U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE

ALASKA'S FISHERY RESOURCES

UNITED STATES DEPARTMENT OF COMMERCE
Maurice H. Stans, *Secretary*
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
Philip M. Roedel, *Director*

Alaska's Fishery Resources
The Sockeye Salmon

By

WILBUR L. HARTMAN

Fishery Leaflet 636
Seattle, Washington
March 1971

CONTENTS

Alaska's Fishery Resources — The Sockeye Salmon

By

WILBUR L. HARTMAN, Fishery Biologist[1]

National Marine Fisheries Service Biological Laboratory
Auke Bay, Alaska 99821

ABSTRACT

Sockeye salmon, Oncorhynchus nerka, are produced in river-lake systems in Canada, Alaska, and the Soviet Union. Alaska production has averaged $32 million to the wholesaler annually since 1945; the value was $72 million in 1965. Female sockeye salmon carry about 3,500 eggs and spawn in late fall in lake inlets and outlets and even the lakes themselves. The following spring, inch-long fry emerge and migrate at night to the lakes. After spending 1 to 4 years growing in the nursery lakes, the fish migrate in schools to the feeding grounds far out in the Pacific Ocean. After 1, 2, or 3 years at sea, the maturing sockeye salmon return through the coastal waters to the freshwater spawning grounds. Sockeye salmon when grown weigh 6 to 9 lb and average 24 inches long. They are captured by a Japanese high seas gill net fishery, an American inshore gill net fishery, and the Alaska native subsistence fishery in the rivers and lakes. The State of Alaska manages the inshore fishery. The National Marine Fisheries Service provides the basis for research needed for rational management and international protection of this valuable natural resource.

INTRODUCTION

The sockeye salmon, Oncorhynchus nerka, also known as the red salmon, is a renewable natural resource of prime economic importance to the State of Alaska. Its deep red flesh, rich in oils, makes the sockeye salmon the most highly prized of the five Pacific salmons for canning or smoking. Historically, the harvest of the commercial fishery for sockeye salmon has been measured by the number of cases of the canned product (48 1-lb cans per case). The greatest sustained abundance over a long period of time was between 1929 and 1938 when the annual harvest exceeded 2 million cases seven times. Between 1945 and 1967, the harvest ranged from a high of 1,945,000 cases in 1965 to a low of 487,000 in 1963 (table 1). The table also shows the wholesale value of the harvest. The record harvest in 1965 was worth $72.1 million--a value that increased many times before the canned product reached the housewife.

Sockeye salmon are produced in river-lake systems in Canada, Alaska, and the Soviet Union around the perimeter of the North Pacific Ocean. The eight major producing systems and the sizes of their annual catches are shown in figure 1. The most important system in Alaska is the Bristol Bay complex, which produces an annual average catch almost as large as the average yearly catch of the seven other systems combined (fig. 1).

[1]Present address: Bureau of Sport Fisheries and Wildlife, Department of the Interior, Sandusky, Ohio 44870.

Table 1.--Number of cases and wholesale value of sockeye salmon caught in Alaska, 1945-67

Year[1]	Cases of salmon[2] (thousands)	Wholesale value (millions of dollars)
1945	1,173	$18.3
1946	1,065	22.9
1947	1,876	45.4
1948	1,635	45.0
1949	968	25.5
1950	1,166	34.2
1951	817	26.0
1952	1,181	33.8
1953	994	28.0
1954	804	23.2
1955	662	21.0
1956	1,016	34.9
1957	763	26.7
1958	488	16.5
1959	585	21.4
1960	1,166	39.7
1961	1,296	47.9
1962	755	27.9
1963	487	20.6
1964	715	29.3
1965	1,945	72.1
1966	1,237	46.2
1967	700	28.9
Average	1,021	$32.0

[1]The figures for 1945-63 are from the 1964 Pacific Fisherman Yearbook; landings 1964-67 from 1968 National Fisherman Yearbook issue; values 1964-67 from Alaska Department of Fish and Game Statistical Leaflets.

[2]A case of salmon contains 48 1-lb cans.

