the lake's shoreline. At the outlet of O'Malley Lake, Mose shot a large eagle that was distinctly different than the common bald eagle. Gilbert (1922) later published a short note on this unusual bird of prey, a Steller's sea-eagle, *Haliaeetus pelagicus*.[34]

Continuing their explorations, the party traveled north along the lake's east shoreline and into the Thumb Lake drainage. At Thumb River, Gilbert found a dead male sockeye of only 200 mm length, but this small fish had mature testes. Finally, they traveled north from the Thumb River and examined several more tributaries, completing their investigation of Karluk Lake. During this circumnavigation, they occasionally took depth soundings in Karluk, O'Malley, and Thumb lakes, and Gilbert began naming prominent shoreline landmarks. They left the lake on 13 August and floated the full length of the river to the new counting weir near Karluk Lagoon.

Gilbert made a third brief survey of the sockeye spawning grounds at Karluk Lake on 18–28 August 1922. The survey crew included Gilbert, his USBF assistant Willis H. Rich, William P. Studdert, and Fred R. Lucas (Superintendent of Afognak Hatchery). The trip from Larsen Bay to Karluk Lake was particularly tiring and time-consuming in 1922. From the APA Larsen Bay cannery, the party traveled by boat to the head of the bay, where six natives packed their gear across the portage trail. Proceeding upriver in an outboard-powered skiff, they went only 3 km before the shallow water rendered the motor useless. They then rowed and pulled the boat 10 km upstream against swift currents, but their progress was slowed by the mounds of gravel pushed up in salmon redds, forcing the party to spend a night on the upper river.

Reaching Karluk Lake the next day, the group erected a tent camp on Camp Island, from which they traveled around the lake for the next week. Again, they noted the abundance of spawning sockeye and explored each tributary upstream to impassable falls or natural salmon barricades. Fewer sockeye were present in the tributaries than in 1921, but they observed fish spawning in the upper Karluk River. Unexpectedly, pink salmon were discovered in some lake tributaries. Gilbert and Rich named many of the lake's landmarks and tributaries in 1922. The survey party floated downriver to the weir on 25 August (a trip of about eight hours) and found it partially washed out, damaged by the masses of pink salmon carcasses that had drifted downstream.[35]

On the regulatory front, the first use of weirs at Karluk and other Alaskan rivers was soon followed by passage of the federal White Act of 1924. This law mandated that 50% of the total salmon run must be allowed to

[32] J. Thomas Barnaby 1930–37 notebooks. Located at NARA, Anchorage, AK.

[33] Charles H. Gilbert 1921 and 1922 field diaries. Location of original field diaries at Stanford University Libraries, Department of Special Collection and University Archives, Palo Alto, CA; typed summary of Gilbert's trips to Karluk Lake at NARA, Anchorage, AK.

[34] Friedmann (1935a) identified the bones of Steller's Sea Eagle from prehistoric sediments of an archaeological excavation made a short distance from the Karluk River watershed. He concluded that this species was a casual visitor to Kodiak Island (Friedmann, 1935b).

[35] Details of the 1921 and 1922 field trips to Karluk Lake can be found in Gilbert and Rich (1927), and in the 1921 and 1922 field notebooks of Charles H. Gilbert (See footnote 33) and Willis H. Rich (1922). Location of copies of Rich's notebook at NARA, Anchorage, AK, and ABL Library, Auke Bay, AK.

escape the fishery; this requirement was monitored for compliance during the run season by closely comparing the weir counts and harvest data. It was assumed that if this proportion of the total run reached the spawning grounds at Karluk Lake each year, the salmon fishery would be placed on a sustainable basis. It was also in 1924 that the commercial fishery began using stationary ocean traps to capture sockeye salmon along the northwest coast of Kodiak Island (Rich and Ball, 1931).

Though Gilbert regularly traveled to Alaska for several more years and often visited Larsen Bay or the Karluk River weir, apparently 1922 was his last trip to Karluk Lake. In 1925 he briefly worked at the weir in June, collecting Dolly Varden scales and sockeye salmon smolts. He also completed two tagging studies in 1925–26, measuring the travel times of adult sockeye in the Karluk River. In the first study in August 1925, he tagged and released 200 adult sockeye off Karluk Spit and then observed their passage of the lower river weir. For the second study in July 1926, he tagged 100 sockeye at the lower river weir and measured their passage of the Portage weir (Gilbert and Rich, 1927). Although not a direct Karluk study, in the early 1920s Gilbert also did several ocean-tagging studies of sockeye salmon in the waters south of the Alaska Peninsula; significantly, he showed that salmon made long-distance ocean migrations and were not just restricted to their home stream vicinity.

Gilbert remained in charge of the sockeye research program at Karluk until 1926, when Willis Rich was given this responsibility. Notwithstanding this leadership change, Gilbert's influence continued for at least the next two years, and the research ideas for Karluk came from both men. Rich obviously respected Gilbert's knowledge and often sought his advice. When Gilbert visited Larsen Bay in 1926 and 1927, Rich specifically went there to discuss the Karluk studies. In 1926 Rich began an ambitious long-term study of the ocean survival of Karluk's sockeye by annually marking and releasing about 50,000 smolts. It is unclear if Gilbert designed this ocean survival study, but it appears likely he was heavily involved because of his intellect, ideas, and dominant personality. His research interests were then focused on Alaska salmon, and as recently as 1925 he had personally collected sockeye smolts at the Karluk River. In any event, Gilbert planned to accompany Rich to Karluk Lake in 1926 and 1927, but declining health prevented him from making the strenuous trip. Barnaby (1944) eventually published the ocean survival research that began during Gilbert and Rich's tenure at Karluk, for the first time documenting that its sockeye salmon had much higher survival rates than expected.

Biological knowledge of Karluk's sockeye salmon greatly advanced under Gilbert's leadership of the research program. Significantly, his discoveries were based on solid scientific data obtained by the annual operation of the counting weir, the regular sampling of the adult and smolt runs, and the examination of scales that revealed the stunning diversity of freshwater and ocean ages present in the run (Gilbert and Rich, 1927). Though such fisheries data are routinely collected nowadays, these were significant accomplishments in the 1920s. Major discoveries on sockeye salmon biology during Gilbert's tenure as research leader at Karluk included the following topics:

1) Escapement numbers reaching the Karluk Lake spawning grounds.
2) Total run size.
3) Seasonal distribution of the run.
4) Number of years spent in the freshwater and ocean.
5) Diversity of age groups present in the run.
6) Seasonal variation in age composition, size, and sex ratios of the run.
7) Timing of downstream smolt migration.
8) Stock-recruitment relationship.
9) Abundance and run timing of other salmonid species.

In conclusion, Gilbert's studies of sockeye salmon at Karluk started the long-term collection of detailed fisheries data that has continued without interruption to the present. While he spent most of his career as a descriptive ichthyologist, it is remarkable that the research he pursued at Karluk falls within the discipline of fishery biology, topics that remain important to current biologists. Although much of Rutter's work at Karluk in 1903 would also be classed in this discipline, Gilbert is often considered the intellectual founder of fishery biology in the U.S. (Dunn, 1996).

Willis H. Rich

Willis Horton Rich maintained an interest in Karluk River sockeye salmon for over 25 years, a long episode that included his direct field research during 1922–32 and his later consulting work and critical reviews of USBF and FWS research programs. He actively led the sockeye salmon studies at Karluk in 1926–30, taking up these responsibilities from Gilbert. As significant as Rich's own field studies were at Karluk, he greatly influ-

Willis Horton Rich (1885–1972). (From 1925 *Pacific Fisherman* 23(12):21)

enced federal research on this system for many years, advancing ideas on the controlling factors of sockeye productivity and inspiring and advising several other Karluk biologists.

1922

Rich first visited Karluk Lake and River in the summer of 1922 as a USBF field assistant for Gilbert, then leader of the sockeye salmon studies. They surveyed the sockeye spawning grounds at Karluk Lake and examined the counting weir on the lower river. Though the trip lasted only 10 days (18–28 August), Rich (1963) became fascinated with the Karluk system and recorded many observations on its salmon, bears, flora, and physical landforms.[36] He prepared a rough map of Karluk Lake by taking bearings with a surveyor's compass and measuring base lines. With Gilbert, he named many of the lake's prominent landmarks and tributary creeks.

[36] Willis H. Rich 1922–1931 notebooks. Location of original notebooks unknown (in 1956, Rich had the original notebooks); copies at NARA, Anchorage, AK, and ABL Library, Auke Bay, AK. In 1963 the BCF ABL published the notebooks as a Manuscript Report.

Following his first brief visit to Karluk Lake and subsequent promotion to lead the USBF Division of Scientific Inquiry, Rich apparently did not return to Karluk during 1923–25, though he did travel to Alaska each field season to study other salmon fisheries. Rich earned his M.A. (1918) and Ph.D. (1924) degrees at Stanford University, with Gilbert serving as his major professor (Dunn, 1997).

1926

As the newly appointed leader of sockeye salmon research at Karluk, Rich spent the entire summer and fall of 1926 (23 May–24 September) at Karluk Lake and River, or nearby at Larsen Bay cannery. He collaborated with Gilbert on some field work that year, but also independently pursued many significant studies with his assistant Seymour P. Smith.

Marked smolts The 1926 field season was important in Karluk's fisheries history because, for the first time, Rich marked thousands of sockeye salmon smolts (by clipping various fins) for future identification when they returned as adults. Initially in 1926, Rich and Smith tried to collect smolts at the Karluk River Portage, but their sampling gear was poorly suited for that site. Moving operations downriver to the lower weir, they successfully marked and released 48,000 smolts during 30 May–16 June 1926. This ambitious mark-and-recapture experiment continued for the next 10 years; the annual smolt marking was the first step in measuring the ocean survival of sockeye salmon. To complete the experiment, Rich and his assistants searched through thousands of cannery-harvested adult salmon in subsequent years to find marked individuals (i.e. those missing various fins). This mark-and-recapture experiment was also designed to accurately measure total smolt out-migration each year, but for unknown reasons this part of the study was never completed.

Smolt observations As Rich marked the sockeye smolts, collected their scales, and measured their lengths, he soon learned that larger and older smolts dominated the early migration, the size and age decreasing with time. Overall, he was impressed by the large size of Karluk's sockeye smolts:

> [Speaking of Karluk's sockeye salmon smolts, 1 June 1926] These migrants are certainly very fine fish—by far the finest I have ever marked and I should not be surprised if we received a high percentage of returns.

> Judging by the results of the best marking experiments in the Columbia River it would not surprise me if we got as high as 10% from these.[37]

The downriver smolt migration lasted about three weeks; the fish moved downstream in pulses, being abundant for several days and then absent for a few days. He also noted their nocturnal migratory behavior. The work of capturing and handling 48,000 smolts gave him data on the proportion of fish with naturally missing fins and the presence of parasitic copepods attached at the base of ventral fins. Further, he recorded the presence of coho and Chinook salmon juveniles.

Adult sockeye behavior at the weir During the three weeks that Rich marked smolts at the Karluk River weir, he closely observed the upstream migratory behavior of adult sockeye. Contrary to past criticisms that the weir harmed migrating adults by preventing their upstream progress, Rich concluded that the weir was not a serious obstacle. He saw that when adult salmon were ready to move upstream, they easily found the open counting gates and passed through the weir.

Salmon travel time up the Karluk River Two counting weirs were operated on the Karluk River in 1926, one on the lower river near Karluk Lagoon and another 20 km upstream at the Portage. Adult spring-run sockeye were marked at the lower weir and their passage was recorded at the upper weir. These salmon needed 4–5 days to travel this distance and about one week to reach Karluk Lake (Gilbert and Rich, 1927).

Exploration of the spawning grounds and observation of the large escapement The 1926 field season was important for Rich because he observed one of the largest runs of adult sockeye salmon at Karluk since commercial fishing began in 1882. In 1926 over 2,500,000 sockeye escaped to the spawning grounds from a total run of over 4,500,000, a huge run never repeated again in the subsequent 80 years. Possibly, Rich may have been the only trained fishery biologist ever to observe a Karluk sockeye run of similar magnitude to those existing before or shortly after commercial fishing began.

Rich was impressed by the number of sockeye salmon flooding onto the spawning grounds, the sight forever affecting his ideas about Karluk's productivity. He regularly traveled around the lake in 1926, visiting the spawning tributaries and beaches, exploring upstream along tributaries, and noting the numbers of dead and live sockeye.[38] Often, tributaries were densely packed with spawning adults or littered with decomposing carcasses. The number of spawners decreased in August, but Rich saw many adult salmon swimming in the lake, causing him to theorize that a certain lake-ripening period was needed before these fish moved to specific spawning sites. He saw that fall-run sockeye were larger than spring-run fish. On a trip downriver on 27 August, he observed many adult sockeye spawning in the first 3 km of river below the lake.

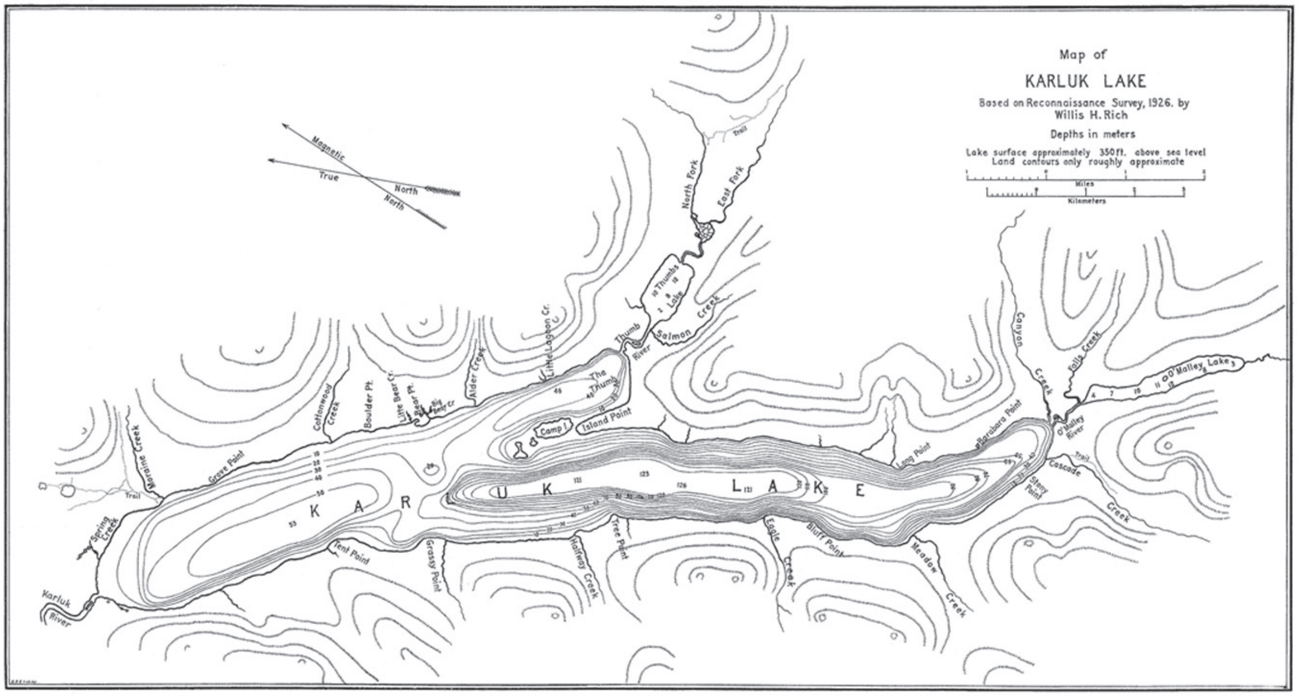
Sockeye carcasses and Karluk Lake's productivity While surveying the spawning habitats at Karluk Lake during July–August 1926, Rich was constantly impressed by the huge numbers of sockeye carcasses present, these even being transported by stream currents and lake waves far from active spawning sites. He observed the rapidity of carcass decay and the action of blowflies in the breakdown. Significantly, on 9 August he noticed a dense phytoplankton bloom in Thumb Lake and linked this to the nutrients that leached from decaying salmon carcasses. He soon realized the possible importance of salmon-carcass nutrients to Karluk Lake's fertility and the sustenance of juvenile sockeye. His 1926 observations at Karluk Lake marked the origin of the theory that salmon-carcass nutrients influenced the lake's productivity and sockeye salmon abundance, an idea that has persisted to present times.

Bathymetric map of Karluk Lake Rich prepared the first detailed bathymetric map of Karluk Lake using a sextant, plane table, aneroid barometer, and sounding line (Gilbert and Rich, 1927). The map showed the lake's three internal basins. He also mapped the two shallow lakes (Thumb and O'Malley) tributary to Karluk Lake. The map aided his future limnological studies of Karluk Lake.

Limnological measurements of Karluk Lake In 1926 Rich collected the first limnological data from Karluk Lake, thus beginning a regular sampling program that, with alterations and interruptions, can be traced to today's limnological monitoring. Rich measured the surface temperatures of Karluk, Thumb, and O'Malley lakes and tributaries, and ran temperature profiles in all three basins of Karluk Lake. In addition, he collected plankton samples, measured water trans-

[37] See footnote 36.

[38] In 1926 Rich spent over a month at Karluk Lake observing sockeye salmon (27–28 June, 12–22 July, and 29 July–27 August).



Bathymetric map of Karluk Lake, showing three internal basins, tributary streams and lakes, and landmarks. (From Gilbert and Rich, 1927)

parencies, and retrieved bottom sediments, though these were largely preliminary efforts at testing the effectiveness of his sampling gear. To monitor changes in the lake's water level, he engraved a permanent benchmark on a rock outcrop at Camp Island.

Salvage of wasted sockeye eggs As Rich and Smith surveyed the spawning habitats at Karluk Lake in 1926, they found many dead, unspawned, sockeye females. Rich was unsure if these premature deaths resulted from the excessively large escapements flooding onto the spawning grounds, the relatively dry summer and reduced water levels, or other factors. Nevertheless, he believed that the unspawned eggs were a regrettable waste of reproductive products and calculated the untold millions of lost eggs. Thinking that dead unspawned females might be a regular feature of the Karluk system and not unique to 1926, he devised a plan to salvage the wasted eggs by culturing them in a lake hatchery. Eggs in dead females seemed to be in good condition for artificial propagation. Testing the idea, he gathered eggs from dead and live females, fertilized and buried them in the substrate, and checked their progress for several weeks. Test results were mixed, but some eggs from dead females developed normally, and Rich concluded "that the eggs from dead females may be successfully fertilized and will pass through at least the early stages of development as well as those from living females. I have no doubt, of course, but that the eggs must be taken before the females have been dead too long ."[39] Yet after spending a few more field seasons at Karluk without again finding dead unspawned females, Rich realized the 1926 conditions were unique and never pursued the hatchery idea. The presence of unspawned females indicated, however, that Karluk's spawning area might be limited and that the spawning capacity was exceeded by the huge escapement of 1926. Nevertheless, though these unspawned females did not contribute to egg seeding and fry production at Karluk, they did add salmon-carcass nutrients to the lake and possibly increased the success of juvenile sockeye.

Sockeye fecundity Just before Rich ended the 1926 field season and left Alaska, he collected eggs from 40 adult sockeye females at Larsen Bay cannery in mid September. From this small sample he obtained a fecundity estimate for fall-run sockeye and learned how fecundity varied with female size (Gilbert and Rich, 1927).

Fry growth rate in Karluk Lake As Rich and Smith traveled around Karluk Lake in 1926, they constantly looked for juvenile sockeye and tried to learn about

[39] See footnote 36 (8 August 1926).

their habitats, growth rates, and food habits. Such data were needed to understand the full life history of Karluk's sockeye salmon and were of special interest to Rich and Gilbert in interpreting scale ages. When the 1926 field season began, they had two specific questions about juvenile sockeye: 1) do any fry emerge and form scales in the same year as egg deposition, and 2) do fry emerge early enough in spring or summer to grow and form scales with circuli? Rich concluded that, "in view of the low temperature recorded on the main spawning streams it seems very unlikely that any of the young salmon hatch and come out of the gravel before spring . . ."[40] He also learned that juvenile sockeye grew and formed scales in their first year following spring emergence. But attempts to catch juvenile sockeye with beach seines were largely unsuccessful in 1926 and Rich planned to use other sampling methods in 1927.

Charr observations Rich examined the food habits and reproductive condition of Karluk's charr in 1926, though it was not yet known that two species were present in this system. All charr at Karluk were then called "Dolly Varden," and they were thought to be serious predators of salmon eggs and young. Rich examined 105 Dolly Varden from the lower Karluk River on 1 June, finding all had empty stomachs and immature gonads. Two months later (8–9 August) he saw many large Dolly Varden feeding on sockeye eggs in the Thumb River and in streams at the south end of Karluk Lake. These brightly colored fish had well-developed gonads and were preparing to spawn. Rich was unconcerned about the egg consumption, stating that "these eggs form the chief food for the dollies at this time, but they are eggs that would be wasted anyway so that no harm is done by the dollies in feeding on them."[41]

Pink salmon A huge run of pink salmon entered the Karluk River in 1924, and many of these reached the lake spawning grounds. Possibly, these pink salmon may have harmed the sockeye by spawning in the same tributaries, digging up previously buried sockeye eggs and depleting oxygen concentrations that killed fish in these small creeks. After the large pink salmon run at the lake in 1924, a similar large run was expected in 1926, and the USBF made plans to protect the sockeye salmon spawning streams. Initially, Rich wanted a weir placed at the lake's outlet to bar pink salmon, but this was logistically impossible. His second plan was to install small wire weirs at sockeye spawning streams to block the pink salmon. But, in fact, the 1926 pink salmon run was small and Rich concluded in late July "that it will not be necessary to put in the web weirs at the mouths of the stream entering the lake unless a much heavier run of fish comes in."[42]

Scale collections Rich and Gilbert collected and read sockeye salmon scales at Larsen Bay and Uyak canneries in May 1926. Rich declared that the scales he examined at Larsen Bay were "the first opportunity I have ever had to examine red salmon scales in any quantity."[43] When Rich and Smith examined sockeye scales at the canneries in early July, they concluded that some of these could not be from Karluk River fish:

> [Larsen Bay cannery, 3 July 1926] S. and I examined the scales from the few reds we got in Larsen Bay on the 3rd and it was very clear that there was a race of fish present which was quite different from the fish of the Karluk River. Out of 16 examined 4 were apparently Karluk River fish but the other 12 were quite certainly of a very different race. These fish have a very small [nucleus] 1 year in the freshwater and most of ours are 5-year fish. The difference in the freshwater growth of these fish and those from Karluk is as distinct as anything of the sort I have ever seen.
>
> [Uyak cannery, 8 July 1926] . . . . we examined the rest of the scales taken from the gill net fish. Found that those taken in the Bay were very similar to the few trap fish in Larsen's Bay; i.e., they contained a large percentage of fish 5_1 and with very similar [nucleus], a race quite distinct from the Karluk River fish.[44]

When Gilbert left Alaska in July 1926 for health reasons, he asked Rich to collect sockeye scales at Karluk Lake and the canneries, and from grilse in the fall-run sockeye. Rich managed to obtain the grilse scales in early September, but found little time to collect scales at the spawning grounds and questioned the value of such samples:

> [Karluk Lake, 22 August 1926] Our collection of scales from tributary streams as desired by Dr. G. has practically fallen through . . . . Since we came back [to Karluk Lake] it has been almost impossible to do anything in the way of collecting the data on account of the mixture of fish of the early run and those of the later run which, of course, show differences in size on account of the longer time spent in the o. [ocean] by the later running fish. In my opinion unless one is careful

[40] See footnote 36 (18 July 1926).

[41] See footnote 36 (23 August 1926).

[42] See footnote 36 (21 July 1926).

[43] See footnote 36 (24 May 1926).

[44] See footnote 36.

> to get representatives from the different tributaries for the small run of fish there is great chance for serious confusion due to the various mixtures of fish of the different runs.[45]

Observations of aquatic flora and fauna Besides his sockeye studies, Rich observed and collected other species of the flora and fauna at Karluk, including aquatic macrophytes and macroinvertebrates. Likewise, Rich and Smith somehow found time to collect and preserve bird eggs for Harold Heath of Stanford University. In exploring this non-fisheries information, Rich was somewhat unique among Karluk's biologists.

Rich and Smith's research accomplishments at Karluk in 1926 were substantial, especially considering the time they spent doing all the necessary practical things to survive and travel in this remote region. For example, early in the field season as they marked smolts at the weir they found scant living accommodations in the abandoned and dilapidated APA hatchery building. After hatchery operations had ceased in 1916, the building's lumber and other parts had been scavenged in the intervening 10 years. In addition, rough seas in Shelikof Strait often prevented boats from landing at the exposed Karluk Spit, making travel and landing supplies tenuous. Once supplies were ashore, they were transported up the shallow estuarine waters of Karluk Lagoon in a small skiff, this travel being easiest at high tide. Fairly modern accommodations then existed at Larsen Bay cannery, and ocean travel around Kodiak Island occurred on USBF patrol vessels or commercial fishing boats.

Yet, travel to Karluk Lake remained nearly the same as when Rich last visited in 1922. This involved an ocean boat trip to the head of Larsen Bay, a strenuous pack of supplies across the portage trail to the Karluk River, and then 14 km of upriver travel in a small skiff. In 1926 the USBF leased a small homestead with several cabins (humorously called Dreadnaught City) at the head of Larsen Bay, and Rich used the cabins to store supplies and as temporary shelter while traveling to and from the lake. Also in 1926 the USBF built a new weir cabin at the Karluk River Portage, this giving another shelter when making trips between the lake and Larsen Bay. Ascending the Karluk River was seldom easy, and the low water of 1926 made it difficult to haul the heavy supplies, scientific gear, and lumber. An outboard motor powered the skiff in the deep water near the Portage, but for most of the trip, the boat was manually pulled upstream in the shallow water, often through rainstorms and hordes of harassing insects.

Since no cabins existed at Karluk Lake in 1926, Rich erected a tent camp on Camp Island, first building a level wooden floor. Though the tent gave tolerable shelter, he still wanted a cabin for future salmon research at the lake. During travels to and from the lake, Rich and Smith occasionally found shelter in a native barabara, one being located near the lake's outlet and another near the Portage. While staying at Camp Island, they supplemented their provisions with fresh fish and waterfowl. When Rich and his field crew left Karluk Lake to float downriver to the Portage on 27 August, the normally easy trip going with the current lasted 6.5 hours, the river being so low they had to drag the boat downstream.

In conclusion, Rich and Smith had a productive field season at Karluk in 1926, and their results greatly increased the knowledge about sockeye salmon. They initiated several studies of sockeye salmon that continued for many years, these long-term data being crucial to understanding this complex and diverse ecosystem. Equally important to the actual field work completed were the new research ideas generated in 1926 about the sockeye salmon's life history and the lake's fertility.

1927

Rich returned to Alaska in 1927 and spent considerable time in the Karluk–Larsen Bay area, including over a month at Karluk Lake.[46] Most of the studies that year continued those started in 1926, including marking 50,000 sockeye smolts at the weir, surveying the abundance of sockeye salmon on the spawning grounds, exploring salmon spawning streams, collecting limnological data at Karluk Lake, seining for juvenile sockeye, and examining charr food habits. Since sockeye salmon escapements to Karluk Lake were much smaller in 1927, Rich saw fewer adults and carcasses on the spawning grounds. Likewise, he found few unspawned dead females and abandoned his idea of salvaging unspawned eggs.

After his preliminary limnological work of 1926, it is likely that Rich was eager to collect further samples in 1927 to test his idea linking salmon-carcass nutrients and lake productivity. Consequently, besides having better collecting gear for plankton, bottom

[45] See footnote 36.

[46] In 1927 Rich was in the Karluk and Larsen Bay area on 26 May–31 August, and at Karluk Lake on 5 July–15 August.

sediments, water transparencies, and water temperatures, the 1927 studies included water chemistry measurements by George I. Kemmerer, Professor of Chemistry, University of Wisconsin. To learn if salmon carcasses affected the water chemistry of lake tributaries, Kemmerer and Rich compared nutrient concentrations above and below the upstream limits of salmon migration—lower stream sections had significantly higher nutrient levels.

