CHAPTER 6

Seasonal Run Distribution

They arrived from the sea in one huge wave—or two—or maybe three waves?

Before commercial fishing began in earnest at Karluk in 1882, what was the seasonal run distribution of its sockeye salmon? Was the original run distribution which existed when the Karluk ecosystem produced millions of adult sockeye drastically altered by commercial fishing? And, was the original distribution the same as has existed since 1921, when accurate measurements of the run began? These questions have persisted throughout much of Karluk's fisheries history, and with good reason. Knowing the original run distribution is important in understanding the true productive potential of Karluk's sockeye salmon and in making wise management decisions to sustain this natural resource. In this chapter, we review the different ideas about the seasonal run distribution of sockeye salmon at Karluk and summarize the historical evidence of the original run pattern that occurred before or shortly after commercial fishing started in 1882.

Before starting this review, some definitions are necessary. The term "escapement" defines the number of sockeye salmon that actually enter the Karluk River and migrate upstream to the spawning grounds. These fish escaped capture in the commercial fishery. Sockeye escapements have been accurately measured at the Karluk River weir ever since 1921; these measurements give detailed data on the seasonal run distribution (Fig. 6-1). Technically, the distribution determined by weir counts would differ somewhat from the true escapement distribution, as measurements would be affected by the time it takes sockeye to travel from the fishery until they pass the counting weir.

The term "catch" defines the number of sockeye salmon harvested in the commercial fishery. Catch numbers have been collected since Karluk's commercial fishery began in 1882, though their accuracy is questioned for some early years. Catch numbers for the early fishery were calculated from annual case-pack production records of the canneries, where one case of canned sockeye salmon equaled 48 1-lb (0.45 kg) cans. About 12–14 adult sockeye were needed to produce one case of canned salmon; the actual number varied seasonally as the size of returning salmon changed. Because seasonal catch or case-pack data have been recorded each year since 1882, these have often been used to reflect the seasonal run distribution.

The term "total run" defines the number of adult sockeye salmon that home to the Karluk River before they are reduced by commercial fishing. The total run is not directly measured in the ocean as these fish approach the Karluk River, but has been determined since 1921 by adding escapement and catch numbers. To determine the seasonal distribution of the total run, adjustments must be made between escapement and catch because of the time needed for salmon to travel from the fishery to the weir. Thus, weir counts must be adjusted back several days or weeks to match when the same group of fish was being harvested in the fishery. The following discussion on seasonal run distribution refers specifically to the total run. It is necessary to make this distinction since the term "run" is often used generally to refer to all types of fish migrations, including movements up the Karluk River and into specific spawning tributaries at Karluk Lake.

Present Seasonal Run Distribution, 1921–2010

Karluk's sockeye salmon run is somewhat unique in Alaska due to its length, from May to October, while many other sockeye runs only last a few midsummer weeks. Since 1921 seasonal records have been kept on the numbers of adult sockeye that migrate up the Karluk River (the weir counts) and on the numbers of salmon caught in the commercial fishery (Figs. 6-1, 6-2). Thus, the seasonal run distribution has been well known since 1921, especially when compared to the uncertainties of the previous 40 years. Of course, vast improvements have been made since 1921 in correctly assigning fish to the Karluk system. Information from

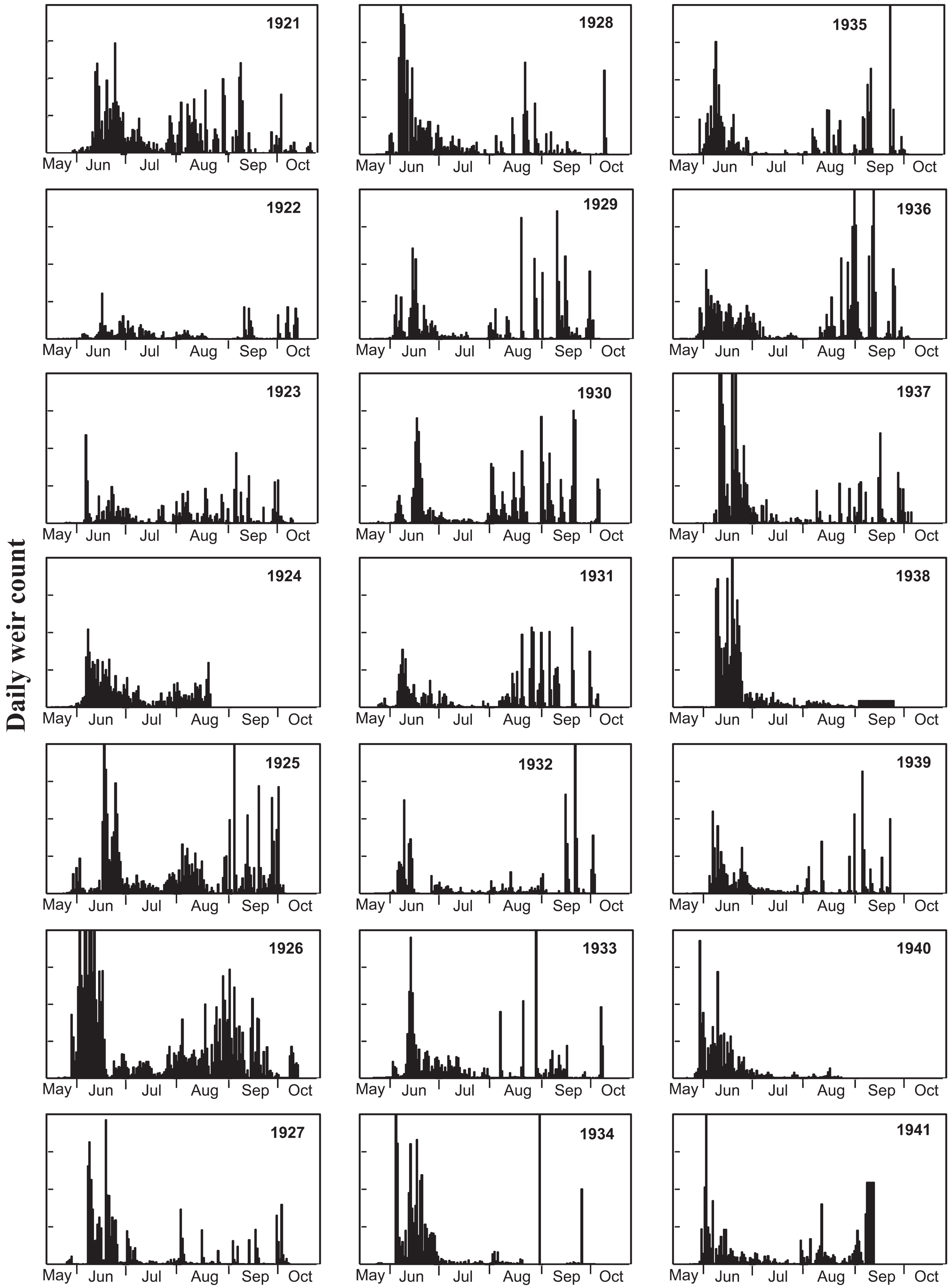

Figure 6-1 (A). Karluk River sockeye salmon daily weir counts, 1921–41. (Vertical scale: 0–80,000.)

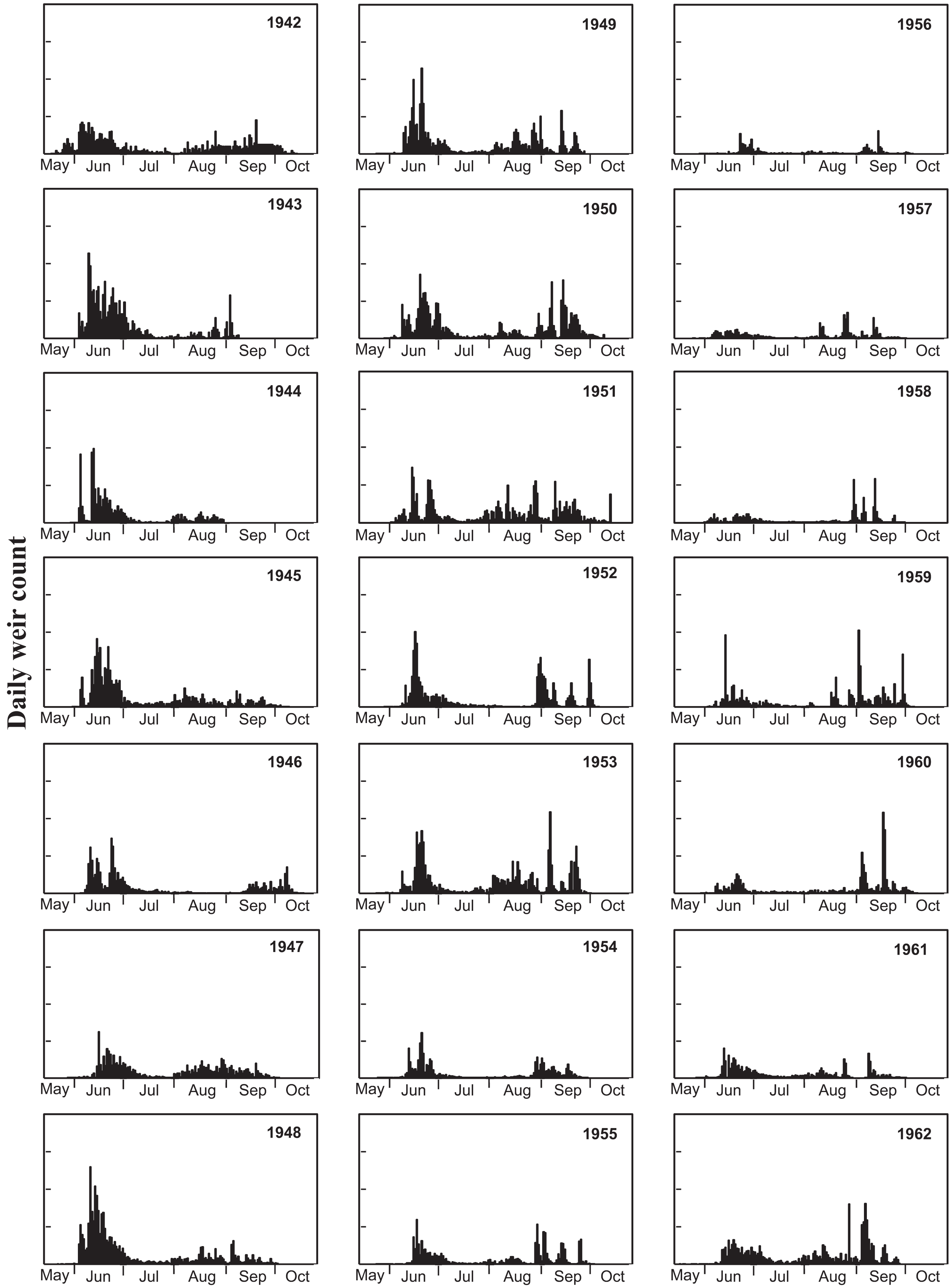

Figure 6-1 (B). Karluk River sockeye salmon daily weir counts, 1942–62. (Vertical scale: 0–80,000.)

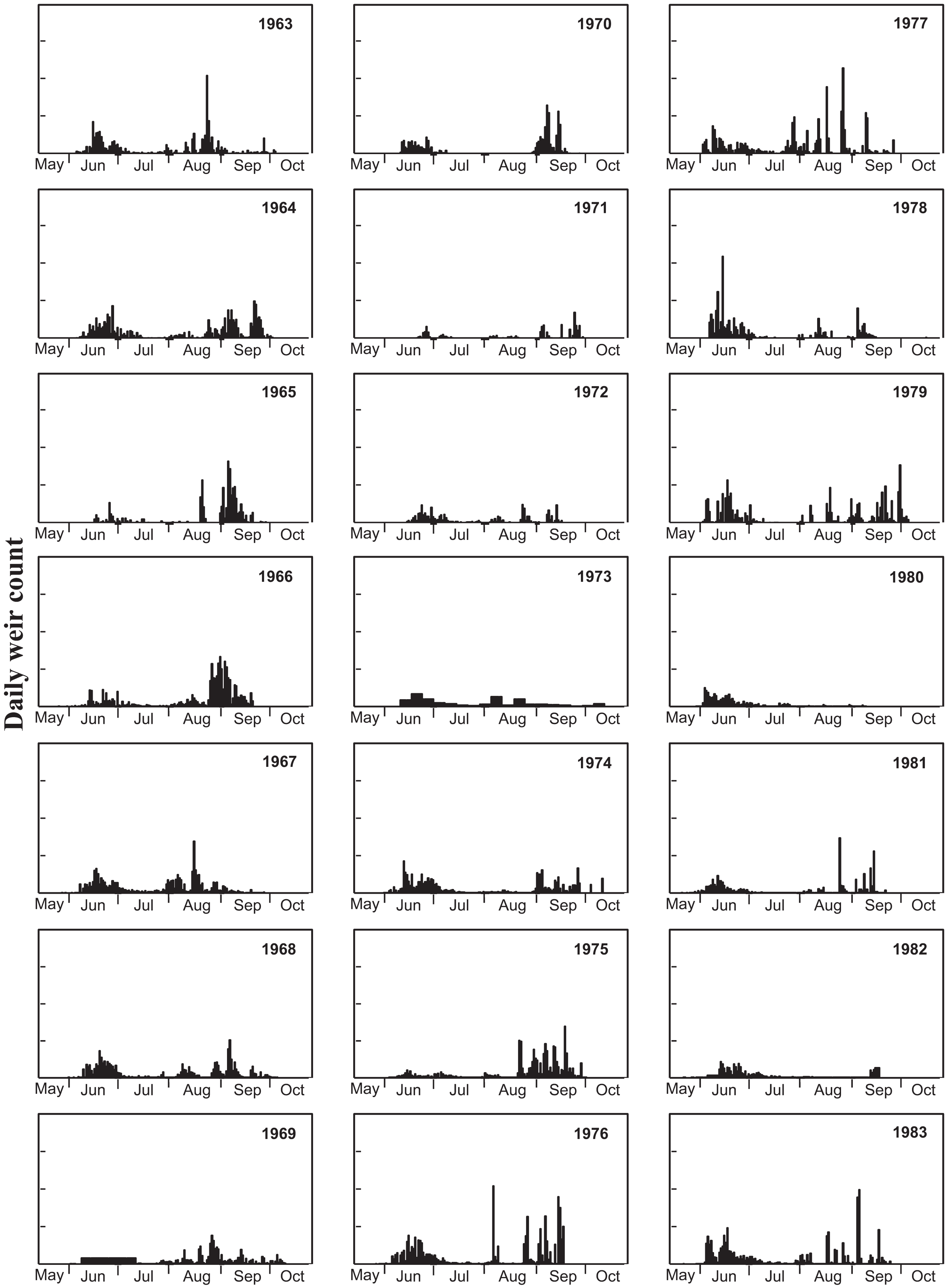

Figure 6-1 (C). Karluk River sockeye salmon daily weir counts, 1963–83. (Vertical scale: 0–80,000.)

