CHAPTER 10

Brown Bear Predation on Sockeye Salmon

We thought we knew about predation, but in reality we only felt.–D.L. Allen, 1954

Few events are more dramatic than the scene of a brown bear pouncing on a spawning sockeye salmon and carrying the hapless, struggling creature off to the bank to devour it while an army of screaming gulls waits impatiently for the leftovers. After seeing such an event, many observers would think that there would be more salmon to catch if we eliminated or greatly reduced the number of bears. No observer would deny the fact that brown bears consume a large number of sockeye salmon when both predator and prey come together on the latter's spawning ground. But whether or not control of the predator would result in an increased number of the prey is not at all clear. The answer depends at least in part on the situation, as we will see in the paragraphs that follow.

Observations of Bear Predation at the Karluk River System Before 1947

Although the first humans to observe a brown bear catch and eat a sockeye salmon in the Karluk River System were the Alutiiq people many thousands of years ago, perhaps the first biologist to witness and document this act was Tarleton H. Bean who visited Karluk Lake in 1889 and wrote: ". . . Goolia's [his guide's] sharp eye discovered a grizzly with two cubs crunching a salmon. . . " (Bean, 1889). During the same trip Bean described the manner in which bears catch and eat salmon: "Bears consume large quantities of the breeding fish. They may be seen standing at the edge of the stream, where the water is shallow, and occasionally striking salmon with their claws and throwing them on the shore, where they are eaten alive" (Bean, 1891). Many authors have reiterated this observation. However, Troyer and Hensel[1] described how bears capture salmon somewhat differently: "They locate salmon visually and immediately pounce with forefeet to pin their quarry to the bottom. The immobilized fish is then clenched in the teeth and taken to a gravel bar or stream bank for ingestion." The senior author has observed this process many times and corroborates the Troyer and Hensel interpretation.

During the 56-year period following Bean's visit to Karluk Lake, many other anecdotal references concerning bear predation on sockeye salmon appeared in the field notes and publications of Karluk investigators (Table 10-1). Most of the observations were made during general surveys of the stream and lake margins because no serious investigations of bear predations were undertaken prior to 1947. Many of the observers were impressed by the magnitude of the bear predation they saw, but none so much as Shuman who estimated that 25 to 33% of the sockeye salmon spawning population was consumed by bears in 1943. Shuman did not state how he arrived at those figures.

On the other hand, in the two monumental publications of the period, Gilbert and Rich (1927) presented only two small quotes from field notes regarding bear predation, while Barnaby (1944) did not mention the subject. Other items of interest presented in Table 10-1 were that bears often ate only parts of the salmon, that they created distinct trails along the streams, that they were more numerous during the war years, and that the impact of bear predation varied with the size of the escapement. Finally, although many early visitors to the Karluk system saw the remains of salmon killed by bears, Hubbs (1941) nevertheless stated that "most intelligent observers do not regard the kill of salmon by bears as of any material significance." This may explain why Gilbert and Rich (1927) and Barnaby (1944) did not dwell on the matter.

[1] Troyer, Willard A., and Richard J. Hensel. ca. 1967. The brown bear of Kodiak Island. U.S. Bureau of Sport Fisheries and Wildlife, Branch of Wildlife Refuges, Kodiak. Unpubl. rep. 233 p. Located at ARLIS, Anchorage, AK.

Table 10-1

Anecdotal references of brown bear predation on sockeye salmon, Karluk River system, 1889–1946.