To obtain water chemistry samples, Rich explored many tributaries much more thoroughly than before, finding that some had newly eroded channels. He collected plankton samples from Karluk, Thumb, and O'Malley lakes in 1927, and he again saw an August phytoplankton bloom in Thumb Lake, though it was less intense because fewer salmon carcasses added nutrients to the lake. It was not until 1932 that the limnological studies at Karluk Lake were published. This scientific paper, with Rich as a co-author, was the first to formally discuss the possibility that the fertility of Karluk Lake and success of juvenile sockeye were affected by nutrients leached from adult salmon carcasses (Juday et al., 1932).

Rich made a special effort in 1927 to collect young sockeye from Karluk Lake to determine their growth and food habits, but found it difficult to consistently capture juveniles in beach seines because the rough substrates often snagged his net. After selecting a smooth beach near Little Lagoon Creek, he collected about 200 juvenile sockeye, plus sticklebacks, sculpins, charr, juvenile coho salmon, and juvenile steelhead, and boasted that ". . .we have today caught more young *Oncorhynchus nerka* during their life in the lake than have ever been caught before".[47] He felt that this one sample was sufficiently large to understand the freshwater growth of juveniles.

The ocean migration routes of sockeye salmon that returned to spawn in Kodiak Island's streams were poorly known in 1927. Rich and Gilbert suspected that adult fish caught along the island's west coast, still far from the Karluk River, in fact homed to that river. To test this idea, Rich tagged and released 700 adult sockeye on 19–20 August at the San Juan #1 fixed trap located just inside Broken Point in Uganik Bay (Rich and Morton, 1930). His experiment showed that, indeed, most of these fish were of Karluk River stock. This result allowed the west coast fish to be more accurately assigned to their true natal stream, an important finding for management purposes.

[47] See footnote 36 (8 August 1927).

Rich found better lodging, travel, and survival logistics at Karluk in 1927. The best improvement at the lake was the 3.7 × 8.8 m cabin built on Camp Island in June 1927. This cabin was now the fisheries research base at the lake. The USBF also purchased the Dreadnaught City homestead and cabins in 1927 for $250. Cabins at Camp Island, the Portage, and Dreadnaught City aided the biologists as they traveled and hauled supplies to and from the lake. In contrast, worse living conditions existed at the weir on the lower river. Weir tenders had lived in the abandoned hatchery building since 1921, but it had deteriorated further each year and gave only marginal shelter. In 1927 Rich and his field crew camped in a small (3 × 5.5 m) wood shed while they marked sockeye smolts.

In 1927 the USBF provided the biologists with a Fordson track-laying tractor and sled, which made it much easier to haul supplies and travel across the portage trail between Larsen Bay and the Karluk River. Supplies were now transported by boat to the head of Larsen Bay, stored in the Dreadnaught City cabins, and hauled across the portage by tractor and sled to the cabin located on the river (then known as "Russellville"[48]). The Fordson tractor was often a mixed blessing for the biologists, being difficult to start, throwing off its tracks, and often sinking into the muskeg. From the Portage cabin, the trip upriver to Karluk Lake was made in a small boat driven by outboard motor, oars, and physical force. Henry O'Malley, then USBF Commissioner, wanted better access to Karluk Lake and proposed in 1927 the construction of a road across the portage and a trail to the lake. Fred Spach of the Alaska Road Commission made a reconnaissance survey of a possible road route in late August 1927. Though a road was never built, this idea continued for the next 20 years until air travel became the standard mode of transportation. Radio communication between Karluk Lake and Larsen Bay was attempted in 1927, but the equipment worked poorly.

1928–30

After their productive studies of Karluk's sockeye salmon during 1926–27, Rich and his assistants continued this research for the next three years. They started each field season by marking about 50,000 smolts, and then spent most of the summer looking for previously

[48] "Russellville" was a temporary name used by biologists for the cabin, boathouse, and few storage sheds at the Portage. It honored USBF employee J. R. Russell, who collected steelhead eggs at Karluk River Portage each spring during 1927–32.

marked adults at the canneries. Scales, length, and sex data were collected from sockeye smolts and adults to learn about their run compositions. Biologists visited Karluk Lake several times each field season to survey the sockeye spawning habitats and to collect limnological data. Juvenile sockeye were occasionally seined in the lake to learn more about their freshwater growth and foods.

Although Rich directed the studies during 1928–30, he spent less time at Karluk in those years.[49] In 1929–30 he helped mark smolts, looked for marked adults at the canneries, and visited Karluk Lake for 10 days each July. While marking smolts in early June 1930, Rich learned he was to be hired as a Professor of Zoology at Stanford University. Thus, after completing the 1930 field season, he resigned his USBF position as Director of Pacific Fisheries Investigations on 1 November 1930. Yet this change in employment did not end Rich's involvement with salmon studies in Alaska.

Little had changed in the transportation, living facilities, logistical supply, and communications for Karluk's fishery biologists during 1928–30. Travel to Karluk and Larsen Bay each field season required a 2-week ocean voyage from Seattle, Washington. USBF patrol vessels or commercial fishing boats provided local ocean travel between Karluk Spit and the canneries. Transport from Karluk Spit to the weir was by small skiff to the eastern end of Karluk Lagoon, though an alternate route occasionally used during rough ocean weather was to travel to the Portage and then float down the Karluk River. Since the APA hatchery building had been totally demolished by 1929, two small cabins were constructed near the weir. Travel to Karluk Lake continued to be the usual route across the portage by tractor and sled, and then by boat up the Karluk River. The Camp Island cabin continued as the fisheries research base at Karluk Lake.

1931–47

After 1930, Rich often returned to Alaska to continue his salmon studies, but he seldom visited Karluk Lake. His field assistant for 1930, Thomas Barnaby, was competent in doing the sockeye studies at Karluk and Rich expressed confidence that "Tom [Barnaby] is, as always, 100%".[50] Rich traveled to Alaska in 1931 with plans to visit Karluk Lake, but eventually relied on Barnaby to do the Karluk work, freeing him for other Alaskan studies:

> Shall not make the trip to Karluk Lake, much as I should like to do so, as I think my time will be better spent at Afognak and elsewhere and I know that Tom [Barnaby] will handle everything as well as though I were along.[51]

Philip Aaron (left), Willis Rich (center), and Tom Barnaby (right), Karluk, 1930. (Joseph Thomas Barnaby, from Lynn L. Gabriel, Herndon, VA)

Rich's confidence in Barnaby came from working with him at Karluk in 1930 and at Stanford University. Likewise, Barnaby greatly respected Rich, once claiming that Rich had been the most positive influence on his fisheries career (Morton, 1980). This mutual respect was further demonstrated by the fact that Rich had collected the first five years of data for the ocean survival study (1926–30), but freely gave it to Barnaby, who published this information in 1944. Rich continued to give guidance to the sockeye studies at Karluk until 1932, often conferring with Barnaby about the work whenever they met at Larsen Bay.

Rich significantly influenced fisheries research at Karluk for many years beyond his direct involvement of 1926–30. He led the North Pacific Fishery Investigations for the FWS during 1943–44, and then served as a consultant for their salmon fisheries studies during 1944–50. In 1946 he reviewed a manuscript that FWS fishery biologist Richard Shuman had prepared for publication on the escapement-return relationship of Karluk's sockeye salmon. Rich strongly argued that the

[49] Rich did not visit Karluk Lake in 1928, the entire field program being done by his assistants, Seymour P. Smith and Alan C. Taft. Rich visited the Karluk region in 1929 (25 May–25 July) and 1930 (23 May–20 July). His field assistants were Merrill W. Brown in 1929 and J. Thomas Barnaby in 1930.

[50] See footnote 36 (29 May 1930).

[51] See footnote 36 (16 July 1931).

historic decline of Karluk's sockeye was caused by nutrient depletion in the lake from loss of salmon carcasses to the commercial fishery. In contrast to Shuman's initial proposal for lower escapements goals at Karluk, Rich wanted higher escapements to reverse past nutrient losses. After Rich's critical review, Shuman added these nutrient depletion ideas into his manuscript and pursued limnological studies with renewed vigor, this work eventually leading to the fertilization experiment at Bare Lake in the 1950s. Rich continued to travel to Alaska in the mid to late 1940s, visiting Shuman and Nelson at Karluk Lake in August 1947 to discuss their research and the possible fertilization of the lake.[52]

Joseph Thomas Barnaby

1930–38

Joseph Thomas Barnaby first worked at Karluk in 1930 as a USBF assistant to Willis Rich. By then, he was well acquainted with field work in Alaska, having spent the previous five summers working at several private and USBF fisheries jobs at Prince William Sound and Southeastern Alaska. He had just earned his B.S. degree in fisheries at the University of Washington in 1929. Barnaby first met Rich in Alaska in 1929 and soon thereafter began graduate studies in zoology at Stanford University while working on Karluk's sockeye salmon.

Following Rich's appointment to Stanford University in late 1930, Barnaby was given full responsibility for the Karluk studies, though he continued to collaborate with Rich until at least 1932. Barnaby led the USBF fisheries studies at Karluk for nine years (1930–38), and his main research goals and field work continued those began by Gilbert and Rich in the 1920s—sockeye salmon ocean survival rates, description of run compositions, and limnology of Karluk Lake. His field seasons usually lasted from May through September,[53] the time being largely devoted to marking sockeye smolts, collecting scales, measuring fish, and looking for marked adults. But he also made at least two trips to Karluk Lake each year to continue the freshwater studies, which then comprised the limnological sampling, surveys and physical descriptions of the spawning habitats, and determination of juvenile sockeye growth and distribution.

Joseph Thomas Barnaby (1903–1998). (Joseph Thomas Barnaby, from Lynn L. Gabriel, Herndon, VA)

One of Barnaby's most important studies at Karluk was the measurement of sockeye salmon ocean survival, from the time when smolts entered the sea until they returned years later as mature adults. He determined this by first marking thousands of smolts and then recording the proportion of marked adults that returned in subsequent years. Each spring of 1930–36 as the sockeye smolts descended the Karluk River and accumulated above the weir, he captured, marked, and released about 50,000 fish, each year using a different combination of clipped fins. By mid June as the downriver smolt migration ended, Barnaby and his assistants shifted their efforts to searching for previously marked adult sockeye at the Larsen Bay and Uyak canneries, a massive effort that required the examination of thousands of harvested adult salmon.

From this data, Barnaby (1944) calculated smolt-to-adult survival rates of greater than 20%, consider-

[52] Richard F. Shuman 1947 notebook (3–7 August). Located at NARA, Anchorage, AK.

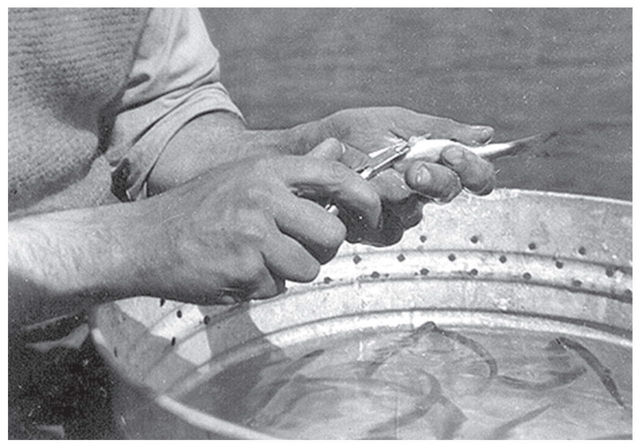
[53] Barnaby's Karluk Lake field work schedule: 22 May–20 Sept. 1930, 2 trips, 20 days; 10 April–30 Sept. 1931, 4 trips, 41 days; 22 May–22 Sept. 1932, 3 trips, 19 days; 17 May–2 Nov. 1933, 2 trips, 13 days; 11 May–15 Sept. 1934, 6 trips, 57 days; 8 May–16 Sept. 1935, 5 trips, 81 days; 21 May–21 Sept. 1936, 4 trips, 63 days; 31 May–25 Sept. 1937, 4 trips, 46 days; May–June 1938, number of trips and days unknown.

ably higher than had been previously reported for sockeye salmon.[54] An initial second goal of this mark-and-recapture experiment was to measure the total smolt out-migration, but for unknown reasons this part of the study was never completed or published. Barnaby understood the importance of knowing the yearly production of smolts from Karluk Lake, but apparently never calculated this abundance from the mark-and-recapture data.

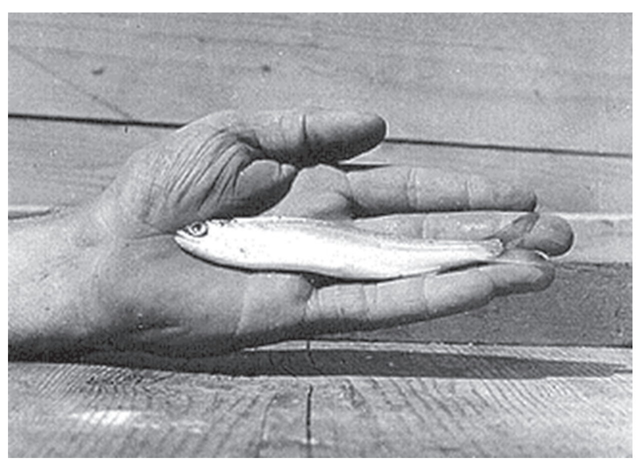
A second important task that Barnaby and his assistants continued for nine years at Karluk was the regular collection of run composition data (age, size, and sex) from thousands of sockeye salmon smolts and adults. For the smolts, the ages and sizes of these young salmon changed during the 3-week out-migration, but males and females were equally abundant. The adult sockeye run, which lasted at least 4–5 months, also had seasonal variations in age, size, and sex ratio. Gilbert and Rich (1927) summarized the run composition data up to 1926, while Barnaby (1944) summarized it up to 1936. Furthermore, the run composition data were needed to calculate the ocean survival rates of sockeye salmon in the mark-and-recapture study. Besides these practical uses, the regular collection of adult scales in the 1920s and 1930s, from both the escapement and catch and over the complete migration season, led for the first time to an exquisite appreciation of the remarkably diverse and complex life cycle of Karluk's sockeye salmon. Thus, starting with the 1920s–1930s field work, it became a routine task for biologists to collect run composition data at Karluk, and these fisheries statistics have continued to be gathered nearly uninterrupted ever since.

Barnaby completed his M.A. degree at Stanford University in 1932; for his thesis he investigated the relationship between body growth and scale size of Karluk's sockeye salmon in 1930–31 (Barnaby, 1932). To find out when scales first formed on young sockeye, he examined newly hatched alevins as they emerged from gravel redds and older juveniles during their early growth stage in Karluk Lake. Scales first appeared once feeding began, when juveniles reached about 36 mm in fork length (range 30–40 mm). From his 1930–31 field data and that collected by Rich in 1926–27, Barnaby discovered that a curvilinear relationship existed between fish length and scale size. Scales first grew faster than fish length, but later grew at a slower rate; a semi-

Tom Barnaby (left) marking sockeye salmon smolts, Karluk River, 1930s. (Joseph Thomas Barnaby, from Lynn L. Gabriel, Herndon, VA)



Marking sockeye salmon smolts by clipping fins, Karluk River, 1930s. (Joseph Thomas Barnaby, from Lynn L. Gabriel, Herndon, VA)



Sockeye salmon smolt, Karluk River, 1930s. (Joseph Thomas Barnaby, from Lynn L. Gabriel, Herndon, VA)

[54] Although smolts were marked yearly until 1936, Barnaby (1944) only analyzed ocean survival rates for those marked during 1926–33, possibly because recoveries of marked adults were not sufficiently complete for 1934–36.

logarithmic formula best fit the data. He determined precisely when juveniles and adults formed seasonal annuli on their scales. He also showed that the size of adult sockeye salmon was controlled by its length of ocean residence.

At Karluk Lake, Barnaby continued with the limnological work first began by Rich, who undoubtedly convinced him that lake studies were crucial for understanding the growth of juvenile sockeye. As a result, Barnaby collected limnological data for all nine years of his tenure at Karluk, regularly collecting or measuring water temperature profiles, plankton samples, transparencies, total residues, and several chemicals (pH, dissolved oxygen, carbon dioxide, phosphorus, silica, and nitrite nitrogen). During 1935–37 he focused his attention on water chemistry and concluded that phosphorus and silica might limit the lake's primary production, which affected the growth and survival of juvenile sockeye. He published the water temperature and chemistry data for 1935–36 (Barnaby, 1944), but most of the limnological data gathered during 1931–38 went unpublished.

Whenever Barnaby visited Karluk Lake in the 1930s, he regularly collected juvenile sockeye from the littoral zone with beach seines and gill nets to learn about their seasonal habitats, distribution, and growth. He measured the size of many young fish and examined their food habits, but most of this data remained unpublished except for that contained in his thesis (Barnaby, 1932). To learn more about juvenile sockeye in 1931, he tried to mark 25,000 sockeye fry at Karluk Lake, but he soon abandoned the idea after clipping the fins of several thousand fish and witnessing their high mortality.

Tom Barnaby with U.S. Bureau of Fisheries boat *Nerka,* Karluk Lake, ca. 1937. (Joseph Thomas Barnaby, from Lynn L. Gabriel, Herndon, VA)

Continuing in the tradition of all previous biologists at Karluk, in the 1930s Barnaby periodically surveyed the spawning sockeye at the lake and estimated the numbers using the lateral and terminal streams, lake beaches, and upper Karluk River. When spawners were abundant, he improved the survey's accuracy by using a standard counting method, rather than just guessing at the numbers. Although his stream surveys were never published, after several years of doing this work he understood that sockeye salmon used the various spawning habitats in a distinct seasonal pattern; these repeatable annual behaviors suggested the existence of subpopulations. Without a doubt, his stream surveys from this period are valuable historic records of how sockeye salmon used specific spawning habitats. In fact, Barnaby pursued these surveys even further and investigated the physical aspects of the different spawning habitats, including the dimensions and water flows of lake tributaries. He found that some small lateral creeks occasionally had such low flows that adult sockeye were excluded from using them. For example, he often checked the flow of Little Lagoon Creek and several times dug a deeper channel to let adult sockeye freely move to and from the creek's pools. In 1935 he twice measured the discharge of the upper Karluk River—15.2 m^3/second on 30 June and 7.2 m^3/ second on 15 August. He monitored the water level of Karluk Lake each field season and found that it fluctuated 38–76 cm. In 1936 he installed a rain gauge on Camp Island and diligently recorded the daily accrual.

Prior to Barnaby's years at Karluk, the charr-sockeye interaction remained largely uninvestigated, though most biologists believed that charr predation on eggs and juveniles reduced sockeye salmon abundance. All charr in the Karluk system were then thought to be one species (called "Dolly Varden"). To explore this subject further, Barnaby initiated several studies of charr in the 1930s; in particular, he investigated their food habits and migratory behaviors. Charr were abundant at Karluk in the 1930s, and Barnaby saw large masses of these fish during their spring–summer river migrations, especially the thousands that accumulated at the weir on the lower river. Initially during 1930–34, he examined a few charr stomachs from scattered locations around the Karluk system whenever the opportunity arose, but as the study developed (1935–37), he specifically sought out charr and inspected larger numbers. Surprisingly, he found little evidence that charr preyed on juvenile sockeye, but they certainly ate many eggs once sockeye adults began spawning. The charr residing in Karluk Lake fed heavily on sticklebacks, stickleback eggs, and insect larvae in early summer.

Barnaby expanded his charr studies in 1937–38 to try to understand their migrations, tagging thousands of fish at the lake and lower river and then searching for marked fish with his USBF assistant, Allan DeLacy. It soon became clear that two charr populations inhabited the Karluk system, one that migrated annually between the lake and ocean and another that remained year-round in the lake. In addition, he gathered data on the growth rates of the two charr populations and documented the amount of straying in the migratory population between different river systems of Kodiak Island. Unfortunately, Barnaby never published his charr studies, except for brief reviews (Higgins, 1938, 1939). When Barnaby left the Karluk research program in July 1938, he gave all of the charr data to DeLacy, who used them in his Ph.D. dissertation (DeLacy, 1941).

During Barnaby's nine years at Karluk, access to the lake was nearly the same as for all previous biologists. Supplies, research gear, and building materials delivered to Larsen Bay cannery by USBF patrol vessels, cannery boats, or chartered ships were transported by USBF dory to Dreadnaught City, the cabins and storage sheds located 6.5 km west of the cannery. Items that were larger or heavier than normal were delivered by USBF vessels to Dreadnaught City. The Fordson tractor and sled were used to haul supplies across the portage trail to the cabin and small boathouse on the river, but at times when the tractor was inoperable, everything was backpacked to the river. Often, one night was spent at the Portage cabin in order to get a fresh start for the lake the next morning. The 14 km trip by small skiff from the Portage to the lake took 7–9 hours depending upon the size of the load, river conditions, weather, and intensity of biting insects. The outboard motor was useful for only the first part of the deep slow river, but once shallow water was reached, the boat was pulled and pushed upstream. Sometimes supplies were temporarily cached on the riverbank to lighten the load. At Karluk Lake, it took another hour to travel 10 km by boat between the outlet and Camp Island cabin.

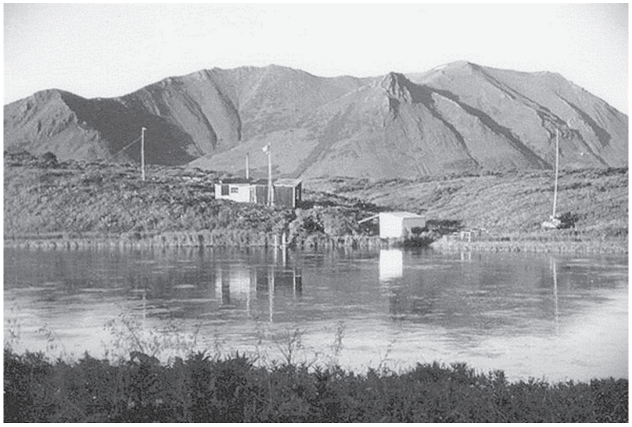
Tom Barnaby hauling boat with Fordson tractor and sled, Karluk portage trail, 1936. (Joseph Thomas Barnaby, from Lynn L. Gabriel, Herndon, VA)

Pulling skiff up the Karluk River to Karluk Lake, 1942. (Allan C. DeLacy, from Catherine J. DeLacy, Seattle, WA)

During this era, the task of hauling supplies to Karluk Lake from Larsen Bay often consumed more than a full day under the best conditions, and often extra time was needed to fix mechanical problems of the tractor or outboard motors. Obviously with these rustic conditions, an important prerequisite for a field biologist was the ability to maintain and repair equipment. Retracing the route, the trip downriver from the lake to the Portage typically lasted 3–5 hours. Upon reaching Dreadnaught City, travel to the Larsen Bay cannery was done by dory or by walking 8.5 km along the beach.

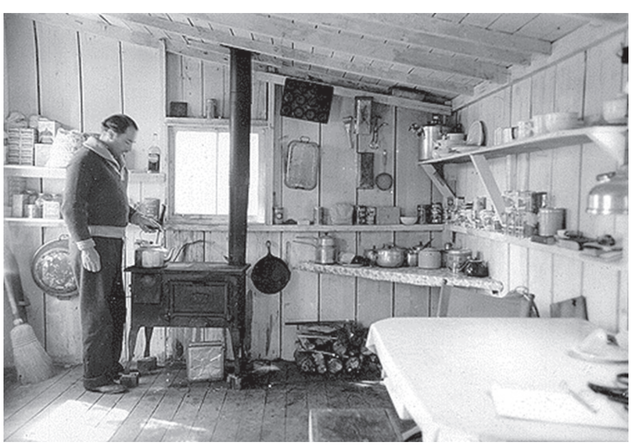
Because of his many ongoing studies in 1930–1938, Barnaby frequently traveled between five locations in the Karluk region: Karluk Lake, Karluk River weir, Larsen Bay cannery, Uyak canneries, and Karluk Spit. To reach the weir from Karluk Lake, he retraced his route to Dreadnaught City and Larsen Bay cannery, traveled 47 km around the island on a large boat to Karluk Spit, and motored by skiff up the lagoon to the weir. Between the canneries and Karluk Spit, he usually caught rides on USBF patrol vessels, cannery tenders, and fishing boats, only rarely attempting the trip in a USBF dory. When the ocean route was too rough to land at Karluk Spit, he instead floated downriver to the weir.

During Barnaby's nine field seasons at Karluk, he only saw airplanes overhead four times and only once flew from Kodiak to Karluk Lake with USBF officials in 1936. Undoubtedly, this was a chartered flight since



U.S. Fish and Wildlife Service cabin and boathouse, Karluk River Portage, 1944. (Jerrold M. Olson, Auke Bay, AK)

U.S. Bureau of Fisheries Camp Island cabin and boathouse, Karluk Lake, 1930s. (Joseph Thomas Barnaby, from Lynn L. Gabriel, Herndon, VA)



Tom Barnaby in Camp Island cabin, Karluk Lake, 1930s. (Joseph Thomas Barnaby, from Lynn L. Gabriel, Herndon, VA)

USBF aerial patrols were not yet common around Kodiak Island, though they were just beginning to be used in other areas of Alaska (Bower, 1937). To reach Alaska and Karluk at the start of each field season during 1930–1938, Barnaby traveled north from Seattle or San Francisco on USBF patrol vessels or APA and commercial steamships.

The USBF cabins at Dreadnaught City, the Portage, and Camp Island were important facilities for Barnaby's research, giving shelter, laboratory space, and storage along the main travel and supply route. He constantly maintained and improved the cabins, added shelves, painted, re-roofed with corrugated metal, patched windows, and repaired leaks. At Camp Island, he added an interior partition and porch to the cabin and built a boathouse and supply cache for winter storage. The lumber and building materials for these projects were arduously hauled by boat up the river.

In contrast with previous field biologists, Barnaby had reliable radios that allowed him direct communication between Karluk Lake, Larsen Bay, and Karluk Spit. When at the lake, he regularly checked on the current escapement figures, directed the work of assistants stationed at the weir or canneries, learned about the arrival dates of USBF patrol vessels and officials, and followed the progress of the commercial salmon fishing season. At Camp Island, he usually planted a garden each year to add fresh vegetables to his diet. With the considerable time Barnaby spent at Karluk each year, it is perhaps not surprising that he occasionally felt earthquakes and experienced ash falls from the volcanoes on the Alaska Peninsula across Shelikof Strait.

Although Barnaby primarily visited Karluk Lake to study its sockeye salmon and collect limnological samples, he was intensely curious about many other species and phenomena, and his notebooks are filled with observations about the region's plants, birds, and bears.[55] For example, he noted the seasonal change in Karluk's landscape—from the brown hills when he arrived each spring, to the slight greening a few weeks later, to the lush green of summer, and to the reds and browns of autumn. The spring growth of "nettle" and "bamboo grass" drew his attention, as did the seasonal succession of different flowers and later development of berries.

Karluk's birdlife was particularly captivating, and he compiled a detailed list of bird species for the re-

[55] J. Thomas Barnaby 1930–37 notebooks. Located at NARA, Anchorage, AK.