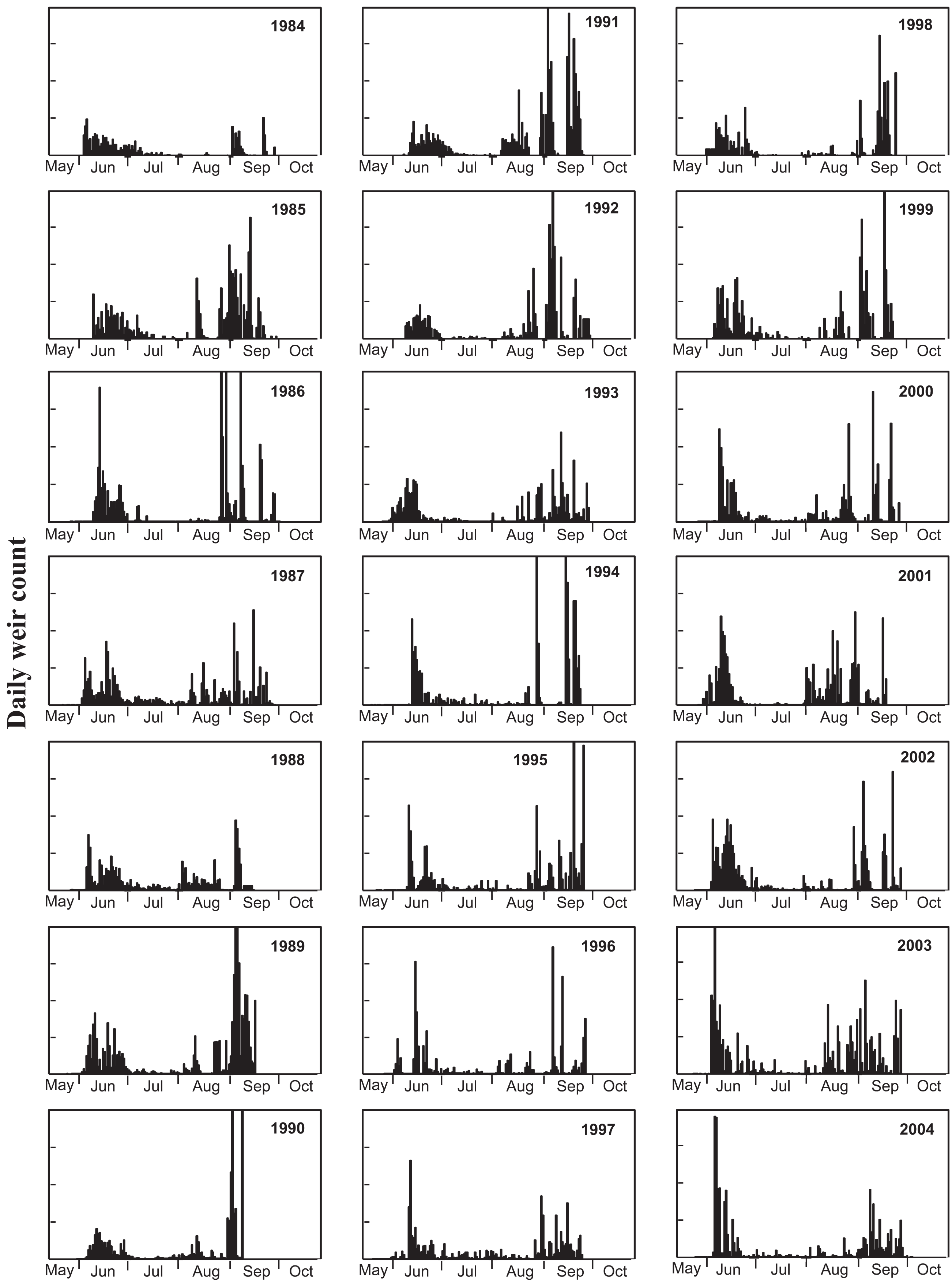

Figure 6-1 (D). Karluk River sockeye salmon daily weir counts, 1984–2004. (Vertical scale: 0–80,000.)

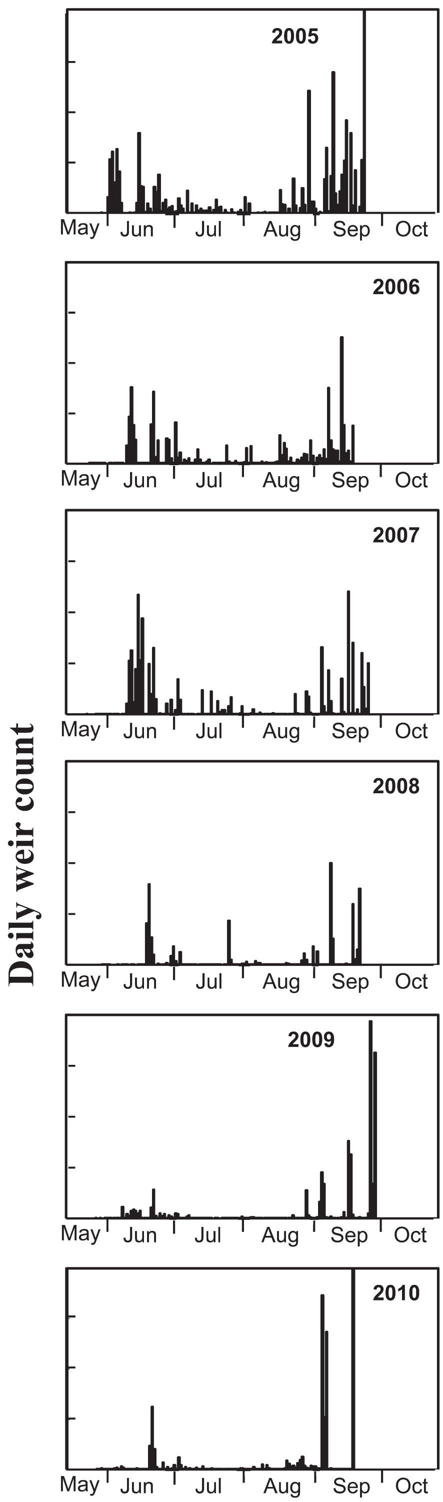

Figure 6-1 (E). Karluk River sockeye salmon daily weir counts, 2005–2010. (Vertical scale: 0–80,000.)

past ocean-tagging studies and run reconstruction methods that use age markers and scale analysis have reliably identified the true stock compositions of sockeye salmon that migrate along Kodiak Island's western coastline (Bevan, 1962; Witteveen et al., 2005).

Seasonal run distributions of Karluk's sockeye salmon have followed a relatively consistent pattern since 1921 (Figs. 6-1, 6-2). Typically, a few sockeye begin ascending the river in mid May and increase in abundance to an initial peak in early to mid June. Following this, the run gradually declines to a minimum in early to mid July. By late July the run normally increases again, reaching a second peak somewhere between early August and early September. The exact timing of the second peak varies from year to year. After the second peak, the run decreases through late September and into October. Rarely, the run continues into November.

Thus, sockeye salmon migration into the Karluk River has been bimodal since 1921, the two distinct runs often being called the "spring" (early) and "fall" (late) runs. These two runs are typically separated by a midseason low occurring about 15 July. Some fishery biologists have divided Karluk's sockeye migration into early (May–June), midseason (July–August), and late (September–October) runs (Thompson, 1950; Van Cleve and Bevan, 1973). For the following discussion, we use the terms "spring run" for the May–June mode, "fall run" for the July–October mode, and "midseason run" for the July–August part of the fall run.

Rounsefell (1958) claimed that Karluk's sockeye run was trimodal, with the first peak in early to mid June, the second peak in early August, and the third peak in early September. Barnaby (1944) also found an apparent trimodal run distribution, but stated that in any individual year it was bimodal. He believed that the trimodal pattern was caused by averaging the distributions of several years, with the fall peak occurring in late July or early August in some years and in early September in other years. It remains unknown why the fall peak varies by as much as a month, while the spring peak consistently occurs at the same time each year. Perhaps flow conditions in the Karluk River may either speed or retard the fall-run's ascent. Or, if serious errors existed in the travel time estimates between the fishery and weir, the apparent first peak of the fall run may be produced by catch data, while the apparent second peak may be produced by weir counts.

While Rounsefell and Barnaby analyzed the sockeye run distribution at Karluk for the years before 1951, Barrett and Nelson (1994) analyzed its escapement

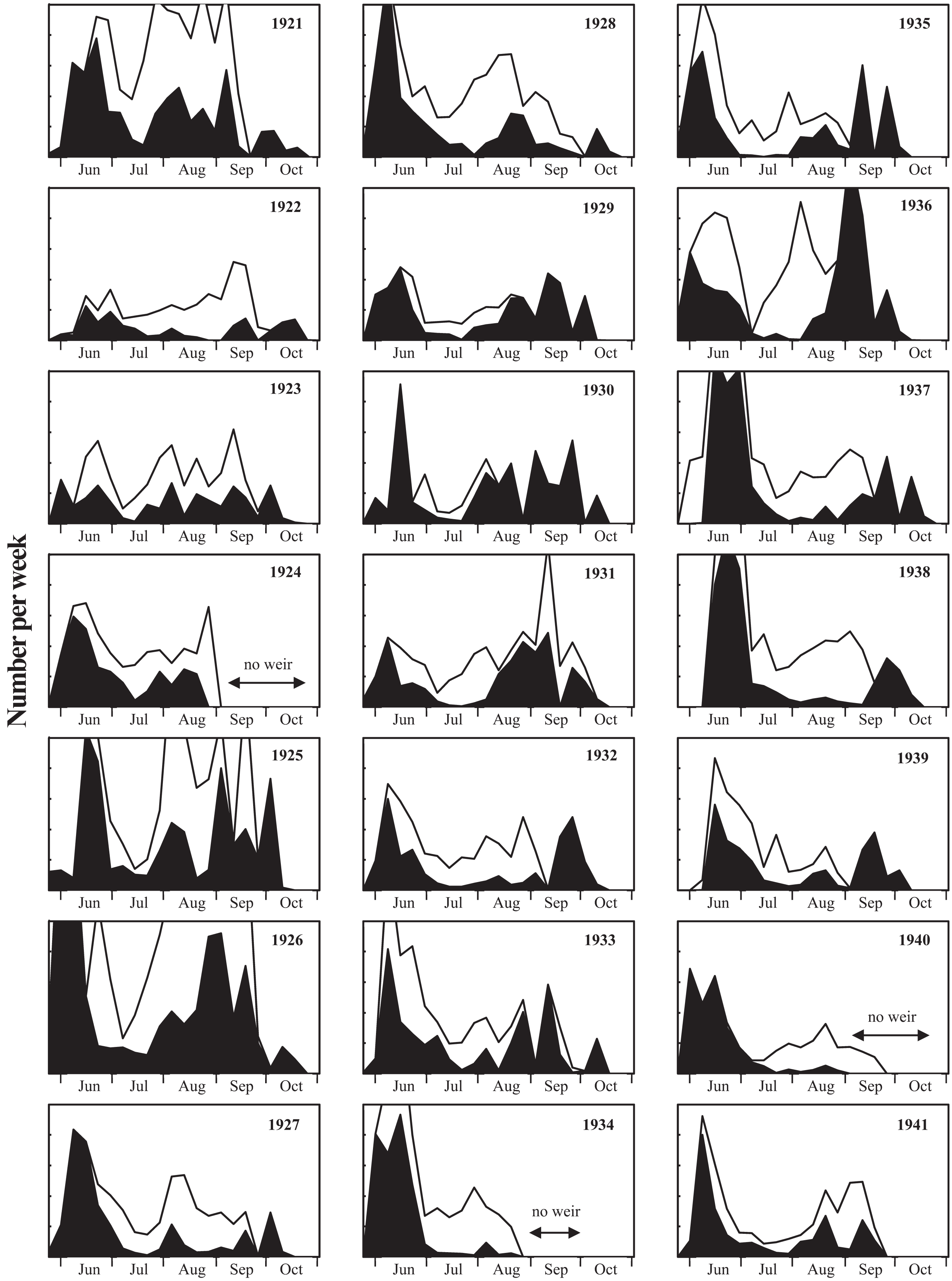

Figure 6-2 (A). Karluk River sockeye salmon weekly escapements (black area of graph) and catches (white area of graph), 1921–41. (Vertical scale: 0–250,000.)

