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History of the Fishery and Summary Statistics of the Sockeye Salmon, *Oncorhynchus nerka,* Runs to the Chignik Lakes, Alaska, 1888-1966

Michael L. Dahlberg

August 1979

U.S. DEPARTMENT OF COMMERCE
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ABSTRACT

Annual runs of sockeye salmon to the Chignik Lakes, Alaska, decreased from an average of 1.9 million during the period 1922-39 to an average of 0.9 million during the period 1949-66. In order to study the dynamics of the runs' historic catch, escapement and age structure data were compiled by spawning stock and brood year. The history of fishing and management of the runs from inception of the fishery until 1966 is described. The high seas and coastal distributions of Chignik sockeye salmon indicated significant interception by the fishery in only one area other than the Chignik Bay and Chignik Lagoon; the fishery at Cape Igvak started in the mid-1960's. Results of the study were used to construct parent-progeny relationships that formed the basis for a management strategy to restore the runs to their former level of abundance.

INTRODUCTION

One approach to restoring sockeye salmon stocks[2] to their former levels of abundance is to precisely regulate the harvest of each major race (Royce 1964). According to Royce (1960), such a course requires that the management agency 1) can define and recognize each major race[3] of salmon, 2) has accurate statistics on catch and escapement, 3) can forecast the returns[4] accurately, 4) knows the number of spawners needed for maintenance, and 5) is aware of the gear and time needed to harvest the desired number of salmon. The management agency does not have all this knowledge for any race of salmon in Alaska, but information has become available on the stocks of one sockeye salmon-producing system of western Alaska, the Chignik River system, from which it can formulate a management strategy based on precise regulation of the harvest.

In this paper, historic catch and escapement statistics are presented for each of the two major stocks of sockeye salmon in the Chignik River system. Current statistics have been routinely published and are later cited.

Sockeye Salmon Research at Chignik, Alaska

The potential of the Chignik watershed for controlled studies of the life history of sockeye salmon was recognized early in the development of salmon research in Alaska (Gilbert and O'Malley 1921). Parallel studies of the life history of sockeye salmon were started by the U.S. Bureau of Fisheries at Karluk in 1921 and at Chignik in 1922 with the main purpose of ascertaining "what relation exists between spawning colonies of varying size and the number of progeny that they furnish" (Gilbert 1929). The Karluk and Chignik Rivers were selected because it was believed the fishery operated solely on fish bound for these particular watersheds.

In 1928 the complexities of the life cycle and dynamics of the sockeye salmon populations of Chignik were brought to light, and intensive study of the freshwater life history of the Chignik sockeye salmon began (Higgins 1930). Considerable progress was made in determining the pattern of the life history of Chignik sockeye salmon and the relationship between the numbers of spawners and returning progeny (Holmes 1934). However, in 1934 research was drastically reduced because of budget restrictions, and the only activity was collection of scales for later study (Higgins 1936). A fish-counting weir was first erected in Chignik River in 1922 to estimate the escapement. The counting weir was not maintained in 1938, from 1940 through 1948, and in 1951. Each year since 1952 a weir has been in operation to count the escapement; because of turbid water and lack of adequate sites, counting towers used in the Bristol Bay district are not feasible at Chignik.

Tagging studies were conducted at Chignik by the Fisheries Research Institute (FRI), University of Washington, in 1949 and 1952, and a research program funded by the Chignik salmon canning industry began in 1955. From 1955 to 1960 the research program consisted of studies of the age composition of the runs, annual enumeration of smolts, and an investigation of predation on juvenile salmon by Dolly Varden, *Salvelinus malma*,

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[2]Stock refers to each aggregation that can be managed separately (Ricker 1966); run, as defined by Mathews (1966), signifies the total number of mature sockeye salmon entering the watershed in 1 yr (catch plus escapement).

[3]Race, the same as stock; see above.

[4]Returns refers to the total number of mature progeny produced by one spawning, regardless of the time of return.

and coho salmon, *Oncorhynchus kisutch*, (Roos[5, 6, 7], 1959, 1960). Beginning in 1961 the FRI intensified ecological studies of the nursery lakes. Results of those studies have been reported by Narver (1966), Phinney (1970), Parr (1972), and Burgner and Marshall[8]. Dahlberg (1973) analyzed the historical records of the fishery and reported on the dynamics of the sockeye salmon returns to Chignik from the inception of the fishery through 1966. Although all five species of Pacific salmon found in North America occur at Chignik, sockeye salmon are the most abundant and commercially important species. This report treats only sockeye salmon at Chignik. Narver (1966) and Parr (1972) described the life histories of fishes associated with sockeye salmon in the Chignik lakes.

The Watershed

The Chignik watershed is located on the Alaska Peninsula approximately halfway between the tip of the Alaska Peninsula and Kodiak Island (Fig. 1). Black and Chignik Lakes drain into the Pacific Ocean and form a natural northwest-southeast pass through the Aleutian Mountain Range. The watershed covers an area of approximately 1,520 km^2 including two lakes of 63.8 km^2 total surface area. Atwood (1911) and Knappen (1929) discussed in detail the geology of the region and briefly described the geography and vegetation; Murie (1959) detailed the fauna of the Alaska Peninsula.

Because the lakes are important as rearing areas for juvenile sockeye salmon, they have been closely studied; a complete description of the two lakes is presented by Narver (1966). Black Lake is shallow (44% of the area is <2 m deep), warms rapidly in the spring, and is usually turbid (typical Secchi disk reading is <1 m) throughout the summer. Chignik Lake, although smaller in area than Black Lake, is six times greater in volume and generally clearer. Although the lakes are different physically (Table 1), together they show a marked contrast in biological activity when compared with 24 other sockeye salmon-producing lakes in western Alaska (Burgner et al. 1969). The Chignik system ranked second in number of spawners per unit of lake surface area, first in rate of photosynthetic activity (area and volume), first in content of chlorophyl *a* per unit of lake volume, and second in content of total dissolved solids, and generally showed high concentrations of trace elements. Black Lake and Chignik Lake had the highest standing crops of phytoplankton among the lakes compared.

The lakes are connected by Black River (12 km long), which flows south along the edge of the Aleutian Mountain Range. Two major spawning tributaries enter Black River. West Fork, entering from the west, drains the northeast slope of Mount Veniaminoff (Fig. 1), a volcano which erupted as recently as 1956 (Roos see footnote 7). Chiaktuak Creek enters from the east and drains a valley parallel to Chignik Lake. Bearskin Creek also enters Black River but is of minor importance as a spawning stream; small numbers of spawners are found occasionally in the upper reaches (Phinney 1970).

The lower lake is drained by Chignik River (7.2 km long), which is normally influenced by tidal action for nearly one-half its length. The highest spring tides affect the river up to the lake outlet.

[5] Roos, J. F. 1959. Report on Chignik adult red salmon studies, 1958. Unpubl. manuscr., 12 p. Fish. Res. Inst., Univ. Washington, Seattle.

[6] Roos, J. F. 1959. Red salmon tagging at Chignik, Alaska during 1959. Unpubl. manuscr., 9 p. Fish. Res. Inst., Univ. Washington, Seattle.

[7] Roos, J. F. 1960. Life history of red salmon, *Oncorhynchus nerka* (Walbaum), at Chignik, Alaska. Unpubl. manuscr., 56 p. Fish. Res. Inst., Univ. Washington, Seattle.

[8] Burgner, R. L., and S. L. Marshall. 1974. Optimum escapement studies of Chignik sockeye salmon. Anadromous Fish Project Final Report for period ending June 30, 1973. Report No. FRI-UW-7401. Fish. Res. Inst., Univ. Washington, Seattle, 91 p.

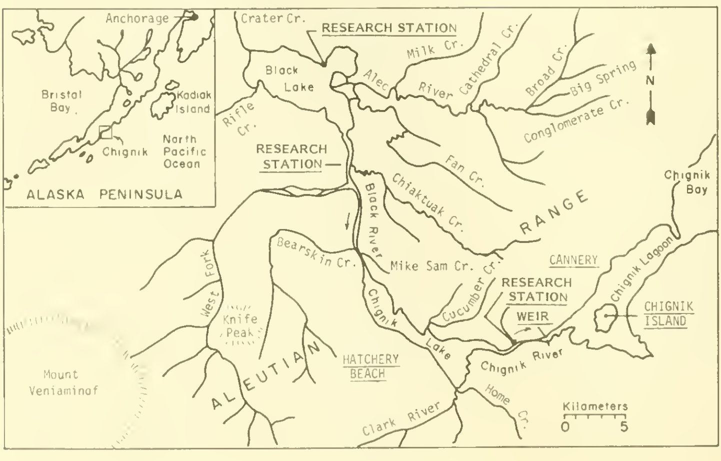

Figure 1.—Map of the Chignik River watershed with inset of western Alaska.

Table 1.—Morphometric measurements of Chignik and Black Lakes and Chignik Lagoon (from Dahlberg 1973).