LIFE HISTORY

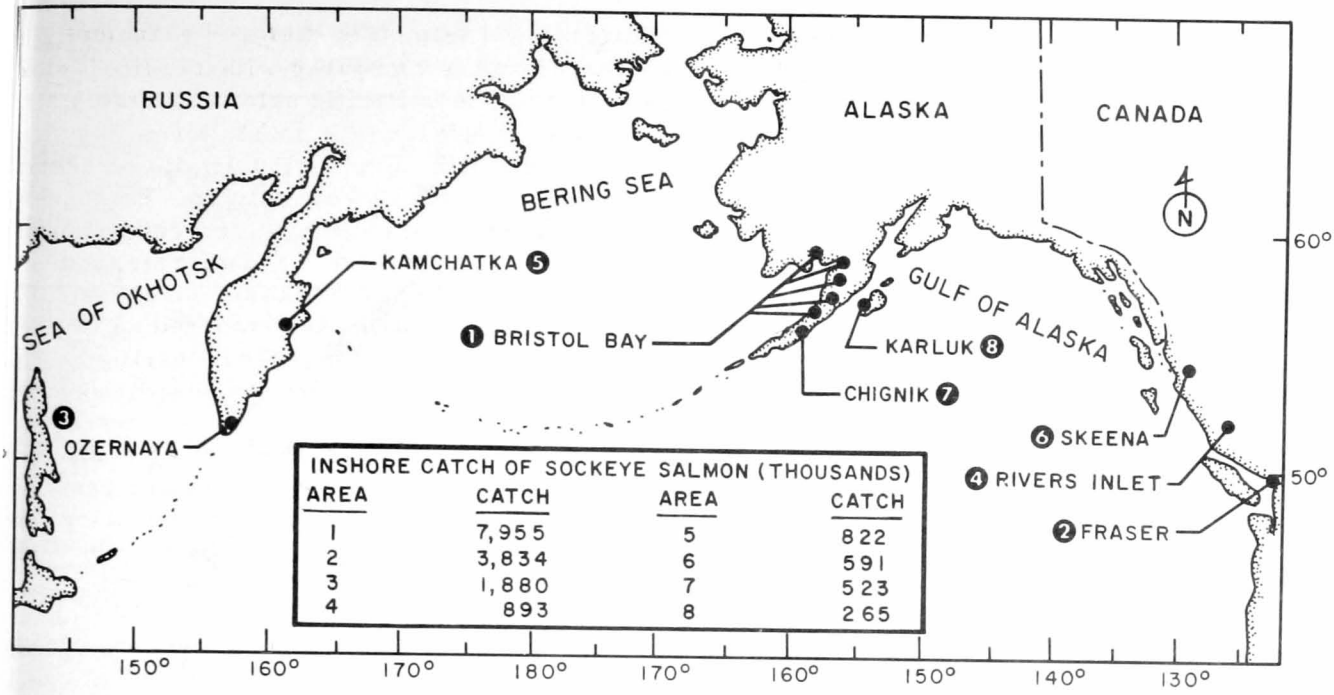
Sockeye salmon spend almost all of their life in fresh water. The adults spawn in late summer and autumn in the inlet and outlet rivers of lakes and in the lakes themselves. The eggs hatch in winter, and the young fry emerge from the spawning gravels and migrate to the lakes in the spring. The young salmon spend 1 to 4 years growing in the nursery lakes before they migrate to the feeding grounds far out in the North Pacific Ocean. After 1, 2, or 3 years at sea, maturing fish return in the spring to the coastal waters. Some are taken by commercial and subsistence fisheries, while the rest continue their journey to the rivers and lakes to produce the next generation. The life history of the sockeye salmon is pictured graphically i figure 2 and is compared with the life histor of the other four Pacific salmons in table 2.