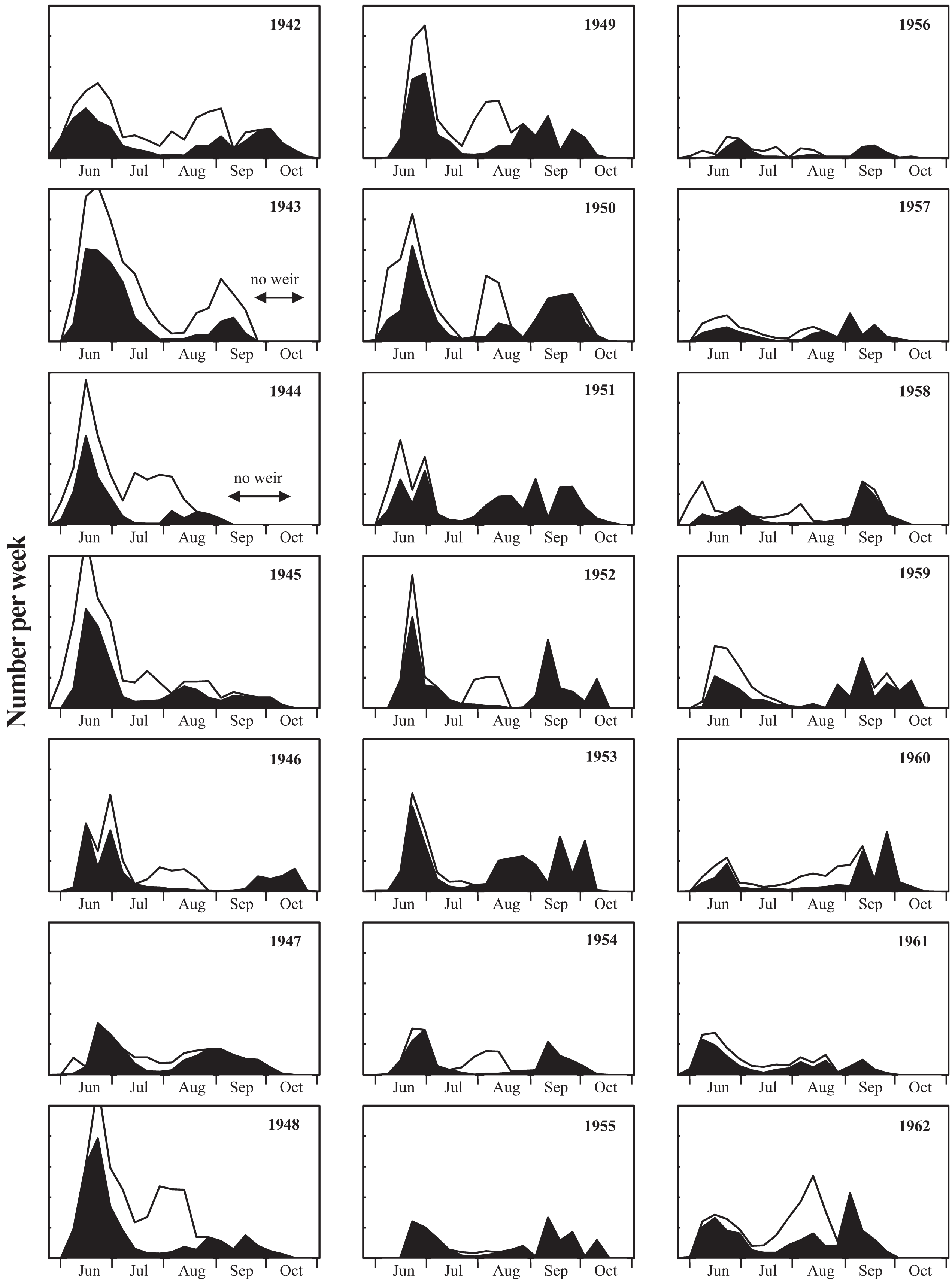

Figure 6-2 (B). Karluk River sockeye salmon weekly escapements (black) and catches (white), 1942–62. (Vertical scale: 0–250,000.)

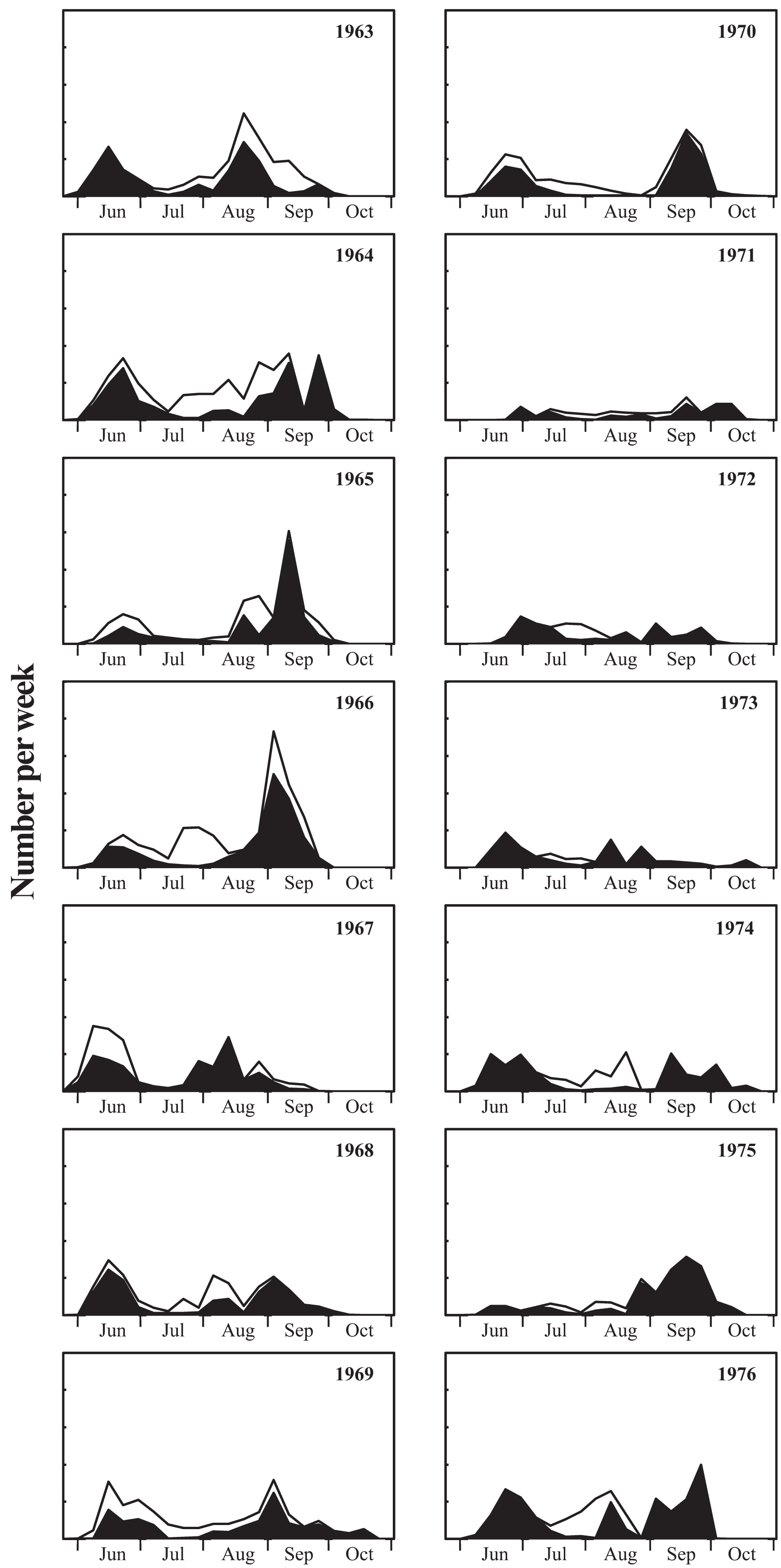

Figure 6-2 (C). Karluk River sockeye salmon weekly escapements (black) and catches (white), 1963–76. (Vertical scale: 0–250,000.)

data for 1984–93 and found a bimodal seasonal pattern with little evidence of trimodality. Their 1984–93 escapement pattern matched that of 1921–36, with an initial peak in mid June, a minimum in late July, and a second peak in early September (Barnaby, 1944; Thompson, 1950). The main difference in run distribution between these two eras was the broad fall-run peak during 1921–36 and the sharp peak during 1984–93. Perhaps the intense commercial fishery that continued for many years on midseason (July–August) sockeye sharpened the bimodal pattern of the run and escapement.

The present bimodality of Karluk's sockeye salmon run also exists, with appropriate lag times, at the counting weir and then again at the spawning grounds at Karluk Lake. When the weir was located near Karluk Lagoon (1921–41, 1976–2010), spring and fall peaks typically occurred at the weir a few days or weeks after the fish escaped the fishery. But when the weir was located 40 km upstream near the lake's outlet (1945–75), it took at least 7–10 days for sockeye to ascend the river from Karluk Lagoon, causing spring and fall escapement peaks to occur later than in the fishery. Since adult sockeye spend one month maturing in Karluk Lake before spawning, peak numbers do not occur at spawning sites for over a month after they escaped the fishery. Thus, spring-run sockeye first appeared on the spawning grounds in late June, increased to maximum numbers in the second or third week of July, and completed spawning in late July and early August (Fig. 6-3). By mid August, few spawning sockeye were present. Fall-run sockeye began occupying their spawning habitats in late August and reached peak abundance in mid or late September.

William F. Thompson's Ideas on the Original Seasonal Run Distribution

Because the seasonal run distribution of Karluk River sockeye salmon has been so consistently bimodal since 1921, this may, in fact, be the original run pattern that has always existed, as determined by the sockeye's evolutionary history and environmental adaptations to the Karluk ecosystem. Yet, FRI Director William Thompson proposed in 1950 that Karluk's bimodal run was not a natural biological feature of its sockeye, but instead reflected intense commercial fishing, especially in the early years when such fishing operated with few regulations or controls. He claimed that Karluk's original sockeye run was unimodal and reached maximum abundance in the midseason (July–August).

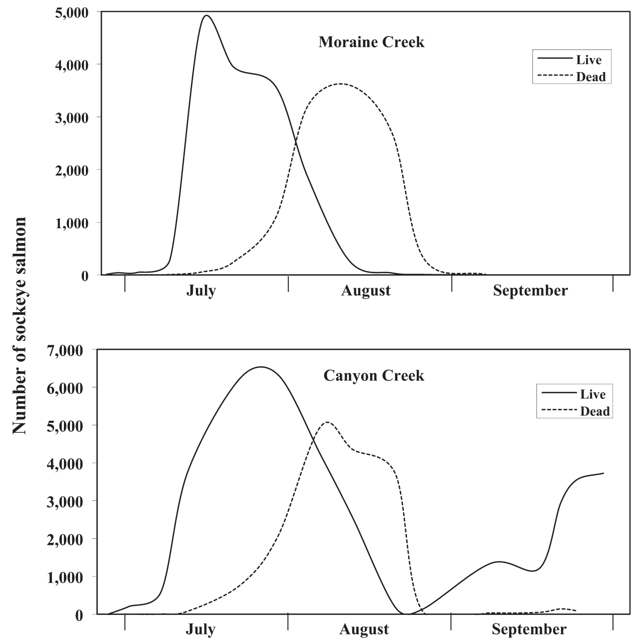

Figure 6-3. Live and dead adult sockeye salmon in a lateral tributary (Moraine Creek, 1953) and a terminal tributary (Canyon Creek, 1953) of Karluk Lake (from Bevan and Walker, 1954).

Thompson reached this conclusion by studying the seasonal case-pack records of one Karluk cannery for 1895–99 and finding that production was unimodally distributed. He assumed that case-pack records reflected the actual run distribution of sockeye salmon. Abundant midseason fish were assumed to be the most productive, while earlier and later runs were thought to be less productive. As he examined the cannery records of subsequent years (1900–19), the unimodal distribution progressively became bimodal. Hence, he concluded that commercial fishing on midseason fish had depleted this particular run segment and changed the seasonal run pattern from unimodal to bimodal. If true, loss of the productive midseason fish may then explain the historic decline in abundance of Karluk's sockeye salmon.

Thompson's ideas on run distribution came from his belief that Karluk's sockeye salmon had many independent subpopulations and that fishing could be intense on some subpopulations, while others went unfished. Thus, commercial fishing might alter the relative abundance and population dynamics of the subpopulations present. Since he felt that Karluk's fishing regulations protected early- and late-run sockeye, but allowed intense midseason fishing, he proposed changes to the fishing effort (Thompson and Bevan, 1955). Ideally, all subpopulations would get some protection to help sustain the full diversity of Karluk's sockeye salmon.

Thompson did not personally conduct field research on Karluk River sockeye salmon, but in 1950 he actively directed the Karluk field studies of other FRI biologists and had a keen interest in solving the problem of its declining runs. He first presented his run distribution ideas to the National Research Council, Washington, DC, on 9 November 1950, in a paper entitled "Some salmon research problems in Alaska."[1] The main points he made in the paper were:

1) Sockeye salmon runs are made up of many independent subpopulations.
2) Subpopulations allow a species to survive many environmental conditions.
3) Subpopulations use different parts of the stream and lake for spawning, and at different times.
4) The seasonal run distribution reflects the relative mortalities that salmon have experienced.
5) The most productive parts of the run are the most abundant and have the best survival chances.
6) Fishermen want to operate when fish are most abundant.
7) Fishing modifies the run distribution.
8) Regulations don't protect the most productive part of the run; the best part gets depleted.
9) Regulations only protect the early and late runs; the midseason run gets depleted.
10) Fishing and regulations changed the run distribution from unimodal to bimodal.
11) Ideal regulations would protect all subpopulations.
12) Sockeye salmon are resilient to heavy fishing pressure.

Influence of Thompson's Ideas

Thompson's idea—that Karluk's sockeye salmon originally had an abundant midseason run that was progressively depleted by commercial fishing—had a powerful influence on fishery biologists and managers for at least the next 20 years. Field studies during the 1950s–1960s were often focused on the relative productivities of spring-run, midseason, and fall-run fish. Managers adjusted fishing regulations and discussed ways to rebuild the midseason run. Further, Thompson's idea that Karluk's sockeye had many independent subpopulations also stimulated field biologists to look for evidence of these different run segments.

Thompson had a great influence on the research topics and methods of the FRI biologists who were then studying Karluk's sockeye salmon. In particular, Donald Bevan focused his 1950–58 field work on gathering sockeye subpopulation data from different run segments; determining the specific spawning habitats used at Karluk Lake by early, midseason, and late runs; and learning which subpopulations the commercial fishery harvested. He also examined historic case-pack records to see if the unimodal midseason peak observed in the early data had been incorrectly caused by non-Karluk fish being transported to Karluk's canneries for processing. Many years after Bevan ended his Karluk field studies, he continued to support Thompson's ideas (Van Cleve and Bevan, 1973).