Observer	Date of observation	Location	Observation
Bean (1889: 368)	19 August 1889	South end of Karluk Lake	". . . Goolia's sharp eye discovered a grizzly[1] with two cubs crunching salmon[2] . . . ."
Bean (1891: 198)	15–21 Aug 1889	Karluk Lake	"Bears consume large quantities of the breeding fish. They may be seen standing at the edge of the stream, where the water is shallow, and occasionally striking salmon with their claws and throwing them on the shore, where they are eaten alive."
Gilbert and Rich (1927: 13)	9 August 1921	Tent Point Creek	"Photos taken of fish off mouth and of fish partly eaten by bears a short distance upstream, where grass was trampled and evidence unmistakable of their presence . . . "
Gilbert[3]	20 August 1922	Tributary of Thumb Lake	". . . with these short and otherwise favorable streams, the greater part of the spawners must fall a prey to the bears."
Smith[4]	13 July 1928	Gull Creek	"As was the case last season the bear had taken a very heavy toll."
Smith[4]	13 July 1928	Canyon Creek	"The trail along the river is well marked by the ages of bear travel to and from the spawning area below the falls."
Smith[4]	3 Sep 1928	Upper Thumb River	"Because of the scarcity of fish the bear seem to be bedding down close to the river bank to take advantage of any opportunity to obtain their food, the salmon."
Hubbs (1941: 161)	1939	Alaska	"Some think that the bears destroy more salmon in Alaska than do any of the birds, but most intelligent observers do not regard the kill of salmon by bears as of any material significance."
Shuman[5]	10 July 1943	Salmon Creek	"Loss of fish to bears apparently enormous, though no estimate in numbers possible. Remains of those killed by bear are everywhere."
Shuman[5]	17 July 1943	Thumb Lake shore and tributaries	"The loss of fish to bear must be extremely high on these streams. . . it was estimated that fully 50% of the living fish . . . bore marks . . . made by bears claws (rarely by teeth)."
FWS[6]	1943	Karluk Lake	"Bear populations appeared to be greater than in any known previous year. (Probably due to lack of hunters, war activities on other portions of the island and a natural high survival of bears during the recent mild winters.) Estimated loss of spawning population (sockeyes) to bear; somewhere between 25% and 33%. . . Many small streams. . . had almost no spawning, all fish being taken by bear."
FWS[7]	1944	Karluk Lake	"Bears populations: appeared to be greater than in 1943. . . . Charlie Madsen (guide in Kodiak) placed the bear population in the Karluk basin at 500. . . . No hunters have been at the lake since 1941. . . A few of the smaller streams slightly (if at all) seeded, as bear killed all fish entering these streams. Bear should be decimated."
FWS[8]	July 1945	Karluk Lake	"On several of the smaller streams it was found that the bear were destroying every salmon entering to spawn, the seeding of the gravels thus remaining zero."
FWS[9]	1945	Karluk Lake	"An estimated 33% of entire escapement eaten or destroyed by bear."
Rich[10]	1945	Karluk Lake	". . . one unexpected result of the war has been to drive much of the Kodiak Island population of *Ursus middendorfi* into the interior. They appear to be concentrated in the area around Karluk Lake. . . and there is no doubt that they could significantly reduce the numbers of spawning fish."
FWS[11]	1946	Karluk Lake	"Bears perhaps not as numerous this year as previous three years. However their depredations were found evident on all streams."

[1] Brown and grizzly bears are now considered to be the same species (*Ursus arctos*), and most people use "brown bear" when referring to that species near the Alaskan coast and "grizzly" when referring to that species in the Alaskan interior.

[2] In the Karluk River system the terms "salmon" or "fish" usually refer to sockeye salmon because that is the species of most interest.

[3] Gilbert, Charles H. 1922 notebook. Original notebook at Stanford University Libraries, Department of Special Collection and University Archives, Palo Alto, CA; typed summary of Gilbert's survey of Karluk Lake, 18–24 August 1922 located at NARA, Anchorage, AK.

[4] Smith, Seymour P. 1928 notebook. Original notebook location unknown; copies located at NARA, Anchorage, AK.

[5] Shuman, Richard F. 1943 notebook. Located at NARA, Anchorage, AK.

[6] Fish and Wildlife Service. 1943. Karluk weir, 1943 (Portage Trail Site). Unpubl. report. 1 p. Located at NARA, Anchorage, AK.

[7] Fish and Wildlife Service. 1944. Karluk weir, 1944 (Portage Trail Site). Unpubl. report. 1 p. Located at NARA, Anchorage, AK.

[8] Fish and Wildlife Service. 1943–52. Monthly Reports of the Alaska Fishery Investigations. Unpubl. reports. Located at NARA, Anchorage, AK.

[9] Fish and Wildlife Service. 1945. Karluk weir, 1945 (Outlet of Lake). Unpubl. report. 1 p. Located at NARA, Anchorage, AK.

[10] Letter (11 May 1946) from Willis H. Rich, Consultant, Salmon Fishery Investigations, to Elmer Higgins, Chief, Division of Fishery Biology, FWS, Washington, DC. Located at NARA, Anchorage, AK.

[11] Fish and Wildlife Service. 1946. Karluk weir, 1946 (Outlet of Lake). Unpubl. report. 1 p. Located at NARA, Anchorage, AK.