With this life cycle in mind, let us now con sider some of the interesting details of the nat ural history of the sockeye salmon. Each sprin millions of the adults leave their feeding ground in the North Pacific Ocean and migrate hundred of miles to return to the lake and stream spawn ing areas from which they emerged as tiny fr (about 1 inch long) a few years earlier. Th navigational systems they use are still unknown yet the unerring return to "home" river-lak systems and the constancy of timing of this re turn each year attests to some rather remark able guidance mechanisms. Some scientist feel that on the high seas, salmon may be usin a celestial object, such as the sun, as clock and compass bearings, much as a sailor navi gates with his sextant and chronometer. Sci entists believe that as the adult salmon ente estuaries and near their natal spawning grounds, the sense of smell guides them to the home spawning area--the area whose combination of inorganic and organic odors most closely re sembles that which the salmon experienced as eggs and young fry in the gravel.

Sockeye salmon reach the spawning stage at different ages. Most are 3, 4, 5, or 6 years old, but some may return to spawn at 2 years and others at 7. A sockeye salmon's age can be determined from growth rings on its scales or on its ear bones, which are called otoliths. Mature sockeye salmon weigh an average of 6 lb and average 24 inches long (range 18 to 30 inches), but some exceed 10 lb.

Many things happen to the maturing sockeye salmon as they near fresh water. They stop feeding, and their digestive systems become nonfunctional and degenerate. From this point on, the spawning fish derive their nourishment from oils in their rich red flesh. The protein reserves in the flesh and skeletal structures and even the scales are drained. Other more evi dent changes take place: The fish lose their silvery ocean sheen, and the body becomes red dish and the head greenish; both sexes develop vicious-looking teeth, and the male's snout be comes very elongate and hooked. By spawning time the males are fire-engine red, and with their misshapen snouts (fig. 3) they display a grotesque but to some extent beautiful costume.

In Alaska the spawning season for sockeye salmon extends from late July to early October, depending on the location. Spawning occurs in inlet and outlet streams and along the gravel beaches of some lakes down to depths as great



INSHORE CATCH OF SOCKEYE SALMON (THOUSANDS)

AREA	CATCH	AREA	CATCH
1	7,955	5	822
2	3,834	6	591
3	1,880	7	523
4	893	8	265

igure 1.--Eight major sockeye salmon-producing systems of North America and Asia. Systems are ranked by number according to the size of their average annual catches in the years 1944-59, except for the catches of the Rivers Inlet system, which are for 1951-67.

s 100 ft. In most systems the amount of spawn-ng in lakes is considerably less than in streams, ut in Karluk and Iliamna Lakes, lake spawning s extensive in some years. In general, spawn-ng coincides with water temperatures of 40° to 0° F, so that fish breeding in lakes or in their utlets spawn later than those in the streams ecause lake waters generally cool off more lowly in late summer than do runoff waters in ake tributaries. Early and late runs do not sually spawn in the same parts of the system.

Both sexes have stereotyped behavior pat-erns that lead to the spawning act and continue ith defense of the nest until the death of the dults. A spawning pair (fig. 4) occupy a ter-itory which they vigorously defend against in-asions by other spawning sockeye salmon--the nale bluffing or fighting off other males and the emale defending against other females. During nis time the female, and the male to some ex-ent, digs a depression in the gravel by lying on er side and stirring the gravel with rapid and owerful strokes of her tail. The dislodged ravel is swept downstream, and soon a pit up o 10 to 16 inches deep is excavated. At the time f spawning the female settles into the pit, and he male approaches her very closely. The eggs nd milt are released into the pit simultane-usly. The eggs lack buoyancy and are slightly dhesive for a few minutes, and most of them ink into crevices between the uncovered stones. Immediately after she spawns the female digs in the gravel upstream from the pit, and the water current carries some of this gravel down-stream to cover the fertilized eggs. Each fe-male spawns three to five times, constructing a new pit in the gravel each time. This dis-turbed area of gravel is called the redd. After her eggs are deposited, the female defends the redd area; the male may also defend it or may move on to spawn with another female. The male and female both die several days after spawning, and their bodies drift downstream and lodge on the banks of the stream (fig. 5).