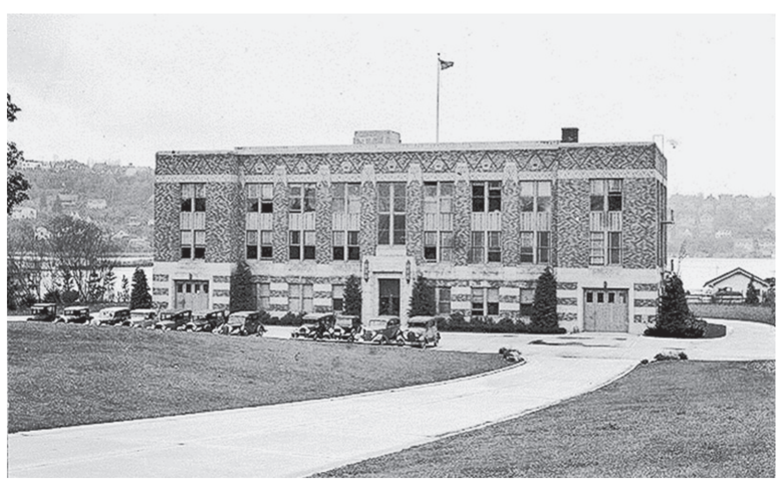
Barnaby Ridge, Karluk River near Portage, ca. 1935. (Joseph Thomas Barnaby, courtesy of Lynn L. Gabriel, Herndon, VA)

gion in 1937 and collected bird skins.[56] While living at Karluk Lake, he raised young seagulls, various waterfowl, and northern shrikes. Yet, his interest in Karluk's birdlife was not entirely observational, and it was common during this era for the field biologists to hunt waterfowl and ptarmigan to supplement their food supply. At Gull Island, the small isle next to Camp Island, biologists infrequently gathered seagull eggs for food, though Barnaby was more interested in recording the numbers of seagull nests, eggs, and young produced each field season. Karluk's brown bears also drew Barnaby's interest, and in 1936 he built a bear-viewing platform 8 m high in a large cottonwood tree at Halfway Creek. His broad interests in Karluk's wildlife were amply recorded with hundreds of photographs.[57]

Prior to 1932 no spruce trees or other conifers existed in the natural vegetation of the Karluk region or southwestern Kodiak Island because these trees had not yet reinvaded the area after the island's glaciers retreated thousands of years ago. Spruce trees had reinvaded and formed thick forests on Afognak Island and northeastern Kodiak Island, but the natural dispersal of these trees southward proceeded slowly, leaving most of southern Kodiak Island clothed with sweeping green vistas of grasses, herbs, shrubs, and occasional groves of cottonwood trees. As a curious sidelight to Barnaby's years at Karluk, in 1932 he transplanted several young spruce trees to Camp Island, first digging them up in Kodiak on 13 July 1932 and then planting them at the island cabin on 22 July. The transplants looked rather sickly the first year, but some survived and grew. Over the next few years, he cared for the spruce trees and occasionally moved them to better sites on Camp Island. The spruce trees reached heights of about 1.5 m in 1944, 1.8 m in 1948, 2.4 m in the 1950s, and much larger in the 1960s. In 1936 he planted a small

56 The 1937 bird list is recorded in his notebook for that year (See footnote 55). It is unknown if the bird skins were placed in a museum collection.

57 Barnaby took hundreds of photographs during 1930–38 of the Karluk landscape, his research activities, sockeye salmon, Karluk River weir, boats, flora and fauna, canneries, biological assistants, and people he met. His photographs included black-and-white stills and movies; many of these were developed in a darkroom at Larsen Bay cannery. Some of Barnaby's still photographs of Karluk from the 1930s have been discovered in his personal collection and at NARA, Anchorage, AK, but the location of his movies remains unknown. The ultimate disposition of Barnaby's photographs following his death in 1998 is unknown, but these likely were retained by his great niece Lynn Gabriel.



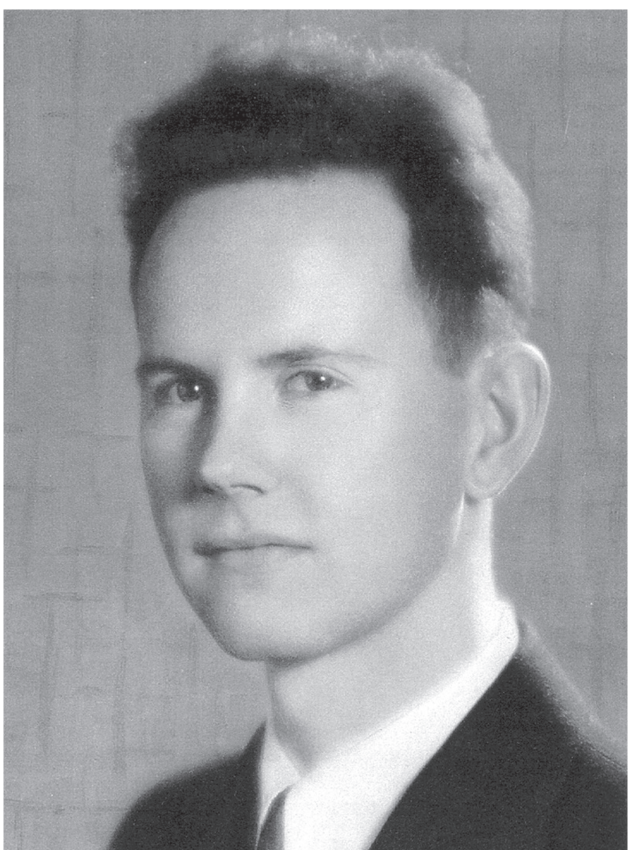
U.S. Bureau of Fisheries, Montlake Biological Laboratory, Seattle, Washington, ca. 1933. (Joseph Thomas Barnaby, courtesy of Lynn L. Gabriel, Herndon, VA) spruce tree on each side of the lake's outlet, but their fate remains unknown.

During Barnaby's tenure as Karluk's research leader, the USBF built the Montlake Laboratory in Seattle, Washington, in 1931. This biological laboratory served as the official federal headquarters of the Karluk sockeye salmon studies for the next 25 years, until those programs were transferred to Juneau, Alaska in 1956.

Allan C. DeLacy

1937–42

Allan Clark DeLacy was hired as a Junior Aquatic Biologist in 1936 by the USBF Montlake Biological Laboratory in Seattle. He first assisted Barnaby at Karluk for 1.5 years and then led these studies for the next 4.5 years until 1942. DeLacy had recently earned his B.S. (1932) and M.S. (1933) degrees at the School of Fisheries, University of Washington. He was placed in charge of the USBF's Karluk studies in July 1938 after Barnaby transferred to the salmon research program at Bristol Bay. During DeLacy's tenure at Karluk, he completed his Ph.D. at the University of Washington in 1941; his dissertation was on Karluk's Dolly Varden and Arctic charr. His fisheries work at Karluk comprised three main topics: Dolly Varden and Arctic charr studies, search for evidence of sockeye salmon subpopulations, and collection of run composition data on sockeye salmon. In 1940, during DeLacy's years at Karluk, the USBF and Bureau of Biological Survey were merged as the U.S. Fish and Wildlife Service (FWS).



Allan Clark DeLacy (1912–1989). (Allan C. DeLacy, from Catherine J. DeLacy, Seattle, WA)

Following on and expanding Barnaby's previous work, DeLacy intensively studied Karluk's two charr species, the Dolly Varden and Arctic charr. His research topics included charr taxonomy, migrations, food habits, and life histories. To capture charr from the full range of habitats in the Karluk ecosystem, he used the Karluk River weir, a temporary weir and trap on the Lower Thumb River, beach seines, gill nets, and a large fyke net that could be fished at any lake depth. To confirm that Karluk's Dolly Varden and Arctic charr were distinct species, DeLacy and Morton (1943) examined numerous anatomical characters of many specimens in 1939–41. DeLacy tagged more than 28,000 charr in 1937–40 and recovered about 4,500 of these through 1942. His results showed that Dolly Varden annually migrated between Karluk Lake and the ocean, while Arctic charr remained in the lake (DeLacy. 1941). Surprisingly, a few of his tagged charr continued to be recovered by biologists until 1949, many years after he had left the Karluk research program. While doing the tagging work, DeLacy also collected data on the age, spawning condition, and size (length and weight) of charr. Since charr scales were too small to age and otoliths (small ear stones that often have visible annual marks) seemed unreadable, he finally used length-frequency diagrams to determine the fish's age. By comparing the size differences of charr between tagging and recovery dates, he was able to calculate their growth rates.

During DeLacy's early years at Karluk, charr continued to be widely condemned in Alaska as serious predators of juvenile sockeye salmon. Barnaby began to examine this assumption in 1935–36, but DeLacy and his assistant, William Morton, wanted to resolve this question. Accordingly, they undertook a comprehensive study of charr food habits during 1939–41. To do this, they examined the gut contents of more than 5,000 charr at Karluk, but unexpectedly, less than 1% contained juvenile sockeye salmon (DeLacy, 1941; Morton, 1982). From this data, DeLacy concluded that Karluk's charr were not serious predators of juvenile sockeye, and instead, suggested that charr may benefit juvenile sockeye by controlling the abundant stickleback competitors. DeLacy also briefly checked the food habits of 20 mergansers *Mergus* sp., and one kittiwake, *Rissa* sp., at Karluk in 1942 and found that most had eaten sticklebacks. Only one merganser contained juvenile salmonids, most likely coho salmon.

Although DeLacy is best known for his charr studies at Karluk, perhaps equally important, but largely unknown to other biologists, was his major study of its sockeye salmon subpopulations during 1939–42 (he used the term "races"). Previous biologists had suggested that Karluk's sockeye salmon had different subpopulations, the most obvious being the spring and fall runs. But DeLacy was the first to examine this question by measuring the anatomical characters of thousands of adults from many Karluk locations. When he first examined adult sockeye taken from the ocean or Karluk Lagoon in 1939–40, he found little evidence of subpopulations. Yet in 1941–42 when he examined adult sockeye from different spawning habitats at Karluk Lake, distinct subpopulation differences were evident:

> [Morton commenting on sockeye subpopulation study at Karluk Lake with DeLacy, 11 July 1941] Worked over statistical data on red salmon with Al after supper—he's found a significant difference between Lake & creek spawners in g.r. [gill raker] & vert [vertebrae] count—as we figured we would.
>
> [Morton's summary of a radio message from DeLacy, 27 July 1941] Find significant statis[tical] diff[erence] between g.r. [gill raker] & vert [vertebrae] count of Moraine Cr. & Lower Thumb Reds. . . .[58]

Because his 1941 results supported the subpopulation idea, DeLacy began tagging adult sockeye at the weir in 1942 and then searched for recoveries on the spawning grounds. This work demonstrated the segregation of different sockeye subpopulations to specific spawning habitats at Karluk Lake:

> [Concerning subpopulations of Karluk's adult sockeye] The analysis of morphomentric data from salmon taken at the mouth of the Karluk River in 1939 and 1940 has revealed no consistent differences between individuals of the early and late runs. However, the analysis of like data from fish taken on various spawning areas within the river system has indicated that such areas are frequented by racially distinct populations. The investigation of this problem is being continued by further collection of morphometric data and by a tagging program, which is being expanded in the present season.
>
> As in 1941 statistically significant differences have again been found to exist between the populations which occupy certain of the spawning grounds from which samples were taken. No differences of statistical significance have been discovered between either vertebral or gill raker counts from samples collected in 1941 and in 1942 at the same place and at the same time of year. It has become evident that even in the relatively small Karluk watershed the segregation of the maturing salmon after they enter the lake and move onto the various spawning grounds is not the result of a random dispersion. The racial studies being conducted at Karluk Lake offer further confirmation of the parent–stream theory and indicate that mature salmon may return to the very tributary in which they originated even though other suitable spawning areas are nearby.[59]

As a dramatic example, DeLacy watched adult sockeye migrating up the O'Malley River, at the head of Karluk Lake, segregate into one group that entered Canyon Creek and another group that continued up the main river. Unfortunately, he never published his 4-year study of Karluk's sockeye subpopulations, this omission causing later biologists to unknowingly repeat much of his work. Such a publication in the early 1940s would have been a remarkable advancement of knowledge about Karluk's sockeye salmon. And yet, considering the tumultuous world events of the early 1940s, DeLacy's lapse of publication is perhaps understandable.

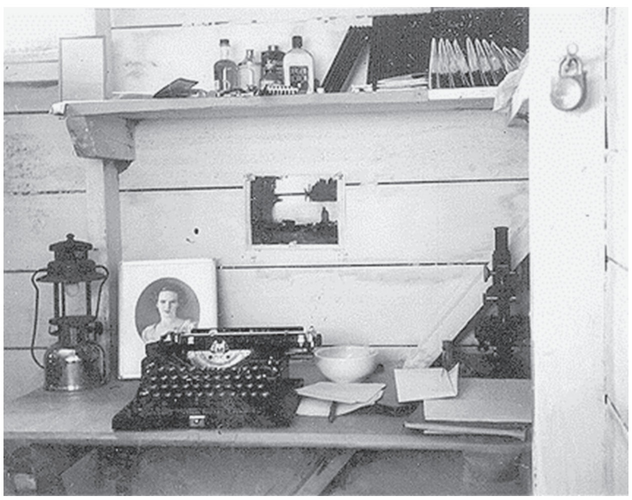
In conjunction with his subpopulation studies, DeLacy was the first Karluk biologist to experimentally test the fidelity of sockeye salmon in returning to their natal spawning site. In 1942 he collected and tagged adult sockeye at Thumb River beach and then transported and released them at other Karluk Lake locations. Most of these fish soon returned to the original beach; clearly adult sockeye salmon were not easily deterred from their natal spawning site.[60] Although his study was not fully appreciated at the time, this extraordinary result gave strong evidence of sockeye subpopulations and the home stream theory.

58 William M. Morton 1939–41 notebooks. Original notebooks in personal papers of Robert S. Morton, Portland, OR.

59 FWS Annual Report of Fisheries Research, 1941 and FWS Monthly Report, October 1942. Located at NARA, Anchorage, AK.

60 DeLacy photographed these seining and tagging activities at Thumb River beach. While DeLacy most likely conducted this tagging experiment, no author was given on the unpublished handwritten report. FWS. 1942. Salmon tagging experiments at Karluk Lake – 1942. Located at NARA, Anchorage, AK.

Installing the Karluk River weir, Portage, 1942. (Allan C. DeLacy, from Catherine J. DeLacy, Seattle, WA)



Biologist's desk at field camp, Karluk, 1941. (Allan C. DeLacy, from Catherine J. DeLacy, Seattle, WA)

By the 1930s and 1940s, part of the Karluk research program was now a routine continuation of studies and tasks begun by previous biologists. Of course, the weir was installed and operated each year with at least some assistance from the research biologists, and run composition data (age, size, and sex) were regularly collected from sockeye smolts and adults. DeLacy installed the Karluk River weir each spring and occasionally helped count salmon, but the weir crew did most of the routine work. He was largely responsible for relocating the weir from the lower river to the Portage, transporting the lumber there in 1941 and installing it in 1942. Sockeye smolts were not marked during DeLacy's years at Karluk, but he continued the ocean survival studies of Rich and Barnaby and spent much of the field season during 1937–39 looking for previously marked adults at nearby canneries. It is unclear why, despite his diligent efforts, these data on marked adults and ocean survival were never used or published. DeLacy routinely collected limnological data at Karluk Lake during 1937–42, yet interest in this topic had waned and none were ever published.[61]

DeLacy and his assistants collected fecundity data from over 500 adult sockeye at Karluk during 1938–41, the first time such data had been gathered since Rich made his small collection in 1926. DeLacy's data were valuable since egg counts were made from all parts of the migration season. Fecundity increased with the season, and more eggs occurred in the left ovary than in the right ovary:

> [Fecundity of Karluk's sockeye salmon, 1940] The fecundity of Karluk red salmon was studied during 1940 by the collection of approximately 10 egg samples per week during the period from June 1 to September 13. Only salmon 60 centimeters in length were used in the experiment. It has been found that the number of eggs per female increased as the season progressed. The average number of eggs per fish was 2955 in June and 3643 in September . . . No explanation of this phenomenon was suggested by an age analysis of the fish . . . Each week during the season the average number of eggs in the left ovary was greater than the number in the right ovary.[62]

DeLacy's fecundity data were later analyzed and published by Rounsefell (1957).[63]

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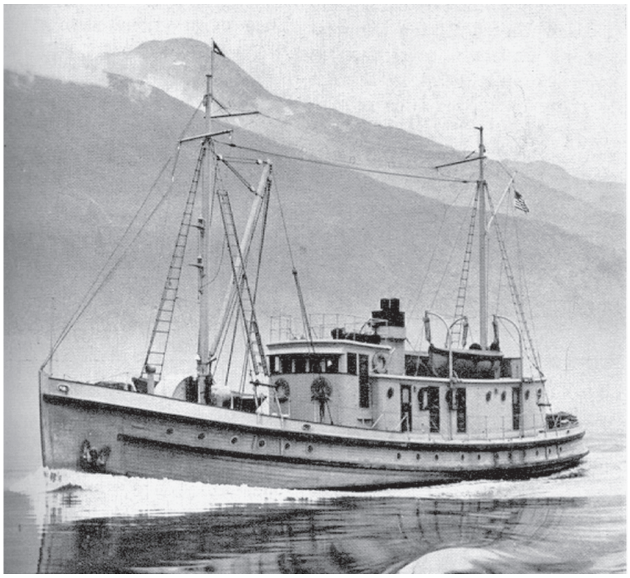
[61] The raw limnological data from Karluk Lake for 1937–42 are located at NARA, Anchorage, AK.

[62] FWS Monthly Report, December 1940. Located at NARA, Anchorage, AK.

[63] Additional egg fecundity data occurs in the records of the sockeye salmon hatchery operated on Karluk Lagoon in 1896–1916. APA. 1906–16. Karluk hatchery yearly reports. Located at NARA, Anchorage, AK.



U.S. Bureau of Fisheries patrol vessel *Crane,* Alaska. (H. C. Scudder, from Thompson, 1957)

During DeLacy's six field seasons at Karluk (1937–42), he divided his time between Karluk Lake, Karluk River weir, and the Larsen Bay and Uyak canneries. At the lake, the USBF cabin on Camp Island served as the research base. This site also had a boathouse and at least two small boats with outboard motors for travel around the lake. Getting to and from the lake typically required a boat trip on the river, often with a stopover at the Portage or Dreadnaught City cabins. DeLacy's assistant, Clarke M. Gilbert, established a new overland trail between Park's Cannery on Uyak Bay and Karluk Lake in 1940. This route followed several creeks and valleys from Uyak Bay and ended at the mouth of Lower Thumb River on Karluk Lake. FWS biologists regularly used Gilbert's trail in 1940–41. As an interesting sidelight to these years, President Theodore Roosevelt's son, Kermit, visited DeLacy at Larsen Bay cannery in 1937 or 1938, and then again at Karluk Lake, where Kermit hunted its brown bears. It was also during DeLacy's time at Karluk that President Franklin D. Roosevelt issued Executive Order 8857 that established the Kodiak National Wildlife Refuge on 19 August 1941. The refuge's main purpose was to preserve a large tract of natural habitat for the island's brown bears; the protected area included all of Karluk Lake and most of the Karluk River.

Each field season DeLacy traveled between Seattle and Kodiak Island on a USBF or FWS vessel (*Crane, Eider,* or *Penguin*) or on commercial passenger steamers. Movements of these vessels came under tight military control during the war years, especially after Attu and Kiska islands in the western Aleutian Islands were captured by Japan in 1942. To prevent enemy detection, the vessels were darkened at night, and travel schedules were kept secret, even from close family members. During the war years, DeLacy and his assistants occasionally spotted military aircraft over Karluk Lake, but they received no support from USBF or FWS airplanes. In the evenings, they anxiously listened to their radios for the latest war news.

William M. Morton

1939–41

William Markham Morton worked at Karluk during 1939–41 as a USBF and FWS biological assistant to DeLacy. Since many of the Karluk studies then were jointly conducted, it is difficult to separate the field activities of Morton and DeLacy. For example, both biologists tagged and recovered charr, examined charr food habits, investigated sockeye salmon subpopulations, and installed the Karluk River weir each year. Yet, Morton conducted several independent studies at Karluk

William Markham Morton (1905–1981). (From 1981 *Fisheries* 6(2):32, courtesy of the American Fisheries Society) and took the lead in some joint studies. Because of his wide-ranging biological interests and many accomplishments, Morton was obviously more than a field assistant to DeLacy. In particular, Morton focused his Karluk research on three topics about Dolly Varden and Arctic charr: their taxonomic differences, their food habits, and their external and internal parasites.

Morton claimed that the greatest discovery of his entire fisheries career was when he found that two distinct charr species inhabited the Karluk ecosystem—Dolly Varden and Arctic charr. He did this during his first field season at Karluk, the holiday of 4 July 1939 being momentous (Morton, 1975). Prior biologists believed that only one charr species, the Dolly Varden, was present at Karluk, though Barnaby's tagging work in 1937–38 distinguished migratory and nonmigratory races (Higgins, 1939).

Morton made his discovery by closely examining the anatomical characteristics, color patterns, and associated parasites of charr (then called "trout"). He first worked with DeLacy at the Karluk River weir in May–June 1939, examining, measuring, and tagging thousands of Dolly Varden as they migrated downstream to the ocean. In late June the biologists went to Karluk Lake to collect charr from the lake, its tributary streams, and the upper river. Almost immediately, Morton noticed differences between the charr at the lake and those at the lower river, and he suspected they may be different species:

> [Karluk Lake, 24 June 1939] Then we loaded up the seine & went across the lake to Half-way Creek & took two hauls for trout—got 52—5 with tags—brot them back to Camp. Al weighed & measured them & I examined their stoms [stomachs]. Such a difference inside & out from the sea-going fish at the weir—hardly know them as the same fish.
>
> [Karluk Lake, 4 July 1939] Altho we were going to do a bit of cannonading with our rifle to celebrate the birth of our nation, we didn't get around to it. I was all excited over something else anyway. I have been strongly suspicious of a set of standard differentiations between the red or lake type Dolly Varden & the green or sea-going type—so I have been spending considerable time on the side making a series of measurements & observations on the red type. Last night when we came in we had 5 green & 5 red types with belly tags. I could hardly wait to look at the green ones—but like a small boy at Xmas eve—I waited with patience until morning—including my hopes in my nightly prayers—so I was up at 6 AM this morning and made breakfast—flapjacks & cereal—cocoa—fruit—& as soon as we did the dishes I set up my lab here in the kitchen. Imagine my gleeful thrill to find several distinct differences in structure esp. in no. of gill rakers on the first gill arch & the total no. of vertebrae—there is a possibility of two distinct species here—which problem I intend to pounce on with all I have! I must examine 500 or 1000 of each from different parts of the lake before making a definite statement on the matter—but I sure got a big kick out of realizing that there is a strong possibility it is staring me right in the face. Al thinks so too—so we are going right after it . . . But I won't forget this safe & sane fourth I don't believe—plenty "bang" in it for me today! Oh! If I only am on the rite road! I'd give my life for it.[64]

To pursue the species question, Morton began gathering morphological and meristic data on charr collected from many aquatic habitats at Karluk. He prepared color drawings and made cast models of the two types. His preliminary data supported the existence of two species, with the possibly of even a third species in some small creeks. He referred to these as the "ocean" or "green" charr for the migratory type (Dolly Varden), the "lake" or "red" charr for the nonmigratory type (Arctic charr), and the "creek" charr for those inhabiting small streams above impassable waterfalls.

Morton's early ideas on charr taxonomy were soon challenged by the noted fish biologist Carl L. Hubbs, who by chance visited the Karluk River weir in August 1939 while conducting a special investigation of USBF operations in Alaska. During the 1-day visit, Morton anxiously presented Hubbs with the recently collected charr data that supposedly distinguished the two species:

> [Karluk River weir, 4 August 1939] Arrived at spit just at 8 & in a few minutes saw *Brant* steam up from behind the Head . . . met Dr. Hubbs. He suggested we motor up to weir in their speedboat & we could talk on the way. So he asked me what I was working on & away we went. I made the fatal error of telling him we thot we had three species of *Salvelinus* here on Kodiak! He smiled & after listening to my descriptions expressed the opinion that they probably were races as in steelhead type & trout type of *gairdenerii.* I said yes I was afraid of that—he said "well—you needn't be afraid of that"—and I felt even more like kicking myself!
>
> I unfolded my sketches & gill raker & vertebrae counts & other charts & he studied them—didn't think much of the sketches—but was very interested in the data sheets—He finally said he was sure it was a racial development—that these ocean going forms developed a distinct race alrite that was similar to salmonoid forms—body shape & silver color etc proved it—while the lake fish being isolated developed another form—stocky & many colored rainbow type of lake environment—also the creek type might be just an offshoot . . . Suggested scale analysis. Says they determine age of brooks that way & also to count scales & check otoliths & pyloric caeca. He believed that extreme emaciation &

[64] See footnote 58 (24 June and 4 July 1939).

parasitization of ocean type would tend to develop into the lake type.

So we went up to the weir & looked at salmon & he took pictures of it. Afterwards he stopped at cabin to examine some of our specimens. And like the spectacular fool I am—I dragged out the only two specimens we have of upstream lake migrants & he asked if I had checked them—no—labelled them—no—well how did I know they were what they were—I blurped—check them yourself I'm sure of them & by Jove—he set me back on my fanny by counting only 19 g.r. [gill rakers] in the only green colored "lake type" we have seen all season in 40,000 trout! Mark—will you never learn to be careful—and a bit less undramatic! All he had to do was point out how nicely this specimen illustrated his theory & I was sunk—but since recovering I have salvaged a lot of spunk—maybe he's rite so I better—record more carefully & accurately after this & be more sure & take it slower. Oh! He's a great guy this Dr. Carl Hubbs of Mich. U. . . . He wants to know where & when & how they all spawn & would then breed true. I suggested lake weir & he seemed in accord with it.[65]

Following Hubbs's suggestion, Morton unsuccessfully tried to age Karluk's charr using their scales. Scale diameters were proportional to fish lengths, but all scales seemed to have 13–16 rings regardless of size, and the scales of larger charr had regenerated centers. The scales of charr, in contrast with most other salmonid species, lacked the distinct annuli that are used to determine age. When Morton examined charr otoliths, he saw distinct growth rings, but was uncertain just how these correlated with age. For comparison, he examined the scales and otoliths of a 360 mm Karluk rainbow trout and found that both body parts had four rings. In contrast, a 360 mm charr had 8–9 otolith rings and 13–16 scale rings. Evidently, Karluk's charr grew much slower than its rainbow trout.[66]

Morton continued to collect taxonomic data on charr during 1939–41 from Karluk Lake and River, lake tributaries, and ocean waters along Shelikof Strait. He caught these fish with a full range of sampling gear (seines, river weir traps, dip nets, hook-and-line, fyke nets, gill nets, and ocean traps). The analysis of these charr specimens included detailed measurements and counts of numerous body features—length, weight, dorsal and anal fin rays, gill rakers, vertebrae, pyloric caeca, branchiostegal rays, scales, otoliths, body color and spotting, liver and swim bladder color, skull bones, and eggs. This mass of data, along with life history information, was used to distinguish the two charr species in the Karluk ecosystem (DeLacy and Morton, 1943). Although some uncertainties still remained about the distinctness of the two charr types at Karluk, most biologists accepted DeLacy and Morton's conclusions, and after 1943 most biological studies at Karluk distinguished the two categories.

Prior to Morton's study, the taxonomy of Karluk's charr was not an official part of the FWS research program. Instead, this work reportedly originated from Morton's curiosity and spare time efforts:

[Karluk, 1939–1941] I began recording morphometric (body) measurements and meristic (scales, bones) counts before dissecting each fish for internal studies which included tabulation of food items found in the stomachs and any parasites found in the alimentary canal or other organs or tissues. This work was done in my spare time, after we had taken the lengths and weights and recorded all tag numbers or marks (fins clipped off in various combinations at an earlier period in their lives) for our official record. (Morton, 1975)

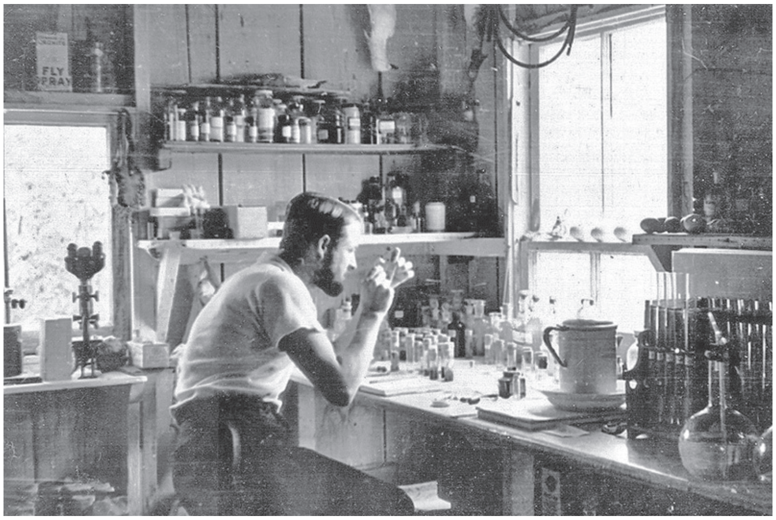
Further, it appears that Morton collected most of the anatomical data on the charr and was the main force pursuing this work, but DeLacy, being the senior FWS employee and having previous experience with fish taxonomy, took the lead in their joint publication (DeLacy and Morton, 1943). Morton highly respected DeLacy as a friend and competent biologist and viewed him as a role model. After working with DeLacy for just a few months in 1939, Morton declared that "in every way I've tested him, he's shaping more & more into a silent model for me to work on".[67] DeLacy, as leader of the Karluk research program, supported Morton's several independent studies.