Thompson's ideas about sockeye salmon had considerable influence beyond the FRI. During the 1950s, his ideas on subpopulations and run distribution caused the FWS to change their sockeye research program and fishing regulations at Karluk. FWS biologists readily accepted that sockeye subpopulations existed, but they questioned his ideas on the original run distribution and the impact of commercial fishing. Based on tagging studies done during 1946–48, FWS biologists Nelson and Shuman understood the seasonal run distribution and where different sockeye subpopulations spawned at Karluk Lake. Shuman felt that Thompson's case-pack data inaccurately reflected the seasonal run pattern and believed that the run had always been bimodal. Nelson also questioned Thompson's ideas on run distribution, but in 1955 planned field studies to test the relative productivities of spring, midseason, and fall-run sockeye:

> [Concerning the research program on Karluk River sockeye salmon, 1955] Dr. W.F. Thompson has stated that the middle portion of the Karluk escapement is more productive than the spring or fall section of the escapement. He bases this on the catch curves of a cannery at Karluk during the years 1900–1905. He believes the decline in the middle section of the run has been the fault of the F. & W. S. He claims this segment of the run has not been given adequate protection. It would appear that we must determine if the middle portion of the escapement is more productive now, and if so, the reasons why this is the case. To do this, we could construct a two-way weir on a stream like Canyon Creek. On this stream, fish from all segments of the escapement spawn. The survival of fish to the fry stage from

[1] Although this oral paper was never formally published, it was issued as FRI Circular Number 11.

each group might be determined by various methods. The survival of fish to the fry stage from each group to the downstream migrant stage and to the adult stage might be measured by a large marking program in which fish from each group were marked with different fin combinations. From such a program we should be able to measure mortalities to the fry stage and to the migrant stage of fish in each group. Also, it might be determined if fish from each portion of the escapement at Canyon Creek return to the creek at the same time as their parents.[2]

Although Nelson never pursued this productivity research, he questioned the claim that midseason sockeye were the most productive. Yet, the FWS modified its fishing regulations in the 1950s to better protect midseason sockeye and attempted to rehabilitate this run segment (Van Cleve and Bevan, 1973). BCF biologists devoted considerable effort during 1957–70 to determining the relative productivities of Karluk's spring, midseason, and fall-run sockeye and the qualities of their spawning habitats.[3]

Challenges to Thompson's Ideas on Seasonal Run Distribution

Thompson presented powerful evidence that sockeye salmon at Karluk originally had a unimodal run distribution and that intense commercial fishing on midseason fish progressively changed it to bimodal. Case-pack data from one Karluk cannery during 1895–1919 demonstrated this change. Nevertheless, this interpretation can be tested further, particularly by considering whether historic cannery harvests accurately reflect the true run distribution of returning salmon. It is difficult to definitely prove or disprove Thompson's ideas on run distribution, but it is worthwhile to examine his assumptions and to consider additional evidence gained since 1950. In the following discussion we explore challenges to Thompson's ideas and pose some questions about the original run distribution.

Do Case-Pack Data Accurately Reflect the Seasonal Run Distribution?

Thompson's ideas about the seasonal run distribution of Karluk's sockeye salmon were based upon an important assumption—that case-pack production from one cannery during 1895–1919 accurately reflected the seasonal run pattern. Thompson did not test this assumption, though reasons exist for a poor correspondence between cannery production and run abundance.

Cannery Operations: It might be argued that the seasonal distribution of case-pack production in the early cannery years at Karluk at least partially reflected the necessary work of restarting operations in the spring after winter closure. This required a certain amount of time before fishing and cannery operations could began. Additionally, there were logistical problems of transporting men and supplies to this remote location. Thus, case-pack production in early spring may have been lower than it should have been based on the number of fish present. Once canneries were fully operational, every effort would be made to quickly meet annual production goals before the weather deteriorated in autumn. Case-pack data may then underestimate early spring sockeye runs and overestimate midseason and later runs. Likely, case-pack production was a combination of the intricacies of cannery operations, fishing effort, and sockeye salmon abundance.

A useful historical study would be to compare cannery startup times at Karluk Spit with spring run timing of sockeye salmon.

Fishing Effort: The seasonal distribution of case-pack production at Karluk's canneries may have partially reflected the commercial fishing effort. Historically, Karluk's sockeye salmon have been commercially harvested by four main fishing methods—beach seines, fixed ocean traps, purse seines, and gill nets. In the early fishery, most harvests were made with beach seines; ocean traps were first used in 1924. Although we know little about the seasonal habits and problems of commercial fishermen in Karluk's early history, seasonal weather differences alone probably caused fishing effort and efficiency to vary irregularly from May to October. Storms in Shelikof Strait often stopped commercial fishing for several days or weeks in the early years, allowing sockeye salmon unhindered access to the Karluk River. The manager of the Alaska Improvement Company, H. J. Barling, claimed in 1895 that at Karluk "about one-fifth of the entire fishing season is stormy, during which time it is impossible to "lay out" or haul a seine or net; but the storms do not prevent or obstruct the entrance of the fish" (Murray, 1896). Unimodal case-pack production in the early fishery may partially reflect better weather

[2] Letter (8 Nov. 1955) from Philip R. Nelson, Fishery Research Biologist, FWS, Seattle, WA, to Administrator, Alaska Commercial Fisheries. Located at NARA, Anchorage, AK.

[3] These studies were done by John B. Owen (1957–59), Robert F. Raleigh (1958–61), Benson Drucker (1961–70), and Richard Gard (1962–66).

conditions in midseason and poorer conditions in spring and fall.

As Karluk's sockeye salmon fishery developed, new fishing gear, improved methods, and larger boats may have allowed fishing to occur earlier and later in the year, making the bimodal run, if present, more obvious. Fishing effort was also affected by labor strikes that temporarily halted cannery operations and by governmental or self-imposed regulations on fishing times, locations, and methods. The proportion of sockeye salmon caught by different fishing gear (beach seines, purse seines, and gill nets) undoubtedly changed over the 25-year period (1895–1919) studied by Thompson. It remains unknown how these variations in fishing effort affected the seasonal case-pack production, but they may have been significant.

The historic changes in fishing effort for Karluk's sockeye salmon would be a worthwhile study. Pertinent data exist in many published and unpublished annual reports prepared by federal agents and wardens. Likewise, a valuable contribution to understanding the impact of commercial fishing on Karluk's sockeye salmon would be a chronological study of the 130 years of salmon fishing regulations.

Five-year Averages: Thompson used 25 years of case-pack data from one Karluk cannery to show that the sockeye's run distribution changed from unimodal to bimodal during 1895–1919. To do this, he averaged the case-pack data for 5-year periods: 1895–1899, 1900–04, 1905–09, 1910–14, and 1915–19. But using 5-year averages may obscure any natural bimodality present since peaks in the run often occur at slightly different times each year. Barnaby (1944) discussed the problem of using averages to understand the true run distributions during 1921–36. For example, he found that run distributions were bimodal each year, but the 16-year average was trimodal because of slight annual differences in run timing. While averaging errors may not be strong enough alone to invalidate Thompson's conclusions, they add doubt to this method of replicating run distributions. It would be valuable to reevaluate Thompson's thesis using case-pack data for individual years.[4]

Mislabeled Case Packs: Although Karluk's early canneries primarily packed sockeye salmon, other salmon species may have been canned and marketed under the same label as sockeye. We have little evidence of this deceptive practice at Karluk, but intense competition for sockeye salmon existed between canneries during the late 1880s and 1890s. Since cannery superintendents were expected to meet annual production goals, it would not be surprising if salmon other than sockeye were sometimes canned. The abundant runs of even-year pink salmon that flooded into the Karluk River in July–August may have been especially tempting to use as a substitute if the sockeye run was then in a midseason low. Canning midseason pink salmon as sockeye would tend to obscure any bimodality present in case-pack data. It is not idle speculation that this misleading practice may have occurred. In the 1904 report of the Alaska Salmon Commission, Jordan and Evermann discussed this problem of deceptively substituting one salmon species for another and recommended clearer standards for salmon canning labels.

Unidentified Salmon Species: Between 1882 and 1896 the total salmon catch at Karluk was not segregated by species (Rich and Ball, 1931). The entire catch was assumed to be sockeye salmon, but the numbers of other salmon species caught remained unknown. Potentially, pink and Chinook salmon may have contributed to the catch statistics, while late-running coho salmon and the small run of chum salmon contributed little. Thus, reported harvests of Karluk's sockeye may have been too high in the early years, and the seasonal distribution of case-packs may have been distorted by including other salmon species. Any bimodality in case-pack production would be completely obscured by pink salmon, which typically run in the midseason between spring-run and fall-run sockeye. Pink salmon runs occur exactly when Thompson claimed midseason sockeye salmon should be present. Pink salmon were considered to be undesirable fish during the early cannery years at Karluk (Roppel, 1986), but many were harvested during 1901–19 (Rich and Ball, 1931).

Salmon Imports to Karluk: Case-pack production during Karluk's early cannery years may have been supplemented by imports of sockeye salmon from other regions. Although these sockeye were not homing to the Karluk River, they were incorrectly added to its case-pack. Sockeye salmon homing to Chignik, Alitak Bay, Uganik Bay, Ayakulik River, and Little River were sometimes transported to Karluk's canneries. This practice altered Karluk's true case-pack data, which then falsely reflected the actual run distribution.

[4] This data is available on microfilm at the FRI Archives, University of Washington, Seattle.

Robert Porter (1893), Superintendent of the U.S. Census Office, mentioned that salmon from other areas were imported to Karluk's canneries in 1890, claiming that "steam tenders carry the fish from all outlying stations to Karluk." Moser (1899, 1902) visited Karluk's canneries in 1897 and 1900 and reported on importation of sockeye salmon:

> The canneries on Kadiak have prospected over this section and at times have sent a steamer to Kukak Bay and obtained a load of redfish.
>
> The canneries at Karluk are chiefly, but not entirely, supplied from the fisheries in Karluk Bight. A few fish are taken in the vicinity of Red River and Ayakulik, on the western side of the island, a few miles south of Seal Rocks; also off the Slide, the bluff next east of the spit; from the Waterfalls, about 3 miles to the eastward of Karluk, where two streams fall in cascades over a bluff; and from Northeast Harbor, a small indentation a few miles eastward of the Waterfalls; but these fish all belong to the Karluk school. Some years ago a few were taken at Little River, which is inside and a little westward of Cape Ugat, and from Kaguyak and Kukak, on the mainland. But all these places supply but a very small percentage of the Karluk pack. Occasionally, when there is a slack in the run at Karluk, one or the other of these places may be visited by the cannery steamer. Before the cannery at Uganuk was built the stream at this place was also fished by the Karluk canneries.
>
> In 1896 the Alaska Improvement Company packed 87,613 cases of redfish, 12 to the case. No other fish were packed and none salted or smoked. Of the above, 15,580 cases were fish taken at Uganuk, which ran 10 to the case; 3,500 cases from Ayagulik; 340 cases from Kaguayak, and 10 cases from Little River. The balance, 68,183 cases, were from Karluk beach and lagoon.
>
> The Karluk canneries this year fished the Spit and adjacent waters, Ayakulik, Uganuk, Little River, Eagle Harbor, and Kiliuda Bay, though the yield from the last two places was not over 9,000 fish.

Shortly after Thompson presented his ideas on the unimodal run distribution, Shuman claimed that case-pack data would not reflect the true run pattern of Karluk's sockeye because of fish imported from other areas:

> Dr. Thompson contends that the low between the spring and fall modes has been caused by over-exploitation during that period, offering catch figures as proof. This is one more example of the errors introduced by unfamiliarity with the subject. It is true, as Dr. Thompson points out, early pack records from the Karluk Spit show a high pack during mid-July. What the records do not show is the origin of fish packed during that period. I have talked to many old-timers, fishermen, packers, and others, all of whom report that in those early days, the run at Karluk dropped almost to zero in mid-July, and during that period, fishing crews were moved to Uganik River, Red River, Little River, Olga Bay, Kaflia Bay, and sometimes Chignik. Fish were captured at these points, hauled to the Spit and canned there. Eventually, their identity was lost, and later generations came to regard them as having been Karluk fish. With this in mind, one must question seriously any statement to the effect that over-fishing "cut the heart out of the run."[5]

In 1953 Bevan further examined the early cannery records of Karluk and those from nearby areas to determine if sockeye had been imported to Karluk and added to its catch.[6] He particularly wanted to learn if midseason case packs came from other sources. If so, this would invalidate Thompson's claim of an original unimodal run distribution. Using the cannery records, Bevan corrected Karluk's case-pack data for the years 1899–1900 and 1906–13. He found that sockeye imports from Chignik and Alitak Bay were relatively minor, but transfers from Little River, Red (or Ayakulik) River, and Uganik Bay were significant in the early years, primarily in June–July. Few imports occurred in August–September.

Bevan concluded that imports affected case-pack data during early season, but not during mid or late season. Thus, Thompson's idea of abundant midseason fish remained intact. Nevertheless, for each of the 10 years Bevan examined, his corrections greatly increased the bimodality of case-pack data. Corrected case-pack data had an initial peak in mid June, followed by a low in early July, and then a second peak usually in August, but occasionally in late July or early September. Sockeye were imported when fish were scarce at Karluk and common elsewhere. Bevan's study demonstrated a bimodal distribution in Karluk's case pack, but also showed an abundance of midseason fish.

In addition to the inaccuracies caused by imported fish, how many sockeye were exported from Karluk without adding them to the case-pack data? The historic fisheries literature does report that exports were made to Chignik and Alitak in years of exceptionally large runs of Karluk River sockeye salmon (Moser, 1899).

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

[6] 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.

Interception of Fish Homing to Other Areas: Sockeye homing to rivers other than Karluk may have been intercepted along Kodiak Island's coast and wrongly assigned to Karluk's catch during 1895–1919. Little was then known of the mixed-stock origins of harvested sockeye, and these fish were simply allocated to Karluk because it was Kodiak Island's largest run. Prior to 1889, sockeye were harvested in Karluk Lagoon and River, so their true origin was known. In 1889 commercial fishing moved to the ocean off Karluk Spit, and, gradually, harvests came from areas further removed from the Karluk River. Sockeye salmon homing to other Kodiak Island rivers and to Upper Cook Inlet are now known to pass through Shelikof Strait and along Kodiak Island's west coast during midseason. The true origins of these fish were not appreciated for many years (Rich and Morton, 1930; Bevan, 1959, 1962; Barrett, 1989; Malloy, 1988; Barrett and Nelson, 1994). Therefore, some intercepted midseason sockeye were likely added to Karluk's case-pack data, but, in fact, were not homing to that river. In the early fishery years when sockeye runs were abundant, significant numbers may have been intercepted and incorrectly included in Karluk's catch statistics. The addition of intercepted midseason fish would tend to obscure any natural bimodal pattern in the run. The ability of biologists to accurately assign catches of returning sockeye salmon to their true natal stream required a long learning process spanning much of the past century. Certainly, the accuracy of sockeye harvests at Karluk has varied substantially between 1882 and 2010, the data becoming much more reliable in recent years.