The redds where the eggs are deposited may include fine and coarse gravel and even stones 3 to 6 inches in diameter. Some sockeye salm-on, in fact, spawn among rocks so large that they cannot be moved by digging. The spawning sites are usually selected where there is good waterflow through the gravel for the eggs, which hatch and develop during winter or early spring. The inch-long fry remain in the gravel for sev-eral weeks living on the nourishment in their attached yolk sacs. During this time they are very active and may move around in the spaces between the stones. Eventually they move up out of the gravel and begin their free life, some-time during the period of April through June.

After the fry emerge in lake tribuaries, they move downstream into the lake; those hatched in lake outlets must move upstream into the

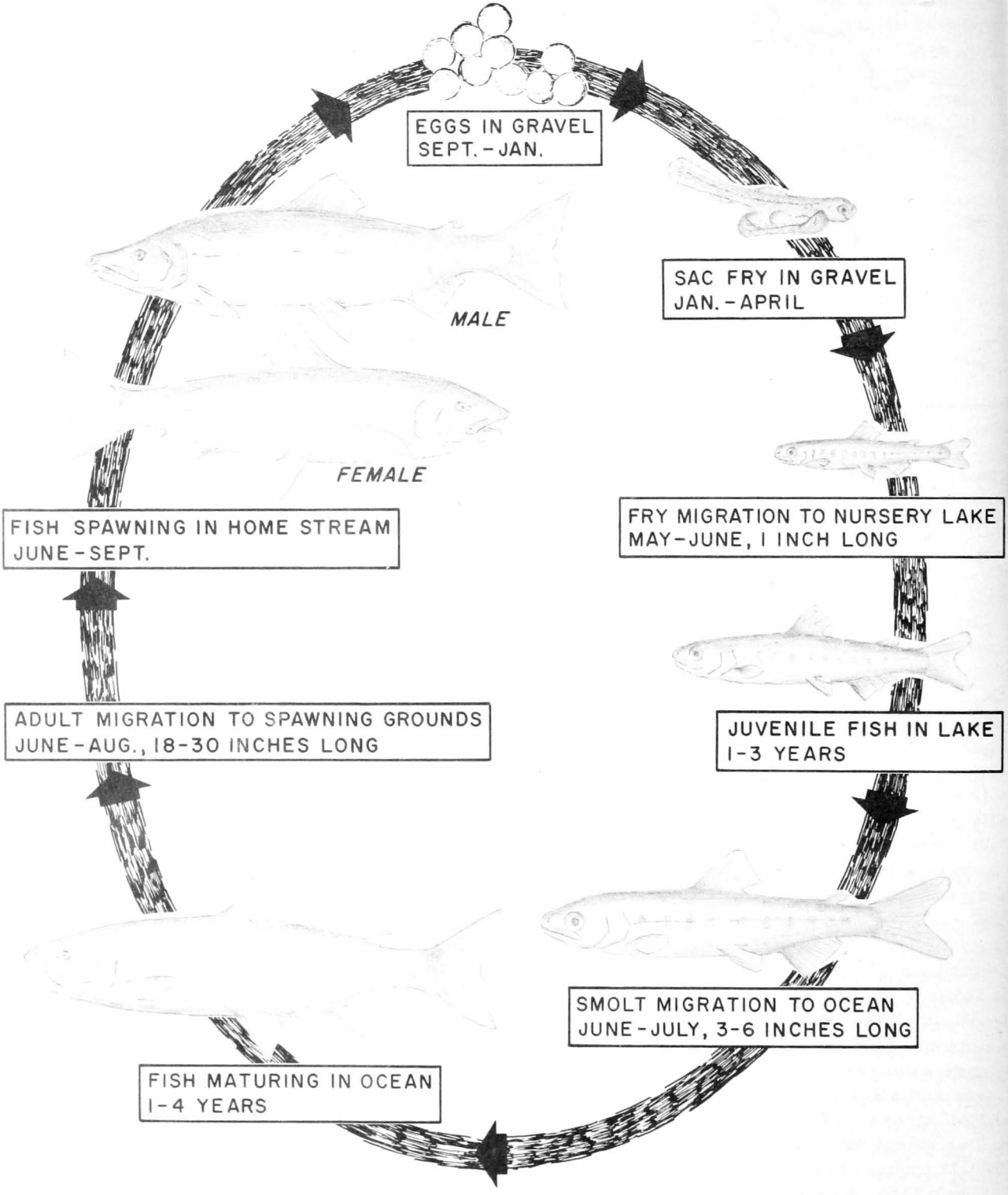


Figure 2.--Life cycle of the sockeye salmon.