Investigations of Bear Predation at the Karluk River System from 1947 to Present

With a study on Moraine Creek in 1947, Shuman (1950) initiated the investigative approach to the bear predation on sockeye salmon question. The basis of the investigation was that a weir was installed near the mouth of Moraine Creek, a lateral tributary near the outlet of Karluk Lake (Fig. 1-5). Adult sockeye salmon were counted into the stream for an extended period each morning and evening. During the height of the run salmon were enumerated throughout the day. Dead fish which drifted downstream onto the weir were examined to determine cause of death (bear-killed or natural) and whether or not they had spawned at the time of death. When an examination of the gonads showed a fish to have completed less than one-half its spawning function, that fish was recorded as unspawned; when more than half had been completed it was recorded as spawned out. Sex was not determined for fish in the escapement or for carcasses that drifted onto the weir.

Results of the study were published in the Journal of Wildlife Management (Shuman, 1950) and are summarized here. Of a total of 14,826 sockeye salmon entering Moraine Creek, 5,393 later drifted back dead against the weir and 71.2% of that sample had been killed by bears; most importantly, 31.3% of the sample was killed unspawned (Table 10-2). Shuman attributed the high predation rate to a large number of bears in the Karluk Lake area due to a lack of hunting during the war years, the migration of bears away from military installations near the city of Kodiak, and a concomitant low sockeye salmon escapement. Shuman then made an extrapolation. Assuming that Moraine Creek was representative of all Karluk Lake spawning streams and after calculating the number of fish available to bear in the entire Karluk system to be 300,699, he multiplied that figure by 31.3%. The product was an unspawned bear kill of 94,119. If those salmon had been added to the commercial pack, he determined that they would have been worth $117,649. After deducting $9,000 for the value of bears shot in the Karluk Lake area, the net loss to bear predation was $108,649. On the basis of that information, Shuman urged immediate control of the bear population.

There were weaknesses in Shuman's paper, the most important of which was the extrapolation from data obtained for one year on one creek to the entire Karluk system, excluding the lake margins. Sockeye salmon spawned in many types of streams including lateral streams such as Moraine Creek, terminal streams such as O'Malley and Thumb rivers and Canyon Creek, and the upper 5 km of the Karluk River. The topography of these streams was vastly different. The lateral streams were shallower, faster, narrower, and shorter than the terminal streams and the upper Karluk River. Bears would have found catching a salmon much easier in a lateral stream like Moraine Creek than in the other stream types. Because the Karluk Lake spawning streams were so diverse, no single stream was representative of the entire system. Additionally, the monetary value of the salmon lost to bear predation was based on a number of questionable assumptions. For example, what assurance was there that every salmon that did not end up in the belly of a bear would have ended up in a can? Finally, the weir prevented the salmon from

Brown bear chasing sockeye salmon, Meadow Creek, Karluk Lake, 1966. (Benson Drucker, Reston, VA)

Table 10-2

Studies of brown bear predation on sockeye salmon using the carcass recovery method, Karluk Lake

				Dead fish examined on the spawning ground					
						Bear-killed sockeye			
							% of sample unspawned at:		
Investigator	Study year	Creek	Escapement to creek	Number	Percent of escapement	Percent of spawning ground sample	Weir	Stream and bank	Weir, stream, and bank
Shuman (1950)	1947	Moraine	14,826	5,393	36.4	71.2	31.3	—	—
Nelson et al. (1963)	1948	Moraine	61,160	18,484	30.2	55.5	26.3	—	—
Nelson et al. (1963)	1948	Halfway	10,230	6,757	66.1	37.3	9.6	12.6	11.1
Clark (1959)	1952	Moraine[1]	10,962	1,472	13.4	73.5	—	—	20.4
Clark (1959)	1952	Moraine[2]	10,962	9,407	85.8	2.5	—	—	0.6
Grogan (1969)	1953	Halfway[2]	2,148[3]	3,437	—	3.7	—	—	1.5
Clark (1965)	1955	Halfway[2]	2,845	2,147	75.5	25.5	0.7	3.3	1.5
Clark (1959)	1956	Halfway[2]	665	526	79.1	66.0	—	—	13.0
Gard (1971)	1964	Grassy Point	9,470	7,583	80.1	74.4	—	—	9.6[5]
Gard (1971)	1965	Grassy Point[2]	6,692	5,772	86.3	20.8	—	—	3.1[5]
Drucker[4]	1967	Grassy Point	1,395[5]	761[5]	54.6[5]	11.8[5]	—	—	1.1[5]
Drucker[4]	1967	Halfway	5,096[5]	2,659[5]	52.5[5]	20.0[5]	—	—	4.9[5]
Drucker[4]	1968	Grassy Point	4,080	2,771	67.9	93.8	—	—	11.2[5]