A second major study that Morton pursued at Karluk was an investigation of charr food habits. During this era, thousands of Dolly Varden were annually destroyed at the Karluk River weir because it was commonly believed that charr predation decreased sockeye salmon populations. In 1939 Morton assisted DeLacy in his study of charr migrations and growth at Karluk, and it was a daily task to dispose of the charr caught at the weir, after first checking them for tags. The down-migrating charr caught at the weir in May–June were thin and emaciated, a glaring fact that seemed to contradict the belief that these fish heavily preyed on sockeye juveniles. Morton was curious to know if these charr had preyed on the sockeye smolts that also were abundant in the river. Thus, before discarding the captured charr, he examined their stomach contents, and, to his astonishment, found that most were empty. Since this direct evidence differed

[65] See footnote 58 (4 August 1939).

[66] See footnote 58 (26 August 1939).

[67] See footnote 58 (8 August 1939).



William Morton studying charr parasites, Camp Island cabin, Karluk Lake, 1940. (William M. Morton, from Robert S. Morton, Portland, OR)

so dramatically from prevailing attitudes about charr predation, Morton began a detailed study of their food habits. To add validity to the study, he examined charr from a wide range of seasons, habitats, and fish sizes. Surprisingly, after checking more than 5,000 charr at Karluk over three years, he found little evidence of predation on juvenile sockeye (Morton, 1982). In contrast, he found that charr ate many sockeye salmon eggs at the Karluk Lake spawning grounds, but believed this was a scavenging behavior, not predation. Soon thereafter, FWS Director Ira Gabrielson ended the Dolly Varden control program, in part because of Morton and DeLacy's results.

While Morton and DeLacy both participated in the charr food studies at Karluk (and benefited from Barnaby's previous work), apparently Morton was mainly responsible for this effort (Morton. 1975, 1982). His field notebooks document that he spent an enormous amount of time examining charr stomachs.[68] Yet, despite the major implications for how biologists should now view the charr-sockeye interaction at Karluk, and potentially for other Alaska regions, their complete study was not formally published for many years. DeLacy (1941) used the 1935–40 food habits data in his Ph.D. dissertation and summarized the results in their charr taxonomy paper (DeLacy and Morton, 1943). Morton tried for 40 years to publish the full results of the food habits study and finally succeeded near the end of his life (Morton, 1982). Unfortunately, the study remained largely unknown to other fishery biologists during these 40 years, and this lapse caused others to partially duplicate this work. Potentially, if Morton's results had been published earlier, Rounsefell (1958) may not have recommended that predatory fishes be eliminated from Karluk Lake as a way to increase sockeye salmon abundance.

Morton's third major study at Karluk was his investigation of the internal and external parasites of Dolly Varden and Arctic charr, though again he claimed that this was a "spare time" project (Morton, 1942). Unlike the charr taxonomy and food habits work that were jointly done with DeLacy, the parasite studies were entirely Morton's. He pursued this research because of long-standing interests in parasitology, not because the USBF or FWS requested them. After graduating from the University of Iowa with an AB degree in 1933, Morton spent three summers during 1935–37 studying parasitology at the University of Minnesota with William A. Riley. Thus, as Morton dissected and measured numerous charr for the taxonomy and food studies, it was only natural for him to record whatever parasites he found.

Morton began investigating charr parasites in 1939, his first year at Karluk, but these were only tentative efforts compared with his intense studies of 1940–41. During this period he enrolled as a graduate student at the University of Washington and worked with James E. Lynch, an invertebrate zoologist and expert in microscopic techniques. Lynch soon became a mentor for Morton and helped him identify parasites and suggested preservation and staining methods. Nevertheless, under the rustic field conditions at Karluk, Morton found that it was a frustrating trial-and-error process to preserve and prepare the parasites on glass slides. Furthermore, he found it time-consuming to collect charr parasites since the process required close examination

[68] See footnote 58.

of all external surfaces and internal organs. For example, he scrutinized the general body surface, fins, gills, muscles, mouth interior, esophagus, stomach, intestines, integument, and various organs (heart, liver, pyloric caeca, gas bladder, gonads, and kidney).

In total during 1939–41, he examined 135 Dolly Varden and 212 Arctic charr for parasites and identified 16 species (plus some unidentified forms). These charr parasites came from five major invertebrate groups—trematodes, cestodes, nematodes, acanthocephalids, and copepods. Dolly Varden and Arctic charr shared some parasite species, but other parasites were unique to each charr species. Morton believed the differences were related to the separate life histories and food habits of each species. Arctic charr were more heavily parasitized than Dolly Varden, and older fish had more parasites than younger fish. Significantly, the results of the parasite study reinforced those of the taxonomic study—that two distinct charr species inhabited the Karluk ecosystem. Morton never formally published the charr parasite results, but used them for his M.S. thesis at the University of Washington in 1942. It is unfortunate his work remained unpublished since this subject became of great interest to parasitologists at the Arctic Health Research Center, Anchorage, when they studied tapeworm life cycles at Karluk Lake in the 1950s (Rausch, 1954; Hilliard, 1959b, 1960).

Besides his focus on charr, Morton collected parasites from an astonishing array of fishes, birds, and mammals whenever the opportunity arose at Karluk. For fishes, he collected parasites from threespine stickleback, steelhead and rainbow trout, coastrange sculpin, juvenile and adult sockeye salmon, pink salmon, Chinook salmon, coho salmon, and Irish Lord sculpins. For birds, he examined mergansers, bald eagles, glaucous-winged gulls, Bonaparte's gulls, kittiwakes, terns, magpies, owls, and various ducks. For mammals, he studied brown bears, meadow mice, and a seal. By examining a broad array of animals, he hoped to understand the full complexity of a parasite's life cycle, especially since different life stages of a parasite often infected different hosts. Stickleback parasites particularly interested him because they could be easily transferred to charr hosts via the food chain. In fact, he theorized that Arctic charr had higher infestation rates of some parasites than did Dolly Varden because of their heavier predation on sticklebacks. Although little of his non-charr parasite work was ever published or presented in informal reports, Morton obviously collected much more information on this subject than was included in his M.S. thesis (Morton, 1942).[69]

Morton spent considerable time investigating the parasites of Karluk's brown bears. Whenever hunters shot a bear, he examined the carcass for parasites, in particular looking for and finding tapeworms. Likewise, during travels around Karluk Lake, he often examined bear fecal piles for parasites and soon realized that bear foods varied seasonally, with elderberries being a major food in late summer. To better understand the tapeworm's life cycle, he sampled Karluk Lake's plankton and found the ceracaria life stage of this parasite.[70]

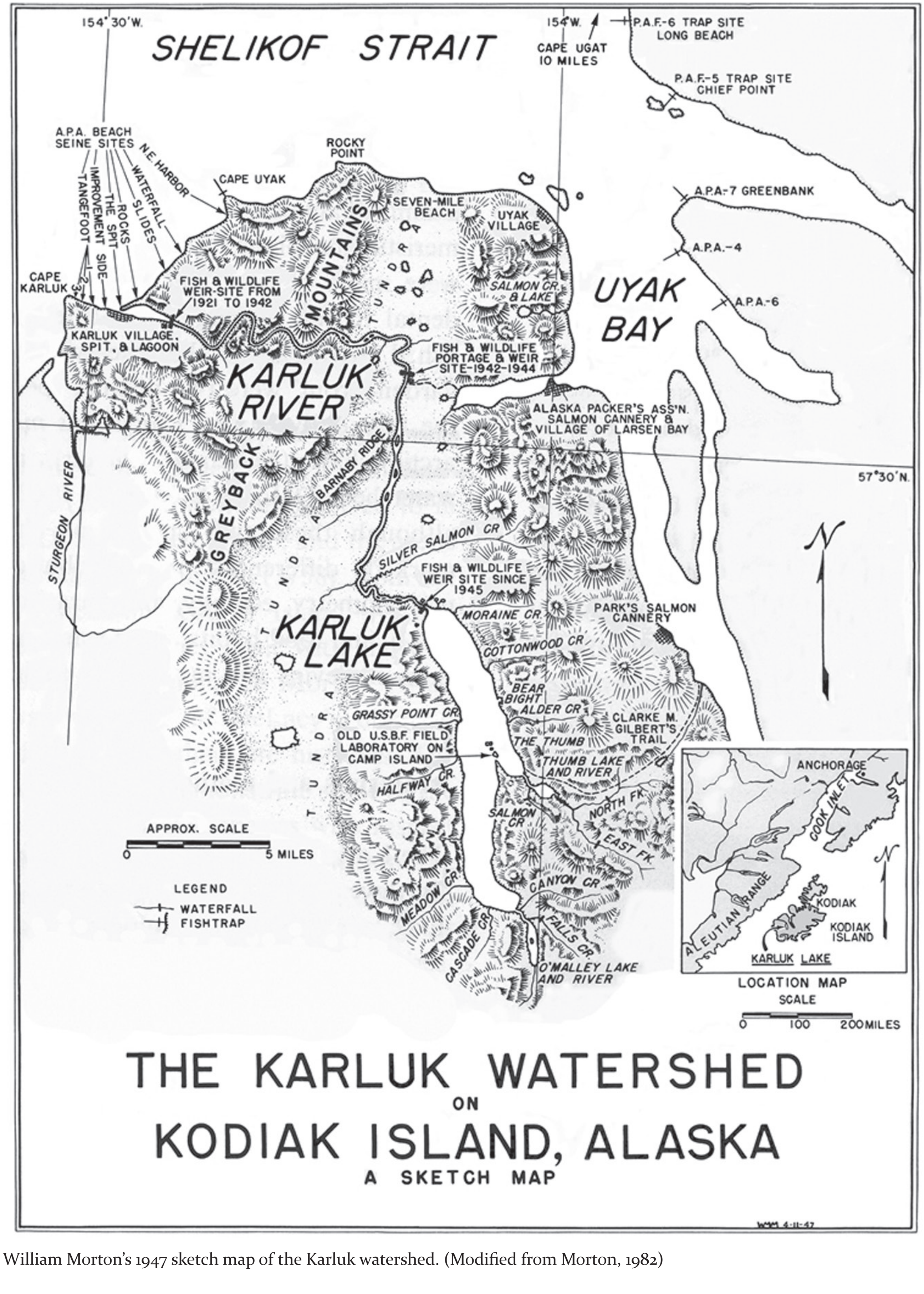
Besides his three main studies at Karluk, Morton was interested in many other biological topics and participated in other research efforts. His three notebooks from 1939–41 provide one of the most detailed, wide-ranging, accounts ever written about USBF and FWS field research at Karluk. They contain detailed chronicles of the seasonal changes in the region's aquatic and terrestrial biota.[71] Following is a brief list of Morton's other interests and activities at Karluk in 1939–41:

- Helped install and operate Karluk River weir, 1939 and 1941.
- Searched for marked sockeye salmon adults in the commercial catch at Larsen Bay cannery, these fish first being marked as smolts by Barnaby in 1935–36.
- Collected egg samples from sockeye salmon to determine their fecundity.
- Collected subpopulation data on sockeye salmon adults (length, number of gill rakers and vertebrae).
- Collected sockeye salmon smolts.
- Collected morphological and meristic data on other salmonids (Chinook, coho, and pink salmon and steelhead).
- Helped install and operate a weir and charr trap on the Lower Thumb River (1939–41) and at the Portage (1941).

[69] During the 1939–1941 field seasons at Karluk, Morton recorded his parasitological observations in a separate notebook and prepared numerous glass slides of collected specimens. We believe his parasite notebook and collection to be valuable Karluk resources, but their location is unknown, possibly having been donated to the University of Washington or some other institution.

[70] See footnote 58 (30 July 1941).

[71] See footnote 58. Each of Morton's field seasons at Karluk lasted about five months: 1939 (8 May–28 Sept.), 1940 (17 June–6 Oct.), and 1941 (12 May–24 September). Other biologists assisting Morton and DeLacy at Karluk during these years were Clarke M. Gilbert (1939–40) and Hal Plank (1941).



William Morton's 1947 sketch map of the Karluk watershed. (Modified from Morton, 1982)

- Helped tag and recapture charr.
- Described sockeye salmon spawning behavior and seasonal changes.
- Made colored drawings and casts of all Karluk fishes.
- Examined stomach contents of most Karluk fish species.
- Collected fishes for museum collections.
- Recorded birds seen in the Karluk area (seasonal changes, behavior, and nesting).
- Examined stomach contents of many Karluk birds and observed bird predation on juvenile sockeye.
- Collected bird skins and eggs for museum collections.
- Recorded seasonal development of the regional flora.
- Collected limnological data from Karluk Lake and its tributaries (water temperature, water chemistry, plankton, and benthos).
- Installed and maintained river thermograph and rain gauge; recorded water level changes of Karluk Lake; measured discharges of tributary streams.
- Mapped upper Karluk River.
- Photographed Karluk (black-and-white prints, color slides, 8mm movies).

It is likely that Morton's personal papers and collected specimens contain valuable and historic Karluk data, but their location remains unknown.[72]

In 1947 Morton prepared a detailed and informative sketch map of the Karluk River watershed. The map gave a clear depiction of the region's villages, canneries, landforms, ocean bays, rivers, and lakes, but it was valuable for showing the locations of six stationary fish traps and nine beach seine sites that existed in the 1940s. In addition, the map showed the three weir locations on the Karluk River and when each was used. For some streams at Karluk Lake, Morton marked where barrier waterfalls stopped the upstream migration of salmon.

Richard F. Shuman

1943–49

Richard F. Shuman, FWS fishery biologist, was placed in charge of the sockeye salmon studies at Karluk after DeLacy resigned in February 1943. Prior to this appointment, Shuman, a recent fisheries graduate of the University of Washington, had studied pink salmon for three years at the FWS Little Port Walter station in southeast Alaska. He led the Karluk studies for seven years (1943–49) and focused his research on six biological topics of sockeye salmon: migration travel time, run segregation to specific spawning sites, escapement-return relationship, bear predation, lake productivity, and fecundity.

Upon arriving at Karluk in the spring of 1943, Shuman first installed the Karluk River weir at the Portage and then worked to improve the portage trail between Larsen Bay and the Karluk River. Improvements were needed for easier transport of supplies across the unstable muskeg with the new FWS tractor (a Cletrac AG) and sled.[73] In July he explored Karluk Lake to survey the sockeye spawning habitats, and was impressed by the many brown bears that preyed on adult salmon. Although just a few months into his new job at Karluk, on this visit to the lake he searched for new sites for a weir and laboratory, wanting to consolidate both nearer the lake where most future research would occur. The Portage weir location, being far removed from the lake,

[72] We made preliminary efforts to locate Morton's specimens and research materials from Karluk. According to his son, Robert S. Morton, Portland, OR, for many years after 1941 his father maintained a research laboratory with specimens and unpublished material in his home basement (Robert S. Morton, personal commun. with Richard L. Bottorff, 1998). Apparently, most of this material was eventually donated to several institutions. In 1977, specimens and research data were donated to the School of Fisheries, University of Washington, in exchange for laboratory space and access to their collections. Whether the donated specimens included his entire collection of Karluk parasites, bird skins and eggs, and fishes is unknown, but at least a few Karluk fishes from De Lacy and Morton do exist in the University of Washington fish collection. Likewise, whether this donation included his raw data and unpublished notes from Karluk is unknown. In 1985, several years after Morton's death, his books were donated to the University of Alaska, Juneau, and an additional six boxes of research materials were donated to Glacier National Park, West Glacier, MT. The latter donation was primarily data and reports from Morton's research in the Flathead Valley, MT, but also included material from other areas. In 1998 Morton's six boxes of research materials remained in storage at Glacier National Park, and had not yet been inventoried (Leo F. Marnell, Glacier National Park, personal commun. with Richard L. Bottorff, 1998). Robert S. Morton retained his father's 1939–41 field notebooks, several colored drawings of Karluk fishes, a few black-and-white Karluk photographs, and three reels of 8mm movie film entitled "Karluk Village Fishing on Spit 1940" and "Karluk Lake and Weir with Peterson, Morton and Gilbert 1941".

[73] In 1943 Shuman shared this job with his two field assistants, Joseph Corkill and Joe Westaby.

Richard F. Shuman (1906–1954). (Richard F. Shuman, from Beryl Shuman, Minnetonka, MN)

made it inconvenient to operate the weir and also conduct biological studies at the lake. Clearly, his first visit to Karluk Lake formed long-lasting ideas that led to many of his future research projects.[74] Besides exploring the lake in 1943, Shuman collected fecundity data from nearly 200 sockeye salmon; Rounsefell (1957) later analyzed and published these data.

By mid August 1943 Shuman was increasingly occupied with operating and securing the Portage weir as decaying aquatic plants drifted downstream, accumulated on the upstream face, and threatened to washout the structure. The weir crew diligently cleaned away the plants for several weeks and kept the weir in service, but the ever increasing masses of plants finally overcame the crew's efforts and they had to dismantle the weir before the sockeye run ended and counting was complete for 1943. This frustrating experience reinforced Shuman's resolve to move the weir to a new site nearer to Karluk Lake, but it was not until September 1943 that he first realized the Portage site had a serious weed problem. By then, for logistical reasons alone, it was too late to change the 1944 weir location. Therefore, he again installed the 1944 weir at the Portage, but, as for 1943, it was rendered unusable late in the season, this time by a combination of decaying plants and pink salmon carcasses that drifted downstream. To prepare for 1945, Shuman and his crew spent most of the 1944 field season hauling materials, by brute force labor, to a new weir site near the lake. When at the lake they also surveyed the sockeye spawning habitats and examined charr stomachs for evidence of predation on juvenile sockeye.

In 1945 Shuman installed the Karluk River weir just below the lake's outlet and built a small cabin nearby for the weir crew and biologists. Because the new weir was now further removed from the commercial fishery, it was essential to know how long it took adult sockeye to reach the weir from the ocean. To measure this migration travel time, Shuman and his assistant, Philip Nelson, tagged thousands of spring- and fall-run sockeye at Karluk Lagoon in 1945 and 1946 and then recorded their passage at the weir (Gard, 1973). With these new travel-time results, commercial catches and escapements could now be better matched for calculating the seasonal variation of the total run and for managing the fishery.

Shuman and Nelson also used tagging methods to study the dispersion of adult sockeye to specific spawning sites at Karluk Lake during 1945–48. Their first indication that adult sockeye salmon might home to specific sites in and near the lake came in 1945–46 when the fish tagged in the travel-time study were later found on the spawning grounds. In 1947–48 they obtained even better records of this dispersion by tagging many sockeye at the weir and later finding them at specific spawning sites. Since the weir was then located near the lake, it was convenient for the crew to regularly survey the different spawning habitats for tagged fish throughout the entire run season. Some sockeye tagged at the weir in September 1948 were seen at spawning sites well into late October and November, including one observed at Thumb Lake under 8 cm of ice on 20 November.[75]

After several years of these tagging studies, Shuman and Nelson understood that sockeye salmon used the different spawning habitats at Karluk in a repeatable seasonal sequence each year. Spring-run sockeye spawned in lateral and terminal tributaries of Karluk Lake, while fall-run sockeye spawned in terminal

[74] Richard F. Shuman 1943–49 notebooks. Located at NARA, Anchorage, AK.

[75] Arthur Freeman 1948 notebook. Original notebook in personal papers of Arthur Freeman, Indianapolis, IN.

Richard Shuman with U.S. Fish and Wildlife Service boat *Nerka,* Karluk Lake, 1944. (Jerrold M. Olson, Auke Bay, AK)

streams, lake beaches, and the upper Karluk River. Of course, previous Karluk biologists had also observed this seasonal dispersion, but Shuman and Nelson were the first to accurately document the behavior. Yet, for unknown reasons, they never published their tagging results and later biologists repeated their work. Their tagging studies also showed that adult sockeye spent about one month in Karluk Lake before spawning, the same maturation period first discovered by Rutter and Spaulding in 1903.

In 1945 Shuman investigated the relationship between the escapements and returns of sockeye salmon at Karluk, possibly being inspired by Barnaby's 1944 paper on the topic. Barnaby analyzed escapement-return data for nine years (1921–29), while Shuman now had 19 years of data (1921–39). Shuman wanted to understand what escapement led to the greatest surplus of sockeye salmon at Karluk. In late 1945 he analyzed the data and prepared a manuscript for publication titled "Observations on escapements and returns of red salmon at the Karluk River," that recommended a relatively low escapement goal (350,000–500,000 per year).[76] Before publication, Shuman sent the manuscript in early 1946 to Willis Rich, who was then advising the FWS on its Pacific salmon studies. Rich argued that in setting an escapement goal it was insufficient to base it on the 1921–39 data alone, but should include information on sockeye abundance prior to 1921. He believed the data for 1921–39 failed to account for the true productive potential of Karluk's sockeye salmon because by that period the run was in a long-term decline. Rich believed that Karluk Lake's reduced fertility had caused the decline as fewer salmon-carcass nutrients supported the food base of juvenile sockeye. Instead, he argued for high escapements (2,000,000 per year) of sockeye salmon to Karluk Lake to restore its fertility.

Shuman and Rich exchanged ideas about Karluk's sockeye during 1946 and discussed ways to improve the manuscript (there was even brief mention of joint authorship). Eventually, Shuman accepted most of Rich's ideas and over the next few years he completely revised and expanded the manuscript and gave it a new title: "Biological studies of the red salmon *Oncorhynchus nerka* (Walbaum) of the Karluk River, Alaska: A report on the trends in abundance, with a discussion of the ecological factors involved."[77] He increased the escapement goals (350,000 spring run and 350,000 fall run) and recommended the fertilization of Karluk Lake to restore its nutrients. He also advocated an expanded research program on limnology, predation, stickleback competition, and marine migration studies. Finally in 1951 Shuman submitted his revised manuscript, "Trends in abundance of Karluk River red salmon with a discussion of ecological factors," for publication in the *Fishery Bulletin*.[78] His paper discussed a full range of subjects on Karluk's sockeye salmon; the table of contents included:

- Problems of conservation
- History of biological program
- Life history
- Composition of catch
- Returns from escapements
- Independence of spring and fall run
- Desired escapements
- Trends in abundance
- Factors affecting survival in fresh water
  - Topography and weather
  - Balance in nature
  - Civilization
  - Predators
  - Competitors
  - Food supply
- Effective escapements
- Spring and fall runs

[76] Shuman, Richard F. 1945. Observations on escapements and returns of red salmon at the Karluk River. FWS, Division of Fishery Biology. Unpubl. report. 17 p. Located at ABL, Auke Bay, AK.

[77] Shuman, Richard F. 1950. Biological studies of the red salmon *Oncorhynchus nerka* (Walbaum) of the Karluk River, Alaska. A report on the trends in abundance, with a discussion of the ecological factors involved. Unpubl. report. 73 p. Located at ABL, Auke Bay, AK.

[78] Shuman, Richard F. 1951. Trends in abundance of Karluk River red salmon with a discussion of ecological factors. Manuscript prepared for *Fishery Bulletin* 71, vol. 52. Unpubl. report. 56 p. Located at ABL, Auke Bay, AK.

Artificial fertilization of lake waters
Immediate steps proposed
Summary
Literature cited

In spite of Shuman's determined efforts to improve this manuscript, it was never published. The paper proceeded to the galley proof stage by late 1951, but then FWS officials stopped its publication. Though it is not clear why publication was canceled, and by whom, Shuman believed George Rounsefell was primarily responsible. Rounsefell, then Chief Editor and Reviewer of FWS publications, undoubtedly had seen Shuman's paper and had the authority to stop its publication, if desired. It is also likely that he knew Shuman was working on the Karluk manuscript well before 1951, and had seen earlier versions, since as Chief of the Branch of Anadromous Fishes he visited Shuman at Karluk Lake in 1947 to discuss the sockeye research program, which then was implementing some of Shuman and Rich's ideas:

> [Karluk Lake, 17 August 1947] Rounsefel, Kelez, Ball in about noon. Discussed plans with Rounsefel. Feeling so-so.[79]

But Rounsefell's involvement with the sockeye studies at Karluk was apparently much deeper in 1951 than a casual interest in the research program and its publications. Sometime in 1949–52, Lionel Walford, FWS Director of Research, assigned Rounsefell the job of analyzing the long-term set of data that had been collected on Karluk's sockeye salmon. Possibly, Rounsefell had already reached his own conclusions about Karluk's sockeye when he first read Shuman's 1951 manuscript, or had already started to write his own paper.

After working on his manuscript for over five years, Shuman gave up further efforts to revise the 1951 version after its publication was blocked. Nevertheless, in December 1952 Rounsefell sent Shuman a large 72-page manuscript entitled, "Population dynamics of the sockeye salmon, *Oncorhynchus nerka,* of Karluk River, Alaska," with Rounsefell as senior author and Shuman as junior author.[80] Joint authorship suggested that they had collaborated on the paper, but Shuman had, in fact, no knowledge of the paper until receiving the December 1952 copy. This new manuscript discussed subjects previously presented in Shuman's 1951 paper, but some conclusions and recommendations of the two manuscripts conflicted, such as the presence of subpopulations, the seasonal distribution of the runs, and how the fishery should be managed. Yet, many of Rounsefell's recommendations were similar to Shuman's, including the need for limnological studies and the possibility of fertilizing Karluk Lake to enhance its fertility.

Shuman forcefully told the FWS Regional Director that he did not want his name on Rounsefell's paper, believing that many conclusions were incorrect and possibly harmful to the run.[81] In particular, the two biologists sharply differed over whether the sockeye salmon run was a single population or had distinct components—Rounsefell declared the run was a single population, Shuman stated that spring and fall runs were independent. Shuman was also concerned about Rounsefell's recommendation to curtail spring and fall escapements in favor of larger mid-summer escapements. In response, Shuman prepared a detailed critique of Rounsefell's paper and recommended that it not be published. Of course, Shuman's response was undoubtedly affected by the unpleasant events that had stopped his 1951 paper. In any event, Rounsefell's 1952 manuscript was an early draft of the large paper he eventually published in 1958.

It was unfortunate that Shuman's 1951 paper went unpublished because it was a well-written statement of then current knowledge about Karluk's sockeye salmon and the actions needed to increase these runs. The paper had great legitimacy because Shuman's analysis was based on many years of firsthand field observations. He gave clear statements about the independence of spring- and fall-run sockeye and explained how the runs used different spawning habitats in the Karluk ecosystem. He provided a still relevant discussion of the factors that affect the freshwater survival of juvenile sockeye and forcefully argued that salmon-carcass nutrients influenced Karluk Lake's fertility and the production of sockeye salmon. Shuman discussed the possibility of fertilizing Karluk Lake to enhance its fertility and recommended detailed studies of the lake's limnology, juvenile sockeye, and sticklebacks. He emphasized the need to accurately measure the sockeye smolt out-migration and recommended changes to the 1924 White Act to allow constant, sustainable escapement goals for the Karluk system.

Of course, Shuman's interaction with Rich was partly responsible for the scope and content of his 1951

[79] See footnote 74.