Source	Altitude (m)	Depth (m) Mean	Depth (m) Maximum	Water area (km^2)	Volume (km^3)	Shoreline Length (km)	Shoreline Development	Flow at outlet (m^3/s)	Flow at outlet Date
Black Lake	15	3	6	41.1	0.10	27.0	1.19	17.0	25 June 1963
Chignik Lake	5	29	64	22.7	0.64	27.7	1.64	79.5	23 June 1963
	—	—	—	—	—	—	—	35.8	13 Aug. 1963
Total	—	—	—	63.8	0.74	—	—	—	—
Chignik Lagoon	—	3	15	41.8	0.13	46.7	2.04	—	—

Chignik Lagoon (12 km long) is a nearly enclosed estuary having a sandy or muddy, flat bottom with scattered patches of algae and extensive areas of eel grass (*Zostera*). Water covers about 42 km^2 at high tide, and about half that at low tide. Low and high tide salinities range from 10 to 17‰ in the upper lagoon and from 30 to 32‰ at the sand spit near the outlet. The importance of the estuary as a secondary rearing area for juvenile sockeye salmon has been investigated by Phinney (1968); large catches of postsmolt sockeye salmon have been taken by beach seine and surface trawl in the lagoon during June and July (Narver and Dahlberg 1965; Phinney 1968).

The Climate

The climate of the region is strongly maritime because the Alaska Peninsula is a comparatively small body of land between two large water masses, the North Pacific Ocean and the Bering Sea. The weather conditions reported by Atwood (1911) and Knappen (1929) remain typical. The summers are short and cool; although there may be many days of wet weather, the rainfall is seldom excessive. A great many overcast days occur. Violent winds often exceeding 161 km/h (100 mph) have been recorded. Winter temperatures are more moderate than those in Bristol Bay; recording thermometers left in cabins over the winters of 1961-67 showed a low of −27°C (−17°F). Ice breakup on the lakes occurs in April or May, much earlier than in the lakes of the Bristol Bay district. Long-term weather records are not available for the immediate area; Kodiak Island (270 km to the northeast) is the nearest location with extensive weather records, although some data are available from nearby Port Heiden on the north side of the peninsula.

History of the Commercial Fishery

Cannery operations.—Commercial exploitation of Chignik sockeye salmon began in 1888 when the Fishermen's Packing Company of Astoria, Oreg., sent a crew to Chignik Bay to prospect for fish; they returned in the fall with 2,160 barrels of salted salmon. In 1889 canning operations were started in plants of the Fishermen's Packing Company, Chignik Bay Company of San Francisco, and the Shumagin Packing Company from Portland, Oreg. (Moser 1899). Operating agreements between the companies proved so successful in 1890 and 1891 that they joined the pool of canneries of the Alaska Packing Association in 1892. In 1893 they all became members of the Alaska Packers Association, and only one cannery was operated as a result of increased operation efficiency (Moser 1899).

The ease with which fish were captured at Chignik attracted more investment into the fishery; in 1896 Hume Brothers and Hume, and the Pacific Steam Whaling Company each built a cannery (Cobb 1930). In 1901 these companies became part of the Pacific Packing and Navigation Company, which in turn became part of the Northwestern Fisheries Company in 1905. In 1910 the Columbia River Packers Association built yet another cannery in the area. Competition was intense until 1914 when the three companies then operating—Alaska Packers Association (APA), Columbia River Packers Association (CRPA), and Northwestern Fisheries Company (NFC)—agreed to an equal division of the catch (Rich and Ball 1930).

Industry relationships remained static until 1926 when H. W. Crosby operated a floating salmon cannery, Salmon King, for one season. In 1932 Crosby returned and built a land-based cannery; the same year, CRPA, NFC, and APA made a combined pack at the APA cannery. The following season, 1933, Pacific American Fisheries (PAF) acquired the Northwestern Fisheries Company, and the PAF, APA, and CRPA combined canning operations. The APA acquired the Chignik interests of PAF and CRPA during the ensuing years and continues to operate their cannery at Chignik (Pacific Fisherman Yearbook 1915-67; National Fisherman Yearbook 1968, 1969; Pacific Packers Report 1970-76).

Crosby changed the name of his operation to Chignik Lagoon Packing Company in 1936, and after two other changes gave it the name Chignik Fisheries Company in 1947. Beginning in 1953, APA and Chignik Fisheries Company entered into an agreement to can all fish in the APA cannery; the cannery of the Chignik Fisheries Company serves as a base of supply and operations for its fishing fleet (Roos see footnote 7). In 1968, Columbia-Wards Company purchased the Chignik Fisheries cannery and has continued operations under the same arrangements with the APA (Pacific Packers Report 1976).

Fishing gear.—Pile traps (Scudder 1970) were the principal fishing gear, and beach seines took a small part of the catch before 1900. The water at Chignik was too clear and the channel too narrow for effective gillnetting (Moser 1899). The number of units of gear operated in

Table 2.—Recapitulation of types of fishing gear and catches of sockeye salmon by gear (percentage), fishing seasons, fishing regulations, and numbers of days fished at Chignik, 1895-1966 (Dahlberg 1968).

Year	Number of units of gear Traps	Seines[1]	Gill nets	Catch by gear (percentage) Traps	Seines	Gill nets	Fishing[2] season	Fishing[3] regulations	Number of days fished	Source
1895	Na[4]	Na	Na	Na	Na	Na	10 June- 2 Aug.	1	45	Moser (1899)
1896	17	10	13	Na	Na	Na	15 June-14 Aug.	1	51	Moser (1899)
1897	23	10	10	Na	Na	Na	7 June-27 Aug.	1	68	Moser (1899)
1898	23	Na	Na	Na	Na	Na	9 June- 8 Aug.	1	50	Moser (1899)
1899	Na	Na	Na	Na	Na	Na	9 June-22 Aug.	1	61	Moser (1902)
1900	24	8	26	70.0	5.0	20.0	11 June-12 Aug.	1	52	Moser (1902)
1901	21	Na	Na	Na	Na	Na	13 June-24 Aug.	1	60	Rich and Ball (1930)
1902	21	Na	Na	Na	Na	Na	9 June-10 Aug.	1	52	Rich and Ball (1930)
1903	29	Na	Na	Na	Na	Na	8 June-23 Aug.	1	63	Rich and Ball (1930)
1904	28	Na	Na	Na	Na	Na	10 June- 9 Aug.	1	50	Rich and Ball (1930)
1905	12	Na	Na	Na	Na	Na	4 June-13 Aug.	1	57	Rich and Ball (1930)
1906	7	Na	Na	Na	Na	Na	11 June-12 Aug.	1	52	Rich and Ball (1930)
1907	8	Na	Na	Na	Na	Na	10 June-12 Aug.	2	50	Rich and Ball (1930)
1908	8	Na	Na	Na	Na	Na	6 June- 8 Aug.	2	44	Rich and Ball (1930)
1909	8	Na	Na	Na	Na	Na	14 June-15 Aug.	2	50	Rich and Ball (1930)
1910	18	Na	Na	Na	Na	Na	16 June-31 Aug.	2	50	Rich and Ball (1930)
1911	29	Na	Na	Na	Na	Na	15 June- 5 Sept.	2	64	Rich and Ball (1930)
1912	37	Na	Na	Na	Na	Na	10 June- 3 Sept.	2	68	Rich and Ball (1930)
1913	37	Na	Na	Na	Na	Na	9 June-24 Aug.	2	60	Rich and Ball (1930)
1914	9	Na	Na	Na	Na	Na	9 June-27 Aug.	2	64	Rich and Ball (1930)
1915	9	Na	Na	Na	Na	Na	10 June-23 Aug.	2	58	Rich and Ball (1930)
1916	9	Na	Na	Na	Na	Na	12 June- 9 Sept.	2	70	Rich and Ball (1930)
1917	12	Na	Na	Na	Na	Na	10 June-14 Sept.	2	78	Rich and Ball (1930)
1918	12	Na	Na	Na	Na	Na	12 June- 4 Sept.	2	67	Rich and Ball (1930)
1919	14	Na	Na	Na	Na	Na	17 June-17 Sept.	2	74	Rich and Ball (1930)
1920	12	Na	Na	Na	Na	Na	16 June-14 Sept.	2	72	Rich and Ball (1930)
1921	9	Na	Na	Na	Na	Na	17 June-29 Aug.	2	58	Rich and Ball (1930)
1922	9	Na	Na	Na	Na	Na	16 June-27 Aug.	2	55	Rich and Ball (1930)
1923	9	Na	Na	Na	Na	Na	15 June-22 Aug.	2	52	Rich and Ball (1930)
1924	9	Na	Na	Na	Na	Na	20 June-16 Sept.	2,5	52	Rich and Ball (1930)
1925	9	Na	Na	Na	Na	Na	19 June-11 Sept.	2,5	46	Rich and Ball (1930)
1926	10	Na	Na	Na	Na	Na	15 June- 3 July	2,5	16	Rich and Ball (1930)
1927	10	Na	Na	Na	Na	Na	16 June-15 Sept.	2	72	Rich and Ball (1930)
1928	11	Na	Na	Na	Na	Na	12 July -23 Sept.	2,5	58	Rich and Ball (1930)
1929	10	Na	Na	Na	Na	Na	13 June-22 Sept.	2	87	Rich and Ball (1930)
1930	6	Na	Na	Na	Na	Na	4 July -11 Aug.	2,5	26	Mgt. Biol. Annu. Rep.
1931	8	Na	Na	Na	Na	Na	4 June-16 Sept.	2,5	78	Mgt. Biol. Annu. Rep.
1932	8	1	5	99.4	0.5	0.1	8 June-17 Sept.	2	81	Mgt. Biol. Annu. Rep.
1933	8	22	4	97.0	2.8	0.2	12 June-19 Aug.	2	54	Mgt. Biol. Annu. Rep.
1934	7	Na	Na	89.5	9.7	0.8	3 June-12 Sept.	2	81	Mgt. Biol. Annu. Rep.
1935	7	Na	Na	78.5	20.6	0.9	4 June-12 Sept.	2,5	80	Mgt. Biol. Annu. Rep.
1936	8	21	4	74.4	23.7	1.9	1 June-10 Sept.	2,5	47	Mgt. Biol. Annu. Rep.
1937	8	Na	Na	Na	Na	Na	8 June- 4 Sept.	2,5	35	Mgt. Biol. Annu. Rep.
1938	4	Na	Na	54.3	43.0	2.7	22 June- 1 Sept.	2,5	68	Mgt. Biol. Annu. Rep.
1939	8	14	6	Na	Na	Na	5 June- 1 Sept.	2	70	Mgt. Biol. Annu. Rep.
1940	4	18	2	2.0	92.8	5.2	2 June- 9 Aug.	2	56	Mgt. Biol. Annu. Rep.
1941	8	23	5	68.2	29.9	1.9	4 June-30 Aug.	3	58	Mgt. Biol. Annu. Rep.
1942	4	18	5	63.2	34.1	2.7	8 June-29 Aug.	3	56	Mgt. Biol. Annu. Rep.
1943	4	15	2	70.3	28.0	1.7	5 June-23 Aug.	3	53	Mgt. Biol. Annu. Rep.
1944	4	21	2	59.0	38.9	2.1	5 June-18 Aug.	3	48	Mgt. Biol. Annu. Rep.
1945	5	17	5	66.4	29.8	3.8	8 June-11 Aug.	3	43	Mgt. Biol. Annu. Rep.
1946	7	22	7	49.0	50.0	1.0	3 June-20 Aug.	3	52	Mgt. Biol. Annu. Rep.
1947	8	58	3	37.2	62.3	0.5	1 June-29 Aug.	4,5	50	Mgt. Biol. Annu. Rep.
1948	7	70	3	34.6	64.8	0.6	1 June-21 July	4,5	28	Mgt. Biol. Annu. Rep.
1949	5	41	2	30.0	69.6	0.4	10 June-15 Sept.	4,10	28	Mgt. Biol. Annu. Rep.
1950	4	55	18	24.5	74.1	1.4	6 June-15 Sept.	4,10	38	Mgt. Biol. Annu. Rep.
1951	4	64	0	22.8	77.2	0	6 June-17 Aug.	4,10	24	Mgt. Biol. Annu. Rep.
1952	4	Na	0	28.4	67.9	3.7	16 June-26 June	4,10	8	Mgt. Biol. Annu. Rep.
1953	4	26	0	25.0	75.0	0	22 June-24 July	4,10	14	Mgt. Biol. Annu. Rep.
1954	4	63	1	24.1	75.8	0.1	22 June-26 June	4,10	5	Mgt. Biol. Annu. Rep.
1955	0	55	0	0	100.0	0	18 June-17 July	5,6	20	Mgt. Biol. Annu. Rep.
1956	0	42	0	0	100.0	0	20 June- 1 Sept.	5,6	20	Mgt. Biol. Annu. Rep.
1957	0	37	0	0	100.0	0	26 June-22 Aug.	5,7	40	Mgt. Biol. Annu. Rep.