Abundance of Spring and Fall Sockeye Salmon During the July Lull: In Karluk's early fishery, when sockeye salmon were very abundant, spring and fall runs undoubtedly overlapped in July. Rutter mentioned this overlap in 1903, claiming "there are two distinct though intergrading runs, the first reaching its maximum about the last of June, the other the first of August."[7] Even with a July lull, sufficient fish may have been present in the early fishery to satisfy cannery demands. If true, case-pack production would reflect the peculiarities of cannery operations, not the seasonal run distribution. As sockeye abundance declined over the years, it is likely that July–lull fish became insufficient to meet cannery demands, and more fishing shifted onto the spring and fall peaks. Thus, case-pack data may have changed from unimodal to bimodal distributions even though the original run was bimodal.

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

Early Evidence of Bimodality: To show the shift from a unimodal to bimodal run distribution, Thompson studied case-pack data from 1895 to 1919. Bimodality was clearly evident in his 1900–19 data, but slight indications of bimodality also existed in his earliest data (1895–99). In these early years, when the overall run appeared to be unimodal, the distribution had a broad shoulder during June and early July that could be interpreted as the first of two modes. If true, this small early mode may have become more prominent as overall sockeye abundance declined. When Bevan studied Karluk's early cannery records, few data existed for the 1895–99 period, except for 1899. In that year case-pack output was bimodal after correcting for imported fish. Thus, even the earliest case-pack data showed some bimodality.

Case-Pack Data Prior to 1895: Thompson's main evidence of a unimodal run distribution at Karluk was the case-pack data from 1895 to 1899. Yet, by 1895 Karluk's commercial fishery had already operated for 13 years, and sockeye harvests had been extremely large for the previous seven years (1888–94), with annual catches often exceeding 3,000,000 fish. The cumulative harvest for 1888–94 was about 22,000,000 sockeye salmon. Sockeye catches remained high for a number of years after 1894, but it can be argued that by 1895 the fishery had already started to decline. Cannery data from 1888–94 may better reflect the original run distribution. Thus, the run distribution shown by Thompson's 1895–99 unimodal data may have already been changed after seven previous years of intense fishing.

Bimodal to Unimodal?: Directly opposite to Thompson's thesis, is it possible that intense fishing on Karluk's sockeye during 1888–94 had modified the run distribution by 1895 from bimodal to unimodal? With intense competition for fish, all run segments were likely harvested once canneries began operations each spring. To reach annual production goals as soon as possible, harvests may have focused on spring sockeye salmon, rapidly depleting their numbers. Reportedly, no sockeye salmon escaped to Karluk's spawning grounds in 1888 because a barricade was placed across the river in May–October (McDonald, 1889). Since the barricade was used

Karluk River sockeye salmon in spawning condition, male (bottom) and female (top). (Benson Drucker, Reston, VA)

Karluk River pink salmon in spawning condition, male (top) and female (bottom). (Benson Drucker, Reston, VA)

again in early 1889 (Bean, 1891), possibly all spring-run sockeye were harvested in 1888–89. Spring-run sockeye were abundant in the early fishery and anticipated by the canneries, but by 1895 cannery superintendents typically expressed disappointment when spring runs failed to return in abundance (Tingle, 1897). Poor spring harvests caused anxiety that the whole fishing season would fail, but usually the large August–September catches made each year a commercial success. While the above argument is speculative, it serves to illustrate the inherent weakness in using case-pack data to infer seasonal run distributions.

Test of Equivalence of Case-Pack Data and Run Distribution: Thompson apparently never tested the suitability of using case-pack data to estimate run distributions. Such a study could still be done, starting with 1921 since accurate data exist on case-pack production and run distributions for Karluk River sockeye salmon during that year. Also, many factors that affect cannery production, other than run abundance, may be similar to the early fishery years. These factors include cannery startups, operations, and goals, and fishing efforts and efficiencies as influenced by seasonal weather patterns. The case-pack and run data could be averaged over five-year periods to match Thompson's methods.[8]

In conclusion, considerable uncertainty exists as to whether historical case-pack data accurately reflect the true seasonal run distribution of Karluk's sockeye salmon during 1895–1919. During the early fishery there were many opportunities for errors in these data. Thus, the idea that the original run distribution shifted from unimodal to bimodal by commercial fishing is questioned. Most evidence suggests that an original bimodal run pattern existed, though midseason fish still may have been abundant.

Migratory Capacity of the Karluk River

Compared with other Alaska and Canada river systems that have bountiful salmon runs, the Karluk River is

[8] The Karluk case pack data for the years up to 1958 are present on microfilm at the FRI Archives, University of Washington, Seattle, or in APA cannery records.

not physically large. Does the Karluk River have a definite limit to the number of salmon that can ascend it at any one time because of the river's size constraints? Specifically, is it physically possible for two major salmon runs, the sockeye and pink, to simultaneously occupy the river during the midseason in July–August? Here, we investigate these questions as they relate to the original run distribution of sockeye salmon.

Thompson claimed that Karluk's midseason sockeye run was originally the most abundant and produced a unimodal run distribution. Historical records dating back to 1880, and recent weir counts, show that pink salmon ascend the Karluk River in July–August, being especially abundant in even-numbered years. If sockeye and pink salmon both reached peak abundance in midseason under natural pre-fishery conditions, then several million fish must have ascended the river simultaneously. In the early fishery years, Karluk's sockeye salmon runs often exceeded 3,000,000 fish and pink salmon runs in excess of 4,000,000 fish have been recorded. It is difficult to imagine that such large masses of salmon concurrently migrated up the Karluk River.

The Karluk River is typically about 90 m wide and less than 1 m deep.[9] Water discharge varies seasonally from about 3–60 m^3 per second (mean discharge is only 12 m^3 per second) (U.S. Geological Survey, 1974–82). Also, the river's flow regime is seasonally bimodal (Fig. 7-2). Discharges are low in winter, but then rapidly increase from spring snowmelt to a first peak in June. This is followed by declining flows through July–August, with often a low stage reached in late August. Autumn rains once again increase the discharge until a second peak is reached in October–November. Winter freezing and snowfall cause the river to recede in December–March. This seasonal bimodal pattern is again reflected in the water levels of Karluk Lake (Fig. 7-7).

If Thompson is correct about abundant midseason sockeye, then millions of sockeye and pink salmon must have migrated up the Karluk River in July–August in the early fishery years, just as river flows were declining and shallow water made upstream travel more difficult. This scenario seems biologically and physically unlikely. Indeed, some historical evidence shows that there are physical limits on the numbers of midseason salmon that can ascend the Karluk River at one time. Bean (1889) claimed that a huge pink salmon run prevented other salmon from entering the Karluk River in 1880:

> [At the Karluk River, 1880] Mr. Charles Hirsch, of the Karluk Packing Company, San Francisco, has recently described to us an unusual run of this salmon in Karluk River. About the 6th of July, 1880, a glut of humpbacks came into the Karluk and continued five weeks, during which time no other salmon could enter the river. It was impossible to pull a boat across the stream.

When Bean (1891) visited Karluk in 1889, he claimed that the river had no natural or artificial obstructions to salmon migrations, "unless we may regard the low summer stage of the water in such a light." In 1924, over 4,000,000 pink salmon ascended the Karluk River during the midseason low flows, and this horde of fish apparently overwhelmed the river's oxygen capacity and caused a massive fish kill:

> [At the Karluk River, August 1924] The large humpback run in Karluk River did considerable damage to the red salmon spawn. On August 21st hundreds of thousands of fish died in the twenty miles of river between the weir and the still water at the Larsens Bay Portage. The mortality included adult red salmon, humpbacks and trout as well as young fish. The cause is unknown unless it was due to overcrowding of humpbacks with a possible fall of water level in the river. Mr. Wood states that a few days later the river was still packed with live fish. There were over four million humps passed up through the weir.[10]

Comparing the size and flow characteristics of the Karluk River with the huge early runs of sockeye and pink salmon, it seems unlikely that two major runs could use the river in midseason. If physical limits exist in the river's migratory capacity, then the run timing of sockeye and pink salmon should be selected by a long evolutionary process to minimize overlap of the two species. Salmon migration patterns since 1921 show little overlap between bimodal sockeye runs and midseason pink runs. Further, pink salmon appear to be better suited than the larger sockeye for navigating Karluk's shallow midseason waters.

Considering the Karluk River's flow regime, it is striking that the migration peaks of spring- and fall-run sockeye salmon often coincide with high or increasing discharges. This correspondence is especially evident in spring-run sockeye, which peak just as the river crests in mid June. The peaks in fall-run sockeye

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[9] Jefferson F. Moser, an APA official, gave testimony in 1912 at a U.S. Senate hearing on Alaska's salmon fisheries and declared that the Karluk River mouth was so narrow that "You can almost jump across it. It is not more than 50 feet . . . It is just a small stream" (U.S. Senate, 1912).

[10] Lucas, Fred R. 1924. Report of Kodiak-Afognak District for the month of September 1924, including the inspection of the Karluk and Uganik spawning areas. Afognak, AK (4 Oct. 1924). Unpubl. report. 9 p. Located at NARA, Anchorage, AK, and at ABL Library Files, Auke Bay, AK.

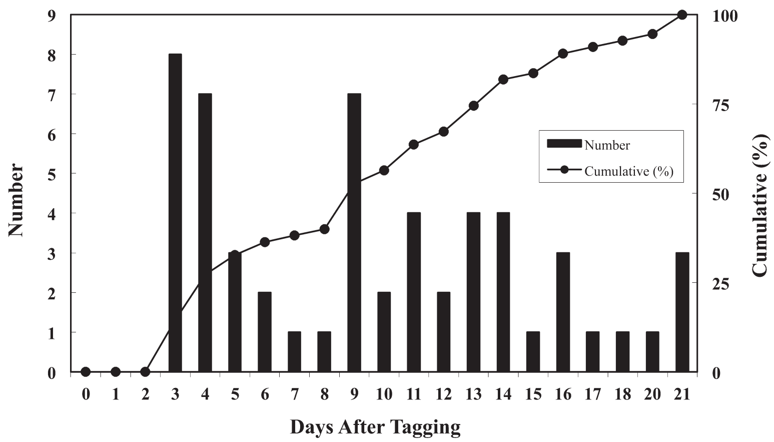

Figure 6-4. Travel time of adult sockeye salmon tagged in the ocean at Karluk Spit on 1 August 1925 until their passage of the lower Karluk River weir. Of the 200 tagged sockeye, 55 were observed at the weir (data located at NARA, Anchorage, AK).

and river flow match less precisely, the discharge being dependent upon the exact timing of autumn rains. Fall-run sockeye have difficulty ascending the Karluk River in some years because of low water, as shown by their longer travel times (Gard, 1973). Fall-run sockeye often linger in Karluk Lagoon for days or weeks and only begin their ascent after rainstorms cause the river to rise. Gard (1973) found a high correlation between fall-run sockeye escapements and rainfall, indicating a linkage between migration timing and water flow.

If sockeye and pink salmon were originally abundant in the midseason, pink salmon must have had difficulty establishing and defending spawning redds in the river during a major sockeye migration. Pink salmon spawning should be more efficient when few other river migrants are present, as occurs presently with the bimodal sockeye run. The midseason pink salmon run fits neatly between the spring and fall sockeye runs. Further, pink salmon can easily occupy the midseason spawning niche since their run timing, unlike sockeye salmon, is not linked to lake plankton blooms or a complex life history in freshwater. Thus, run-timing evidence of sockeye and pink salmon in the Karluk River does not support the idea that sockeye had an original unimodal run pattern with maximum midseason abundance.

Effect of Travel-Time Inaccuracies on Seasonal Run Distribution

The total run of Karluk River sockeye salmon is determined by adding weir escapement counts and commercial fishery catches. The catch for any particular day is added to the weir count made several days or weeks later. The lag between catch and weir count is caused by the time needed for escaping fish to travel from the fishery to the weir. To correctly measure seasonal run distribution, catch and escapement figures should come from the same group of fish being caught and escaping the fishery at the same time. To do this, true travel times must be known. Inaccurate travel times will distort calculated run distributions and times of peak abundance. In determining travel times of Karluk's sockeye salmon, it is important to distinguish the season and at least two travel segments: 1) from the fishery to Karluk Lagoon, and 2) from Karluk Lagoon to the weir. The weir was located on the lower Karluk River only 5 km from the ocean during 1921–41 and 1976–2010, but was located near Karluk Lake's outlet about 40 km upstream from the ocean during 1945–75.

Several biologists conducted travel-time studies on sockeye salmon early in Karluk's research history. Rutter tagged 400 spring-run sockeye and released them off Karluk Spit in 1903.[11] These fish entered the river within one day and few remained in the lower river after one week. They reached Karluk Lake in about 10 days. Gilbert tagged 200 sockeye salmon in the ocean off Karluk Spit on 1 August 1925 and recorded their weir passage.[12] These fish had a mean travel time between the ocean fishery and lower Karluk River weir of 9.7 days (range of 3–21 days), surprisingly long for the relatively short distance of only 5 km (Fig. 6-4). In mid July 1926, Gilbert tagged 100 sockeye

[11] See footnote 7.

[12] 1) Letter (18 Aug. 1925) from Ray S. Wood to Fred R. Lucas. Located at NARA, Anchorage, AK.
2) Letter (11 Sept. 1925) from Ray S. Wood to Fred G. Morton. Located at NARA, Anchorage, AK. Only 55 of the 200 tagged fish were seen to pass the weir and it is unclear what happened to the other 145 fish. Possibly, some tagged fish passed the weir without being detected and some may have remained for several weeks in Karluk Lagoon before moving upstream. Since sockeye salmon were counted through the weir until 6 October in 1925, any late-migrating tagged fish should have been seen.

salmon at the lower weir and recorded their passage at the Portage weir. These fish had a mean travel time of 4 days (range of 2–9 days) over the 20 km between the two weirs. Rutter and Gilbert's results suggested significantly different migratory behaviors for spring- and fall-run sockeye. Barnaby (1944) used 7-days of travel time when he calculated the total run during 1921–36; this became the standard figure used by biologists for many years, without adjustments for season or weir location.