[80] Rounsefell, George A., and Richard F. Shuman. 1952. Population dynamics of the sockeye salmon, *Oncorhynchus nerka,* of Karluk River, Alaska. FWS, Woods Hole, MA. Unpubl. report. 72 p. Located at ABL, Auke Bay, AK.

[81] Memo (7 January 1953) from R. F. Shuman, FWS, Juneau, to Regional Director, FWS, Juneau AK. Located at ABL, Auke Bay, AK.

unpublished paper. Discussions with Rich in 1946 had convinced Shuman of the need to study the lake's limnology, and, indeed, a full range of lake data were collected during 1947–49. Soon thereafter, Shuman and Nelson wanted to field test the lake fertilization idea and selected Bare Lake for the trial. Although Nelson was in charge of the Bare Lake experiment after Shuman left the Karluk studies, the lake fertilization idea began with Rich and Shuman.

Of Shuman's many studies at Karluk, he is perhaps best known for his research on brown bear predation of sockeye salmon. Ever since his first field season in 1943, Shuman was interested in the brown bears at Karluk Lake and the many adult sockeye these predators killed:

> [Salmon Creek, 10 July 1943] Bears *extremely* numerous on this branch. Saw 5 bear here, being charged by female with cubs. Outcome fortunate! Must observe extreme caution on all these streams in future . . . Loss of fish to bears apparently enormous, though no estimate in numbers possible. Remains of those killed by bear are everywhere.
>
> [Karluk Lake, 17 July 1943] Bears were *very* numerous over entire Upper Thumb, Lower Thumb and Lake shore. Several were seen, some within a few feet. Others were heard. These showed no fear of man, and were often threatening in action though none actually charged. Care must be observed on all these streams. Suggest police whistle or small mouth siren . . . to announce presence. Shouting of no value! The loss of fish to bear must be extremely high on these streams. Besides the countless carcasses seen, it was estimated *that fully 50 % of the living fish* in the stream bore marks of varying severity—made by bears claws (rarely by teeth). Many of these wounds would be fatal within a few hours—probably before spawning, for the bear show every evidence of preferring the brighter fish to the older, darker ones.[82]

Bears were abundant at Karluk Lake in 1944, and Shuman's assistant noted "we estimated that bears kill and eat 240,000 fish out of this system."[83] Whenever Shuman surveyed the spawning areas in 1943–46, he found the waters and stream banks littered with bear-killed sockeye, especially in the small creeks. This apparent major source of sockeye mortality and the ever-declining runs alarmed Shuman, causing him to study bear predation at Moraine Creek in 1947, followed by a second study with Nelson at Moraine and Halfway creeks in 1948. When Shuman published the 1947 predation study (Shuman, 1950), his recommendation to control the bear population created such public controversy that the 1948 study was never formally published (Nelson et al., 1963).

Adult brown bear and four cubs, Karluk Lake tributary, 1949. (Richard F. Shuman, from John B. Owen, Grand Forks, ND)

In his last year at Karluk (1949), Shuman tried to build a permanent two-way weir on the Karluk River just below the lake's outlet. This weir was intended to count up-migrating sockeye adults and down-migrating smolts, but logistical and mechanical problems prevented its construction. Nevertheless, Shuman understood the importance of measuring both the sockeye escapement and smolt out-migration, goals that were finally achieved in the 1950s and 1960s by other biologists.

During Shuman's leadership of the Karluk studies in 1943–49, the ease and mode of travel greatly changed. Initially during the war years, biologists traveled to and from Alaska on commercial steamships or FWS vessels and these were under tight military control.[84] It was not until 1946 that biologists flew on commercial or naval airplanes between Seattle, Anchorage, and Kodiak, yet access to Karluk Lake remained nearly the same as for Bean's 1889 visit. In 1944 Shuman and his crew received no assistance from airplanes in moving supplies to the lake, though they occasionally saw military planes overhead. Because of the lake's remoteness, the FWS discussed in 1946 the need for a road to connect Larsen Bay and Karluk Lake, but air travel was then becoming more common around Kodiak Island and naval planes frequently landed at the lake to let their crews sport fish. In late 1946 a FWS official flew to Karluk Lake in a Waco amphibious airplane to visit the weir and research station. While the airplane was briefly available, gasoline

[82] See footnote 74.

[83] Jerre Olson 1944 notebook (18 July). Original notebook in personal papers of Jerre Olson, Auke Bay, AK.

[84] Jerre Olson, Auke Bay, AK, personal commun. with Richard L. Bottorff, 1997.

U.S. Fish and Wildlife Service Grumman Widgeon N 728 (left) and Grumman Goose NC709 (right), Karluk Lake, 1949. (E. P. Haddon, U. S. Fish and Wildlife Service, National Digital Library, FWS-933)

and supplies were flown to Karluk Lake; this one 45-minute round trip from Larsen Bay saved the biologists six laborious river trips. Finally in 1947, the Karluk research program was supported by frequent air transport of supplies and personnel directly to the lake by several FWS Grumman Goose and Widgeon amphibious airplanes. Thereafter, airplanes provided the main access and supply to Karluk Lake. Without a doubt, solving this huge logistical problem greatly expanded the scope of research possibilities for Karluk's biologists.

During Shuman's years at Karluk, communication between remote field locations and more-populated sites around Kodiak Island was done by short-distance radio, though direct radio contact between Karluk Lake and the FWS Kodiak headquarters was seldom possible. Instead, messages were relayed by people located at closer and more powerful radio stations (Larsen Bay and Karluk Village) or aboard boats around the island. During this period, Archie "Scotty" Brunton, an employee of the Larsen Bay cannery (radio KOT), often forwarded messages to Kodiak for the biologists at Karluk Lake since their 1.5 watt U.S. Forest Service radio had a range of only 25 km.[85]

Richard Shuman's career as a FWS fishery biologist ended tragically when he died in an airplane crash in southeast Alaska on 1 September 1954. Shuman received a fitting tribute to his memory and fisheries work in Alaska by the official naming of Mount Shuman, which towers over the southern half of Karluk Lake.

[85] Letter (24 October 1998) from Arthur Freeman, Indianapolis, IN, to Richard L. Bottorff, South Lake Tahoe, CA.

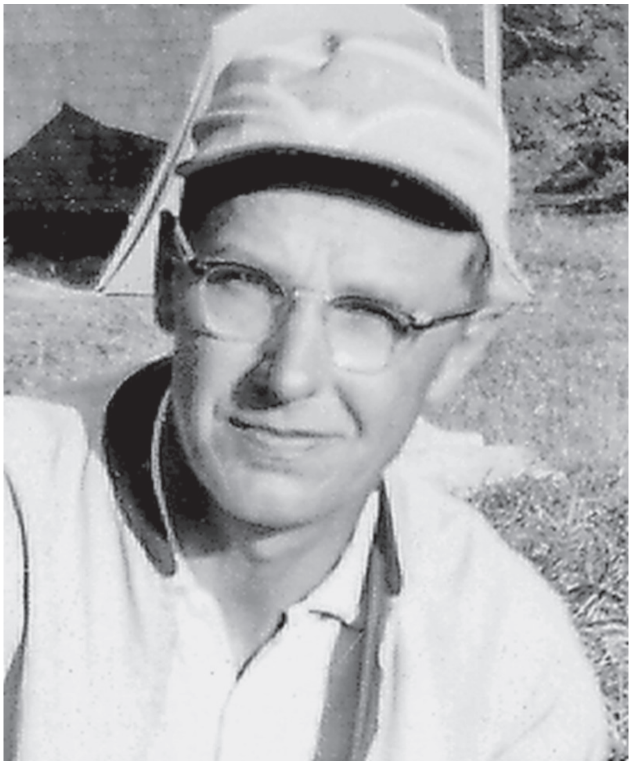
Several important federal actions impacting Karluk salmon fishermen and canneries were made during Shuman's years as research leader. In 1943 Secretary of the Interior Ickes established the Karluk Reservation for the Alutiiq people (Public Land Order 128). This reservation included 35,000 acres (14,164 hectares) of land and water near Karluk Village and the beach seining sites on Karluk Spit. The reservation boundary included the ocean waters 3,000 feet (914 m) from shore. For many years, the APA had dominated the fishing at Karluk and the Alutiiq fishermen had been excluded from prime beach seine locations, causing impoverishment for local residents (Grantham, 2011). Despite the reservation order, conflicts continued between beach seiners and purse seiners over access to the ocean waters within the boundary. Non-Alutiiq fishermen believed they could not be denied access to this fishing area because of provisions in the White Act. When federal fishing regulations in 1946 allowed only Alutiiqs to fish within the boundary, a lawsuit, *Hynes v. Grimes Packing Co et al,* was brought to settle the issue. In 1949 the U.S. Supreme Court (337 U.S. 86) ruled that 1) Secretary of Interior was authorized to establish the Karluk Reservation, and 2) Karluk inhabitants could not bar access to the waters and fish within the reservation.

Philip R. Nelson

1946–56

Philip R. Nelson, FWS and BCF fishery biologist, studied Karluk's sockeye salmon for 11 years, first assisting Shuman in 1946–49 and then leading the research in 1950–56. Nelson, a graduate of the School of Fisheries, University of Washington, served in the military before working at Karluk. His research at Karluk comprised four main topics—stickleback life history, Bare Lake fertilization experiment, survival of gill-net-marked sockeye salmon, and sockeye salmon egg survival. In 1955, during Nelsons's later years at Karluk, the Fish and Wildlife Service split into the Bureau of Commercial Fisheries (BCF) and Bureau of Sport Fisheries and Wildlife.

During the four years he assisted Shuman, Nelson actively participated in all of the ongoing Karluk studies and was largely responsible for some. Routine tasks included installation and operation of the weir, collection of run composition data, surveys of sockeye spawning sites, and collection of limnological data. Nelson and Shuman jointly did the tagging studies on adult sockeye during 1946–48 to determine their travel time,



Philip R. Nelson (1918–). (Philip R. Nelson, Largo, FL)

one-month ripening period before spawning, and dispersion to specific spawning sites. Nelson also made major contributions to the bear predation studies at Moraine and Halfway creeks in 1947 and 1948, though Shuman apparently initiated both studies. They jointly prepared a manuscript on the 1948 bear predation study ("Further studies of bear depredations on red salmon spawning populations in the Karluk River system, 1948"), but it was not published.[86] Following Shuman's death in 1954, Nelson and several colleagues modified the 1948 bear predation manuscript several times and tried for over 10 years to publish it, without success (Nelson et al.. 1963). Despite this one lapse, Nelson, in contrast with many other biologists at Karluk, managed to publish most of his research.

An early research effort by Nelson was his life history investigations of threespine sticklebacks at Karluk Lake. He pursued this topic after Shuman and Rich refocused the Karluk research program in 1946 onto the factors that affected juvenile sockeye and the lake's limnology. Since the huge population of sticklebacks in the lake appeared to be serious competitors of young sockeye, it was prudent to gather basic biological information on this species. As a result, Nelson began the life history studies in 1948–49 and irregularly continued them until 1956, eventually expanding them to include Bare Lake's sticklebacks. His investigation did not measure the competition between sticklebacks and young salmon, but it did gather basic biological data on sticklebacks (Greenbank and Nelson, 1959).

Perhaps Nelson's most ambitious and important research project during his tenure at Karluk was the artificial fertilization experiment at Bare Lake, a small lake 25 km southwest of Karluk Lake. This field experiment originated from Rich's 1946 recommendation that the FWS study Karluk Lake's limnology to better understand the linkages between salmon-carcass nutrients, plankton, and young sockeye. By 1947–49 the FWS was actively considering the enrichment of Karluk

Brown bear, Karluk Lake tributary, ca. 1950–54. (Charles E. Walker, Sechelt, BC)

Bare Lake cabin, June 1954. (Clark S. Thompson, Shelton, WA)

[86] Shuman, Richard F., and Philip R. Nelson. 1950. Further studies of bear depredations on red salmon spawning populations in the Karluk River system, 1948. FWS. Unpubl. report. 33 p. Located at NARA, Anchorage, AK.

Sockeye salmon smolts, Bare Lake, 1955. (Clark S. Thompson, Shelton, WA)

Bare Lake outlet, weir, and salmon research gear, 1954. (Clark S. Thompson, Shelton, WA)

Lake to improve its fertility and sockeye salmon production, but the consequences of adding artificial fertilizers to a large Alaskan lake were then unknown.[87] Therefore, in 1949 they decided to first test the lake enrichment idea on a small lake before attempting it at Karluk Lake. To get the project underway, Nelson and Shuman searched Kodiak and Afognak islands for a suitable experimental lake and after a brief survey of possible sites selected Bare Lake in July 1949.

Nelson was fully responsible for the fertilization experiment at Bare Lake, though he collaborated with Professor W. T. Edmondson of the University of Washington and was assisted by many FWS officials and field employees. Each summer for seven years (1950–56), he added artificial fertilizers to Bare Lake and monitored the lake's chemical and biological response, especially that from its sockeye salmon (Nelson and Edmondson, 1955; Nelson, 1958, 1959). Fertilization rapidly increased the lake's photosynthetic rate and phytoplankton populations, which decreased water transparencies and increased pH values. Zooplankton populations did not immediately increase, but were much more abundant by 1957 (Raleigh, 1963). For the sockeye salmon, fertilization increased juvenile growth, smolt size, and ocean survival, but the number of returning adults seemed to be unaffected. Populations of juvenile coho salmon and resident Dolly Varden may have increased during the fertilization years, but stickleback growth rates did not increase (Nelson, 1959; Raleigh, 1963).

In many respects, Nelson's fertilization experiment at Bare Lake was a huge success, showing that lake enrichment increased juvenile sockeye growth, smolt size, and ocean survival. The ultimate desired result—greater numbers of returning adults—did not occur, perhaps because of factors beyond the influence of the nursery lake. In fact, since Bare Lake had a rather small original run of sockeye salmon, the number of returning adults was always highly vulnerable to chance events of commercial fishing, marine factors, and low flows in Bare Creek. In any event, this fertilization study was an innovative test of the linkage between lake nutrients and salmon production in an Alaska lake. The Bare Lake experiment was an important first step for the lake enrichment idea to become an accepted method for enhancing and rehabilitating depleted stocks of sockeye salmon in Alaska. Though the FWS initially planned the Bare Lake experiment as a prelude to fertilization of Karluk Lake, the idea was eventually discarded as new research topics at Karluk Lake became dominant. Nevertheless, in 1986–90 the ADFG fertilized Karluk Lake to enhance its fertility and sockeye salmon.

In another project, Nelson and his assistant Carl E. Abegglen measured the survival of gill-net-marked sockeye salmon at Karluk in 1953 (Nelson and Abegglen, 1955). This study responded to concerns that commercial gill nets may cause a greater loss of sockeye salmon than revealed in the catch statistics. That is, fish that escaped from a gill net with body injuries may later die unrecorded. To investigate this problem, Nelson and Abegglen trapped thousands of adult sockeye in Karluk Lagoon in 1953 and subjected them to varying

[87] Discussions within the FWS about the value of fertilizing Karluk Lake included Shuman and Nelson, and higher officials such as Elmer Higgins (Chief, FWS Division of Fishery Biology), Lionel A. Walford (FWS Director of Research), George B. Kelez, (Chief, FWS Alaska Fishery Investigations), Ralph P. Silliman (Chief, FWS Section of Anadromous Fisheries), and Clarence J. Rhode (FWS Regional Director).

degrees of physical damage from gill nets. Injured fish were tagged and released, along with a group of uninjured control fish, to proceed up the Karluk River. The study showed that 10–20% of the fish that escaped gill nets died from their injuries and mortality increased with wound severity. Yet, they found no difference between damaged and control fish in their travel times between the lagoon and the weir and between the weir and the spawning grounds.

Nelson and his assistants devoted considerable effort during 1947–53 to a study of the development, density, and survival of sockeye salmon eggs buried in various spawning substrates at Karluk. They regularly dug into spawning redds to assess the condition of the eggs. To monitor the seasonal development of eggs, they placed some inside baskets or cartridges and re-buried them in creek substrates; the containers were periodically retrieved and examined to assess the state of the eggs. At times the biologists found numerous leeches and oligochaete worms in the substrate and suspected that these invertebrates were destroying many eggs. Despite their labors and the reams of data collected, the outcome of the egg study was unclear, and, as a result, this research never was formally published or summarized in FWS reports.

William Francis Thompson (1888–1965). (From Stickney, 1989, University of Washington, School of Aquatic and Fishery Science, Seattle, WA)

William F. Thompson

1948–58

William Francis Thompson had a long and productive career as a fishery scientist and educator on the Pacific Coast of the United States and Canada in the early and mid 1900s (Stickney, 1989; Dunn, 2001a, b, c). He first investigated several of the most important marine fisheries in California and British Columbia, including halibut, herring, sardines, and albacore tuna, before focusing his scientific talents on Pacific salmon. Educated at Stanford University, he earned his B.A. (1911) and Ph.D. (1930) degrees while working with two eminent ichthyologists, David Starr Jordan and Charles H. Gilbert (Dunn, 2001a). For much of his fisheries career, Thompson was associated with the University of Washington (1930–58), first as Director of its School of Fisheries and later as Director of its Fisheries Research Institute (FRI).

Thompson's involvement with sockeye salmon research at Karluk began soon after he founded the FRI at the University of Washington in 1947. This institute, which had the goal of improving the scientific foundation of management of Alaska's salmon fisheries, was formed in response to concerns by the salmon packing industry about the depleted salmon runs, especially those at Bristol Bay. Initially, the salmon packing industry funded FRI's studies at Bristol Bay and other areas of Alaska, but as the scope of this research program expanded, by the mid 1950s this private source was inadequate and new funding sources were secured from the federal government, and later, from the State of Alaska (Stickney, 1989; Dunn, 2001a). The FRI began their studies of Karluk's sockeye salmon in 1948 and continued these until 1958 under Thompson's guidance.

Thompson was an important figure in the fisheries research history of Karluk for two reasons—his management of FRI research and his ideas about Karluk's sockeye salmon. First, Thompson actively directed the Karluk field research of FRI biologists Donald Bevan and Charles Walker, often recommending topics to investigate and offering advice as the sockeye studies progressed. Though he personally never did fieldwork at Karluk, Thompson annually visited each FRI research station for a few days and maintained an active interest in the ongoing operations, progress, problems, and results of each project. He set high standards for the salmon research and expected scientifically sound results from his field biologists. The field notebooks of FRI biologists document that he was a major intellectual force in the planning and operation of FRI's salmon studies in Alaska.[88] Specifically, he secured funds for FRI's studies of the ocean migration routes (1948–49) and subpopulations (1950–54) of Karluk's sockeye salmon, both important and largely unexplored topics at the time. Thompson also acquired funds for a long-term study of juvenile sockeye salmon in Karluk Lake (1950–54) and for the first attempts to measure smolt out-migration from the lake. Thus, Thompson was a major influence on the planning and progress of FRI research at Karluk during 1948–58.

Second, Thompson was important in the research history for his insightful ideas on sockeye salmon biology and the commercial fishery. In particular for Karluk, he presented these ideas in an influential talk given at the National Research Council in Washington, DC, on 9 November 1950. In his presentation entitled "Some salmon research problems in Alaska," he stated his belief that Karluk's sockeye salmon had many independent subpopulations, a topic largely uninvestigated. Further, he claimed that the seasonal distribution of adult sockeye salmon that returned each year to Karluk had been greatly modified by past commercial fishing. To demonstrate this impact, he used early case pack records (1895–1919) from a single Karluk cannery to show that the run had shifted over the years from a unimodal to bimodal seasonal pattern. Thompson argued that adult sockeye returning during the midseason (15 July–31 August) were originally the most abundant and productive part of the Karluk run, but that the fishery had depleted these fish and left only the early and late runs. Furthermore, he reasoned that the loss of productive midseason fish may explain the overall long-term decline in sockeye salmon numbers at Karluk.

If Thompson's ideas were true, fishery managers needed to change their regulations to better protect midseason fish. Without a doubt, his idea about overharvested midseason subpopulations soon led to changes in the Karluk research programs of the FRI, FWS, and BCF. In particular, Bevan did a detailed study of the ages, sizes, and specific spawning habitats of midseason fish during 1950–54 and a few years later Owen attempted to measure the productivity of these subpopulations. Thompson's 1950 presentation, though never formally published, was issued as an FRI Circular (Thompson, 1950). In October 1951 Thompson again presented his analysis of Karluk's sockeye salmon at a meeting of the International Council for the Exploration of the Sea, Amsterdam, The Netherlands (Thompson, 1951).

In the years since Thompson presented his ideas on the subpopulations and run distribution of Karluk's sockeye salmon, the existence of subpopulations has been well substantiated. He certainly deserves great credit for focusing the attention of fishery biologists onto this biological feature of salmon and for stimulating considerable research on this topic in the 1950s and 1960s. Yet, questions remain about the original run distribution of Karluk's sockeye and whether past harvests of the commercial fishery produced the current bimodal seasonal pattern. Present fishery managers must deal with the reality of a bimodal sockeye run that has existed for at least 90 years and the fact that midseason fish never increased in abundance when protected from commercial fishing. Thus, Thompson's ideas on the original run distribution of Karluk's sockeye salmon have yet to be validated.

Thompson believed in the early 1950s that wooden picket weirs installed across a river to count salmon might harm these migrating fish by being a barrier to their free movements. Instead, he claimed that counting towers had significant advantages since they did not have a physical structure in the river that impeded the movements of sockeye adults and fry. Undoubtedly at Thompson's suggestion, Bevan and Walker explored the Karluk River in 1955 to find a suitable tower site and made several trial counts on the lower river. Soon thereafter, the FRI ended its sockeye research at Karluk, but Thompson's ideas about weirs eventually led to changes in the location, type, and operations of the counting structures used by the FWS, BCF, and ADFG. For example, the BCF replaced their traditional picket weir at Karluk with a counting tower in 1958–59, but after experiencing many problems that decreased the accuracy of the salmon counts, they returned to the picket weir in 1960. To further address concerns about the weir, they modified the structure in the 1960s to aid the upstream migration of sockeye fry. Van Cleve and Bevan (1973), both colleagues of Thompson at the Univer-

[88] Donald E. Bevan 1948–55 notebooks and Charles E. Walker 1950–55 notebooks. Located at FRI Archives, University of Washington, Seattle, WA.

sity of Washington, also believed that Karluk's weir harmed its sockeye salmon and recommended its removal from the upper river spawning area. In 1976 the ADFG moved the weir to the lower Karluk River, in part because of the concerns initially voiced by Thompson.

Thompson (1950) stated that sockeye salmon in the Karluk River and other river systems of the Pacific Coast were resilient to the effects of heavy commercial fishing and that these fish populations would respond to proper management:

> [Concerning the management of salmon fisheries] In fact, such resilience is the only explanation possible for the continuance of great runs into the Sacramento, the Columbia, the Fraser, the Karluk, and Bristol Bay despite tremendous fisheries over three-quarters of a century. This should give regulatory authorities in Alaska the courage to experiment. Every year is not a life and death crisis.

In 1954 he criticized the existing regulatory quota system used to harvest sockeye salmon at Karluk, where 50% of the total run must be allowed to escape to the spawning grounds. Further in 1955, he suggested that the FWS should experiment with the fishery regulations to get dramatically different harvests in alternate years (Thompson et al., 1954; Thompson and Bevan, 1955). He recommended greater commercial fishing on Karluk's spring-run sockeye and less on the midseason run. Apparently, these management ideas were not adopted, but Thompson showed a willingness to experiment with the fishing regulations to halt the long-term decline of its sockeye salmon. Ideally, he wanted regulations that permitted adequate escapements from all sockeye subpopulations. In this way, the full natural biological diversity of Karluk's sockeye salmon would be preserved to give them long-term resilience to fishery harvests and environmental challenges (Thompson, 1950).

In summary, Thompson was a remarkable individual in Karluk's fisheries history because his impact came from the force of his ideas and the guidance and inspiration he gave to other biologists. His intellectual energy extended well beyond his immediate sphere of influence at the FRI and included many other fishery biologists, agencies, commissions, and commercial interests. In contrast to most biologists in this history, he did not do field studies at Karluk, nor did he formally publish papers on its sockeye salmon. Nevertheless, he profoundly influenced the direction of sockeye salmon research at Karluk for many years.

Donald E. Bevan

1948–58

Donald E. Bevan maintained a deep interest in the salmon fisheries of Kodiak Island for his entire 50-year professional career as an FRI research biologist and Professor in the College of Fisheries, University of Washington. This region of Alaska and its fishes had fascinated him ever since he intensively studied the sockeye salmon at Karluk as a young biologist during 1948–58. After serving in the military (1942–46) in World War II as an artillery officer in Europe and being awarded the Purple Heart and Bronze Star, Bevan returned to civilian life and studied at the University of Washington, receiving his B.S. degree in fisheries in 1948. That same year, the FRI hired him as a research associate and project leader of the Kodiak Island research program, which then investigated the sockeye salmon at Karluk. He continued to study its sockeye salmon until 1958, after which he shifted his main research interests to the pink salmon

Donald Edward Bevan (1921–1996). (From Stickney 1989, University of Washington, School of Aquatic and Fishery Science, Seattle, WA) of Kodiak Island. His sockeye salmon studies at Karluk were centered on four main subjects: ocean migrations of returning adults, sockeye subpopulations, Karluk Lake's limnology, and a review of historic salmon catches.

The ocean migration routes and home-stream composition of adult sockeye salmon that traveled from the Gulf of Alaska through Kupreanof Strait and along the west coasts of Afognak and Kodiak islands were poorly known in the mid-1940s. In particular, were these west coast sockeye salmon homing just to the Karluk River, to several other local home streams, or to more distant streams on Alaska's mainland? If these salmon were composed of multiple stocks, what proportion went to each home stream and how did the proportions change throughout the run season? Knowledge of these ocean migrations was crucial to the proper management of these salmon, since commercial fishing along the west coast potentially intercepted fish homing to the Karluk River. Indeed, an earlier tagging study at Uganik Bay in 1927 suggested that Karluk River fish were being caught well before they reached the Karluk District (Rich and Morton, 1930).

Bevan's first research project at Karluk (1948–49) investigated the ocean migrations and homing of adult sockeye salmon on the west coast of Kodiak and Afognak islands. In the first year, he tagged nearly 4,000 adult sockeye along the northwest coast of Kodiak Island in June–August 1948 and then searched the area for recoveries (Bevan. 1959, 1962). The vast majority of sockeye tagged between Afognak Island and Cape Karluk, in fact, homed to the Karluk River, with very few recoveries found in distant areas. In the second year, he tagged more than 7,000 fish from four sites on the northwest coast of Kodiak Island in June 1949. Because his results from the previous year showed there was little mixing of sockeye stocks, he used the 1949 tagging and recovery data to estimate Karluk's total sockeye run. He found that the tagging process altered the sockeye's migratory behavior for about 48 hours. Spring-run fish typically reached the Karluk River weir, then located at the lake's outlet 40 km upstream from the ocean, about nine days after they were tagged in the ocean. Bevan (1959) used his 1948–49 tagging studies for his Ph.D. dissertation at the University of Washington.

In 1950 Bevan began a detailed study of sockeye salmon subpopulations at Karluk, gathering run composition data (age, length, and sex) to see how these factors varied seasonally in the commercial fishery and at different spawning sites.[89] Some initial data had already been collected in 1948–49, but he greatly intensified his efforts in 1950–54 and sampled many thousands of adult sockeye at the canneries, river weir, and lake spawning grounds. Even after the FRI curtailed their active studies at Karluk Lake in 1954, Bevan continued to collect this run composition data at Karluk's canneries until 1958. Although it is difficult to find in the Karluk and FRI literature a clear statement of Bevan's goals for these adult sockeye studies, he apparently wanted to document the existence of subpopulations and learn which groups were most heavily harvested in the commercial fishery. Of course Thompson, Bevan's immediate supervisor and mentor, strongly believed that sockeye salmon subpopulations existed. To pursue this idea, Bevan prepared hundreds of length-frequency graphs of sockeye sampled from diverse locations and seasons at Karluk, and, indeed, these showed distinct size differences between spring- and fall-run fish.[90] On an even finer level, sockeye that homed to specific spawning habitats at Karluk Lake also had definite size differences. While previous Karluk biologists (Barnaby, DeLacy, Shuman, and Nelson) knew about these size variations and the seasonal segregation of the sockeye runs, Bevan collected massive amounts of scientific data on these dissimilarities. Unfortunately, he failed to publish his subpopulation evidence, causing later biologists to repeat this work for at least the next decade. At the time, scientific proof of subpopulations in Karluk's sockeye salmon would have been a major accomplishment.