Table 2.—Continued.

Year	Number of units of gear: Traps	Seines[1]	Gill nets	Catch by gear (percentage): Traps	Seines	Gill nets	Fishing[2] season	Fishing[3] regulations	Number of days fished	Source
1958	0	40	0	0	100.0	0	18 June-22 Aug.	5,8	27	Mgt. Biol. Annu. Rep.
1959	0	29	0	0	100.0	0	17 June-18 Sept.	5,8	44	Mgt. Biol. Annu. Rep.
1960	0	17	0	0	100.0	0	5 June-11 Sept.	5,7	61	Mgt. Biol. Annu. Rep.
1961	0	33	0	0	100.0	0	8 June-27 Aug.	5,6	32	Mgt. Biol. Annu. Rep.
1962	0	25	0	0	100.0	0	20 June-19 Aug.	5,9	41	Mgt. Biol. Annu. Rep.
1963	0	22	0	0	100.0	0	3 July - 1 Sept.	9,10	56	Mgt. Biol. Annu. Rep.
1964	0	21	0	0	100.0	0	14 June-27 Aug.	9,10	69	Mgt. Biol. Annu. Rep.
1965	0	24	0	0	100.0	0	19 June-28 Aug.	9,10	42	Mgt. Biol. Annu. Rep.
1966	0	25	0	0	100.0	0	30 June- 7 Sept.	9,10	44	Mgt. Biol. Annu. Rep.

[1]For the period 1954-66 the number of seines is the weighted daily mean.

[2]Inclusive dates for beginning and end of entire fishing season.

[3]Fishing regulations coded: 1. Weekly closure of 30 h, 0000 Friday to 0600 Sunday. 2. Weekly closure of 36 h, 1800 Saturday to 0600 Monday. 3. Weekly closure of 60 h, 0600 Wednesday to 0600 Thursday; 1800 Saturday to 0600 Monday. 4. Weekly closure of 60 h, 1800 Friday to 0600 Monday. 5. Periodic closure by management biologist. 6. Weekly closure of 3 days. 7. Weekly closure of 2 days. 8. Weekly closure of 4 days. 9. Weekly closure (5 days or 4 days) changed during season by the management biologist. 10. Fishing periods changed by emergency regulations set by management biologist.

[4]Na = not available.

Chignik Lagoon and Chignik Bay, length of fishing seasons, and fishing regulations have varied considerably during 1895-1966 (Table 2; Fig. 2).

Because of the unique time of entry of the Black Lake and Chignik Lake stocks into Chignik Lagoon, to be shown later, the distribution of open and closed fishing periods within each season indicates to some extent which stock was exploited (Fig. 3). In 1954, for example, there was only one short open period which resulted in a fourfold difference in rates of exploitation between stocks. The lengthy season and the large number of traps concentrated in this small area (Chignik Lagoon is about 12 km long) indicate an intense fishery from 1900 to 1914. Moser (1902) visited Chignik in 1898 and again in 1900 and stated, "the lagoon and approaches and the river ap-

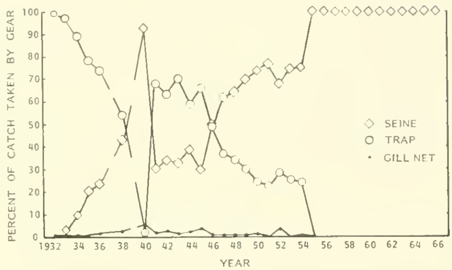

Figure 2.—Percentages of catches of sockeye salmon caught by trap, seine, and gill net in the Chignik fishery, 1932-66.

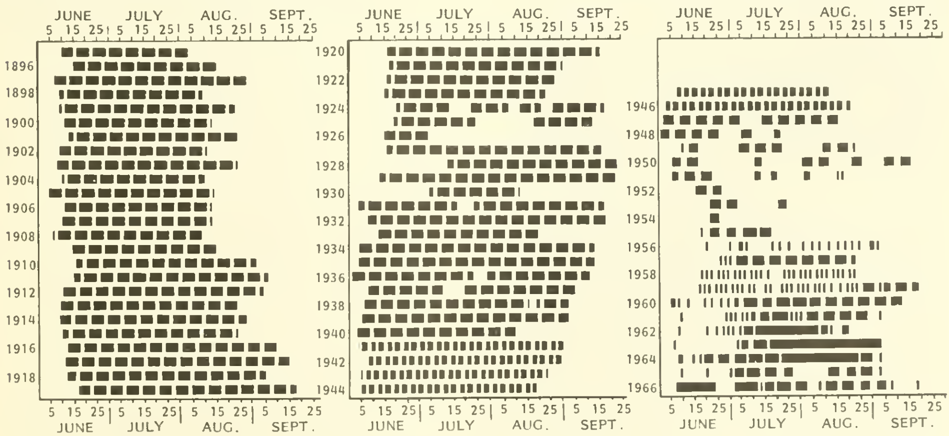

Figure 3.—Open and closed fishing periods for the Chignik fishery, 1895-1966; bars represent time periods open to fishing.

proaches are studded with traps, some with leads 3,500 feet long, and sometimes so interlaced that at a distance the channel appears completely blocked, and it hardly seems possible for a fish to pass." Dahlberg (1968) presented figures showing the location of traps fished in Chignik Lagoon during 1899 and 1902.

Because there is some question as to the effectiveness of the older types of gear, I calculated fishing effort from the data on gear (Table 2) and catch data. The unit of effort chosen was the trap-day, i.e., the number of traps fished, which yields the total trap days in season i. Total trap catch in season i divided by total trap days within season i yields catch per unit of effort.[9]

The fishing effort from 1905 to 1909 was low and the catch of sockeye salmon per unit of effort (CPUE) was exceedingly high (Fig. 4). The sharp drop in the CPUE

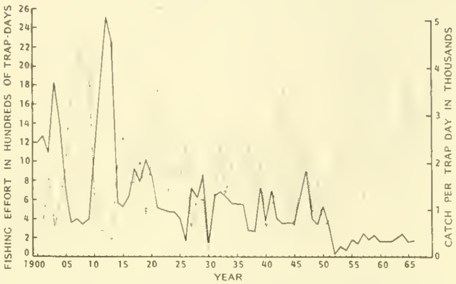

Figure 4.—Trends in fishing effort (solid line) and catch (dotted line) of sockeye salmon per unit of effort at Chignik, 1900-66.

and the concomitant rise in units of gear between 1909 and 1913 indicate "keen competition" between companies during this period (Rich and Ball 1930). The agreement in 1914 to equally divide the catch among the three companies brought about much more efficient conduct of the fishery; however, its intensity was to no extent reduced in later years (Rich and Ball 1930), e.g., in 1922 more than 75% of the run was harvested (Alaska Fishery and Fur-Seal Industries 1922).[10] While it appears from Figure 4 that the CPUE may have risen during the period 1950-65, this may be due to a change in the efficiency or catchability of the newer gear. With the introduction of powered seine blocks, synthetic fiber nets, and modern seine boats in recent years, one would expect greater efficiency per unit of gear.