After the weir was moved to Karluk Lake's outlet in 1945, Shuman and Nelson tagged adult sockeye and measured their travel times over the 35 km between upper Karluk Lagoon and the lake. Spring-run sockeye ascended the river in 6–7 days, but fall run fish needed 10–11 days (Gard, 1973). Shuman and Nelson did not measure the additional time that sockeye needed to travel from the fishery to upper Karluk Lagoon. Their results agreed with Rutter's over the same distance, but differed from Gilbert's findings that fall-run fish needed more than 10 days to reach the lake. In a 1949 tagging study, Bevan (1959, 1962) found that spring-run sockeye needed 9 days to travel from the fishery to Karluk Lake and discussed how slight changes in assumed travel time affected the calculated run numbers. When Walker and Bevan tagged midseason sockeye at Karluk Lagoon in 1952, these fish needed, on average, 21 days to reach the lake, much longer than the 6.5 days needed by spring-run fish.[13] Similarly, when Nelson and Abegglen (1955) tagged sockeye at Karluk Lagoon in June–August 1953, the later runs had longer travel times. Gard (1973) also found that sockeye tagged in August–September 1963 took much longer to ascend the river than did spring runs. Thus, despite some unexplained differences in these early tagging results, evidence was mounting that spring- and fall-run sockeye had different travel times.

After many years of using the standard 7-day travel time, the ADFG tested this assumption in 1970 by tagging adult sockeye in Karluk Lagoon and recording their passage of the weir at the lake's outlet.[14] They found that the 7-day travel time was reasonably accurate for spring-run sockeye, but fish tagged in July–August had mean travel times from 23 to 35 days. Incredibly, some midseason fish spent up to 54 days in the lagoon and river before they reached the lake. The ADGF study did not include the extra travel time between the fishery and Karluk Lagoon. More recently, Barrett and Nelson (1994) reported travel times for the 5 km between Karluk Spit and the lower weir as 5 days for early-run and 10 days for late-run sockeye, similar to Gilbert's 1925 results.

Clearly, the travel times of Karluk River sockeye salmon vary seasonally—spring-run fish quickly move up the river, fall-run fish need more time. Since most seasonal run distributions have been calculated using the standard 7-day travel time, substantial errors exist for midseason and later runs. These errors became obvious in 1970 when the ADFG calculated the sockeye run distribution using two different travel time methods: 1) the standard 7-day travel time assumption, and 2) their actual tag-determined travel times as measured in 1970.[15] Both methods showed a bimodal run distribution for Karluk's sockeye salmon, but large differences existed in the times of peak abundance. For the tag-determined method, the longer travel times in July–August shifted the peak run abundance about one month earlier than normally expected from using the 7-day method (i.e. from mid September to mid August). Also, the sharpness of the fall peak was substantially lowered, the sockeye run being spread over more time. Thus, the contrasting migratory behaviors of spring-run fish that quickly moved upstream and fall-run fish that lingered in Karluk Lagoon enhanced the bimodality of weir counts and spawning-ground use. These results suggest that the natural run of sockeye salmon in ocean waters as they home to the Karluk River also has a bimodal seasonal distribution, with a sharp spring peak and a broad fall peak.

The different travel times of spring- and fall-run sockeye salmon raise several questions. Why do midseason sockeye (July–August) have longer travel times than do spring-run sockeye? Are travel time differences innate to each run, or are they caused by environmental factors? What advantage, if any, is there for fall-run fish to remain for many weeks in Karluk Lagoon rather than proceeding directly to the spawning grounds? Are past errors in estimating travel time responsible for the reported trimodal run distributions of Barnaby (1944) and Rounsefell (1958), with the middle peak being caused by catch data and the later peak being caused by weir count data?

[13] 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.

[14] Simon, Robert J., Jack Lechner, Martin F. Eaton, Peter B. Jackson, and Louis A. Gwartney. 1970. Kodiak area management annual report, 1970. ADFG. Unpubl. report. Located at ASA, Juneau, AK.

[15] See footnote 14.

Two environmental factors may cause different travel times in Karluk's sockeye salmon: 1) seasonality of river discharge, and 2) pink salmon abundance. The Karluk River has a bimodal flow regime; the first peak occurs in June from snowmelt runoff, the second peak occurs in October–November from autumn rains. Snowmelt runoff is a predictable seasonal event each year, but the timing of autumn rains varies. Typically, low or declining river flows exist in July–August. Spring-run sockeye have short travel times because abundant river flows exist each June. These fish enter Karluk Lagoon and continue with little hesitation to the spawning grounds. Ascent of the river is relatively easy because of high flows and the absence of adult pink salmon.

In contrast, migratory conditions change substantially in July–August as flows decline and pink salmon enter the river, especially in even-numbered years. Sockeye salmon entering Karluk Lagoon in late July and August must now contend with low river waters and numerous pink salmon, both hindering free upriver migration. In abnormally dry years, the Karluk River can have very low flows that cause fall-run sockeye to hold in Karluk Lagoon for extended periods awaiting better conditions. This phenomenon has been observed many times by field biologists and weir tenders:

> [1897] . . . in many localities much depends upon the stage of water in the river. If the water is low, so the fish can not ascend, they are held in the salt or brackish water and do not seem to ripen so rapidly, but if there is sufficient water they do not remain around the mouth of the river very long, but pass rapidly to the lakes.
>
> [At Karluk, 1903] After entering the brackish water estuary, salmon play about for a day or two before continuing their migration up the river, and sometimes they remain in the estuary a much longer time. One tagged specimen was taken in the estuary a month after it had been released there, and several were taken as much as a week after tagging . . . The Karluk salmon are about ten days reaching the lake from the mouth of the river, which makes the rate about three miles a day.
>
> [At Karluk, 25 November 1921] During the latter part of the run the fish would stop over in the lagoon long enough for a red tinge to become noticeable on the skins of about half of them passing through the gates. The early part of the run, the fish were fresh and bright and were not observed schooling up in the lagoon.
>
> [At Karluk, 1923] The incoming fish displayed the same habits as heretofore in schooling up in the deep pool at the head of the lagoon until a large school gathers; then something starts them upstream in a body. Sometimes it seems to be a raise in the river, at other times there is no apparent cause. Old timers in the locality say that the fish always have acted so and it is especially noticeable during the latter part of the season.
>
> [At Karluk, 1926] About July 1 water became quite low as the snow fall last winter was very light and this summer rather dry. During August the river became very low and the salmon seemed rather reluctant to make the ascent, many staying in the lagoon until they became quite red. When the river would rise slightly they would at once commence to go up in numbers. . . . Red salmon continued to run steadily all through the month of September. An occasional rain would raise the river slightly making their passage easier.
>
> [At Karluk, 22–24 September 1935] We made a survey of the lagoon and estimate there are from 50 to 75 thousand fish here, many of them have become so weak they will never reach the Lake. Water very very low. . . . Heavy rain last night, river raised about two inches, had the largest run of fish for the season. Starting in to rain to night again. Expect we will clean lagoon of fish tomorrow. [16]

Besides the river's flow conditions, the presence of pink salmon apparently reduces the number of migratory pathways for sockeye. Pink salmon establish and guard spawning redds in the main river channel, and upmigrating sockeye must pass through these defended areas. Significantly, Walker and Bevan noted that abundant pink salmon in even-numbered years delayed upmigrating sockeye and reduced their vitality:

> [Speaking of Karluk River sockeye salmon, 1952] One further point, during the tagging of mid-run fish in Karluk Lagoon in 1952, the individuals were easily netted and presented no problem during the handling process connected with tagging. The behavior was very unlike that demonstrated by fish treated similarly on other occasions in the same general area. It would appear that in 1952, the heavy concentration of pink salmon affected the vitality of the sockeye salmon, which could have resulted in delayed upstream migration and/or mortality.[17]

Likewise, ADFG found in their 1970 study that sockeye tagged in July–August needed much longer

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[16] 1) Moser (1899).
2) See footnote 7.
3) Letter (25 Nov. 1921) from Fred R. Lucas, Fish Culturist, Parkplace, OR, to Henry O'Malley, Field Assistant, Seattle, WA.
4) Lucas, Fred R. 1924. Report of the red salmon census at Karluk Alaska during the season of 1923. Dep. Commerce, USBF. Unpubl. report. 4 p.
5) Hungerford, Howard H. 1926. Report of operations at Karluk Weir (Lower) season of 1926. Dep. Commerce, USBF. Unpubl. report. 4 p.
6) Hungerford Howard H. 1935 notebook. References (3)—(6) located at NARA, Anchorage, AK.

[17] See footnote 13.

times to reach Karluk Lake and suggested that pink salmon hindered their migration.[18] These midseason fish had higher mortalities than early-run fish. The ADFG proposed repeating the tagging study in 1971 to measure travel times in a year with few pink salmon, but this study was not done. We believe a comparative travel-time study between two years with drastically different pink salmon runs may give insights into the migratory behavior of fall-run sockeye. Such a study is appropriate since perusal of weir-count data suggests that fall-run sockeye change their migratory behavior between even- and odd-numbered years.

We contend that fall-run sockeye have longer travel times because of two environmental factors, water flow and pink salmon abundance, not because of innate features of these subpopulations. In years with high river flows and few pink salmon, fall-run sockeye arrive at Karluk Lagoon and proceed with little delay to the spawning grounds. In years when the ascent is harder, fish hold in Karluk Lagoon and only reach Karluk Lake with difficulty. These different responses to environmental conditions, which vary considerably from year-to-year, may explain why peak weir counts of fall-run sockeye vary from early August to early September. When environmental conditions are favorable, peak weir counts occur in early August; when conditions are unfavorable, peak weir counts occur later.

In summary, the calculated run distributions are distorted by errors made in estimating the travel times of sockeye salmon between the fishery and weir. These errors tend to enhance the natural bimodal distribution, since fall-run fish that have escaped the fishery may remain for several weeks in Karluk Lagoon before passing the weir. Seasonal distribution of weir counts is not the same as seasonal distribution of escapements. Natural environmental variations in river flow and pink salmon abundance affect the travel time of fall-run sockeye, while spring-run sockeye quickly migrate upstream. Because spring- and fall-run sockeye have different travel times between the fishery and lake, the run distribution becomes more bimodal once fish enter the Karluk River, as compared with their ocean migration along the coast of Kodiak Island. Travel time errors have caused midseason sockeye abundance to be underestimated, while abundance in September has been overestimated. This conclusion further brings into question the idea that intense fishing on midseason fish caused the bimodal run distribution. It suggests that depletion of midseason fish, in relation to the other run segments, has been less severe than indicated. These errors in calculating seasonal run distributions have occurred ever since the Karluk River weir began operations in 1921, and were significant during 1945–75 when the weir was located at Karluk Lake, 40 km from the ocean.

[18] See footnote 14.

Genetic Differences

Wilmot and Burger (1985) examined the genetic variation of spring- and fall-run sockeye salmon in the Karluk River during 1978–81. Spring and fall runs had significant genetic differences and were reproductively isolated subpopulations, as Thompson (1950) had predicted. The biochemical evidence did not directly dispute the idea of an originally unimodal sockeye run, but the differences in spring and fall runs were thought to be of natural origin rather than from overfishing the midseason fish.

Persistence of Productive Subpopulations

Thompson believed that Karluk's sockeye salmon had many independent subpopulations, the most plentiful originally being midseason fish. Despite several decades of effort to protect and enhance this run segment since 1950, these fish failed to increase and the run distribution has remained bimodal into present times. If midseason sockeye were originally abundant and productive, why didn't they respond to rehabilitation efforts? One reason might be that they were completely exterminated, though a fishery is seldom so efficient that abundant subpopulations are entirely harvested. River barricades, such as those used on the lower Karluk River in 1888 and part of 1889, completely blocked the sockeye migration and potentially allowed all fish to be harvested. Continued use of such river barriers would decimate all or part of a sockeye run, but these were not used at Karluk after 1889 because of federal prohibitions and rivalry between canneries. Reportedly during the early fishery, beach seines functioned as a barrier at Karluk Spit, the nets being continuously operated so sockeye salmon could not enter the river (Roppel, 1986). Yet, once the fishery moved to the ocean off Karluk Spit in 1889, fish freely entered the river at times during stormy weather and fishing closures, though harvests in the lagoon continued until 1898. Because of fishery inefficiencies it seems likely that at least some midseason sockeye, if abundant, reached the spawning grounds and should have increased in abundance when protected.

In 1952 Nelson questioned the idea that midseason sockeye were originally abundant and productive at Karluk, wondering how they could be so drastically reduced in the early fishery without spring and fall runs also being depleted. Supposedly, the spring and fall subpopulations were less productive and less able to withstand heavy fishing:

> [Concerning Karluk River sockeye salmon] The FRI through the cooperation of the Alaska Packers Association at San Francisco has obtained certain daily catch records for the early years, that is 1890 or so, until 1921. From these records they find that the major run occurred during the mid-season or during July. At that time the curve of appearance of the run according to Bevan was unimodal. It is their contention that overfishing during the mid-season has depleted the heart of the run, and now only the early and late runs are apparent. . . . As to whether the FRI is correct is problematical, but the possibility exists. It must be remembered that before the White Act in 1926 fishing occurred during the entire season. Under such conditions, how it was possible to destroy the center run without destroying the early and late runs, when according to the FRI the center run is the most prolific, is not clear to me.[19]

Thompson (1950) believed that Pacific salmon had great resilience in maintaining their populations despite intense fishing and expected midseason sockeye to respond to new regulations at Karluk (Thompson and Bevan, 1955):

> 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.
>
> Historically, the best run occurred during July and August in early days, a period now very poor. Under the theory that the period of the largest natural run is the most productive, it would be indicated that the original, but now nearly lost, runs of those two months are what need restoration, and that the earlier part of the season does not. Thus any shift in the fishing time toward the early part of the season will be desirable.