Besides collecting run composition data, Bevan and Walker regularly surveyed the spawning habitats of sockeye salmon at Karluk Lake during 1948–54 (Bevan, 1953; Bevan and Walker, 1954, 1955).[91] During their first inspections in 1948–49, they described the physical features of each spawning tributary and explored upstream to the limits of salmon migration, usually an impassable waterfall or cascading barrier. Typically, they surveyed these habitats every week,

[89] Donald Bevan and Charles Walker assisted each other in the field at Karluk and collaborated on their respective adult and juvenile sockeye studies.

[90] All of Bevan's run composition data on Karluk River sockeye salmon for the period 1948–58 are stored in the FRI Archives, University of Washington, Seattle. These include original data sheets of length and sex, scale impressions, and tapes used in the fish-measuring machines.

[91] Bevan, Donald E. 1951. Karluk Lake stream surveys, 1948–1951. Kodiak Island Research Group, FRI, University of Washington, Seattle, WA. Unpubl. report. 45 p. Located at FRI Archives, University of Washington, Seattle, WA.

Donald Bevan, Karluk Lake, ca. 1952. (Charles E. Walker, Sechelt, BC)

but in some years and locations they made regular inspections every few days. Consequently, they amassed accurate records of when sockeye used the different spawning habitats over the full spawning season. Their surveys revealed a distinct, repeatable pattern of use each year—early-run sockeye spawned in lateral and terminal tributaries, while middle- and late-run sockeye spawned in terminal streams, lake beaches, and the upper Karluk River. This repeatable segregation of sockeye runs by spawning habitat and season implied the existence of subpopulations, but Bevan and Walker presented their survey data in FRI reports without comment.

Bevan and Walker also collected limnological data at Karluk Lake during 1948–54. In the first four years, they simply measured surface water temperatures wherever they traveled, but in the next three years they collected weekly depth profiles of water temperature and transparency in all three of the lake's internal basins (Bevan, 1953; Bevan and Walker, 1954, 1955). They monitored the lake's water level and river's flow in 1952–54 and plotted a discharge-rating curve for the Karluk River (Bevan and Walker, 1955). Also during this period, they recorded climatological data at the lake research station. In 1952 Bevan briefly studied the lake's phytoplankton and zooplankton for a limnology class he took at the University of Washington.[92]

To aid his study of Karluk's sockeye salmon, Bevan collected and microfilmed historic case-pack records from many salmon canneries on Kodiak Island, a job he was uniquely positioned to do since the salmon canning industry funded his research.[93] In 1953 he examined these data to learn if sockeye salmon in the early fishery had been transported to the Karluk canneries from other areas of Kodiak Island and the Alaska Peninsula.[94] If these imports were large, the number of fish attributed to Karluk's run might be erroneously high. Indeed, he found that sockeye caught at Red River, Little River, and Uganik Bay had been transported to Karluk's canneries and added to its catch statistics, especially in June–July, but transfers from Chignik and Alitak were minor. After removing non-Karluk fish from the Karluk catch statistics, the seasonal catch distributions in these early years became more bimodal, though many midseason fish were still present.

The FRI ended its sockeye salmon studies at Karluk Lake after the 1954 field season, but Bevan and Walker spent part of 1955 searching for a suitable counting tower site on the Karluk River. They wanted to briefly operate a counting tower to learn if it was superior to the traditional wooden picket weir. At the time, Thompson and Bevan, and perhaps Walker and Van Cleve, believed that the picket weir at the lake's outlet harmed sockeye adults and fry. Bevan and Walker temporarily operated a counting tower at Karluk Lagoon and the Portage in 1955, but various problems caused them to abandon the idea.

Despite Bevan's many years of research on Karluk's sockeye salmon, he formally published only two papers on the topic: the 1948–1949 tagging study and an analysis and discussion of the historic decline of its sockeye runs (Bevan, 1962; Van Cleve and Bevan, 1973). In the 1973 paper, Bevan provided detailed field knowledge about Karluk's sockeye, while Van Cleve

[92] Bevan, Donald E. 1952. Karluk Lake plankton. Kodiak Island Research, FRI, University of Washington, Seattle, WA. Unpubl. report. Located at FRI Archives, University of Washington, Seattle, WA.

[93] Microfilm rolls containing historic catch records for Karluk area canneries are located in the FRI Archives, Seattle, WA. This microfilm collection contains many records, reports, and statistics, including cannery catches, case packs, APA superintendent's reports, APA hatchery operation reports, USBF and FWS reports, stream surveys, escapement counts, and ocean tagging data.

[94] Bevan, Donald E. 1953. The effect of red salmon catches from nearby streams on the Karluk pack. *In* Rae Duncan, Karluk, Packs of red salmon, 1895–1930. FRI, University of Washington, Seattle, WA (April 21, 1953). Unpubl. report. 26 p. Located at FRI Archives, University of Washington, Seattle, WA.

Donald Bevan (left), Kim Clark (center), and Charles Walker (right), Karluk Lake, ca. 1952. (Charles E. Walker, Sechelt, BC)

had only briefly visited the research station.[95] Besides the two formal papers, Bevan produced over 40 unpublished reports during 1950–85 that contain data on Karluk's salmon. Most of these reports were issued as FRI Circulars that summarized his annual surveys of pink salmon on Kodiak Island.[96] Yet some of the FRI Circulars from the 1950s contain data on Karluk Lake's limnology, stream surveys of spawning sockeye salmon, and daily weather conditions. His 1953 unpublished report on the historic harvests of sockeye salmon from areas near Karluk was insightful for understanding the original run distribution.[97] Sometime after 1955 Bevan and Walker prepared a summary report of all FRI studies on Karluk's sockeye salmon, but the location of this document remains unknown.[98]

It is unclear why Bevan did not produce additional formal publications on Karluk's sockeye salmon, most notable being his subpopulation results of 1950–54. Possibly, he may have been influenced by Thompson, who held high research standards and wanted a complete examination and understanding of a fisheries question before publication. Bevan's heavy work load, which then included his studies of Kodiak Island's pink salmon in 1958 and completion of his Ph.D. dissertation in 1959, may have prevented publication of these earlier studies. Nevertheless, Bevan's research accomplishments on Karluk's sockeye salmon were substantial.

Charles E. Walker

1950–55

Charles Edward Walker spent six field seasons (1950–55) at Karluk as a FRI fishery biologist, his primary interest being the freshwater life stages of juvenile sockeye salmon.[99] He wanted to understand all stages of the early life history of these fishes from the time when alevins or fry emerged from their gravel incubation sites, until several years later when they left the lake as smolts for the ocean. Specifically, Walker wanted to document the time of fry emergence from spawning gravels and their migration to Karluk Lake, the distribution and movements of juveniles in the lake, the sizes and summer growth rates of these lake residents, the effects of environmental factors on juveniles, and the smolt sizes, ages, and times of migration to the ocean. Thompson was eager for these studies because he believed that previous biologists had incorrectly aged the young fish at Karluk, counting false annuli and, thus, recording scale ages that were too old. In fact, the sockeye salmon

[95] Bevan's field research on Karluk River sockeye salmon was greatly aided during 1948–58 by many competent field assistants, including John Bridgeman, Rae Duncan, Allan C. Hartt, Edward S. Iversen, John W. Martin, Wesley J. Morgan, William Mulligan, Wallace H. Noerenberg, Clinton E. Stockley, Fredrik V. Thorsteinson, Charles E. Walker, and Raymond A. Willis.

[96] FRI Circulars were distributed to several fisheries libraries in Alaska and along the Pacific Coast, making them somewhat more accessible to biologists than most unpublished reports.

[97] See footnote 94.

[98] According to Charles Walker, only three copies of this summary report were prepared—one for Bevan, one for Walker, and one for FWS biologist Robert F. Raleigh. Walker and Raleigh's copies have since been lost and the location of Bevan's copy is unknown. A copy of the summary report may exist in Donald E. Bevan's papers, Manuscripts and University Archives Division, University of Washington Libraries, or the FRI Archives. We mention this unpublished report because of its potential importance to the Karluk research history. Letter (10 October 1996) from Charles E. Walker, Sechelt, BC, Canada, to Richard L. Bottorff, South Lake Tahoe, CA.

[99] Walker, Charles E. 1954. Karluk young fish study, 1950–1954. Kodiak Island Research, FRI, University of Washington, Seattle, WA. Unpubl. report. Located at FRI Archives, University of Washington, Seattle, WA.

Charles Edward Walker (1921–). (Charles E. Walker, Sechelt, BC)

smolts at Karluk were then considered to be unusual because they migrated seaward in their third and fourth years, much older than had been recorded for most other sockeye systems.

Walker diligently collected juvenile sockeye salmon from many locations at Karluk for five field seasons (May–October). He collected these fish with a wide range of sampling gear—various lengths and designs of beach seines, dip nets, hand seines, fyke nets, box traps, and trawls. Wherever he went at Karluk Lake, he looked for young sockeye and made notes on their presence, size, schooling behavior, and movements. He tried to collect juveniles from the limnetic zone of Karluk Lake by using a trawl, but the equipment operated poorly and no further attempts were made to sample the open-water habitat. Hence, most of his collections were made in the littoral zone of the lake or the shallow waters of tributary streams and the upper Karluk River.

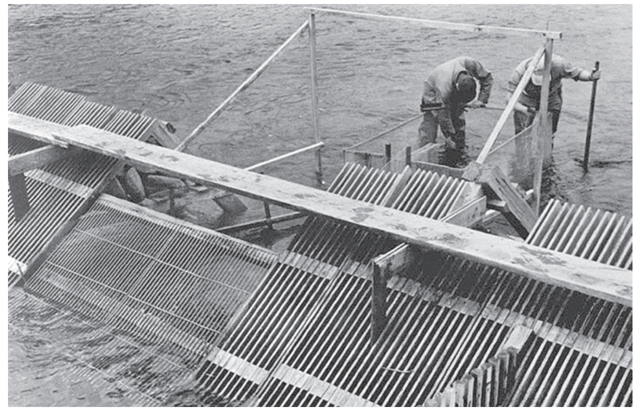
Over the years, he made hundreds of beach seine collections and measured the size of thousands of young sockeye. Juvenile size, plotted as length-frequency diagrams, documented the first summer's growth of newly hatched sockeye fry as their lengths progressively increased from 25–30 mm in May to 50–60 mm in October. Unexpectedly, Walker observed a north–south gradient in juvenile size in Karluk Lake, with larger-sized fish at the north end. Since he rarely caught older and larger juvenile sockeye in the lake's littoral, and failed to sample the limnetic zone, he realized his studies were incomplete. Even with these sampling limitations, his results on the early life stages were significant.

During several of his years at Karluk, Walker made a special effort to observe the spring emergence and migration of sockeye fry between their natal tributary streams and the lake. This part of the sockeye's early life cycle, however, was often difficult for biologists to examine because winter-like conditions often still prevailed into spring and the ice-covered lake prevented boat travel to the tributary streams. When Walker arrived at Karluk Lake on 5 May 1951, the lake was still ice-covered and the fry migration was already underway. In 1953 he successfully measured the fry emergence and migration in two Karluk tributaries; Halfway Creek had one migration period (May), while Canyon Creek had two periods (May and July). The migration patterns of these two streams differed because only spring-run sockeye spawners had used Halfway Creek the previous year, while both spring- and fall-run spawners had used Canyon Creek. That is, both egg deposition and fry migration had similar distributions, but these two events were separated in time by the egg-development period. About 10 months of development separated egg deposition and fry emergence in these tributary creeks. Walker also discovered that newly emerged sockeye fry in tributary creeks migrated downstream to the lake at night.

In direct contrast to the down-migrating fry of tributary creeks, sockeye fry in the upper Karluk River moved upstream toward the lake along both river banks. Further, these young sockeye migrated upstream

Beach seining for sockeye salmon juveniles, Karluk Lake, ca. 1952. (Charles E. Walker, Sechelt, BC)

U.S. Fish and Wildlife Service biologist Carl Abegglen (left) and Fisheries Research Institute biologist Charles Walker (right), Karluk River weir near Karluk Lake's outlet, ca. 1954. (William F. Thompson, Fisheries Research Institute, Seattle, WA)



Sockeye salmon smolt trap, Karluk River weir, 1954. (William F. Thompson, Fisheries Research Institute, Seattle, WA)

in two periods, the first as newly emergent fry (28 mm length) in May and early June and the second as larger fry (47 mm length) in late July through August. The later migration showed that some young sockeye resided in the upper river for several months after emergence before moving to the lake. Fry inhabited the upper Karluk River as far downstream as the Portage, a slower reach of the river having dense growths of aquatic plants. Walker and Bevan expressed concern that the counting weir might impede up-migrating fry from reaching the lake, or perhaps bruise or damage these fish as they passed through the wooden pickets. Eggs spawned in the upper river needed about 8–8.5 months of development until the fry emerged, considerably less time than required in the tributary creeks and lake beaches.

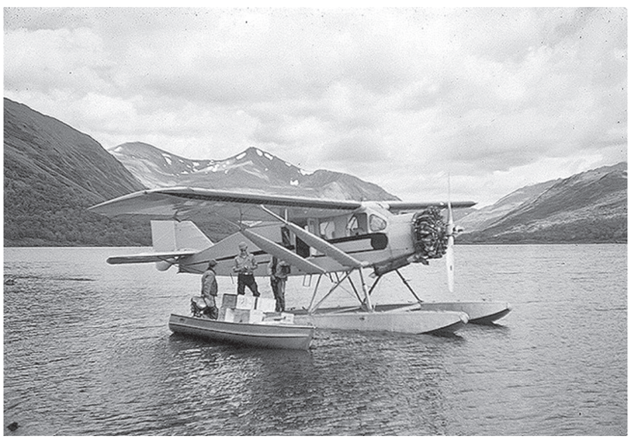
One of Walker's goals of 1950–54 was to measure the composition and total production of sockeye smolts from Karluk Lake. Each spring, he observed these smolts at the lake outlet weir and recorded their downriver migration from late May to mid July. Two size and age groups of smolts predominated (3- and 4-year), with the larger smolts migrating earlier in the season. The overall migration peaked in the first three weeks. Both the FRI and FWS wanted to accurately measure the total smolt out-migration, but this was a daunting task given that adequate collecting gear and statistical protocols had yet to be developed.

In any event, Walker experimented in 1953 with several methods to measure smolt abundance. He first tried to concentrate the smolts into a small area as they left the lake and entered the upper river, and then to count them using a photographic method, but this system worked poorly. Eventually, he built smolt traps into the wooden picket weir to census the migration. The smolts were attracted to the trap opening because some of the wooden pickets were replaced with metal grates; this alteration increased the water flow through that weir section. Walker operated three smolt traps at the Karluk weir in 1954; trap catches gave him a smolt abundance index, but not an exact estimate of the total numbers. Nevertheless, the 1954 smolt traps were an important first step in the eventual development of an accurate method for measuring the total smolt out-migration.

In 1951 as Walker and Bevan watched the commercial beach seines being hauled ashore on Karluk Spit, they were surprised to see many sockeye salmon smolts also being incidentally captured in the nets.[100] They observed that the smolts easily escaped through the

[100] Walker, Charles E., and Donald E. Bevan. ca. 1968. Factors possibly contributing to the condition of the Karluk sockeye salmon run. Unpubl. handwritten report. 18 p. Located at FRI Archives, University of Washington, Seattle, WA.

Weather station, Karluk Lake, ca. 1952. (William F. Thompson, Fisheries Research Institute, Seattle, WA)



Unloading supplies for the research biologists, Karluk Lake, ca. 1952. (Charles E. Walker, Sechelt, BC)

net openings when few adult salmon were caught, but the young fish were unable to escape when many adults were present, the adult bodies blocking their exit. As the seine was hauled onto the beach, the frantically thrashing adult salmon destroyed most of the smolts.

During Walker's years at Karluk, he examined the stomach contents of predatory fishes and birds for juvenile sockeye, though it is unclear how many of these he sampled. He believed that newly emerged sockeye fry suffered substantial fish predation, but that larger juveniles did not; both coho salmon juveniles and charr (he called all charr at Karluk "Dolly Varden") preyed on the young sockeye. He claimed that small charr (90–180 mm) heavily preyed on juvenile sockeye, as did some larger charr in the upper Karluk River. Unexpectedly, he found a few large juvenile sockeye that had preyed on small sockeye. Of the bird stomachs he examined, mergansers rarely preyed on juvenile sockeye, but more commonly ate sticklebacks. While recording these food habits, Walker also examined the internal parasites of juvenile sockeye in 1953 and found roundworms in the pyloric caeca of 2-year fish and tapeworm cysts in the smolts.

In many respects, Walker's studies of Karluk's juvenile sockeye salmon were pioneering. With the exception of the previous smolt-marking studies of 1926–36, little had been previously published about these young salmon. Earlier Karluk biologists certainly realized the importance of understanding the freshwater life stages of sockeye salmon and had collected samples or made field observations, but many life history details remained unknown or unpublished. Walker also failed to publish his studies, but did present his results in several FRI reports[101] that were eventually used and cited by Van Cleve and Bevan (1973). His 1954 report was useful and circulated widely among Karluk's biologists.

Besides his sockeye salmon research, Walker devoted some time to life history studies of threespine sticklebacks at Karluk Lake.[102] Sticklebacks were very abundant lake residents in the 1950s, and Walker consistently caught many more of them in each beach seine than juvenile sockeye. He witnessed the stickleback mass migration in Thumb and O'Malley rivers in May–June and realized that these fish spawned in the shallow tributary lakes (Greenbank and Nelson, 1959). He also collected some large sticklebacks in Karluk Lagoon.[103] Walker was the first biologist since Rutter in 1903 to observe ninespine sticklebacks at Karluk Lake (Evermann and Goldsborough, 1907; Greenbank and Nelson, 1959).

Walker participated in all of the FRI research projects at Karluk Lake, and, in particular, helped Bevan survey the different spawning sites and age the adult

[101] 1) See footnote 99.
2) Walker, Charles E. 1956b. Karluk young fish study—scale graphs, 1950–1954. FRI, University of Washington, Seattle, WA. Unpubl. report.
3) Walker, Charles E. 1959. The enumeration of the Karluk red salmon smolt run in 1954. FRI, University of Washington, Seattle, WA. Unpubl. report. 15 p. All three reports located at FRI Archives, University of Washington, Seattle, WA.

[102] Walker, Charles E. 1954. Comments on the life history of Karluk Lake stickleback (Gasterosteus aculeatus). Kodiak Island Research, FRI, University of Washington, Seattle, WA. Unpubl. report. A reference to this report was located in the FRI Archives card catalogue, University of Washington, Seattle, WA, but we were unable to find a copy.

[103] Memo (20 August 1956) from Philip R. Nelson, Fishery Research Biologist, FWS, Seattle, WA, to John Greenbank, FWS, Juneau, AK. Located at NARA, Anchorage, AK.

sockeye salmon scales.[104] He routinely collected weather data and limnological samples at the lake. Camp Island served as the base of FRI operations in 1950–53, followed by facilities at the Karluk River weir in 1954. Transportation around the lake was by a small Aluma Craft skiff (4.3 m) and 10 horsepower Johnson outboard motor. Supplies were periodically flown to Camp Island via amphibious aircraft. In 1955 Walker and Bevan explored the entire Karluk River for a counting tower site and briefly tested several locations. While exploring the river, Walker added to his observations of sockeye juveniles and sticklebacks, and he collected both species in Karluk Lagoon.

In summary, Walker's studies of the juvenile sockeye salmon at Karluk Lake gave new information on their freshwater life; his work was the first detailed investigation of these young fish. Many previous biologists initiated brief studies of the early life stages, but little such data exists in Karluk's historical literature—surprisingly, more than 50 years after Walker's studies, much remains unknown about the juvenile sockeye salmon of Karluk Lake. Personally, Walker highly valued his years of field research at Karluk, claiming that it "provided me with the greatest learning experience of my life (in biology that is) and the lessons carried me throughout my career".[105]

Richard Van Cleve

Richard Van Cleve (1906–1984). (From Stickney 1989, University of Washington, School of Aquatic and Fishery Science, Seattle, WA)

Richard Van Cleve had a long and distinguished career as a fisheries research biologist and educator at the University of Washington, being appointed Director of the School of Fisheries in 1949 and then Dean of the College of Fisheries in 1958–71. During his many years at the University of Washington, Van Cleve undoubtedly followed the progress of ongoing FRI fisheries studies on Karluk's sockeye salmon and discussed the results with colleagues Thompson, Bevan, and Walker, but there is no evidence that he personally did field research there. Beyond his duties as a Professor of Fisheries, he occasionally served as a consultant to the FWS and BCF on their fisheries research in Alaska, and at times this included their studies of sockeye salmon at Karluk.

Van Cleve's main contribution to the knowledge about Karluk's sockeye salmon was his 1973 scientific publication with Bevan. At the time, Van Cleve was Professor Emeritus at the University of Washington. Their paper discussed the reasons for the historic decline of sockeye salmon runs at Karluk and offered ideas for rehabilitation. It summarized and analyzed both published and unpublished data, much of it from Bevan and Walker's field work of 1948–58, but also data from FWS and BCF biologists. Van Cleve and Bevan emphasized that many subpopulations were present, with perhaps the largest group being the fall-run stock that spawns in the upper river. They believed that the importance of the river-spawning subpopulation to the overall productivity of the Karluk run had not been fully appreciated and suggested protective measures

[104] 1) Walker, Charles E. 1955. Scale analysis, 1948–1953. University of Washington, FRI, Kodiak Island Research. Unpubl. report. Located at FRI Archives, University of Washington, Seattle, WA.
2) Walker, Charles E. 1956. Age analysis of the Karluk red salmon runs, 1922, 1924–1936, and 1952–1955. FRI, University of Washington, Seattle, WA (January 31, 1956). Unpubl. report. 29 p. Located at FRI Archives, University of Washington, Seattle, WA.

[105] Letter (5 April 1998) from Charles E. Walker, Sechelt, BC, Canada, to Richard L. Bottorff, South Lake Tahoe, CA.

for these fish. Further, they recommended that research on Karluk's sockeye salmon be curtailed and claimed that these activities harmed the productive midsummer runs that had already been depleted by heavy commercial fishing. Their recommendation to enhance midseason runs apparently had little impact on the ADFG fishery managers, who faced the reality of distinct spring and fall sockeye salmon runs.

When Van Cleve and Bevan's paper was published in 1973, the Karluk River weir was located just below the lake's outlet, and fall-run sockeye spawned in the river above and below the weir. Van Cleve and Bevan believed that the weir harmed the sockeye salmon by 1) restricting the natural to-and-fro homing behavior of fall-run river spawners, 2) slowing the downstream migration of smolts, and 3) impeding the upstream migration of newly emerged fry to the lake. Because of these potentially serious impediments, they recommended complete removal of the weir in order to aid rehabilitation of the sockeye salmon run. Thompson (1950) had previously argued that weirs interfered with salmon homing behavior, and Bevan and Walker searched the Karluk River in 1955 for a counting tower site to replace the traditional picket weir. During a brief visit to the Karluk research station in July 1957, Van Cleve expressed his concerns about the picket weir to the BCF field biologists and recommended the weir's removal.[106] His visit and recommendation convinced the BCF to substitute a counting tower for the wooden picket weir in 1958–59, though they soon returned to a picket weir. Many years later, Van Cleve and Bevan's 1973 paper helped convince the ADFG to move the 1976 weir to the lower Karluk River and away from the spawning habitat of fall-run sockeye salmon. This action returned the upper river to its natural, unfettered spawning condition.

It is unclear what stimulated Van Cleve's interest in Karluk's sockeye salmon since he never studied them in the field and only visited the FRI research station a few times. Perhaps it was his regular contact with Thompson, Bevan, and Walker and his desire to solve the long-standing fisheries question of what had caused the sockeye salmon decline at Karluk. He must have followed the progress of sockeye research by the FRI and FWS field biologists in the late 1940s and early 1950s. The 1973 paper was the culmination of views held for at least 20 years; many of the ideas likely originated from Thompson and were supported by Bevan and Walker's field studies.

George A. Rounsefell

1951–58

George Armytage Rounsefell worked as a USBF and FWS fishery scientist for 39 years (1925–63), followed by another 13 years as Professor of Marine Science at the University of Alabama (Rounsefell, 1977; Skud and Everhart, 1977). His interests in fisheries and marine science ranged over many topics and fish species, including Pacific salmon. Of his 89 career publications, nine dealt with Pacific salmon and three discussed or presented data on Karluk's sockeye salmon. Though Rounsefell never did field research at Karluk, he summarized and analyzed data collected by other USBF, FWS, and BCF fishery biologists.

Well before his direct involvement with the sockeye salmon research data from Karluk, Rounsefell followed the progress of the long-term field studies there through his professional contacts with fellow fishery biologists and former classmates of Stanford University. He was familiar with Alaska and its fisheries, hav-

George Armytage Rounsefell (1905–1976). (Brigham Collection BRI #845, Historical Photo Collection, Northeast Fisheries Science Center, National Marine Fisheries Service, Woods Hole, MA)

[106] John B. Owen 1957 notebook. Original notebook from the personal papers of John B. Owen, Grand Forks, ND; notebook to be donated to NARA, Anchorage, AK.

ing studied its herring during his early career with the USBF. As Acting Director of the USBF Fisheries Biological Station in Seattle in 1934, he regularly reported to higher officials on the progress of the sockeye studies at Karluk. These studies eventually came under his direct supervision in 1947–48 when he became the FWS Chief of the Branch of Anadromous Fisheries, and in that capacity he briefly visited the Karluk Lake research station in August 1947 to discuss the field work with Shuman.[107] Consequently, for many years, Rounsefell knew about the declining sockeye salmon runs and the attempts to find the cause. He was aware of the long-term research program at Karluk and the plans for future studies.

Of Rounsefell's three scientific publications on Karluk's sockeye salmon, his 1958 paper, which analyzed and discussed the causes of the declining runs, was a significant accomplishment that focused the attention of many fishery biologists on this productive salmon system. This paper indelibly linked his name to Karluk's sockeye salmon and altered the direction of field research there for many years. Yet it is unclear exactly when or why Rounsefell began his independent analysis of Karluk's sockeye salmon, though this occurred sometime in 1949–52 after Lionel Walford, FWS Director of Research, gave him the assignment. Obviously, Walford wanted FWS biologists to publish more papers from the large mass of data they had already collected. In any event, by December 1952 Rounsefell produced a preliminary manuscript, "Population dynamics of the sockeye salmon, *Oncorhynchus nerka,* of Karluk River, Alaska," with Shuman listed as junior author.[108] The 1952 manuscript had many topics of interest to fishery biologists; its major subject headings were:

The Problem
Normal seasonal occurrence of the runs
Age composition of the runs
Relations of migrant age and total age with the time of the runs
Estimation of numbers and age composition of the runs
Relation between season of smolt migration and ocean age
Spawning potential
  Fecundity
  Sex ratio
Seasonal trends in size at maturity
Relation of ocean temperature to size at maturity
Season of ocean growth
Relation of ocean growth seasons to size at maturity
Relation of ocean growth seasons to sex ratio
Fecundity of various age groups
Seasonal distribution of the escapement
Factors affecting the size of smolts
Relation between escapement, size of smolts, and returns
Interpretation of relations between escapements and returns
Conclusions
Recommendations
References

Shuman critically reviewed the manuscript, declined joint authorship, and recommended that it not be published. Ralph Silliman, FWS Chief of the Section of Anadromous Fisheries, also reviewed the manuscript and questioned the data analysis:

> My general comment is that the data have been almost over-analyzed. The extreme complexity of the analysis, the omission of the data which do not conform, and the use of highly derived estimates detract from the confidence which might be placed in the results for application to fishery regulation.[109]

Rounsefell continued to analyze the sockeye salmon data and revised the 1952 manuscript over the next 4–5 years until it was finally published in 1958.[110] By then the scientific paper, which still focused on the causes for the long-term decline of the sockeye salmon runs, had grown to over 80 pages, with many tables, graphs, statistics, and appendices. To restore Karluk's sockeye salmon runs, Rounsefell recommended eliminating predatory fishes, enhancing the midseason run, restoring natural

[107] See footnote 74.
[108] See footnote 80.