[9]Since beach seines gradually replaced traps over the years (Fig. 3, Table 2), I chose to convert the effort by gill nets and seines to trap effort in order to make all the fishing effort data comparable between years. I calculated relative fishing powers, by gear type, from the percentage of the catch of each type of gear and the number of units of each type of gear operating concurrently. I found that on the average, one trap was the equivalent of 5.9 beach seines or 26.2 gill nets. These figures are to be used with caution since the selectivity of trap sites and the efficiency of beach seines used during the period 1940 to 1954 and those used in the 1970's are probably not the same. However, these relative fishing powers can be used for gross comparisons of fishing effort.

[10]The data for 1917 to 1950 were taken from the publication series Alaska Fishery and Fur-Seal Industries. This series was published annually as appendices to the Report of Commission of Fisheries until 1940. Beginning in that year, they were published in the U.S. Fish and Wildlife Service's Statistical Digest Series.

Fishing regulations.—There was little, if any, enforcement of fishery regulations in the Chignik fishery before 1922. There were no statutory regulations prior to 1895, only a weekly closure of 30 h for the period 1895-1906, and one of 36 h for 1907-40 (Table 2). Cooley (1963) pointed out that starting in 1892 the U.S. Fish Commission had funds to support only one inspector and an assistant for the enforcement of fishing regulations in the entire territory of Alaska. They were forced to depend on industry transportation to make their rounds during the 3-mo season.

A fish-counting weir was first established in Chignik River in 1922 by the U.S. Bureau of Fisheries. The weir has not been installed every year since that time, but a management agent has been on duty to check the fishing area during closed periods. However, inspection of Figure 2 shows that until 1925 there had never been <40 days of fishing during the season. In 1924, with the passage of the White Act,[11] which required 50% escapement in streams where counting weirs were maintained, the fishery was subjected to periodic closures by the management agent. In 1925 it was required that the minimum annual escapement at Chignik be set at 1 million fish (Rich and Ball 1930). This requirement was met nearly every year until 1938. Management of the Chignik fishery was based mainly on the rule of 50% escapement and 50% catch under the White Act until the time of its repeal in 1957.[12] In recent years target escapements estimated from spawner-return relationships have been used as management guidelines to secure adequate spawning densities (Dahlberg 1973).

Catch trend.—The general trend of catch declining not long after the inception of the fishery is typical of many other salmon fisheries in Alaska (Fig. 5). Catches

[11]Public Law 204, 68th Congress, 1924 (Cooley 1963).
[12]Public Law 296, 85th Congress, 1957.

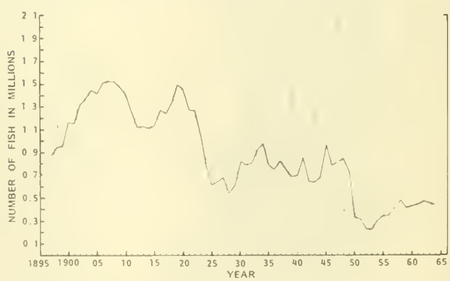

Figure 5.—Commercial catches of sockeye salmon at Chignik, 1895-1966; unsmoothed curve (broken line) and curve smoothed by a moving average of 5 (solid line).

gradually increased as the fishery developed, leveled off until the White Act took effect in 1924 at which time they decreased, remained at an intermediate level for several years (1925-48), and then dropped sharply after 1949 to a low level. The catch data for the Nushagak district of Bristol Bay (Mathisen 1971), show a unique similarity in trend (Fig. 6) except for the timing of the fall from initial high production. The decline of sockeye salmon production in the Nushagak district preceded that at Chignik by a few years. It is noteworthy that these two independent sockeye salmon systems exhibit the same historical development and both show a decline in return per spawner.

Figure 6.—Commercial catches of sockeye salmon in the Nushagak district, Bristol Bay, 1893-1966 (after Mathisen 1967); unsmoothed curve (broken line) and curve smoothed by a moving average of 5 (solid line).

CATCHES AND ESCAPEMENTS OF THE CHIGNIK SOCKEYE SALMON RUNS, 1888-1966

Catch and escapement, age and size composition, sex ratio, timing of the run, and distribution of the escapement on the spawning grounds are among the important required statistics for setting management regulations for the establishment and maintenance of maximum sustained yield.

Catches and Escapements

Escapement records began accumulating after erection of a weir in Chignik River in 1922. Catch statistics have been recorded from the beginning of the fishery in 1888; more detailed records have been kept since the Chignik canners joined the Alaska Packers Association in 1893 (Moser 1899). The long-term changes in abundance of Chignik sockeye salmon have been about twofold (Table 3).

Catch records.—Several sources of information were used to compile a complete record of the annual catches of Chignik sockeye salmon since 1888 (Moser 1899, 1902; Rich and Ball 1929, 1930; Alaska Fishery and Fur-Seal Industries 1917-50; Kasahara 1963; Pacific Fisherman Yearbook 1915-67; Pacific Salmon Inter-Agency Council 1966; Roos[13], see footnotes 5, 7; Calkins[14]). The two most valuable sources were 1) annual reports of the Chignik cannery superintendents, Alaska Packers Association, over the years 1895-1955; and 2) various reports of the management agents for the U.S. Bureau of Fisheries (1922-39), the U.S. Fish and Wildlife Service (1940-59), and the Alaska Department of Fish and Game (1960-66) (microfilms of these documents are on file in the archives of the FRI). I resolved inconsistencies in the reports compiled and issued by various agencies and individuals by cross-checking several sources; in the event of a major disagreement, I accepted the daily catch figures compiled by either the management agency or canning industry. Many arithmetical errors were discovered in the historical records; in these instances, I used the summation of the daily catch figures (Dahlberg[15]). Catch records were complete for all the years covered in this study (1888-1966).

Escapement records.—Daily weir counts were used to compile annual escapement records for those years in which a weir was operated in the Chignik River. The counting weir was not maintained in Chignik River during 1938, from 1940 through 1948, and in 1951. Moreover, in some years (1924, 1931, 1933) the weir was

[13]Roos, J. F. 1957. Report on Chignik adult red salmon studies, 1955-1956. Unpubl. manuscr., 58 p. Fish. Res. Inst., Univ. Washington, Seattle.

[14]Calkins, T. P. 1958. Report on Chignik adult red salmon studies, 1957. Unpubl. manuscr., 59 p. Fish. Res. Inst., Univ. Washington, Seattle.

[15]Dahlberg, M. L. 1967. Chignik catch-escapement analysis. Fish. Res. Inst., Comput. Program FRD 295, Univ. Washington, Seattle, 4 p.

Table 3.—Long-term changes in abundance of Chignik sockeye salmon (Dahlberg 1968).

	Chignik Lake				Black Lake				Total run			
	Catch 1,000's	Escapement 1,000's	Total 1,000's	Rate of exploitation[1]	Catch 1,000's	Escapement 1,000's	Total 1,000's	Rate of exploitation[1]	Catch 1,000's	Escapement 1,000's	Total 1,000's	Rate of exploitation[1]
Mean 1922-39	504	563	1,067	0.472	290	497	787	0.368	794	1,060	1,854	0.428
Mean 1949-66	240	326	566	0.423	145	201	346	0.419	385	527	912	0.422
Percent change[2]	−52.5	−42.1	−47.0	−10.4	−49.8	−59.5	−55.9	+13.9	−51.5	−50.2	−50.8	−3.8

[1]Rate of exploitation as defined by Ricker (1958:20).

[2]Expressed as a percentage of the mean for the period 1922-39.

damaged by high water, and the escapement was inaccurately assessed. Because it was desirable to have a continuous record of past escapements, estimates were used for missing data (Table 4). The estimates for 1924, 1931, and 1933 were made by U.S. Bureau of Fisheries personnel stationed at Chignik in these years; the estimate for 1951 represents the total of weekly estimates of escapement made by the management agent, U.S. Fish and Wildlife Service, at Chignik in that year.

Table 4.—Estimated escapements of sockeye salmon at Chignik, Alaska, for those years in which weir counts either were not available or were unreliable (Dahlberg 1968).

Year	Escapement estimate	Description of run[1]	Time period	Source
1924	115,000	—	4 June - 5 July	U.S. Bur. Fish. personnel
1931	107,600	—	To 10 July	U.S. Bur. Fish. personnel
1933	426,000	—	After 25 June	U.S. Bur. Fish. personnel
1938	482,000	550,000	All year	FRI, Dahlberg
1940	329,000	1,100,000	All year	FRI, Dahlberg
1941	906,000	Very light	All year	FRI, Dahlberg
1942	960,000	Very light	All year	FRI, Dahlberg
1943	1,907,000	Excellent run	All year	FRI, Dahlberg
1944	643,000	Unusually poor	All year	FRI, Dahlberg
1945	369,000	Far below average	All year	FRI, Dahlberg
1946	1,514,000	Good escapement	All year	FRI, Dahlberg
1947	3,781,000	Best run in many years	All year	FRI, Dahlberg
1948	698,000	—	All year	FRI, Dahlberg
1951	616,000	—	All year	U.S. Fish and Wildlife Service personnel

[1]Source: Alaska Fishery and Fur-Seal Industries (1938, 1940-48).