Uniqueness of Bimodality

Even though most sockeye salmon streams on Afognak and Kodiak Island have unimodal run distributions, Karluk's bimodal run is not unique to the region. Two streams entering Olga Bay on Southwest Kodiak Island, Upper Station and Akalura, have bimodal sockeye runs (Barrett and Nelson, 1994). Furthermore, bimodal sockeye runs are known from the Alaska Peninsula and Cook Inlet. Thus, Karluk's bimodal sockeye run is not an exclusive phenomenon for Kodiak Island and southwestern Alaska.

Later Doubts by Thompson?

Throughout the 1950s Thompson continued to assert that Karluk's sockeye run was originally unimodal and that commercial fishing on midseason fish changed this to bimodal. Bevan's corrections of early case-pack data were not large enough to change his conclusions.[20] In 1955 Thompson and Bevan proposed greater protection of Karluk's midseason sockeye, hoping these fish would recover to their former abundance.

Shuman and Nelson evaluated Thompson's ideas and the consequences for the FWS's research program at Karluk. Shuman rejected Thompson's thesis, citing as evidence that sockeye runs had always been bimodal as far back as cannery personnel and beach seine bosses could remember. He believed that the early case-pack data incorrectly reflected run distributions because of fish imported to Karluk's canneries. Nelson claimed that the bimodal run pattern existed at least as far back as 1912:

> [Concerning Karluk River sockeye salmon] To begin with, we find upon plotting the time of appearance of the run for each year that generally two modes are apparent. These modes usually occur in the latter part of June and the latter part of August. This condition has prevailed since 1921 and according to Mr. Axel Carlson, beach seine boss at Karluk, this has been apparent to him as far back as 1912.[21]

By 1958 Nelson questioned whether Thompson still believed in the original unimodal run pattern and midseason productivity of Karluk's sockeye:

> [Concerning Karluk River sockeye salmon, 1958] As to whether the middle portion of the Karluk run is more productive then the spring or fall runs is still questionable in my mind. Is this hypothesis still held by Dr. Thompson? I recall that he mentioned to Clint Atkinson a couple of years ago that this was one of the most serious mistakes he ever made. He did not mention the reasons for this. Possibly this might have caused some hardship to the packing industry when the Fish and Wildlife Service imposed increased restrictions to protect the center of the run or possibly he errored in the interpretation of the data.[22]

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[19] Letter (21 Oct. 1952) from Philip R. Nelson, Fishery Research Biologist, Seattle, WA, to John Lutz, FWS, Kodiak, AK. Located at NARA, Anchorage, AK.

[20] See footnote 6.

[21] See footnote 19.

[22] Memo (16 April 1958) from Philip R. Nelson, Fishery Research Biologist, Annapolis, MD, to W. F. Royce, Assistant Regional Director in Charge of Research. Located at NARA, Anchorage, AK.

Nevertheless, Van Cleve and Bevan (1973) continued to affirm that Karluk's original sockeye salmon run was unimodal and had abundant midseason fish, suggesting that Thompson had not changed his conclusions.

Historical Evidence of the Seasonal Run Distribution

Because Karluk's sockeye salmon were abundant during the early fishery, knowing the original run distribution is important for research and management purposes. To gain some insight into the original run distribution of Karluk's sockeye salmon, we searched the historical fisheries literature prior to 1910 for evidence of unimodal or bimodal run patterns. Following is a chronological listing of quotations about run timing, with an assessment of whether the citation indicates a unimodal or bimodal run distribution.

1790: Merck

The naturalist Carl Heinrich Merck visited Three Saints Bay, Kodiak Island, in late June and early July 1790 as part of a Russian voyage of exploration to Alaska. Merck described in his journal, along with a later compilation of the voyage by Z. D. Titova, the seasonal movements of salmonid fishes on Kodiak Island, but did not specifically mention the Karluk River (Pierce, 1980):

> The red fish comes up the rivers from May to September, but not into every river. The white fish also come up the rivers, and the *gorbusha. Chavych* comes only at the beginning of the season, and only a few of them. People catch the fish with nets made of thin strings of sinews . . .
>
> [Speaking of the Alutiiq residents of Kodiak Island] In the month of April they move from winter to summer dwellings, which are in places rich in fish and whales . . . The first fish which they get are halibut . . . The other fish are the red, humpback, kizhuch, and the white fish (sig). They catch these fish until September . . . In October, when all fishing is ended, they return to the winter dwellings . . .

These statements give no information on unimodal or bimodal run distributions, but do convey a general idea of the salmon migrations in 1790.

1802–03: Davydov

The Russian naval officer Gavriil Ivanovich Davydov (1977) spent the winter and spring of 1802–03 studying Kodiak Island and its Alutiiq people. He mentioned Karluk in his journal as a location to stock up on dried salmon, but his notes about fishes were general comments for Alaska and eastern Russia:

> The time when the fish will appear is so well known by the inhabitants that they place as much, if not more, reliance in it than others do in the ripening of a crop. Nearly all the fish coming up the river are of the salmon species, but not every species comes up every river, and in some rivers the fish go up early and in some late. The inhabitants, in anticipation of this, block the river with a dam or fish weir. . . .
>
> [Speaking of sockeye salmon] This appears first in almost all the rivers.

His statement gives little information on salmon run distributions, except that sockeye arrived first at streams. The reference to early and late runs may refer to sockeye, but could also refer to other salmon species.

1824–25: Khlebnikov

Kiril Timofeevich Khlebnikov, an office manager for the Russian-American Company, was stationed at Sitka, Alaska, from 1818 to 1832. His duties required him to travel widely in Alaska, and in June 1825 he visited the Kodiak district to gather data on company operations and possibly visited Karluk (Khlebnikov, 1994):

> [Speaking of the Karluk River, 1824 or 1825] A stream has been discovered here which is regularly visited by enormous quantities of ocean fish every year, so with great difficulty a reliable wooden fish weir has been built. During the fish run free women are brought in to clean them and are paid for the time they work. The principal preparation is of iukola or dried fish from red and humpback salmon. The early run of fish begins in April, while the real run begins from the middle of June or the beginning of July and lasts up to October. Hence, it [the iukola] is issued to Aleuts being sent to hunt sea otters and is sent by boat or baidaras to Pavlovsk Harbor.

The cited dates refer to the Julian calendar, which in the 1800s was 12 days behind the modern calendar. Thus, mid June (Julian) = late June (modern).

It is uncertain from Khlebnikov's statement if the run pattern was unimodal or bimodal. The beginning and ending of the salmon run match present-day knowledge, but Khlebnikov was unclear whether sockeye or pink salmon composed the "real run" starting in late June or mid July. If he were speaking of sockeye salmon, this would be evidence of a unimodal pattern; if he meant pink salmon it may be evidence of a bimodal pattern. The exact year that Khlebnikov described is also unclear. He visited the Kodiak district in 1825, but the Karluk data may have come from that visit or from reports by Russian workers in 1824. This makes it impossible to conclude if the "real run" was a migration of even-year pink salmon or odd-year sockeye salmon.

1861: Golovin

Pavel N. Golovin, a Russian Naval Captain, was sent to Russian America in 1861 to investigate conditions in the Alaskan colonies. He described the existing fishing industry and discussed Russian plans to develop commercial salted-salmon operations at the Karluk River. However, his observations on salmon run distribution were general comments for the Kodiak Island area, not specifically for Karluk (Dmytryshyn and Crownhart-Vaughan, 1979):

> Fish are prepared in the colonies for the most part as food for the inhabitants; only a small amount goes abroad for sale. Seasonal fish begin to appear along the coast in March, sometimes in February, especially herring. On Kodiak they come in June and November, . . . Red fish of the salmon variety begin to appear in May; these have various names in the colonies. This fish is generally salted and dried, in which state it is known as iukola.

This gives no information on sockeye run distribution, except that it began in May.

1880: Bean

Tarleton Bean, an ichthyologist of the U.S. Commission of Fish and Fisheries, traveled north to Alaska in 1880 with William Dall, Commander of the U.S. Coast Survey schooner *Yukon*. They stopped at Kodiak on 9–14 July 1880, but did not visit the Karluk River. While in Kodiak, Bean interviewed several residents who knew about Karluk River salmon and later corresponded further with these people. In his 1887 report he described the 1880 operations of two companies that prepared salted salmon at Karluk Spit, the Western Fur and Trading Company, and Smith and Hirsch:

> [Speaking of the Karluk River sockeye salmon, 1880] In the beginning of July red salmon became scarce, and after the run of humpbacks (*O. gorbuscha*) set in (July 12), the red salmon (*O. nerka*) disappeared altogether. Smith & Hirsch stopped fishing until August 14, when the red salmon again made their appearance. . . . Red salmon are abundant every year at Karluk.

Bean clearly described a bimodal run distribution for Karluk's sockeye salmon, and his statement was powerful in being made by a trained biologist prior to large cannery harvests. The season run distribution he described in 1880 matches present-day run characteristics.

In many later publications, Bean (1889, 1890, 1891, 1894) mentioned Karluk's huge pink salmon run of 1880 and gave further information on pre-fishery sockeye runs:

> [Speaking of the 1880 pink salmon run, Karluk River] Mr. Charles Hirsch, of the Karluk Packing Company, San Francisco, has recently described to us an unusual run of this salmon in Karluk River. About the 6th of July, 1880, a glut of humpbacks came into the Karluk and continued five weeks, during which time no other salmon could enter the river. It was impossible to pull a boat across the stream.
>
> We have seen how an unexpected run of Humpbacks may prevent the Red Salmon altogether from entering its chosen river.

These statements imply a bimodal run distribution for sockeye, with a seasonal low in early or mid July. The large pink salmon run of 1880 occurred for five weeks starting in early July, just when midseason sockeye, if present, would be expected to enter the Karluk River. Bean claimed that pink salmon excluded other salmon from entering the river, but this seems unlikely for biological reasons. Salmon returning to their natal stream tenaciously pursue their spawning grounds, no matter what obstacle. If abundant midseason sockeye actually returned to the river in 1880, they would migrate upstream with the pink salmon. Since pre-fishery midseason sockeye runs, if present, should have been large in 1880, it is doubtful they would be denied access to the river. More likely, the lack of sockeye salmon in July 1880 reflected their natural midseason lull between the spring and fall runs. Run timing for the 1880 pink salmon was the same as in present times.

1889: Bean

Bean returned to Alaska in 1889 and studied Karluk's fisheries from 2 August to 7 September. Although Karluk's salmon canneries began operating in 1882, sockeye catches remained fairly small until 1888. Thus, Bean's 1889 observations at Karluk were made halfway through the second year of large harvests. His 1891 report gave the first detailed description of the commercial fishery, the sockeye salmon runs, and Karluk Lake spawning grounds:

> [Speaking of Karluk River sockeye salmon, 1889] For some reason unknown to us the salmon were late in making their appearance at Karluk in 1889. Up to the first of August the outlook for the fishermen was very discouraging, but during the month of August the arrivals of fish were numerous and the schools very large.
>
> When we left Karluk at the end of August the Red Salmon were still running into that river, but had greatly diminished in numbers and had become so dark in color as to be unfit for canning. . . . The season usually begins in June, and fish, which have not yet spawned, continue to arrive as late as the beginning of September. Spawning certainly takes place in August,

> as we know from personal observation. Dead fish and others which have spawned and are already dying are very abundant about the middle of this month. We did not find many Red Salmon on our way up the Karluk River.

These descriptions of Karluk's sockeye salmon runs in 1889, very early in the commercial fishery, match the present-day bimodal pattern. Bean arrived at Karluk during the lull between the spring and fall runs, saying fishermen were disappointed, but the large fall run arrived in August and greatly increased the harvests. Upon traveling to Karluk Lake in mid August, he was surprised to see few live spawning fish, but many salmon carcasses from the large spring run littered the spawning grounds. These seasonal events are typical of present-day bimodal conditions on the spawning grounds, with a lull between the spring and fall runs.

1889: Stone

Livingston Stone, a fish culturist with the U.S. Fish Commission, traveled with Bean to Karluk in 1889 to investigate Alaska's salmon fisheries and explore the region for potential hatchery sites. After observing the commercial fishing and cannery operations at Karluk Spit in early August, Stone and Bean visited Karluk Lake for a firsthand view of the sockeye's spawning grounds (Stone, 1894):

> The Karluk River, on Kadiak Island, is probably the most wonderful salmon river in the world. On August 2, 1889, the cannery nets caught on Karluk Beach, at the mouth of the river, 153,000 salmon by actual count. A short time after, the writer went up the Karluk River in a bidarka—the skin boat of the natives—expecting to see myriads of salmon spawning and thousands on their journey to the spawning-grounds, but instead of the wonderful sight we anticipated, our whole party, I think, saw less than a dozen in the river till we reached the lower spawning-grounds, and then, to our astonishment, we saw only a few scattering fish spawning, such as one might expect to see in the most commonplace salmon river in the world; 153,000 salmon caught in one day at the mouth of the river, and none to speak of going up the river to reproduce their species. Every one can draw his own inference. The fact is significant enough.

Stone was obviously surprised by the huge commercial harvest of sockeye salmon and disappointed by the apparent paucity of spawning fish at the lake in August. From this dramatic contrast he concluded that Karluk's commercial fishery was decimating the sockeye salmon; this eventually caused him to propose a National Salmon Park on Afognak Island. However, his mid August observations of few spawning sockeye at Karluk Lake match the normal lull between the spring and fall runs.

1890: Porter

Robert Porter (1893), superintendent of the U.S. Census Office, reported on Alaska's population and resources for the Eleventh Census (1890) and included information on Karluk's sockeye salmon:

> [Concerning the Karluk River sockeye salmon, 1890] During the season of 1890, when the fishermen at Karluk were paid a bonus on each fish caught, the accounts footed up considerably over 3,000,000 fish. The season or "run" extends from June until the beginning of September, but it is interrupted at various times by "slack intervals", lasting from 1 to 2 weeks.

The slack intervals he mentioned may indicate the lull between spring and fall runs.

1896: Tingle

George Tingle (1897), U.S. Inspector of Salmon Fisheries, briefly visited Karluk in mid August 1896 on his annual inspection tour of Alaskan canneries:

> [At Karluk, mid August 1896] The business is conducted here with perfect system, more fish being at hand any day than the canneries in operation could pack. The run of fish in June did not amount to anything; indeed, the Alaska Packers Association did not pack a salmon in that month, on the spit, but July, August, and up to late in September the sea swarmed with fish. . . . From August 15 to September 1 the red salmon run was at its height. It was not unusual to haul in 25,000 to 40,000 fish.