[109] Memo (6 March 1953) from Ralph P. Silliman, Chief, Section of Anadromous Fisheries, to Chief, Pacific Salmon Investigations. Located at ABL, Auke Bay, AK.
[110] A historical sidelight exists about Rounsefell's publications on Karluk's sockeye salmon. He prepared his 1952 Karluk manuscript while stationed at the FWS Woods Hole Laboratory, MA. Upon completing the manuscript and sending Shuman a review copy, Rounsefell departed for two years to Turkey as Leader of the Fishery Mission, Food and Agriculture Organization, United Nations. In early 1953, Ralph Silliman, FWS Chief of the Section of Anadromous Fisheries, sent a letter to FWS Chief of North Atlantic Fishery Investigations requesting return of the Karluk research data possessed by Rounsefell. The ultimate disposition of these important Karluk data is unknown. The Karluk research data to be returned included: 1) pink salmon escapements, 2) smolt migration data (1937–49), 3) Karluk Lake water levels (1931–50), 4) Karluk Lake thermocline charts (1921–47), 5) Kodiak weather records (1881–1951), 6) sockeye salmon escapements, catch, and total run (1937–50), 7) sockeye salmon age compositions and return from escapements, and 8) Karluk Lake weather records (1921–48).

cycles of abundance, fertilizing Karluk Lake, improving spawning habitats, and increasing egg deposition.[111]

Although the large size, format, and statistical analyses made Rounsefell's 1958 paper difficult for many fishery biologists to digest, it nevertheless had a great impact upon those involved in sockeye salmon research at Karluk. The paper received close scrutiny and generated heated discussions within the FWS and BCF, and was even the subject of departmental seminars and conferences as biologists and managers evaluated the paper's conclusions and debated how the research program should be altered. These discussions began within the FWS even before the paper's formal publication, as preliminary review copies circulated within the agency. Donald McKernan, FWS Administrator of Alaska Commercial Fisheries, stated in 1956 that Rounsefell's "findings are quite radical," but McKernan altered the management policies at Karluk to follow some of these new recommendations.[112]

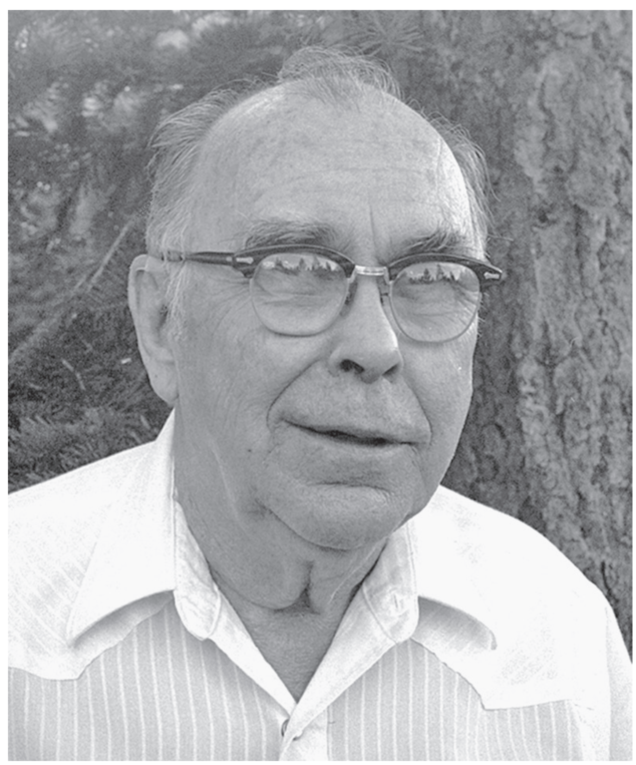
In challenging the then prevailing ideas about Karluk's sockeye salmon and in stimulating future research, Rounsefell's 1958 paper was a success. His paper intensified discussions about these salmon and motivated fishery biologists to either pursue some of the new ideas or design studies to disprove some of Rounsefell's conclusions. In particular, some biologists strongly disagreed with his claim that Karluk's sockeye salmon run was one population. Instead, they knew, after years of field observations and tagging studies, that at least the spring and fall runs were distinct subpopulations. And they suspected that even finer distinctions might exist for fish that appeared to home to specific spawning sites. To conclusively prove their point and highlight Rounsefell's error, several biologists actively pursued subpopulation studies in the years after the 1958 paper; this work continued until the existence of discrete groups was proven. Further, several decades after the 1958 publication, additional errors were found in Rounsefell's analysis, such as the influence of pink salmon on sockeye salmon, the energetics of juvenile sockeye, and the relative importance of different phosphorus nutrient sources to Karluk Lake (Koenings and Burkett, 1987b; Schmidt et al., 1998). Significantly, corrections of these inaccuracies changed the paper's conclusions. For example, when errors were corrected in the phosphorus inputs to Karluk Lake, it became clear that salmon-carcass nutrients were much more important to the lake's fertility than Rounsefell had originally determined.

Rounsefell published two other scientific papers dealing with Karluk's sockeye salmon (Rounsefell, 1957, 1973). His 1957 paper on sockeye salmon fecundity was based on data collected by Rich in 1926, DeLacy in 1938–41, and Shuman in 1943. His 1973 paper responded to Van Cleve and Bevan's (1973) analysis of Karluk's sockeye salmon and defended the conclusions of his 1958 paper.

John B. Owen

1956–59

John Baxter Owen, fresh from earning his Ph.D. at Iowa State University, was hired by the BCF in late 1956 to lead the sockeye salmon research program at Karluk after Nelson was promoted to a new position in Washington, DC. Just before starting his official duties, Owen visited the research station at Karluk



John Baxter Owen (1918–). (Richard Lee Bottorff, South Lake Tahoe, CA)

[111] In 1956 Rounsefell also proposed a novel experiment to increase sockeye salmon egg production by poisoning all leeches and oligochaete worms inhabiting the spawning substrates of a Karluk tributary. These invertebrates were thought to destroy many buried salmon eggs. FWS notes (19 January 1956) on a conference with George Rounsefell. Located at NARA, Anchorage, AK.

[112] Letter (12 March 1956) from Donald L. McKernan, Administrator of Alaska Commercial Fisheries, Juneau, to Milton E. Brooding, Chairman, International North Pacific Fisheries Commission, San Francisco. Located at ABL, Auke Bay, AK.

Lake in July 1956 and helped with the last fertilization of Bare Lake. As a BCF biologist, he worked for two field seasons at Karluk (1957–58) and started several new studies of sockeye salmon.

Owen joined the BCF at a unique time in Karluk's fisheries research history. For the previous 10 years, research had focused on the possibility of fertilizing Karluk Lake to enhance its production of juvenile sockeye, and the enrichment experiment at Bare Lake was intended to test this rehabilitation idea. By 1956 Bare Lake had been fertilized for seven years and the nutrient additions had produced some positive results—the size of sockeye smolts and the smolt-to-adult ocean survivals had increased—but the abundance of returning adults seemed to have been unaffected.

Because of the positive results, considerable support still existed within the BCF to fertilize Karluk Lake. Nevertheless, by 1956 BCF officials and biologists were reviewing pre-publication copies of Rounsefell's large paper on Karluk's sockeye salmon. Rounsefell also recommended that Karluk Lake be fertilized, but at the same time he questioned the theory of declining lake fertility and discounted the potential effectiveness of any enrichment. He instead believed that predatory fishes would quickly increase in abundance and absorb any temporary benefits of fertilization. Further, he questioned if the experimental results from Bare Lake, a small shallow body of water, could be applied to a large stratified lake such as Karluk. Since no one could persuasively answer these questions, his arguments added uncertainty to the lake fertilization idea. Owen and other fishery biologists accepted the idea that fertilization may be ineffective in restoring Karluk's sockeye salmon run, and this caused them to pursue some of Rounsefell's new research ideas in the 1957 field season. Consequently, the BCF research program of 1957 included both post-fertilization studies of Bare Lake and new research ideas at Karluk Lake.

U.S. Bureau of Commercial Fisheries employees (from left) George Harry, John Owen, Ted Merrell, and Charles Conkle, Karluk Lake field laboratory, Camp Island, 1958. (Ted Merrell, Auke Bay, AK)


U.S. Bureau of Commercial Fisheries biologists Charles Conkle (left) and John Owen (right), Karluk Lake, 1957. (Auke Bay Laboratory, Auke Bay, AK)

The 1957 field season was crucially important for Owen's understanding of Karluk's sockeye salmon and the research ideas he pursued. When he first arrived at the Karluk field station, Owen knew of Rounsefell's belief that its sockeye salmon were one population, but he quickly realized that this idea was mistaken. Instead, he found that there were many distinct subpopulations, each with its own spawning time and habitat. He learned of this heterogeneity by regularly visiting the spawning areas and watching the fish segregate to specific sites as the season progressed. His assistant, Charles Y. Conkle, was instrumental in recognizing these subpopulations, having worked at Karluk since 1955 and knowing just when each sockeye run appeared at different spawning sites.

Of course, Owen and Conkle were only the latest of many previous biologists to understand that distinct run components used the spawning grounds in a repeatable sequence each year. Yet surprisingly, no one had published this evidence. If subpopulations were present, Owen began to wonder if certain spawning groups and habitats differed in their ability to produce sockeye eggs and fry. And he considered the possibility that the historic decline of Karluk's sockeye was caused by excessive commercial fishing on the most productive subpopulations.[113] Thus, much of Owen's research at Karluk focused on the productive qualities of the dif-

[113] Letter (30 September 1957) from John B. Owen, FWS, Karluk Lake, AK, to W. F. Royce, FWS, Juneau, AK. Located at NARA, Anchorage, AK.

ferent sockeye salmon subpopulations and their spawning habitats.

Owen's reluctance to pursue the artificial fertilization of Karluk Lake and his disagreement with Rounsefell over sockeye subpopulations made this an uncertain and complicated time for deciding on the proper direction of the Karluk research program. Some BCF officials wanted to continue the fertilization work, but Rounsefell discouraged this. Conversely, some BCF officials discouraged subpopulation research since it conflicted with Rounsefell's belief in one population. This situation was particularly difficult for Owen, being a newly hired and untested young biologist, while Rounsefell was a respected senior scientist within the BCF.

Even with these conflicts and uncertainties, Owen managed to initiate new studies at Karluk in 1957–59, particularly on sockeye spawning habitats and their different abilities to incubate eggs and produce fry.[114] He separated the spawning habitats at Karluk Lake into four categories—lateral tributary streams, terminal tributary streams, lake beaches, and upper 5 km of the Karluk River (Owen et al., 1962). Apparently, Owen was the first biologist to use the terms "lateral" and "terminal" to distinguish the two primary types of spawning streams entering Karluk Lake. Further, he measured the areas of all sockeye salmon spawning habitats in the Karluk system and described the stream gradients and substrate compositions. Owen and his field crew regularly surveyed all of the spawning habitats in 1957–59 and documented a similar pattern of spawning use each year.

Owen also studied the distribution and behavior of sockeye salmon that spawned in several creeks at Karluk Lake in 1957–58. After adult sockeye were tagged at the lake, Owen closely monitored the movements and spawning status of these fish.[115] This study provided new information on the longevity of spawning salmon, their diurnal movements into and from spawning creeks, how quickly redds were established and eggs were deposited, and the extent of bear predation. In one instance, his field crew continuously monitored the movements and behavior of a single female sockeye salmon for three days until she spawned. Spring-run sockeye quickly established redds, spawned, and disappeared from the creeks, while later spawners had longer lives and spawning periods. The disappearance of tagged sockeye salmon varied seasonally with bear predation. Owen tried unsuccessfully to measure the total egg deposition of sockeye salmon in several creeks in 1957, but accomplished this task in 1958 with the use of FRI's egg pump. Sockeye salmon buried their eggs much deeper in terminal streams than in lateral streams. In another study, he used spawning pens to accurately assess the fate of sockeye eggs in different habitats, but this effort had limited success. [116]

Although Owen questioned the need to fertilize Karluk Lake, he nevertheless studied its limnology and several tributaries in 1958 to learn if significant declines had occurred in the nutrient levels and productivity since 1927. In fact, a few limnological changes had occurred in the 30 years, but overall most nutrient concentrations were unchanged. This apparent long-term stability in nutrients indicated to him that the lake's fertility had not declined, a conclusion that reinforced his belief that fertilization of Karluk Lake was unnecessary. The results also supported Rounsefell's skepticism of this rehabilitation idea.

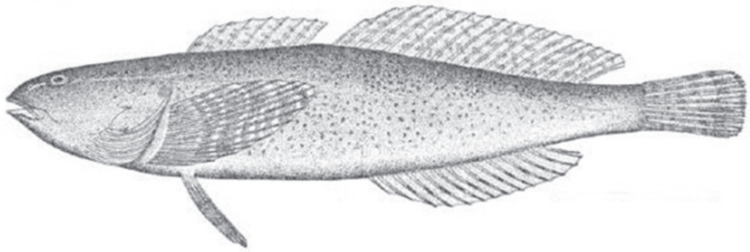
During Owen's tenure as project leader, several assistants did semi-independent studies of sockeye salmon and other fishes at Karluk Lake. For example, Conkle studied sockeye salmon fecundity in 1958 and published the results, along with similar data from Brooks Lake, Alaska (Hartman and Conkle, 1960). This paper described the relationship between female size and fecundity and noted that larger sockeye females had more eggs in the left ovary than in the right ovary. When the 1958 fecundity data were compared with earlier periods, adult female size and fecundity appeared to have experienced a long-term decline. In 1957, BCF biologist John T. Greenbank studied the life history of coastrange sculpins (Greenbank, 1957, 1966) and the food habits of Dolly Varden at Karluk Lake.[117] Since

[114] 1) Owen was greatly aided with the Karluk field studies by his two BCF assistants, Charles Y. Conkle and Robert F. Raleigh, and by many temporary personnel.
2) Owen, John B. 1958. Red salmon survival studies in Karluk Lake, Kodiak Island, 1957. Field Report. Salmon survival investigations. BCF, Alaska Region (February 18, 1958). Unpubl. report. 27 p. Located at ABL Office Files, Auke Bay, AK.

[115] 1) Letter (13 July 1957) from John B. Owen, Fishery Research Biologist, to W. F. Royce, FWS, Juneau, AK. Located at NARA, Anchorage, AK.
2) Letter (28 October 1969) from John B. Owen, Associate Professor, University of North Dakota, Grand Forks, ND, to Ben Drucker, Supervisor, Karluk Lake Research Station, Auke Bay, AK. Located at NARA, Anchorage, AK.

[116] Owen, John B. 1958. Karluk Lake weekly reports (22 June–27 September 1958). FWS, Karluk Lake, AK. 8 unpubl. reports. Located at NARA, Anchorage, AK.

[117] Greenbank, John T. 1957. Dolly Varden studies, Karluk Lake, 1957. Field Report (1 October 1957). Unpubl. report. 11 p. Located at NARA, Anchorage, AK.



Coastrange sculpin. (Drawing by Albertus H. Baldwin, from Evermann and Goldsborough, 1907.)

sculpins consumed many sockeye salmon eggs, Owen wondered if these small fishes might reduce fry production. To answer this question, he proposed a novel field experiment whereby sculpins would be excluded from a spawning creek to see if fry numbers increased, but this idea was never tested.

Each year Owen and his field crew continued with the routine tasks of collecting run composition data from sockeye adults and smolts and counting salmon through the weir. They operated the standard wooden picket weir in 1957 and a counting tower in 1958, a major new challenge for the biologists. Their attempt to measure the total smolt out-migration was unsuccessful in 1958 because of frustrating problems with the traps. Storm water and floating debris in the river damaged the traps and the smolts avoided them.

Perhaps Owen's most enduring achievement from his time at Karluk was his 1962 report that reviewed the research literature and concisely summarized the major conclusions then known about Karluk's sockeye salmon (Owen et al., 1962). He worked on this report during most of his years at Karluk and for some time afterward, preparing it for publication with co-authors Conkle and Raleigh. The report included their 1957–59 field results and discussed the possible factors that affected sockeye salmon production. They emphasized for the Karluk ecosystem the many sockeye subpopulations present, the different reproductive potentials of the many age groups, the distinct productive qualities of different spawning habitats, and the possibility that commercial fishing had altered sockeye abundance by disproportionately harvesting certain age groups and subpopulations. The BCF reviewed the manuscript for several years and eventually issued it as an ABL Manuscript Report. Though not a formal publication, the report was subsequently read, appreciated, and cited well beyond the BCF over the next 30 years, and in many respects it was functionally equivalent to a formal scientific paper. Many recent fishery biologists have stated that Owen's report was seminal to their understanding of Karluk's sockeye salmon, even though they disagreed with him on some conclusions. These positive responses demonstrated the report's long-term value.

At least four reasons explain the wide acceptance of Owen's unpublished report. First, it concisely summarized the established biological facts about Karluk's sockeye salmon. Because research had extended over many years and dealt with many complex topics, a periodic review of current knowledge is always beneficial to biologists. Second, Owen emphasized the existence of sockeye subpopulations, directly opposite to Rounsefell's idea of one population. This helped to shift the research effort in the 1960s toward finding scientific evidence of these subpopulations. Third, the report described the different types of spawning habitats in the Karluk system and how the returning sockeye used these in a similar seasonal sequence each year. Previous biologists (USBF, FWS, BCF, and FRI) also knew how returning sockeye dispersed to the spawning habitats, but Owen was the first to succinctly present this information. This repeatable spawning pattern each year was strong evidence of subpopulation differences. Fourth, the report summarized and related all of the run composition data, including sockeye salmon age, sex ratio, size, fecundity, and migration season. This large mass of salmon statistics, plus their seasonal variation, can overwhelm non-experts. Yet Owen condensed these data and interrelations into a simple table and discussed how these factors affected the sockeye salmon's reproductive potential. In summary, Owen's report provided biologists with a thoughtful and useful analysis of Karluk's sockeye salmon.

Robert F. Raleigh

1956–62

Robert Franklin Raleigh worked as a BCF fishery biologist at Karluk and Bare lakes for six field seasons in 1956–62. During this time, the research program transitioned from studying lake fertilization to researching sockeye salmon subpopulations. Raleigh spent the early part of his first field season assisting Nelson with the Bare Lake study and then temporarily led the proj-

Robert Franklin Raleigh (1926–   ). (Robert F. Raleigh, Saint George, UT)

ect when Nelson transferred to Washington, DC, in June 1956. After Owen joined the BCF as Karluk's research supervisor in December 1956, Raleigh assisted him in 1957–58.

Both Raleigh and Conkle proved to be particularly capable field assistants to the research leaders because of their previous field experience at Karluk and Bare lakes during 1955–58. By 1957 they knew the field operations at both lakes, often assumed responsibility for some of the studies, and provided leadership during Nelson and Owen's absence.

Raleigh temporarily left the Karluk project in mid 1957 to study the subsistence use of salmon in western Alaska (between Cape Newenham and Point Hope) and returned to the Karluk studies in 1958. Raleigh led the research program at Karluk staring in early 1959, a position he held for three years until early spring 1962.[118] He completed his B.S. (1954) and M.S. (1960) degrees at Utah State University and Ph.D. degree (1969) at the University of Idaho.

During the time that Raleigh worked at Karluk Lake, Alaska gained statehood (on 3 January 1959) and assumed full responsibility for the management of its fisheries (on 1 January 1960). Immediately, the State of Alaska made fish traps an illegal method for capturing salmon in the commercial fishery. Despite this change from federal to state authority for Alaska's fisheries, the BCF continued its long-term research program on Karluk's sockeye salmon for the next decade.

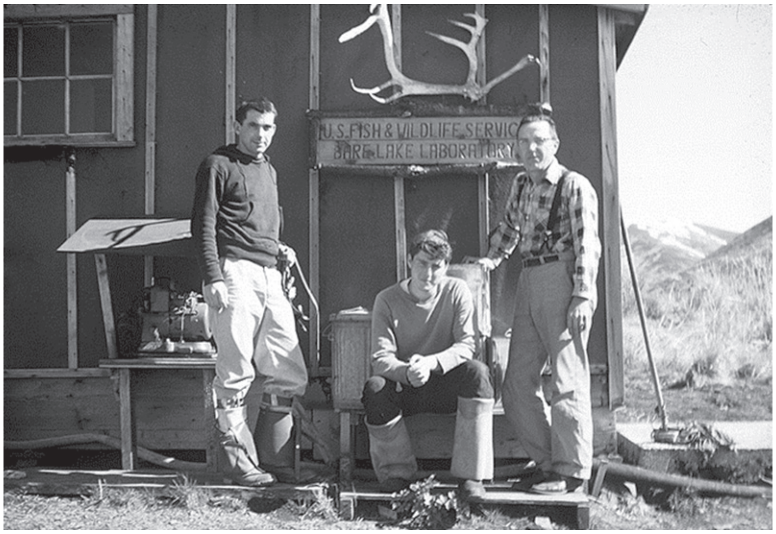
Raleigh helped Nelson complete the final fertilization of Bare Lake in 1956 and then continued post-fertilization studies on the lake until his last field season in 1961. In 1957 he studied the zooplankton of Bare Lake to learn how the previous seven years of fertilization had affected this group; he used this research for his M.S. thesis at Utah State University (Raleigh, 1960, 1963). Zooplankton abundance changed little in the first few years of fertilization, but had increased threefold by 1957. Surprisingly, the abundance of many zooplankton taxa varied with lake depth, even though Bare Lake normally was thermally unstratified. Since little post-fertilization work was done at Bare Lake in 1958, the actual number of out-migrating smolts and returning sockeye adults that year is uncertain, but smolt abundance appeared to greatly decline two years after the last fertilization. During 1959–61 Raleigh and his assistants annually collected run composition data and made detailed counts of the sockeye salmon smolts and adults. They also estimated the Dolly Varden population in Bare Lake. Following Raleigh's last field season in 1961, no further post-fertilization studies were done at Bare Lake.

Raleigh's research at Karluk was influenced by his collaborations with Owen and Conkle (Owen et al., 1962) and by Rounsefell's (1958) paper. In particular, he wanted to study two of Rounsefell's conclusions—that Karluk's sockeye run was a single population and that midseason spawners in the upper Karluk River were strays. Raleigh believed that subpopulations existed and that midseason river spawners were significant. He was opposed to fertilizing Karluk Lake because its smolts continued to be larger than those found in other river-lake systems and the Bare Lake fertilization study was incomplete.

In an early study of sockeye salmon subpopulations in 1959, Conkle and Raleigh examined the age, size, and morphology of adults at different spawning sites of Karluk Lake.[119] They found significant differences in adult size between sites; this indicated non-random use of the available habitats and the presence of subpopulations.

[118] Charles York Conkle served as Raleigh's assistant at Karluk in 1959–60, and Benson Drucker assisted in 1961.

[119] Conkle, Charles Y., and Robert F. Raleigh. 1960. Red salmon investigations. Field operations report, 1959. Sockeye salmon survival studies at Karluk Lake, Kodiak Island. BCF, Alaska Region (April 27, 1960). Unpubl. report. 20 p. Located at ABL Office Files, Auke Bay, AK.

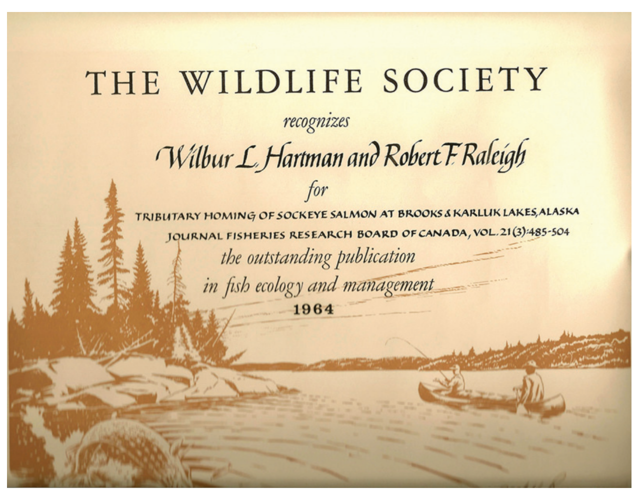


U.S. Bureau of Commerical Fisheries biologists Robert F. Raleigh (center) and Philip R. Nelson (right), Bare Lake, 1956. (Robert F. Raleigh, Saint George, UT)

Exploring the subpopulation idea further, Raleigh and BCF fishery biologist Wilbur L. Hartman conducted independent studies of tributary homing behavior by adult sockeye salmon at Karluk and Brooks lakes in 1960–61, with Raleigh doing the work at Karluk (Hartman and Raleigh, 1964). They found that rather than dispersing randomly to available spawning sites, sockeye had distinct preferences and tenaciously sought out specific lake tributaries. If blocked from entering their chosen tributary, the salmon continued to seek access until they died, rather than using an alternative spawning site. Further, when adult sockeye first entered Karluk Lake, they could not be conditioned to accept an alternative spawning creek. These impressive results confirmed that Karluk's sockeye salmon arrived at the lake spawning grounds as distinct subpopulations. Although previous biologists at Karluk had recognized the distinctiveness of spring- and fall-run sockeye, Raleigh and Hartman documented a much finer segregation that was determined by homing to specific spawning sites. The Wildlife Society honored Raleigh and Hartman for these studies, giving them their annual award for the best scientific paper in 1964.

Perhaps Raleigh's most significant research on Karluk's sockeye salmon was his innovative laboratory experiments on the migratory behavior of newly emerged fry (Raleigh, 1967, 1969). Sockeye fry from lateral and terminal streams were known to move downstream into Karluk Lake each spring, but it was less clear where the fry went that emerged in the upper Karluk River. That is, did these river fry inherently know that their nursery lake lay upstream and that they must swim against the river's current to reach the lake?

In 1958 Raleigh and Conkle arrived at Karluk Lake in early April to observe the spring fry migration. In a lateral stream, fry were absent during daylight hours, but they began migrating downstream at dusk and continued at night for about four hours. By operating upstream and downstream traps in the upper river, they discovered that fry moved slowly upstream along the riverbanks toward the lake, even in daylight, and that the entire migration lasted several weeks longer than that in lateral streams. Thus, newly emerged fry at Karluk had distinctly different responses to the direction of water flow depending on their natal site. These field observations formed the basis of Raleigh's 1965–66 laboratory experiments at the University of Idaho, where



The Wildlife Society award for outstanding publication in fish ecology and management given to Wilbur L. Hartman and Robert F. Raleigh in 1964 for their research on tributary homing of sockeye salmon at Brooks and Karluk lakes, Alaska. (Robert F. Raleigh, Saint George, UT)

Karluk River weir (center), counting huts (left), and smolt traps (right), 1957. (Robert F. Raleigh, Saint George, UT)

he tested whether the direction of fry migration had a genetic basis. In the experiments, he collected sockeye eggs from three different spawning habitats at Karluk—a lake tributary, a lake beach, and the upper Karluk River. He incubated the eggs under identical conditions at an Idaho fish hatchery. Fry produced from these Karluk eggs were placed in an artificial stream and their upstream or downstream movements recorded. Nearly all fry from lake tributaries moved downstream during the night, while most fry from the upper river moved upstream during both day and night. The different migration directions were highly significant and Raleigh concluded they were genetically determined. His experiments showed, once again, the vital importance of subpopulation differences in Karluk's sockeye salmon. He used the fry migration experiments as part of his Ph.D. dissertation at the University of Idaho (Raleigh, 1969).