Providing estimates of the escapement for 1938 and the period 1940-48 was more complex since daily or weekly estimates of the escapement were not available. In these cases, the ratio of escapement to catch was calculated from data obtained immediately before and after the period, and escapement in the period was estimated by taking the product of the catch and the calculated ratio of escapement to catch. Rounsefell (1958) used a similar method for estimating the escapement to Karluk Lake prior to 1921; however, I attempted to correct for an apparent trend in the ratio (Fig. 7).

The predicted ratios were estimated by linear interpolation:

$$y = y_0 + \frac{y_1 - y_0}{x_1 - x_0}(x - x_0)$$

where x_0 = 1936,

y_0 = average ratio of escapement to catch for the period 1933-37 and 1939,

x_1 = 1951,

y_1 = average ratio of escapement to catch for the period 1949-53,

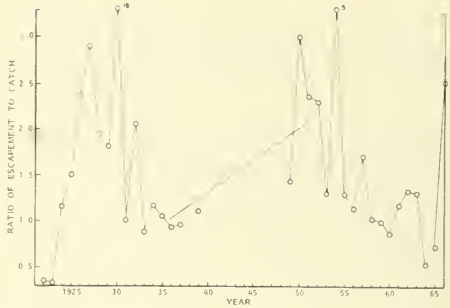

Figure 7.—Trend in the ratio of escapement to catch for Chignik sockeye salmon, 1922-66. Ratios read from the straight line were used where data were missing, 1940-48.

x = year in which an estimate of escapement to catch was desired,

y = estimated ratio of escapement to catch.

The predicted ratios were calculated from:

$$y = 1.03 + \frac{(2.10 - 1.03)}{(1951 - 1936)}(x - 1936).$$

The estimates were calculated from the ratio and catch for each of the years and compared with qualitative descriptions of the yearly runs (Alaska Fishery and Fur-Seal Industries 1938, 1940-48) (Table 4). The estimate for 1938 is in close agreement with the figures shown in Alaska Fishery and Fur-Seal Industries (1938). The estimate of the escapement for 1940 is far from that shown in Alaska Fishery and Fur-Seal Industries (1949); however, since no rationale is given for the published figure, the one calculated from the ratio of escapement to catch was used. Although the quantitative estimates and qualitative descriptions in Table 4 are not directly comparable, they do seem to agree in magnitude.

Catches, Escapements, and Total Runs by Stock

Estimated migration times and delays between fishery, lagoon, and weir.—Regulation of the Chignik fishery requires knowledge of the daily total run, which is the total of the daily catch and daily escapement. Escapement was counted at the weir in Chignik River. The daily catch could not be added to the escapement for the same day because of the migration time between the fishing area and weir. In addition, until 1966, Chignik fish were caught in significant numbers only in one nearby fishing area that was within the management district. Migration times must be considered before catch and escapement data can be combined.

Travel time between Cape Kumlik and Chignik Lagoon.—Starting in 1960 some purse seine boats in the Chignik management area began catching significant numbers of sockeye salmon in Aniakchak Bay and its western terminus, Cape Kumlik, which is 72 km (45 mi) east of Chignik Lagoon. Since that time tagging studies have shown that almost 95% of the sockeye salmon in this area are bound for Chignik Lagoon (Lechner[16]). In order to assign these fish to the catch of a given day in Chignik Lagoon, one must know the migration time from Cape Kumlik to Chignik Lagoon. Travel time can be estimated from the interval between the release of fish tagged at Aniakchak Bay and the recovery of the same fish in Chignik Lagoon. Fish were tagged in Aniakchak Bay by Richardson[17] on 7 July 1963 during a closed fishing period. The commercial fishery in the district resumed operations on 8 July at 0600 h and continued operations from 0600 to 1800 h each day through 12 July. The recovery of tagged fish in Chignik Lagoon reached a peak 2 days after release (Fig. 8). Hartt (1966) has shown that tagging delays the migration of mature sockeye salmon on the high seas about 1 day. It appears from Figure 8 that many sockeye salmon can travel from Cape Kumlik to Chignik Lagoon in 1 day, allowing 1 day for tagging delay. This is a rate of travel of about 72 km (45 mi) per day; Hartt (1966) has shown that the rate of travel for returns to Bristol Bay is as much as 56 km (35 mi) per day, becoming faster as the fish near the coast.

[16]Lechner, J. 1969. Identification of red salmon stocks taken in the Cape Kumlik - Aniakchak Bay fishery, Chignik area, 1967. Alaska Dep. Fish Game Inf. Leafl. 133, 32 p.

[17]Richardson, T. H. 1963. Aniakchak tagging program. Alaska Dep. Fish Game, Juneau, 2 p.

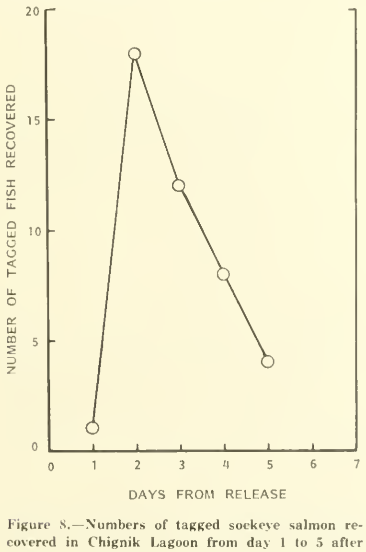

Figure 8.—Numbers of tagged sockeye salmon recovered in Chignik Lagoon from day 1 to 5 after release of fish tagged at Aniakchak Bay in July 1963 (data from Richardson, see text footnote 17).

Travel time between Chignik Lagoon and Chignik weir.—The commercial catch in Chignik Lagoon on a given day is not taken from the same group of fish that are counted through the weir on the same day; the migration time between the fishing area and the weir must be considered. Normally, sockeye salmon move upstream from the lagoon on each high tide and pass immediately through the weir; few fish loiter in the river downstream from the weir. In tagging experiments to determine time of entry of the stocks, fish tagged and released in Chignik Lagoon during closed fishing periods were later counted as they passed through the weir. In addition, other fish were tagged and released immediately downstream from the weir and these tagged fish also were counted as they passed through the weir. Since the same sampling gear (seine), type of tags (25 mm diameter disks), and tagging crew were used in both tagging operations, the difference between migration times through the weir for the two groups of fish should reflect the migration time between the lagoon and weir (Figs. 9, 10; Table 5).

Two results are apparent from the tagging data: 1) Tagging delayed migration approximately 1 day, i.e., fish tagged immediately downstream from the weir did not pass through until about 1 day later as shown from the mode in Figure 9; and 2) assuming a delay in migration of 1 day due to tagging, the migration time from Chignik Lagoon to the weir was about 2 days. Since catch and escapement are recorded by 1-day intervals, a 2-day lag between the catch and escapement was used as the

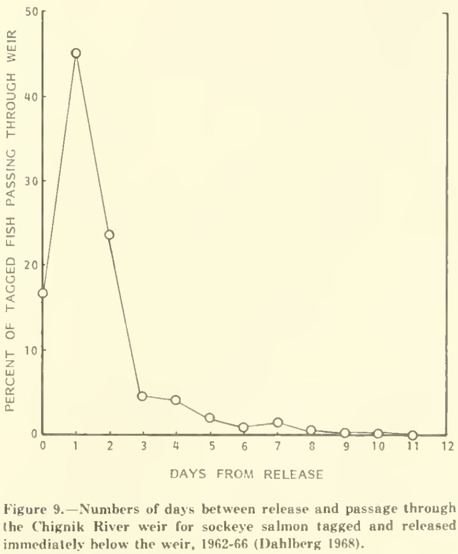

Figure 9.—Numbers of days between release and passage through the Chignik River weir for sockeye salmon tagged and released immediately below the weir, 1962-66 (Dahlberg 1968).

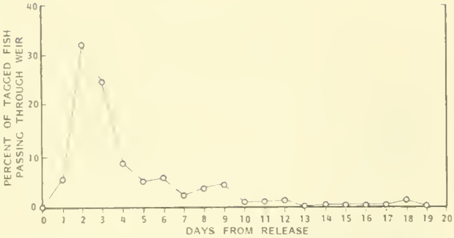

Figure 10.—Numbers of days between release and passage through the Chignik River weir for sockeye salmon tagged and released at Chignik Lagoon, 1962-66 (Dahlberg 1968).

Table 5.—Average duration of time from release to passage through the weir for sockeye salmon tagged in Chignik Lagoon and sockeye salmon tagged immediately below the Chignik River weir (combined data from 1949, 1962-66) (Dahlberg 1968).

Tagging location	Number of tagged fish counted through weir	Average time from release to passage through weir (days) Mean	Median	Mode
Lagoon	488	4.16	2.48	2.00
Weir	306	1.60	0.73	1.00
Difference	—	2.56	1.75	1.00

correction factor for the migration time between the lagoon and weir.