ble 2.--General life history features of the five species of Pacific salmon in Alaska. (Exceptions to these general descriptions occur frequently)

ecies of mon	Freshwater habitat	Time spent in fresh water after emergence from gravel	Time spent at sea (years)	Year of life at spawning	Average weight of adults[1] (lb)	Average eggs per female (thousands)
ckeye	Short streams and lakes	12-48 months	1-3	3-6	6	3.5
nk	Short streams	Usually less than 1 day	1	2	4	2.0
ium	Short and long streams	Less than 1 month	2-4	3-5	8	3.0
oho	Short streams	12-24 months	1-1/2	3-4	9	3.5
inook	Large rivers	3-12 months	1-4	3-6	20	4.0

[1]Weight of whole or round fish. Source: Int. N. Pac. Fish. Comm., Bull. 12, p. 48.

igure 3.--Severely hooked jaws of a spawning male sockeye salmon. Males are vicious defenders of their nesting areas.

Figure 4.--Pair of sockeye salmon on spawning redd.

Figure 5.--Decomposed and dried carcasses of sockeye salmon on a beach below a spawning stream.

lake. They migrate singly during the darkest hours of the night, thus minimizing the dangers of predation by char, sculpins, trout, and birds. Once in the lakes the fry move about in schools and feed on minute plants and animals (fig. 6). During this part of their life cycle the young sockeye salmon eat many of the same foods as sticklebacks, whitefish, and other small fish. They are preyed upon by larger fish, such as lake trout and Arctic char, and birds, such as mergansers. Their lake residency may be as short as 1 year or as long as 4.

When they leave the lake the young sockeye salmon, now called smolts, are ready for their life at sea. The smolts, like the fry, migrate rapidly downstream, usually during the darkest hours of the night. Driven and guided by as yet

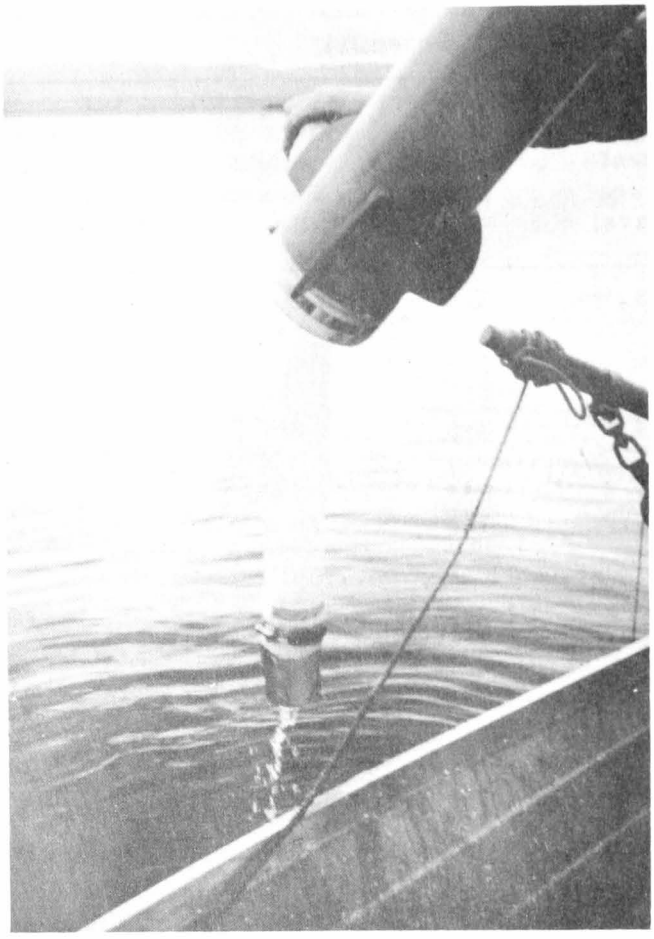


Figure 6.--A net such as this is towed in the nursery lakes to sample the microscopic plants and animals that constitute the diet of juvenile sockeye salmon.