Raleigh's laboratory experiments also showed that some newly emerged fry from the upper river initially moved downstream, seemingly in the wrong direction if they were to rear in the upstream nursery lake. This confusing result may be explained by Walker's studies of fry migration in the upper Karluk River during 1950–53. Walker recorded two waves of upstream fry migration in the upper river, one in the spring by smaller fry and another in late summer by larger fry.[120] This suggests that upon emerging from the river gravels, some fry proceeded directly to Karluk Lake, while others spent several months rearing in the upper river and its side sloughs before moving to the lake.

In 1962 Raleigh co-authored an important report with Owen and Conkle on Karluk's sockeye salmon, showing the existence of subpopulations that had different productive capacities (Owen et al., 1962). Raleigh later expanded on this report and prepared a new manuscript with Owen in 1969 ("Heterogeneity, homing, and selective mortality of sockeye salmon in Karluk River, Alaska") that discussed the discrete spawning subpopulations and the effects of selective fishing mortality.[121] Both reports documented that adult sockeye salmon homed to specific spawning sites at Karluk Lake in a predictable seasonal pattern each year, and that the midseason run had a higher production potential than the early and late runs. The presence of these many subpopulations suggested that commercial fishing should be spread over the entire run rather than being concentrated on the midseason, as had often occurred in the past. Unfortunately, neither of these two reports was ever formally published.

Each spring huge numbers of sockeye salmon smolts leave Karluk Lake and migrate downriver to the ocean. For many decades, biologists had wanted to accurately measure the total out-migration of smolts, but for various reasons had been frustrated by the task. Smolt out-migration was a valuable statistic to know because it integrated all of the many factors that influenced the freshwater growth and survival of juveniles. This annual output of smolts, so important to future adult returns, was also a measure of the overall productivity of Karluk Lake. Biologists experimented with different methods to measure smolt out-migration during 1954–57, but their efforts had only

[120] See footnote 99.

[121] Raleigh, Robert F., and John B. Owen. 1969. Heterogeneity, homing, and selective mortality of sockeye salmon in Karluk River, Alaska. BCF, Biological Laboratory, Seattle, WA. Unpubl. report. 25 p. Copy in personal papers of Robert F. Raleigh, Council, ID.

U.S. Bureau of Commercial Fisheries laboratory, Camp Island, Karluk Lake, ca. 1961. (Robert F. Raleigh, Saint George, UT)

U.S. Bureau of Commercial Fisheries, Auke Bay Biological Laboratory, Auke Bay, Alaska, ca. 1963. (Richard Gard, Auke Bay, AK)

gained them a relative index of abundance. Raleigh devoted much effort during his Karluk years to design a statistically reliable way to measure smolt out-migration. Though unsuccessful in 1958, he experimented with different methods in 1960 and finally succeeded in 1961 by operating smolt traps at the weir using a Latin Square statistical design. Because sockeye smolts detected slight differences in water flow, much time was devoted to observing their migratory behaviors and designing an effective trap.

Raleigh participated in many other projects at Karluk Lake, some becoming routine tasks of the research station, such as counting sockeye escapements, collecting run composition data (scales, sex, size) from sockeye adults and smolts, surveying the spawning habitats, and measuring weather data. In 1958–59 Raleigh helped build and operate the counting tower that temporarily replaced the picket weir on the upper river. Also in 1959 Raleigh used SCUBA to observe sockeye smolts migrating in the upper river and adults spawning at lake beaches.[122] He saw that the eggs of beach spawning sockeye were eaten by Arctic charr, coho salmon juveniles, and sockeye salmon grilse, but not by sticklebacks. He observed the male-female behavioral sequence that synchronized the spawning act of sockeye salmon and noted the actions of participating male grilse. Raleigh also discovered that sockeye spawning behavior differed in the lateral and terminal streams of Karluk Lake. At lateral streams, spawners entered in the morning, some dug redds and spawned, but by mid-afternoon all males and unspawned females returned to the lake for the night. Spawned females guarded their redds. At terminal streams, spawners remained there until they died. Raleigh at-

[122] BCF. 1958–1960. Monthly research report. BCF, Alaska Region. Unpubl. reports. Located at ABL Office Files, Auke Bay, AK.

tributed these two behaviors to the different vulnerabilities of spawners to nocturnal bear predation.

Besides his numerous research projects, Raleigh helped to develop the BCF research facilities on Camp Island during 1959–1961. Prefabricated materials for a new laboratory building and Pan Abode living quarters were flown by helicopter to Karluk Lake in late 1959, though these activities were interrupted when the helicopter crashed near Karluk Village. All building materials eventually reached Camp Island by late October 1959, and a work crew poured the concrete foundations before leaving for the winter. The next summer, Raleigh, Conkle, and Charles DiCostanzo, with Molly McSpadden's supervision, erected the buildings. In 1961 the new Pan Abode building was finished and the laboratory was shingled, followed in 1962 with a new 5 KW diesel power plant for electricity. In addition to the new buildings, during the 1960s some biologists and their families lived in the original cabin built on Camp Island in 1927. Raleigh renovated this old cabin in 1958 for use by his family during the field season.

During Raleigh's years at Karluk, several changes occurred in the federal management of Alaska's fisheries research. The headquarters for all federal studies of Alaska's salmon was transferred in 1956 from the Montlake Laboratory in Seattle to Juneau, Alaska. In 1960 the BCF built the Auke Bay Biological Laboratory near Juneau, and this facility served as the federal headquarters for Karluk's sockeye salmon studies until this long-term field research program ended in 1969.

Richard Gard

1962–1966

Richard Gard was the BCF project supervisor of sockeye salmon research at Karluk for four years, from July 1962 to July 1966. Previously, he had completed his Ph.D. degree at the University of California (1958) and studied Sierra Nevada trout streams; his formal training and research interests included salmonid fishes and mammalogy. Gard's field studies at Karluk focused on three research topics: the survival rates of different life stages of sockeye salmon, sockeye subpopulations, and brown bear predation on adult sockeye. He was assisted with the Karluk research by Benson Drucker, and both provided leadership to the program during 1962–66, often alternating their fieldwork at Karluk Lake and office work at the BCF's recently constructed Auke Bay Biological Laboratory near Juneau, Alaska.

Richard Gard (1928–). (Richard Gard, Auke Bay, AK)

A full program of sockeye salmon research was pursued at Karluk by the BCF during 1962–66; some studies continued those began a few years previously and others were new. The research topics on sockeye salmon included fry migrations, lake residence of juveniles, timing and abundance of smolt out-migration, travel times of adult migration, adult escapements to individual tributaries, fecundity, egg deposition, brown bear predation, and limnology of Karluk Lake (Fig. 2–3). Routine tasks included the weir installation and operation, sockeye escapement counts, collection of run composition data, stream surveys, and weather records.

Many years before Gard began to study the survival rates of different life stages of Karluk's sockeye salmon, fishery biologists had fully understood the importance of this research topic. If biologists could determine when the greatest mortality occurred in the life cycle, it then might be possible to isolate specific factors that had caused the declining sockeye runs. Barnaby (1944), after documenting remarkably high marine survival rates for Karluk's sockeye salmon, shifted his studies to the freshwater life stages. Yet, previous attempts to measure the freshwater survival were unsatisfactory because of unsolved research problems with

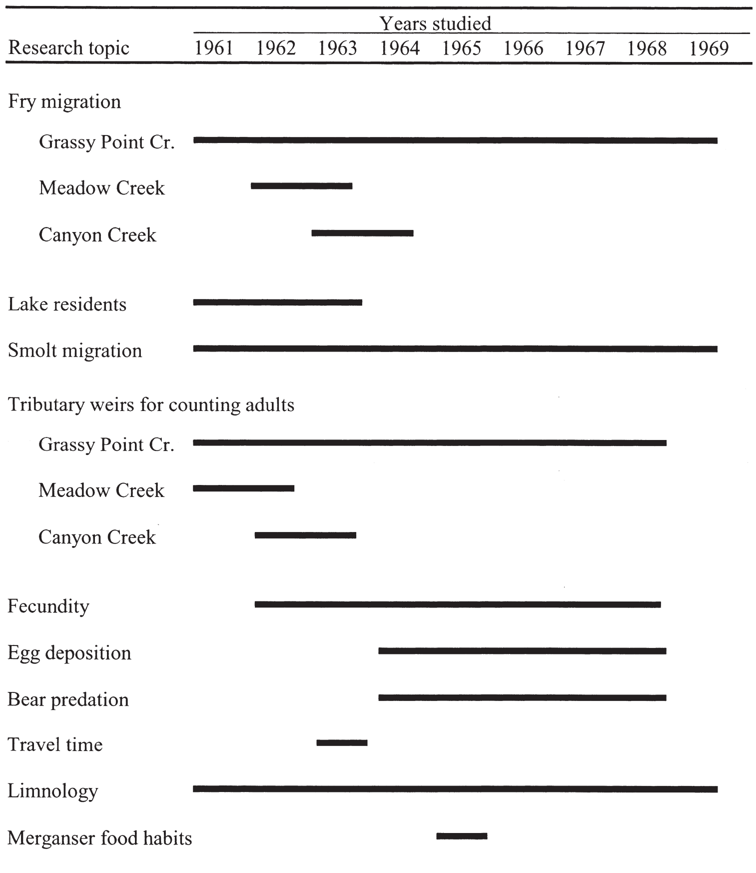


Figure 2-3. Karluk sockeye salmon research, 1961–69.

field gear and sampling methodology. Fortunately, when Gard began his studies in 1962, four important advances in field gear and methods had just been made: 1) accessory weirs to accurately count the adult sockeye that entered specific spawning streams, 2) an egg pumping device to measure egg densities in stream substrates, 3) traps in tributary streams to precisely count emerging fry, and 4) traps in the Karluk River weir and a statistically valid design to measure total smolt out-migration.

Using these new field improvements, along with data on sockeye salmon fecundity, abundance, and run composition, Gard obtained the freshwater survival rates at several lateral and terminal streams at Karluk Lake. Specifically, he determined the number of eggs brought into a stream by the adult females (potential egg deposition), live and dead eggs buried in the substrate at the end of the spawning season (actual egg deposition), live eggs in the substrate (egg survival in September–October), and fry produced the following spring and summer (over-wintering survival). Only 10–15% of eggs brought into the stream survived as live eggs at the end of the spawning season, but 30–40% of those survived through the winter and produced fry. Most egg mortality occurred during the spawning act, and losses decreased once eggs were buried in the stream gravels. Egg mortality during spawning was caused by eggs retained in females, eggs washed away before they were buried in the substrate, superimposition of spawning redds, and bear predation on spawning females. Egg-to-fry survival rates were greater in terminal streams than in lateral streams. Total freshwater survival (potential egg deposition to smolt produced) was typically less than 0.5%. Marine survival (smolt-to-adult) was 30–50%, much higher even than Barnaby (1944) reported, but similar to Ricker's (1962) estimates. Since freshwater survival rates at Karluk were lower than in many other sockeye salmon systems, Gard concluded that "some factor(s) in the freshwater environment must be important in maintaining the low level of the run" (Gard and Drucker, 1966b). Thus, these studies were noteworthy in obtaining, for the first time, accurate survival data on several freshwater life stages and additional measurements of the marine stage.

Gard devoted considerable effort during 1962–65 to gathering field evidence of sockeye salmon subpopulations, especially after Rounsefell (1958) discounted their presence. Gard collected morphological and behavioral data at different sites and seasons at Karluk, looking for discrete sockeye salmon groups. Stream

Karluk Lake and Camp Island (near), looking toward Thumb River valley, 1966. (Richard Gard, Auke Bay, AK)

surveys showed that adult sockeye returned to different spawning habitats in a repeatable seasonal pattern each year, and these differences were evident in lateral and terminal streams, lake beaches, and the upper river. Likewise, significant site and seasonal differences occurred in fry and adult sizes, ages, and fecundity. Female size and fecundity differences showed that reproductive potential varied by spawning site and for spring- and fall-run fish.[123] Gard concluded that Karluk's sockeye salmon had at least two major subpopulations and that each principal spawning habitat likely had its own discrete group (Gard et al., 1987).

Gard measured the travel time of fall-run adult sockeye salmon between the Karluk River Portage and upper weir (14 km) in 1963 and compared his results with the 1945–46 unpublished tagging study of Shuman and Nelson (Gard, 1973). Spring-run sockeye ascended the entire river in about 7 days, while fall-run fish needed about 10 days. As the spawning season progressed and the fish approached sexual maturity, travel times declined for both spring and fall runs.

Gard studied brown bear predation on sockeye salmon at Grassy Point Creek, a lateral tributary of Karluk Lake, in 1964–65. In both years he counted the number of adult sockeye that entered the creek, salmon carcasses, and bear-killed salmon and their spawning status. Bears had free access to the creek in 1964 and killed many salmon, though most fish had spawned before dying. An electric fence partially excluded bears from the creek in 1965, greatly reducing the number of bear-killed salmon. Gard (1971) concluded that bear predation had little effect on the overall production of sockeye salmon in Grassy Point Creek.

[123] Most of this fecundity data remained unpublished, though some was published (Gard et al., 1987) or presented in ABL Manuscript Reports.

Karluk Lake and Five Fingers Mountain, viewed from Camp Island, 1965. (Richard Gard, Auke Bay, AK)

Most of Gard's sockeye research data during 1962–66 were presented in five ABL Manuscript Reports, one for each field season (Gard and Drucker, 1963, 1965, 1966a, b; Drucker and Gard, 1967). Though never formally published, these reports were distributed to several fisheries libraries and were of great interest to other salmon biologists because they contained scientific information about little-known aspects of sockeye biology. For example, using downstream fish traps placed in Karluk's tributaries, Gard recorded the number and timing of newly emerged sockeye fry in the spring migration. Significantly, the pattern of fry migration closely matched that of the adult spawners from the previous year. Similarly, regular smolt collections documented the seasonal out-migration of sockeye and coho salmon, including their diurnal movements, lengths, weights, and ages. These reports also summarized data on the sockeye escapements, weir operation dates, run composition, and stream surveys. Limnological and climatological data were regularly collected at Karluk Lake during 1962–66, but none were included in these reports.

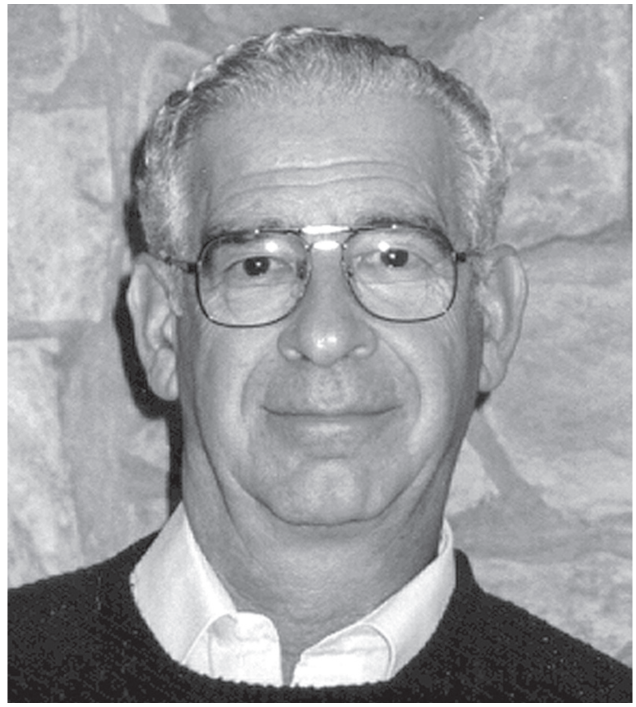
Gard briefly studied the food habits of mergansers (*Mergus merganser* and *M. serrator*) at Karluk Lake and the upper river in June 1965. Of 18 individuals examined, seven from the lake had eaten sticklebacks. Five mergansers from the O'Malley and upper Karluk rivers had eaten salmonid fry or smolts and some were sockeye salmon. One merganser collected at the Karluk River near Silver Salmon Creek had eaten 43 salmonid fry.

Benson Drucker

1961–70

Benson Drucker worked as a BCF fishery biologist at Karluk for nine field seasons during 1961–70. He assisted Raleigh in 1961 and Gard in 1962–1966 before leading the Karluk studies in 1966–1970. Drucker was hired by the BCF in December 1960 after completing his M.S. degree at the University of Miami. The BCF research program underwent dramatic changes during his years at Karluk, including an expansion of the facilities on Camp Island in the early 1960s and then a complete end of all field studies in 1969. This period was also notable for the transition of responsibilities from the BCF to the ADFG for the fisheries research and management of Karluk's sockeye salmon. Though Drucker's last field season at Karluk was 1969, he continued to analyze his research data through 1970 before leaving Alaska in May 1971.

Drucker participated in most of the field studies of sockeye salmon while assisting Raleigh and Gard during 1961–66 and, in fact, led some projects. Sockeye salmon research then comprised fry migrations in tributary streams, egg survival and fry production of different spawning sites, distribution of juveniles in Karluk Lake, tributary homing of adults, evidence of sockeye subpopulations, bear predation on adult sockeye, smolt out-migrations, and post-fertilization monitoring of Bare Lake. Drucker also helped with the routine annual tasks of installing and maintaining the Karluk River weir, counting escapements, collecting run composition data of sockeye adults and smolts, surveying spawning streams, and gathering limnological and climatological data.



Benson Drucker (1931–2000). (Benson Drucker, Reston, VA)

Drucker helped to determine the total out-migration of sockeye smolts from Karluk Lake during his first field season in 1961. This was the first statistically accurate measurement of smolt out-migration, while all previous attempts since 1954 only had given a relative abundance index. To do this, traps were built into the weir and operated in a statistical design to obtain the smolt abundance for that year. The ability to measure smolt production was a significant achievement for the Karluk research program since it now allowed the freshwater and marine survival rates of sockeye salmon to be known. Operation of the weir traps each spring also gave the biologists accurate data on the timing and composition of the smolt migration.

Pumping stream substrate for sockeye salmon eggs, Karluk Lake tributary, 1966. (Benson Drucker, Reston, VA)

Sockeye salmon fry migration nets, Grassy Point Creek, 1963. (Benson Drucker, Reston, VA)

Transporting adult sockeye salmon to Halfway Creek, Karluk Lake, 1968. (Benson Drucker, Reston, VA)

Drucker studied the juvenile sockeye of Karluk Lake in 1961–62 as part of a much larger investigation of many sockeye salmon systems in southwestern Alaska by the BCF, FRI, and ADFG (Burgner et al., 1969). For the first time, the fishes of Karluk Lake were collected with littoral beach seines and limnetic tow nets; both sampling methods were needed to understand the distribution of juvenile sockeye in the lake. Ellis (1963) published some of the data on fish distribution and abundance in Karluk Lake, and Drucker prepared another report around 1965 with additional information.[124] Though his report was never published, some of the data were later used in a comparative study of salmon nursery lakes (Burgner et al., 1969).

Continuing work started in the early 1960s, Drucker investigated the sockeye salmon spawner abundance, egg survival, and fry production of Grassy Point Creek during 1967–69. Each year he measured the number of sockeye spawners that entered the creek, the egg density in the substrate, and the number of fry produced the following spring. Again, most of the egg mortality occurred during the spawning process, but once eggs were entrained in the substrate mortality was low. Fry production was negatively correlated with the number of spawning females that entered the creek (at least for the range of 2500–5700 females).

To further examine the fry-spawner relationship, Drucker (1968, 1970) experimentally reduced the number of spawners allowed to enter the creek in 1967–68. Lower spawning densities increased initial egg survival, but winter egg survival and fry production decreased, possibly because too few adults were present to adequately clean the spawning gravels. The adult sockeye salmon that were prevented from entering Grassy Point Creek were transported 3 km south and released into Halfway Creek, where a weir kept them from returning to their home stream. Higher spawning densities in Halfway Creek increased the egg retention of transferred females, but these alien fish eventually spawned among themselves and with native sockeye.

In 1968 Drucker recorded unusually low egg survival (3%) between those brought into Grassy Point Creek in female bodies and those found in the gravel after spawning ended. In previous years he had found much higher egg survivals (12–23%) and attributed the huge loss of eggs in 1968 to bear predation on the sockeye spawners. Reportedly, 97% of the recovered female carcasses had been killed by bears.

Drucker prepared a report on this bear predation in 1970 and compared the alarming 1968 data with that of 1966–67. His report was revised several times over the next few years and given a new title but was never published.[125] Drucker claimed that spring-run sockeye in small lateral creeks were most vulnerable to bear predation, while later spawners in larger terminal streams and lake beaches were in less danger. This conclusion matched previous observations that spring-run fish quickly spawned after entering lateral creeks (Conkle, Raleigh, and Owen, 1959).[126] After considering all the facts, Drucker concluded that bear predation had little overall effect on sockeye salmon abundance at Karluk, but was intense at specific times and places.

Drucker co-authored several formal scientific papers on Karluk's sockeye salmon. First, he described the migratory behaviors of fry and smolts at Karluk and compared these with other river-lake systems in Alaska and British Columbia (Hartman, Heard, and Drucker, 1967). The data for this paper were collected at Karluk during 1961–64, the first time that both fry and smolt migrations had been accurately measured. His study included underwater observations of migrating fish in Karluk Lake and River. The paper gave information on the seasonal timing of fry and smolt migrations, diel variations of migrations, environmental factors initiating migrations, schooling behavior, depth and orientation of fish to stream currents, and fry and smolt predators.[127] Years later, Drucker co-authored a formal paper with Gard on the sockeye salmon subpopulations at Karluk, documenting the differences in adult size and age, fecundity, spawning habitat, and fry migration and

[124] Drucker, Benson. ca. 1965. Age, size, abundance and distribution of juvenile sockeye salmon (*Oncorhynchus nerka*) at Karluk Lake, Alaska, 1961–1962 (Original title: "Juvenile sockeye salmon resident studies at Karluk Lake, Kodiak, Alaska, 1961–1962"). BCF, ABL, Auke Bay, AK. Unpubl. report. 30 p. Located at NARA, Anchorage, AK.

[125] Drucker, Benson. 1973. Determining the effect of bear predation on spawning sockeye salmon on the basis of rate of disappearance of tagged salmon. (Original 1970 Title: "Extreme bear predation on sockeye salmon spawners at Grassy Point Creek, Karluk Lake, Kodiak, Alaska"). BCF, ABL, Auke Bay, AK. Unpubl. report. 54 p. Copy in the personal papers of Richard Gard, Juneau, AK.

[126] Owen, John B. 1958. Red salmon survival studies in Karluk Lake, Kodiak Island, 1957. Field Report. Salmon survival investigations. BCF, Alaska Region (February 18, 1958). Unpubl. report. 27 p. Located at ABL Office Files, Auke Bay, AK.

[127] It is of historical interest that this paper was selected for the 1968 "Charles Y. Conkle Annual Publications Award" from the BCF Auke Bay Biological Laboratory, AK. This annual award was initiated to honor BCF Fishery Biologist, Charles York Conkle, who worked as a young biologist at Karluk Lake during 1955–60. Conkle's promising career as a fishery biologist was prematurely ended by a fatal illness.

U.S. Bureau of Commercial Fisheries research facilities, Camp Island, Karluk Lake, 1977. (Auke Bay Laboratory, Auke Bay, AK)

size (Gard et al., 1987). This paper, in addition to several others from this era, finally settled the question about the existence of sockeye salmon subpopulations in the Karluk run (Owen et al., 1962; Hartman and Raleigh, 1964; Raleigh, 1967; Wilmot and Burger, 1985). In addition to these formal publications, Drucker wrote many ABL Manuscript Reports that summarized the sockeye salmon data collected each year from Karluk during 1962–68 (Drucker, 1968, 1970; Drucker and Gard, 1967; Gard and Drucker 1963, 1965, 1966a, b). He also compiled a bibliography of published and unpublished studies done at Karluk and Bare lakes (Drucker, 1971).

Besides his sockeye salmon research, Drucker studied the life history of coho salmon at Karluk during 1961–68, gathering data on the adults and smolts, ages, sizes, fecundity, eggs, and seasonal and diel migrations (Drucker, 1972). Karluk's juvenile coho salmon, similar to its sockeye, resided longer in freshwater than reported for other river systems, and adults had high fecundities (4,700 eggs per female). The coho smolt migration peaked about 1–2 weeks after that of sockeye smolts.

During Drucker's nine field seasons at Karluk Lake, the BCF research facilities at Camp Island were greatly enhanced. Improvements included new living quarters, research laboratory, storage sheds, boathouse, and boats. Personnel and supplies reached the lake via agency aircraft (Grumman Goose) or chartered flights. A diesel power plant and generator supplied electricity to the buildings, and reliable radios provided direct communication between the biologists and managers around Kodiak Island.

Nevertheless, federal funding for salmon research at Karluk became increasingly scarce in the 1960s. These fiscal constraints led Drucker to request in October 1966 that the ADFG assume responsibility for the Karluk River weir and collection of run composition and smolt out-migration data. To conserve funds in 1967–69, the BCF hired fewer temporary workers for the field studies.[128] In contrast to the BCF's situation, federal funding to the ADFG increased after passage of the Anadromous Fish Act. Consequently, beginning in 1967 the ADFG operated the Karluk River weir and collected the run composition data, while the BCF installed the weir and measured the smolt out-migration. The BCF ended all field research on Karluk's sockeye salmon on 15 July 1969; in that year they restricted their studies to the fry migration at Grassy Point Creek, smolt out-migration, and limnological sampling. Measurement of the spring 1969 fry migration was more difficult than normal because winter-like conditions persisted and the lake was still ice-covered in April, making it difficult to reach the creek. Drucker and his assistant, Ray Sautter, reached Camp Island in early April on a Kodiak Airways Bell 206 turbine helicopter.[129]

Drucker experienced several curious events during his many field seasons at Karluk. For example, when extra funds became available in 1961 to study several sockeye systems in southwestern Alaska, the BCF purchased three new boats for the Karluk research program. The boats (two dories and a cabin cruiser) were delivered to Karluk Village on the lower river in July

[128] Beyond the funding shortages, the BCF found it difficult to hire temporary workers in 1968 because of the Vietnam War. Typically, college students were hired for these summer jobs, but in early 1968 some students were reluctant to leave school for fear of being drafted.

[129] The BCF rarely used helicopters for transport to Karluk Lake.

1961, and Drucker and his assistant, Darrell Farmen, physically pulled the boats 40 km upriver to Karluk Lake, a grueling task because the river was especially low that year. Their feat is the first record of a full ascent of the Karluk River while hauling a boat and supplies, though many biologists had brought boats 14 km upriver between the Portage and lake. Drucker and his assistant, James Romero, also brought a new Boston Whaler boat upriver to Karluk Lake in 1967, but this time they started at the Portage.[130]

On another occasion, King Mahendra and Queen Ratna of Nepal used the BCF research station on Camp Island as their base camp for an 8-day bear hunt in November 1967. These facilities normally accommodated 6–8 people, but the royal hunting party and supporting personnel totaled 35, causing Drucker to add several improvements (room heaters, walkways, and insulated toilet). As part of a wider big-game safari in Alaska, the royal party shot a bear at Karluk Lake.[131]

Finally, Drucker helped the crew members of Jacques Cousteau's vessel *Calypso* film a movie about sockeye salmon at Karluk Lake in August 1969. The movie crew photographed sockeye salmon and brown bears and filmed an interview with Drucker. The movie, *Tragedy of the Red Salmon,* later won an award at the Cannes Film Festival in France.

[130] Over the many years that boats (often loaded with supplies) were pushed and pulled up the Karluk River, at least one person died from this strenuous effort. In the spring of 1963, bear hunting guide Griska Nikolai, then age 53, suffered a heart attack as he pushed a boat up the O'Malley River (Dodge, 2004).

[131] Apparently, the King shot a bear in an area recently closed to hunting. The area had been closed because of concern that bear harvests at Karluk Lake were excessive (Van Daele, 2003). A description of the King and Queen's visit to Alaska, their bear hunt at Karluk Lake, and the subsequent controversy has been written from the viewpoint of Al Burnett, head guide (Connelly, 1969).