Separation of stocks by time of entry.—For management purposes, the sockeye salmon runs to the Chignik watershed are considered to be composed of two stocks: Chignik Lake stock and Black Lake stock (Dahlberg and Phinney[18]). Counting the catch and escapement of the two stocks is complicated. The two stocks travel through the same fishing area and trunk stream on their spawning migration, and their times of entry overlap. They do segregate on the spawning grounds, and their peak spawning activity generally occurs at different times.

Results of preliminary tagging studies in 1952, 1959, 1960, and 1961 indicated 1) that most of the fish entering Chignik Lagoon in early June were bound for the spawning areas of Black Lake and Black River tributaries, and 2) that fish entering in late July were bound for the spawning areas of Chignik Lake and certain Black River tributaries (Narver and Dahlberg 1964; Roos, see footnote 6).

The FRI conducted more intensive tagging studies from 1962 to 1966 to determine the consistency of timing of the runs and to measure overlap in entry time between the two stocks. Colored, 25 mm diameter disk tags were used in all the experiments; a different color combination was used during each tagging session. Recovery was by foot survey of each major spawning area at the peak of spawning (Table 6).

[18]Dahlberg, M. L., and D. E. Phinney. 1967. Studies of mature sockeye salmon at Chignik, 1966. Univ. Washington, Fish. Res. Inst. Circ. 67-7, 41 p.

Table 6.—Summary of tagging experiments to determine time of entry of the sockeye salmon stocks of Chignik, Alaska, 1962-66 (Dahlberg 1968).

Year	Total fish tagged	Total fish recovered	Percentage recovered	Tagging location
1962	966	120	12	Lagoon and weir
1963	1,411	165	12	Weir
1964	1,658	175	11	Lagoon and weir
1965	1,448	150	10	Lagoon and weir
1966	1,816	160	9	Lagoon and weir
Total	7,299	770	11	

I classified the tagged fish into early-season and late-season spawners and calculated their relative percentages for each tagging date (early spawning peaked in the first week of August, and late spawning peaked in the last week of August and early September). Because tagging sites varied between the lagoon and weir, all tagging dates were standardized to correspond with releases at the weir. Dates of tagging at the lagoon were adjusted to compensate for the 2-day migration between the lagoon and weir.

To obtain a quantitative estimate of the proportion of each stock present in the catch and escapement on a given day, I sought a suitable mathematical model. One approach was to consider the proportion of a stock present on a given day as a quantal response to the independent variable (time) and proceed with probit analysis (Finney 1952). However, another approach to analysis of data of this nature was proposed by Moore and Zeigler (1967), namely:

$$P = \frac{1}{1 + e^{(a + bt)}} + \epsilon$$

where P = proportion of early spawners,
$1\text{-}P$ = proportion of late spawners,
e = base of Napierian system of logarithms,
t = coded time in days measured from 15 June (day 1),
a, b = parameters estimated from tagging studies,
ϵ = error term, assumed random.

A method of nonlinear least squares which utilized the techniques of steepest descent and linearization (Gales 1964) was used to fit curves to data collected in each year and to all tagging data combined (Fig. 11, Table 7).

The entry pattern was nearly the same from year to year, but the time of entry changed slightly (the data for 1962 all fall to the left, or earlier entry; whereas, the data for 1965 and 1966 are to the right, or later entry). Time of entry might be expected to vary with annual fluctuations in environmental conditions, such as, weather and water temperatures; nonetheless, the curves can be used to separate approximately the early and late spawners by entry time and to indicate the daily proportion of each stock in the fishery and escapement.

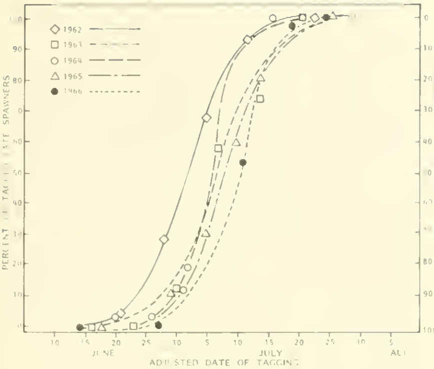

Figure 11.—Patterns of time of entry for tagged Black Lake and Chignik Lake sockeye salmon, 1962-66 (Dahlberg 1968).

Table 7.—Estimates of a, b, and $s_{p/t}$ for tagging studies of time of entry of Chignik sockeye salmon, 1962-66, after the formula of Moore and Zeigler (1967), see text.

Year	a	b	$s_{p/t}$	Number of observations
1962	−4.562	0.254	0.010	5
1963	−5.252	0.228	0.058	6
1964	−9.040	0.422	0.013	6
1965	−6.084	0.250	0.007	6
1966	−7.741	0.295	0.031	7
Combined	−5.451	0.239	0.090	30

To precisely regulate the escapement to the Chignik system, it is imperative to know where the progeny of the various spawning groups are reared, because management is based on the nursery area carrying capacity of each lake. A knowledge of the time of entry of early- and late-season spawners is not adequate in itself, because all the progeny of the Black River tributary spawners (early season and late season) are reared in Chignik Lake (Narver 1966). About 13% of the early spawners use the river (Table 8).[19] The progeny of the remainder of the early spawners (which utilize the Black Lake tributaries) are reared in Black Lake; whereas, all the progeny of the late spawners are reared in Chignik Lake. On the average, the portion of the escapement for a given date whose progeny will be reared in Black Lake is the value read from the entry curve for the year in question (Fig. 11) minus 13%, the part of the escapement whose progeny is reared in Chignik Lake. This relationship implies that all Black Lake fry remain in Black Lake; this condition may not hold true in every year.

[19]The percentage of early spawners in the Black Lake tributaries is determined from aerial surveys of the spawning grounds in each year. The total number of spawners in Black River tributaries divided by the total number of spawners counted on all early spawning areas is the proportion used. For the years before 1960 the geometric mean ratio for the years 1960-66 was used. The proportion of Black River spawners observed each year from 1960 to 1966 is shown in Table 8. A test of the consistency of using aerial survey data to calculate the Black River proportions of the early escapement was conducted in 1965. An Alaska Department of Fish and Game management biologist aerially surveyed the early spawning grounds and from his counts determined a proportion of 0.0308 Black River spawners; he accounted for 76% of the early escapement. On the same day, I made the same survey using the same airplane with the same pilot. I calculated a proportion of 0.0312 Black River spawners and accounted for 53% of the early escapement. Thus, although the total counts were quite different, both observed the same relative proportion of spawners in Black River tributaries.

Table 8.—Proportions of Black River spawners in the early sockeye salmon escapements, 1960-66 (Dahlberg 1968).

1960	1961	1962	1963	1964	1965	1966	Geometric mean
0.264	0.279	0.279	0.060	0.079	0.031	0.158	0.125

(Proportion of Black River spawners: 1960–1966.)

Calculation of catches and escapements by stock.—The information on catches and escapements was processed by computer program after the records had been compiled and estimated portions collated with the observed data (Dahlberg see footnote 15). The daily catches and escapements were divided into Chignik Lake and Black Lake stocks on the basis of the time of entry relationship. Time of entry was determined from tagging studies and the distribution of spawners on the spawning grounds. For years in which these data were not available, the average relationship was used. Catches were adjusted to allow for migration time from Cape Kumlik to Chignik Lagoon and the migration time between the lagoon and counting weir. Escapements of the two stocks were corrected for weir leakage (Lechner[20]) and the proportion of Black River spawners in the early escapements.

Estimates of the total catches by stock for the years 1888-1921 were produced from the computer program (Table 9). Table 10 presents the catches, escapements,[21] and runs by stock for the years 1922-66. Table 11 presents ratios of escapement to catch, rates of exploitation, and percentages of escapement for each stock. Figures 12 through 15 show the data in graphical form.

Beginning in 1967, summaries of the annual catch and escapement of the runs of sockeye salmon to Chignik have been reported by either FRI (Dahlberg and Phinney see footnote 18; Parr and Pedersen;[22] Wells and Parr[23]) or the Alaska Department of Fish and Game (Phinney and Lechner;[24] Pedersen and Seibel;[25]

[20]Jack Lechner, Area Management Biologist, Alaska Department of Fish and Game, pers. commun., August 1965.

[21]Includes estimates of missing data for certain years as described previously. See also Table 6.

[22]Parr, W. H., Jr., and P. C. Pedersen. 1969. Studies of adult sockeye salmon at Chignik in 1968. Univ. Washington, Fish. Res. Inst. Circ. 69-16, 40 p.

[23]Wells, J. W., and W. H. Parr. 1971. Studies of adult sockeye salmon (*Oncorhynchus nerka*) at Chignik, Alaska, in 1969 and 1970. Univ. Washington, Fish. Res. Inst. Circ. 71-7, 61 p.

[24]Phinney, D. E., and J. Lechner. 1969. Studies of adult Chignik sockeye salmon in 1967. Alaska Dep. Fish Game Inf. Leafl. 130, 43 p.

[25]Pedersen, P. C., and M. C. Seibel. 1970. Forecast of the 1970 Chignik system red salmon run. Alaska Dep. Fish Game Inf. Leafl. 144, 24 p.

Table 9.—Summary of estimated catches by the fishery of Chignik sockeye salmon by stock, 1888-1921 (Dahlberg 1968).