unknown forces, they migrate out through the estuaries and disappear into the Pacific Ocean. They are 3 to 6 inches long and have silvery bodies with green backs (fig. 7). They first feed mainly on minute crustaceans, but as they grow larger they gradually shift to squid, shrimp, and small fish. The size of the sockeye salmon at the approach of sexual maturation and the start of the migration to the "home" spawning grounds depend on the genetic makeup of the stocks, the length of ocean life, and the distance of the migration to the spawning grounds. The migration timing is probably related to the seasonal temperature conditions of the spawning grounds and must influence the size of the sockeye salmon by controlling the amount of ocean growth in the final ocean year.

Certain populations of sockeye salmon become landlocked in lake systems. These fish, called kokanee, survive by adapting their entire life cycle to fresh water. They do not leave the lakes as smolts but rather grow and mature in

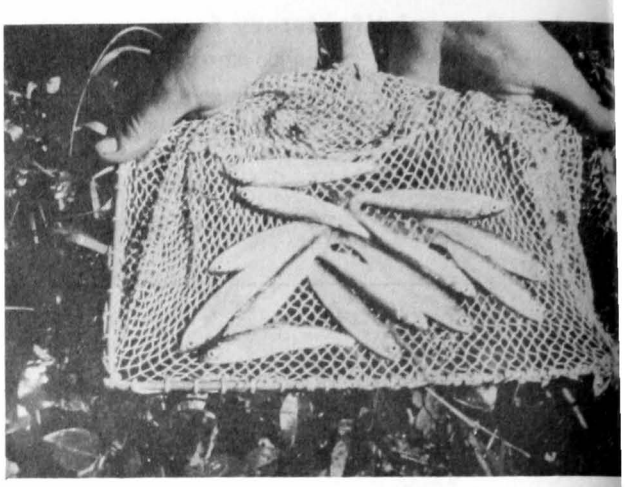


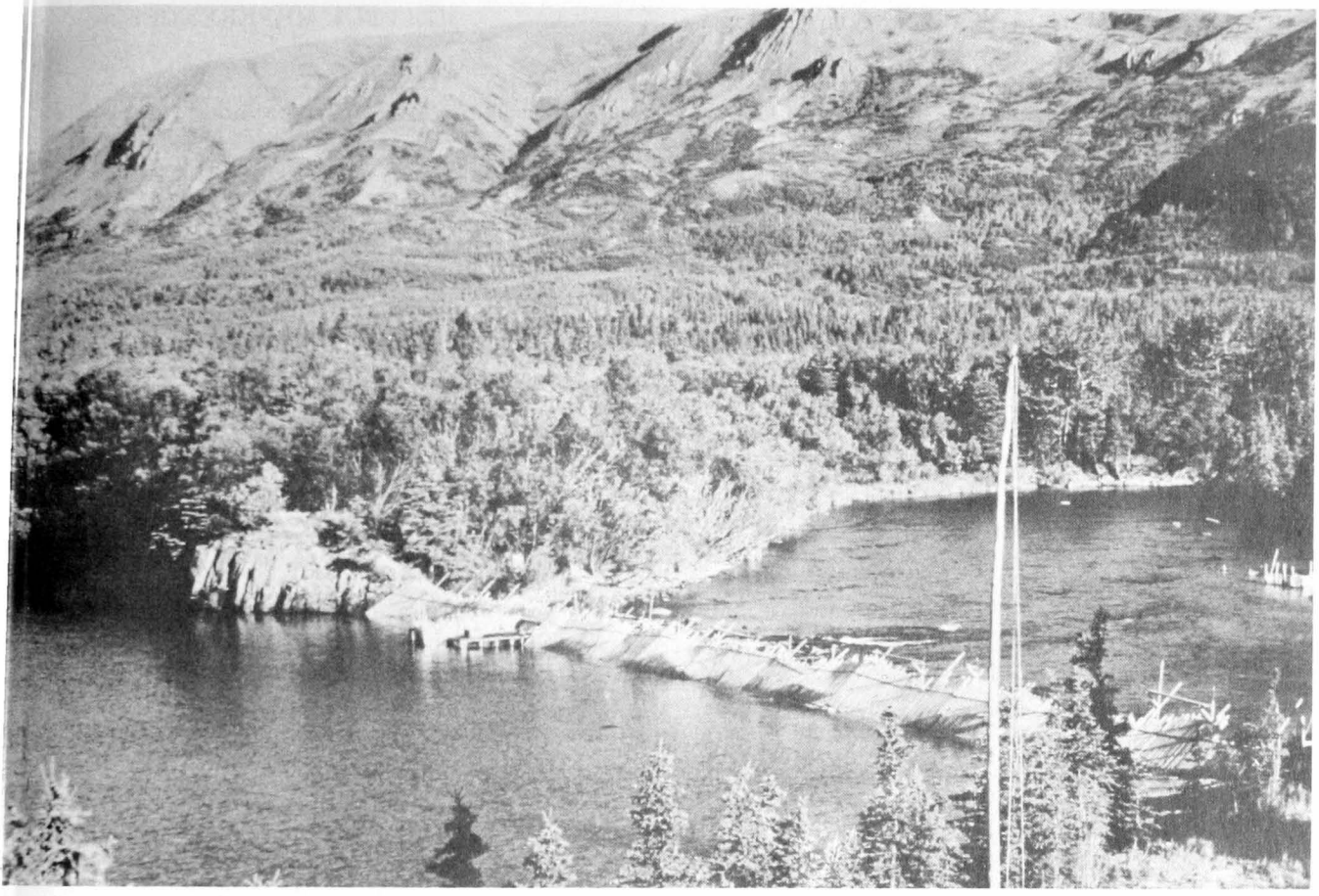
Figure 7.--Sockeye salmon smolts, 4 to 6 inch long, are sampled on their migration to sea

the lakes until the time of spawning. Althou kokanee are not usually younger than socke salmon at the time of spawning, they are co siderably smaller, often less than 14 inch long, because they have not grazed on the lu pastures of food in the ocean. Like the sea-r sockeye salmon, kokanee all die after spawnin