Tingle's comments may indicate either a unimodal or bimodal run distribution. Failure of the June run suggests a unimodal pattern existed in 1896, but canneries anticipated a spring run, indicating that it normally occurred. Peak run abundance occurred from 15 August to 1 September, similar to the present-day pattern for fall-run sockeye.

1897: Moser

Jefferson Moser, US Navy Commander of the Steamer *Albatross,* investigated Alaska's salmon fisheries in 1897 for the US Fish Commission and visited Karluk's canneries on 18–20 July and 2–6 August. Fisheries expert Alvin B. Alexander of the US Fish Commission gathered most of the data at the Karluk canneries and hatchery (Moser, 1899):

> [Speaking of Karluk River sockeye salmon, 1897] . . . it will be noticed that they run first in the Karluk district,

where packing usually begins during the first days of June. . . . At Karluk the early run usually consists of fish from 14 to 15 and even as high as 17 to the case, but as the season advances they come down to 12.

The time of run is no less remarkable than the numbers of fish. The canneries count for a certainty on obtaining fish from the middle of June to the middle of September. Some years the packing has commenced the latter part of May, and again it has continued into October. Some cannerymen state that the Karluk packing season is from June 1 to September 30. . . . There are undoubtedly straggling redfish very early in all localities in Alaska, and in a place like Karluk, with a catch of nearly 2,000,000 fish, these early stragglers must come in sufficient numbers to warrant commencing cannery operations, . . . Proximity to the sea is, no doubt, also favorable to early runs. The late runs may be accounted for by similar reasoning. It is said that the fish in the late runs are in excellent condition.

Few salmon were taken at the hatchery for spawning purposes from the 20th of July to the 5th of August. . . . The cause for this remarkable scarcity of salmon at the hatchery was attributable to the frequent seine hauls made inside the mouth of the river near the canneries, from 8,000 to 10,000 being taken there daily. Fish which escaped the seines off the spit were almost certain of capture before they could get very far up the river, thereby minimizing the chances of many being secured at the hatchery. . . . It was subsequently learned that during the latter part of August a number of good hauls of salmon were made off the hatchery.

[18–20 July and 2–6 August 1897] At the time of the writer's visit to the river the daily catch of salmon was small. . . .

While Moser and Alexander's statements have some ambiguity, their observations indicate an early and late run of sockeye salmon, each run with differently sized fish. As typical of most regulatory visits to the early canneries, the inspectors arrived at Karluk during, or near to, the lull period between the early and late runs.

1898–1900: Kutchin

Howard Kutchin (1899), U.S. Special Agent for Protection of Alaska Salmon Fisheries, briefly visited Karluk in mid July and early August 1898 on his annual inspection tour of Alaska's salmon canneries:

[12 July 1898] At Karluk, where is located the most extensive plant in Alaska, the property of the Alaska Packers' Association, the season at this date was a practical failure. The spring run had not materialized, and the catch was to be counted by hundreds of cases instead of thousands as usual.

[10 August 1898] As I learned that little or nothing was doing at Karluk, there still being no run of salmon worthy of the name, it did not appear advisable to spend so much time there.

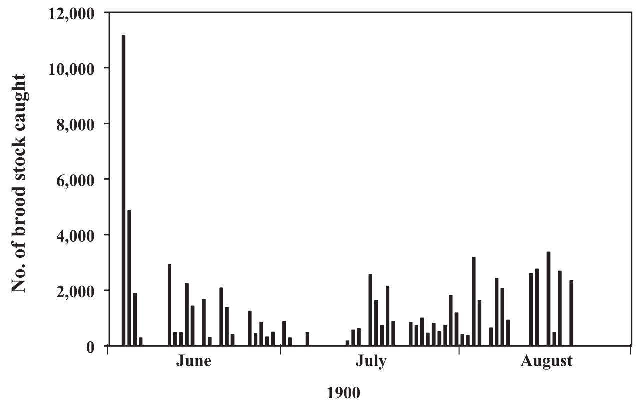

Figure 6-5. Seasonal capture of adult sockeye salmon brood stock at the Karluk Lagoon hatchery, June–August 1900 (Kutchin, 1901).

Though the early sockeye run was weak in 1898, Kutchin called it the "spring run" and indicated that it previously supplied the canneries with thousands of canned salmon cases. He arrived at Karluk during the lull between spring and fall runs.

Kutchin (1901) found similar run conditions in 1900:

[At Karluk, 13 July 1900] The run of fish up to date very light, and the prospect for a good fall run extremely poor. Had it not been for the exceptional supply of salmon at Eacolek River the Karluk pack would certainly have been a failure. . . . The spring run usually begins about June 10, and is composed of the smallest fish which is put up anywhere in Alaska. It lasts only a couple weeks. The fall run starts in about July 20 and usually continues through August.

[James A. Richardson, Superintendent, Karluk River hatchery, 9 November 1900 letter] We find the earlier eggs and the September eggs were the best, while a portion of the eggs taken during the middle part of the season were of indifferent quality.

Kutchin identified the spring and fall sockeye runs; their bimodal seasonal pattern in 1900 matched present-day run timing. Likewise, daily catches of sockeye brood stock for the Karluk hatchery from 3 June to 20 August 1900 had a bimodal pattern, with a low point in early July (Fig. 6-5).

1900: Moser

Moser again investigated Alaska's salmon fisheries in 1900 and visited Karluk's canneries and hatchery on 7–9 August. Harry Fassett of the U.S. Fish Commission inspected the Karluk Lagoon hatchery for Moser (1902):

[Karluk River hatchery, August 1900] The period of incubation varies with the temperature of the water, of course, but it is also believed to be of less duration with eggs taken from the spring run than is the case with those of the later or fall run. That is, the eggs of the spring run of redfish seem to have a more vigorous vitality, hatching more rapidly under similar thermal conditions; . . . It would appear from the above that the eggs eye very much faster with the spring run, and that the hatching range covers a much longer period. It is also apparent that in considering the hatching of redfish at Karluk the two runs must be treated separately—the runs are so marked and the prevailing conditions so radically different.

Fassett identified the spring and fall runs and mentioned biological differences between their egg development and hatching times.

1901–02: Kutchin

Kutchin (1902, 1903) again inspected Karluk's canneries and hatchery on 1–4 August 1901 and 10 August 1902:

[At Karluk canneries, 1–4 August 1901] Up to this time the run of salmon had been extremely light, and although Superintendent Bankoroski was not at all despondent, he admitted that the season might prove pretty nearly a failure. The season runs late here, last year closing September 11. So it was possible that the later catch would be good. Later advices informed me that this is just what occurred, and that fish swarmed along the spit in quantities that have never been known since the palmy days when Karluk was the greatest salmon fishery in the world. At the time of my visit a haul of 2,000 fish was above average, but when the great fall run set in it was reported 110,000 were taken in at one haul. The profusion was so stupendous that all the adjacent canneries at Uyak, Alitak, and Chignik eked out the scarcity at those points and made good packs.

[At Karluk, 10 August 1902] Captain Bankoroski, superintendent of the Alaska Packers' Association canneries at Karluk, was so kind as to come aboard and give me the particulars of the situation at this fishery at this time. He reported that the spring run had been very light, but that the summer run, which had just begun, promised to assure a good pack. However, Karluk is always liable to have surprises in store, and the pack might be materially helped out by an unexpected large run or by the surplus from Chignik. The figures given elsewhere show that this is just what resulted.

Kutchin distinguished the spring and fall runs, though he used the term "summer run" to describe the mid August beginning of the fall run. Spring runs in both years apparently were small.

1903: Rutter

Cloudsley Rutter, U.S. Fish Commission, studied Karluk's sockeye salmon as a member of the Alaska Salmon Commission in the summer of 1903. He observed the sockeye run for four months (May–August), the longest biological study yet of these salmon at Karluk:

[Concerning Karluk River sockeye salmon, 1903] The season of 1903 was a poor year at Karluk, . . . Apparently there was a considerable run of salmon during June, for there was certainly an enormous number reached the lake. But, although there were at least two millions reached the lake, they were not noticed at Karluk. This was probably because of the strong northeast winds that prevailed during that month, which made fishing impracticable most of the time. . . . The regular run of salmon begins at Karluk sometimes during the first of June, usually about the tenth, though there are a few stragglers much earlier. In 1903 the first specimen was taken May 11, and fishing began for the cannery June 9, but good catches were not made till about July 18 or 19. The first red salmon was seen in the upper part of the river on the 20th of May. . . . Karluk has a very long season, and salmon are usually running in paying numbers till the first of September. There are two distinct though intergrading runs, the first reaching its maximum about the last of June, the other the first of August. These were not noticed in 1903.[23]

Rutter clearly described the bimodal run distribution of Karluk's sockeye salmon and how these two runs intergraded in July. The run distribution he described for 1903 was similar to present-day patterns.

1904–05: Kutchin

Kutchin (1905, 1906) again visited Karluk's canneries and hatchery on 8 August 1904 and 31 July 1905:

[At Karluk canneries, 8 August 1904] The season has been an extremely bad one. Scarcely any "spring" salmon ran. The first pack was made June 3. A good share of the fish packed to date were received from Alitak and Chignik Bay. It is hoped that there might be a heavy fall run, . . .

[At Karluk canneries, 31 July 1905] At Karluk, likewise, the early run had been very disappointing, and up to the time of my visit to Kodiak, July 31, practically no fish had been taken. Later, however, the run was better . . .

Although the early harvests of sockeye salmon were weak in both years and might indicate a unimodal pattern, Kutchin mentioned the spring and fall runs.

[23] See footnote 7.

1907: Marsh and Cobb

Millard Marsh, U.S. Agent of the Salmon Fisheries of Alaska, and John Cobb, USBF Assistant Agent, inspected Alaska's canneries in 1907 (Marsh and Cobb, 1908):

> [At Karluk canneries, 1907] A very good run of fish into the lagoon early in the season soon slackened and for some time the plants were behind their packs of the previous year; but later exceptionally large runs enabled them to make up the deficiency, and to ship, as early as July 30, the first full cargo of salmon to come out of Alaska in 1907.

They described the early run, lull period, and late run of Karluk's sockeye salmon in 1907.

1910: Fassett

Harry Fassett, USBF Inspector of Fisheries in Alaska, inspected the Karluk River hatchery on 1–8 September 1910:

> [At Karluk River hatchery, 1–8 September 1910] The red-salmon eggs at Karluk are reported to be very variable in size, and a big difference is said to be noted between those of the early, or "spring", run and those of the later, or "fall", run. The fall fish are themselves larger, and have larger eggs, the eggs are more regular in size, and are in greater number. The superintendent said his average through the year is a little less than 3,000 eggs per fish.[24]

Fassett described Karluk's spring and fall sockeye runs and mentioned significant biological differences between the two, characteristics that continue to present times.

In conclusion, although some historical records of Karluk's sockeye salmon runs were ambiguous or possibly indicated a unimodal distribution, most reports described a seasonal bimodal pattern (Table 6-1). Historical records of distinct unimodal distributions and abundant midseason fish were lacking. Observations made before Karluk's commercial fishery began in 1882, or shortly thereafter (1887–95), provide stronger evidence of the original run pattern than those made in 1895–1910. By 1895 Karluk's sockeye salmon run already had sustained 8–9 years of intense commercial fishing, and later observations may reflect these heavy harvests. Thus, Bean's observations of a bimodal run pattern in 1880 and 1889 are particularly noteworthy.

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

Table 6-1
Historical records of seasonal run distribution for Karluk River sockeye salmon.

Year	Source	Unimodal or bimodal distribution
1790	Merck	No information
1802–03	Davydov	No information
1824–25	Klebnikov	Possibly either
1861	Golovin	No information
1880	Bean	Bimodal
1889	Bean	Bimodal
1889	Stone	Bimodal
1890	Porter	Possibly bimodal
1896	Tingle	Possibly either
1897	Moser	Bimodal
1898–1900	Kutchin	Bimodal
1900	Moser	Bimodal
1901–02	Kutchin	Bimodal
1903	Rutter	Bimodal
1904–05	Kutchin	Bimodal
1907	Marsh and Cobb	Bimodal
1910	Fassett	Bimodal

Conclusions

Thompson's idea that commercial fishing altered the original run distribution of Karluk River sockeye salmon from unimodal to bimodal deserves serious consideration, but valid questions remain about his assumptions and conclusions. In particular, significant weaknesses exist in using historic case-pack data to predict seasonal run distributions. In fact, later corrections of the case-pack data made run bimodality more apparent in the early years, even though many midseason (July–August) sockeye were still present.

We believe that most evidence shows that Karluk River sockeye salmon originally had a bimodal run distribution (Table 6-1). Historical observations of sockeye runs prior to commercial fishing support this view. While intense commercial fishing may alter the run distributions of salmon, it seems unlikely that the bimodal run pattern that has existed for at least 130 years (1880–2010) would continue unless it was a natural biological feature of Karluk's sockeye salmon. If midseason subpopulations once bore the brunt of intense fishing and were heavily depleted, this run segment should have responded at some time to the different fishery regulations implemented.

Ever since the Karluk River weir began operating in 1921, errors in estimating the travel time of sockeye salmon between the fishery and weir have caused midseason escapements to be underestimated and later escapements to be overestimated, incorrectly enhancing reported run bimodality. Some midseason fish thought to be depleted by the fishery were actually present in later weir counts. Run bimodality increases in the Karluk River because spring- and fall-run sockeye have different travel times to Karluk Lake, the speed being affected by river flow and pink salmon abundance. Spring-run sockeye rapidly ascend the river, while fall-run sockeye have longer travel times, a fact not always appreciated. Because travel times between the fishery and weir vary seasonally, escapement and weir count distributions differ.

One of Thompson's main contributions to understanding the seasonal run distribution of Karluk's sockeye salmon was his emphasis on the many independent subpopulations present, this biological diversity allowing these salmon to survive varying environmental and fishing conditions. His focus on Karluk's sockeye subpopulations stimulated research on this topic for many years, until their existence was documented.