Year	Chignik Lake	Black Lake	Total
1888	Na	Na	13,000
1889	Na	Na	560,000
1890	Na	Na	453,000
1891	Na	Na	775,000
1892	Na	Na	522,000
1893	Na	Na	600,000
1894	Na	Na	600,000
1895	377,820	305,499	683,319
1896	615,671	234,329	850,000
1897	424,084	340,916	765,000
1898	797,466	367,953	1,165,419
1899	382,164	521,585	903,749
1900	588,532	458,839	1,047,371
1901	730,901	176,449	907,350
1902	895,888	886,127	1,782,015
1903	899,462	250,528	1,149,990
1904	1,409,452	280,190	1,689,642
1905	981,906	315,209	1,297,115
1906	1,112,235	211,349	1,323,584
1907	1,284,349	338,638	1,622,987
1908	1,208,984	421,693	1,630,677
1909	1,427,100	303,704	1,730,804
1910	978,174	336,498	1,314,672
1911	956,734	120,861	1,077,595
1912	949,857	380,975	1,330,832
1913	616,174	217,046	833,220
1914	795,200	261,429	1,056,629
1915	828,295	501,736	1,330,031
1916	710,934	291,977	1,002,911
1917	1,227,044	229,422	1,456,466
1918	1,429,709	112,998	1,542,707
1919	774,379	110,559	884,938
1920	1,407,882	364,828	1,772,710
1921	1,497,970	330,887	1,828,857

[1]Na = Not available.

Pedersen and Petersen[26]). Annual reports for the Chignik Management District are compiled each year by the area management biologist, Alaska Department of Fish and Game, and filed with the regional office in Kodiak, Alaska. Detailed records of the runs by stock, age group, and sex for the period 1922-66 can be found in Dahlberg (1968).

I used the information on age composition, catch, and escapement to estimate spawner-return relationships for the two stocks of sockeye salmon in the Chignik River system (Dahlberg 1973). Subsequent estimates of target escapements from these spawner-return functions have been considered by the management agency in controlling the annual catch.

SUMMARY

1. The abundance of stocks of sockeye salmon at Chignik, Alaska, decreased from an average of 1.9 million during the period 1922-39 to an average of 0.9 million during the period 1949-66. The average rate of exploitation during the two periods was nearly the same—0.428 in the early period and 0.422 in the recent period.
2. The high-seas and coastal distributions of Chignik sockeye salmon were investigated to determine whether or not Chignik sockeye salmon were intercepted by fisheries along the coast of the Alaska Peninsula. The Cape Kumlik fishery and, later, the Cape Igvak fishery harvest an important portion of the sockeye salmon bound for Chignik. This catch should be counted as part of the annual Chignik run.
3. Chignik sockeye salmon have been exploited since 1888; several companies operated canneries in the early phase of the fishery. The salmon canning industry coordinated their operations in the 1930's. From 1953 through 1966, two companies operated in the area, Chignik Fisheries Company and the Alaska Packers Association.
4. Enforced regulation of the fishery did not exist before 1922; after that year, management agents were stationed at Chignik each year to inspect the fishing gear during periodic closures. The White Act required an escapement equal to 50% of the yearly run; this requirement was met in most years.
5. Catch records and weir counts were used as a basis for studying the productivity of the system during the last 40 yr. Since there were no escapement records from 1940 through 1948, a ratio of escapement to catch was used to estimate the missing data.
6. Separation of the catch and escapement records for the two stocks was facilitated by time-of-entry relationship. Results from tagging studies of 1962-66 were used to estimate the relationship; an average time of entry curve was used to analyze the records before 1962.
7. Estimated annual catches and escapements for each of the two stocks were compiled for the period 1922-66, based upon the methods summarized above.

[26]Pedersen, P. C., and D. Petersen. 1971. Forecast of the 1971 Chignik system red salmon run. Alaska Dep. Fish Game Inf. Leafl. 151, 13 p.

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Table 10. Summary of estimated catches and escapements of Chignik sockeye salmon by stock, 1922-66 (Dahlberg 1968).

	Catch			Escapement			Total run		
Year	Chignik Lake	Black Lake	Total	Chignik Lake	Black Lake	Total	Chignik Lake	Black Lake	Total
1922	900,823	346,011	1,246,834	352,807	86,421	439,228	1,253,630	432,432	1,686,062
1923	562,316	80,556	642,872	213,781	4,642	218,423	776,097	85,198	861,295
1924	767,424	110,937	878,361	910,521	121,983	1,032,504	1,677,945	232,920	1,910,865
1925	436,985	260,999	697,984	677,566	386,364	1,063,930	1,114,551	647,363	1,761,914
1926	173,161	242,054	415,215	695,314	289,009	984,323	868,475	531,063	1,399,538
1927	303,401	137,566	440,967	429,525	857,881	1,287,406	732,926	995,447	1,728,373
1928	774,667	8,595	783,262	1,020,520	507,353	1,527,873	1,795,187	515,948	2,311,135
1929	689,123	359,861	1,048,984	914,307	995,832	1,910,139	1,603,430	1,355,693	2,959,123
1930	27,306	888	28,194	359,405	92,955	452,360	386,711	93,843	480,554
1931	503,584	206,256	709,840	631,986	96,201	728,187	1,135,570	302,457	1,438,027
1932	871,112	704,130	1,575,242	1,113,859	2,151,734	3,265,593	1,984,971	2,855,864	4,840,835
1933	345,469	249,452	594,921	310,088	223,913	534,001	655,557	473,365	1,128,922
1934	525,294	583,048	1,108,342	447,642	866,890	1,314,532	972,936	1,449,938	2,422,874
1935	409,893	209,449	619,342	462,469	194,636	657,105	872,362	404,085	1,276,447
1936	453,914	526,811	980,725	376,838	548,039	924,877	830,752	1,074,850	1,905,602
1937	422,254	207,064	629,318	406,618	205,613	612,231	828,872	412,677	1,241,549
1938	260,879	150,111	410,990	305,827	175,972	481,799	566,706	326,083	892,789
1939	652,780	827,580	1,480,360	512,754	1,142,852	1,655,606	1,165,534	1,970,432	3,135,966
1940	116,336	134,098	250,434	152,957	176,307	329,264	269,293	310,405	579,698
1941	383,764	270,145	653,909	531,904	374,420	906,324	915,668	644,565	1,560,233
1942	354,518	303,987	658,505	516,621	442,981	959,602	871,139	746,968	1,618,107
1943	788,636	459,182	1,247,818	1,205,418	701,859	1,907,277	1,994,054	1,161,041	3,155,095
1944	219,545	182,431	401,976	351,212	291,844	643,056	570,757	474,275	1,045,032
1945	90,563	130,390	220,953	151,326	217,882	369,208	241,889	348,272	590,161
1946	424,682	444,337	869,019	739,884	774,130	1,514,014	1,164,566	1,218,467	2,383,033
1947	768,694	1,316,128	2,084,822	1,393,990	2,386,733	3,780,723	2,162,684	3,702,861	5,865,545
1948	166,244	204,085	370,329	313,319	384,637	697,956	479,563	588,722	1,068,285
1949	418,156	124,390	542,546	574,715	213,269	787,984	992,871	337,659	1,330,530
1950	318,450	34,742	353,192	861,070	206,270	1,067,340	1,179,520	241,012	1,420,532
1951	143,521	115,494	259,015	490,899	125,126	616,025	634,420	240,620	875,040
1952	20,393	106,675	127,068	260,540	34,155	294,695	280,933	140,830	421,763
1953	109,450	185,738	295,188	221,408	168,375	389,783	330,858	354,113	684,971
1954	19,232	72,334	91,566	277,912	184,953	462,865	297,144	257,287	554,431
1955	168,987	179,539	348,526	201,409	256,757	458,166	370,396	436,296	806,692
1956	421,251	246,442	667,693	483,024	289,096	772,120	904,275	535,538	1,439,813
1957	224,757	77,423	302,180	328,779	192,479	521,258	553,536	269,902	823,438
1958	179,949	141,180	321,129	212,594	120,862	333,456	392,543	262,042	654,585
1959	251,547	165,000	416,547	308,645	112,226	420,871	560,192	277,226	837,418
1960	418,356	274,048	692,404	357,230	251,567	608,797	775,586	525,615	1,301,201
1961	278,609	53,852	332,461	254,970	140,714	395,684	533,579	194,566	728,145
1962	292,528	71,562	364,090	324,860	167,602	492,462	617,388	239,164	856,552
1963	323,080	80,258	403,338	200,314	332,536	532,850	523,394	412,794	936,188
1964	427,940	128,950	556,890	166,625	137,073	303,698	594,565	266,023	860,588
1965	152,521	477,032	629,553	163,151	307,192	470,343	315,672	784,224	1,099,896
1966	143,098	79,696	222,794	183,525	383,545	567,070	326,623	463,241	789,864

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Table 11.—Selected ratios of catch and escapement statistics for Chignik Lake, Black Lake, and total runs, 1922-66.