With the migration of Alaska adult socke salmon from the ocean feeding grounds to t spawning grounds, we have come full circle their life cycle. Many of the salmon will harvested by (1) a Japanese high seas fisher (2) the American inshore gill net fishery, (3) the Alaska native subsistence fishery in t rivers and lakes. Those escaping these vario fisheries will enter their home streams to spaw and propagate the species.

MANAGEMENT OF THE FISHERY AND SCIENTIFIC RESEARCH

Conservation of the sockeye salmon resour in terms of wise use requires rational manag ment of the fishery and of the sockeye salmo producing systems themselves. Since Stat hood in 1959, the State of Alaska has assum responsibility for regulating the fishery. T National Marine Fisheries Service continues provide the scientific research basic to ration management of the fishery. Because of inte national complications during the past 15 yea (brought on by the exploitation of the resour by a Japanese high seas gill net fishery), t Service shares with the State the responsibili of preserving the resource and safeguarding t rights of U. S. fishermen through internation treaties and negotiations. Each year as t adult sockeye salmon leave the ocean and hea



igure 8.--Fences like this one at Brooks Lake, Alaska, are used to sample and count the migration of adult sockeye salmon to certain spawning grounds each year.

oward the coastal waters to spawn, the fishery anagers face the difficult task of allowing a aximum yield to the fishery while permitting nough fish to escape to the spawning grounds perpetuate future generations. Management nd research efforts by the State and the Service ust provide the information needed to deter- ine the strength of the runs and to control e many factors that bear on production and urvival.