Year	Chignik Lake				Black Lake				Total run			
	Catch/ escape- ment	Escape- ment/ catch	Rate of exploi- tation	Escape- ment (prop)	Catch/ escape- ment	Escape- ment/ catch	Rate of exploi- tation	Escape- ment (prop)	Catch/ escape- ment	Escape- ment/ catch	Rate of exploi- tation	Escape- ment (prop)
1922	2.553	0.391	0.718	0.281	4.003	0.249	0.800	0.199	2.838	0.352	0.739	0.260
1923	2.630	0.380	0.724	0.275	17.353	0.057	0.945	0.054	2.943	0.339	0.746	0.253
1924	0.842	1.186	0.457	0.542	0.909	1.099	0.476	0.523	0.850	1.175	0.459	0.540
1925	0.644	1.550	0.392	0.607	0.675	1.480	0.403	0.596	0.656	1.524	0.396	0.603
1926	0.249	4.015	0.199	0.800	0.837	1.193	0.455	0.544	0.421	2.370	0.296	0.703
1927	0.706	1.415	0.413	0.586	0.160	6.236	0.138	0.861	0.342	2.919	0.255	0.744
1928	0.759	1.317	0.431	0.568	0.016	59.028	0.016	0.983	0.512	1.950	0.338	0.661
1929	0.753	1.326	0.429	0.570	0.361	2.767	0.265	0.734	0.549	1.820	0.354	0.645
1930	0.075	13.162	0.070	0.929	0.009	104.679	0.009	0.990	0.062	16.044	0.058	0.941
1931	0.796	1.254	0.443	0.556	2.144	0.466	0.681	0.318	0.974	1.025	0.493	0.506
1932	0.782	1.278	0.438	0.561	0.327	3.055	0.246	0.753	0.482	2.073	0.325	0.674
1933	1.114	0.897	0.526	0.473	1.114	0.897	0.526	0.473	1.114	0.897	0.526	0.473
1934	1.173	0.852	0.539	0.460	0.672	1.486	0.402	0.597	0.843	1.186	0.457	0.542
1935	0.886	1.128	0.469	0.530	1.076	0.929	0.518	0.481	0.942	1.060	0.485	0.514
1936	1.204	0.830	0.546	0.453	0.961	1.040	0.490	0.509	1.060	0.943	0.514	0.485
1937	1.038	0.962	0.509	0.490	1.007	0.992	0.501	0.498	1.027	0.972	0.506	0.493
1938	0.853	1.172	0.460	0.539	0.853	1.172	0.460	0.539	0.853	1.172	0.460	0.539
1939	1.273	0.785	0.560	0.439	0.724	1.380	0.420	0.580	0.894	1.118	0.472	0.527
1940	0.760	1.314	0.432	0.567	0.760	1.314	0.432	0.567	0.760	1.314	0.432	0.567
1941	0.721	1.386	0.419	0.580	0.721	1.386	0.419	0.580	0.721	1.386	0.419	0.580
1942	0.686	1.457	0.406	0.593	0.686	1.457	0.406	0.593	0.686	1.457	0.406	0.593
1943	0.654	1.528	0.395	0.604	0.654	1.528	0.395	0.604	0.654	1.528	0.395	0.604
1944	0.625	1.599	0.384	0.615	0.625	1.599	0.384	0.615	0.625	1.599	0.384	0.615
1945	0.598	1.670	0.374	0.625	0.598	1.671	0.374	0.625	0.598	1.670	0.374	0.625
1946	0.573	1.742	0.364	0.635	0.573	1.742	0.364	0.635	0.573	1.742	0.364	0.635
1947	0.551	1.813	0.355	0.644	0.551	1.813	0.355	0.644	0.551	1.813	0.355	0.644
1948	0.530	1.884	0.346	0.653	0.530	1.884	0.346	0.653	0.530	1.884	0.346	0.653
1949	0.727	1.374	0.421	0.578	0.583	1.714	0.368	0.631	0.688	1.452	0.407	0.592
1950	0.369	2.703	0.269	0.730	0.168	5.937	0.144	0.855	0.330	3.021	0.248	0.751
1951	0.292	3.420	0.226	0.773	0.923	1.083	0.479	0.520	0.420	2.378	0.296	0.704
1952	0.078	12.775	0.072	0.927	3.123	0.320	0.757	0.242	0.431	2.319	0.301	0.698
1953	0.494	2.022	0.330	0.669	1.103	0.906	0.524	0.475	0.757	1.320	0.430	0.569
1954	0.069	14.450	0.064	0.935	0.391	2.556	0.281	0.718	0.197	5.054	0.165	0.834
1955	0.839	1.191	0.456	0.543	0.699	1.430	0.411	0.588	0.760	1.314	0.432	0.567
1956	0.872	1.146	0.465	0.534	0.852	1.173	0.460	0.539	0.864	1.156	0.463	0.536
1957	0.683	1.462	0.406	0.593	0.402	2.486	0.286	0.713	0.579	1.724	0.366	0.633
1958	0.846	1.181	0.458	0.541	1.168	0.856	0.538	0.461	0.963	1.038	0.490	0.509
1959	0.815	1.226	0.449	0.550	1.470	0.680	0.595	0.404	0.989	1.010	0.497	0.502
1960	1.171	0.853	0.539	0.460	1.089	0.917	0.521	0.478	1.137	0.879	0.532	0.467
1961	1.092	0.915	0.522	0.477	0.382	2.612	0.276	0.723	0.840	1.190	0.456	0.543
1962	0.900	1.110	0.473	0.526	0.426	2.342	0.299	0.700	0.739	1.352	0.425	0.574
1963	1.612	0.620	0.617	0.382	0.241	4.143	0.194	0.805	0.756	1.321	0.430	0.569
1964	2.568	0.389	0.719	0.280	0.940	1.062	0.484	0.515	1.833	0.545	0.647	0.352
1965	0.934	1.069	0.483	0.516	1.552	0.643	0.608	0.391	1.338	0.747	0.572	0.427
1966	0.779	1.282	0.438	0.561	0.207	4.812	0.172	0.827	0.392	2.545	0.282	0.717
1922-1939:												
Mean	1.018	1.883	0.463	0.537	1.844	10.456	0.431	0.569	0.965	2.163	0.438	0.561
95% confidence limits												
Upper	1.340	3.334	0.538	0.613	3.822	23.966	0.551	0.689	1.340	3.918	0.518	0.641
Lower	0.696	0.432	0.387	0.461	−0.132	−3.053	0.311	0.448	0.589	0.409	0.358	0.481
1949-1966:												
Mean	0.841	2.733	0.411	0.588	0.873	1.982	0.411	0.588	0.779	1.687	0.413	0.586
95% confidence limits												
Upper	1.127	4.738	0.495	0.671	1.223	2.763	0.495	0.672	0.974	2.220	0.473	0.646
Lower	0.555	0.727	0.328	0.504	0.523	1.201	0.327	0.504	0.583	1.153	0.353	0.526
Combined:												
Mean	0.930	2.308	0.437	0.562	1.359	6.219	0.421	0.578	0.872	1.925	0.426	0.574
95% confidence limits												
Upper	1.136	3.492	0.491	0.616	2.326	12.802	0.490	0.648	1.075	2.799	0.473	0.621
Lower	0.723	1.125	0.383	0.508	0.391	−0.364	0.351	0.509	0.668	1.051	0.378	0.526

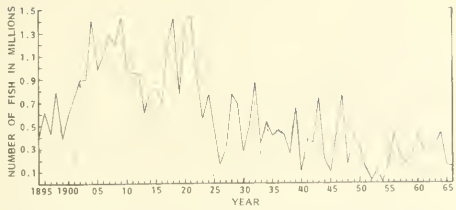

Figure 12.—Calculated catches of Chignik Lake (solid line) and Black Lake (dotted line) sockeye salmon, 1895-1966, based on time of entry of the stocks in recent years (Dahlberg 1968).

Figure 13.—Catch trends for Chignik Lake (dotted line) and Black Lake (solid line), 1895-1966, smoothed by a moving average of 5 (Dahlberg 1968).

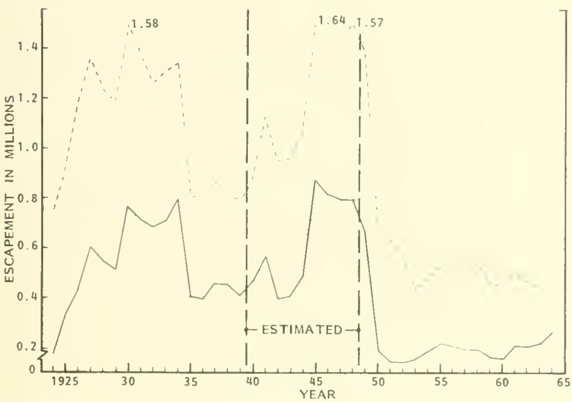

Figure 14.—Escapement trends for Chignik Lake (dotted line), Black Lake (solid line), and combined stocks (broken line), 1922-66, smoothed by a moving average of 5 (Dahlberg 1968).

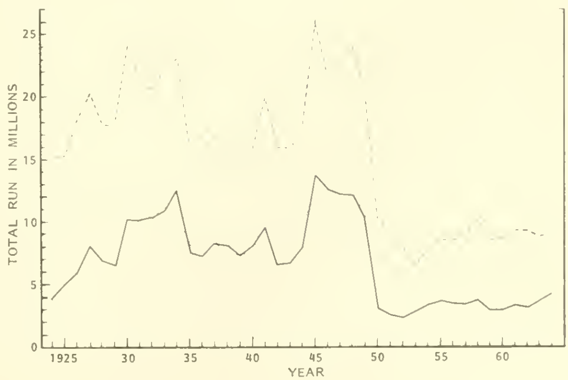

Figure 15.—Trends in total run for Chignik Lake (dotted line), Black Lake (solid line), and combined stocks (broken line), 1922-66, smoothed by a moving average of 5 (Dahlberg 1968).

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