A great many vital statistics are gathered to nswer such questions as: How many sockeye almon were caught in each fishing district? ow many escaped to various spawning grounds fig. 8)? What were their ages? How many ggs were successfully buried in the spawning ravels? What was the survival of these eggs hatching? How many young sockeye salmon eft the nursery lakes this spring? How old and hat size were they? What is the average ma- ine survival until the adults return to the fish- ry? How big will next year's run of adults to e fishery and the spawning grounds be?

To supplement these statistical data, biologi- cal and environmental information is gathered to answer such questions as: How many sockeye salmon can spawn in a certain area without its being overcrowded? How much oxygen in the water do eggs need for embryological develop- ment? How much sand and silt in the spawning gravels will suffocate eggs? What fish prey on sockeye salmon fry and how extensively? What do young sockeye salmon eat in the nursery lakes, and what factors influence the richness of this food supply? When do sockeye salmon leave for the ocean, and what are the hazards along the way?

Let us look now at a typical survival schedule for Alaska sockeye salmon. Of the 4,000 eggs carried by a spawning female, only about 400 ever survive the spawning losses, the freezing gravels and disease during incubation, and the predation during their migration as fry to the lakes. Only about 32 of these survive to leave the nursery lakes as smolts. Of these, only six survive ocean hazards to return to the inshore fisheries; from these six, at least one male and one female (carrying 4,000 eggs) must be per-

mitted to escape and spawn to start the next generation. This survival schedule leaves an average of only three adults from the original 4,000 eggs available to the fishery. Any catch greater than three of every six fish could short-change the escapement, to the detriment of future production. Survival schedules deviate, of course, from this typical one. We must learn the survival schedule of each major population so that fishery managers will have continually improved guidelines for proportioning the sockeye salmon between the fishery and the spawning grounds.

In addition to assuring optimum escapements to the spawning grounds, the fishery manager has other means of maximizing freshwater production. New spawning grounds can be made available to salmon by removing or bypassing natural or artificial barriers to migration. Hatcheries and seminatural spawning channels can augment fry production materially. Sands and silts that suffocate eggs can be cleansed from valuable spawning grounds. Predator or competitor fish can be removed in small lakes. And spawning adults, eggs, or fry can be transplanted to strengthen old populations or establish new ones.

In conclusion, the sockeye salmon of Alaska is a tremendously valuable protein resource and an economic benefit to the nation. The salmon, however, continually face such hazards as overfishing, dams along the migration routes, siltation of the spawning gravels, and pollution of the rearing areas, plus all the natural physical, chemical, and biological hazards of each environment. Only continued and increased support of the fishery managers and the research scientists will result in wise and maximum use of this resource.

HELPFUL REFERENCES

BARNABY, JOSEPH T.
1944. Fluctuations in abundance of red sal on, Oncorhynchus nerka (Walbaum), of Karluk River, Alaska. U.S. Fish Wil Serv., Fish. Bull. 50: 237-295.

FOERSTER, R. E.
1968. The sockeye salmon, Oncorhynch nerka. Fish. Res. Board Can., Bull. 1 422 pp.

HARTMAN, W. L., W. R. HEARD, and DRUCKER.
1967. Migratory behavior of sockeye saln fry and smolts. J. Fish. Res. Board C. 24: 2069-2099.

HARTMAN, WILBUR L., and ROBERT F. R LEIGH.
1964. Tributary homing of sockeye salm at Brooks and Karluk Lakes, Alaska. Fish. Res. Board Can. 21: 485-504.

HASLER, ARTHUR D.
1966. Underwater guideposts, homing salmon. Univ. Wis. Press, Madison, 1 pp.

IDYLL, CLARENCE P., and ROBERT F. SIS ON.
1968. The incredible salmon. Nat. Geog Mag. 134(Aug.): 194-219.

LAGLER, KARL F.
1956. Freshwater fishery biology. 2d e Wm. C. Brown Co., Dubuque, Iowa, 4 pp.

THOMPSON, WILLIAM FRANCIS.
1959. An approach to population dynamics the Pacific red salmon. Trans. Ame Fish. Soc. 88: 206-209.

MS. #50