[1] Area above electric fence.
[2] All or part of area within electric fence.
[3] Partial escapement count due to defective weir.
[4] Drucker, Benson. 1973. Determining the effect of bear predation on spawning sockeye salmon on the basis of rate of disappearance of tagged salmon. BCF, ABL, Auke Bay. Unpubl. report. 46 p. Copy in the personal papers of Richard Gard, Juneau, AK.
[5] Females only.

returning to the lake which they would have done in an unbarricaded stream every afternoon or whenever a bear entered the stream. Because the salmon were held captive, bears could have caught them more easily with the result that the predation rate would have been higher than in an open stream. Despite these weaknesses, Shuman provided a valuable service to science by his study. He pioneered the investigative approach to understanding the question of bear predation on salmon and he stimulated several subsequent studies, all of which utilized weirs.

Shuman's paper proved to be controversial and the political implications were considerable. The sequence of events was as follows: Shuman prepared the manuscript during the winter of 1947–48 and submitted it to the FWS Washington office on 12 January 1948. Following a revision, official permission to publish was received from Washington on 3 May 1948. Perhaps this permission had been granted without a thorough review because Clarence Rhode, FWS Regional Director, Juneau, wrote the following letter to Albert Day, FWS Director, Washington, DC:

> When this report first came to my attention it had been cleared for publication and I felt then, as now, that it did not receive proper routing in the Central Office. This, however, is certainly no fault of Mr. Shuman's. . . [2]

In any event, from the revised edition mimeographed copies were prepared by the FWS Regional Office in Juneau and released on 4 February 1949. Some of these copies found their way to the Alaska Territorial Legislature, which was then in session. Partly because of Shuman's study, the Alaska House of Representatives on 16 February 1949 passed Memorial No. 3 which urged the removal of the limit on brown bears. Alaska was a Territory at that time and actions taken by the Territorial Legislature were only recommendations to be considered by a branch of the federal government, in this case the U.S. Department of the Interior. Apparently House Memorial No. 3 was not viewed favorably by the Secretary of the Interior because the limit on brown bears was kept the same as before – one bear on Kodiak Island.

The next meeting of the Alaska Territorial Legislature was in 1951 and Shuman's paper was again a subject of debate. Following a proposal by the Kodiak Island

[2] Letter (ca. July 1951) from Clarence J. Rhode, Regional Director, Juneau, AK, to Director, Washington, DC. Located at NARA, Anchorage, AK.

Bear-killed sockeye salmon, Karluk Lake, July 1948. (Auke Bay Laboratory, Auke Bay, AK)

cattlemen to have the season and limit on bears removed (bears do kill some cattle) and a rebuttal by hunting guides and the FWS, came a summary of Shuman's findings. This was the same information that was presented in the 1949 legislative session, the only difference being that the results had now been formally published (Shuman, 1950). There was a second rebuttal, but when it came to a vote, the House and Senate passed Joint House Memorial No. 6 which urged that the season and bag limit on bears be removed. Curiously, although Shuman's work was presented during the debate, it was not mentioned in the Memorial itself as it was in 1949. As was the case with the 1949 Memorial, the 1951 Memorial was not supported by the Secretary of the Interior.

A third political event involving Shuman's paper was initiated in June 1951 when Frank Dufresne published an article in *Field and Stream* magazine (Dufresne, 1951). Dufresne apparently was trying to cause a split in the FWS into a commercial fisheries group and a sport fish and wildlife group because he thought they had different missions and should be separated. He accused Shuman of causing dissension in the FWS by publishing material that was contradictory to the official FWS policy concerning bear control. Both Shuman[3] and Clarence Rhode denied this accusation:

> [Discussing Shuman's 1950 paper] I hate to think that the sportsmen of America will join hands with the salmon packers to split the fisheries from wildlife, but that could be one result of this article. Frank [Dufresne] was looking for something "hot" and this was the only thing he could find that apparently suited his purpose. . . . we are infinitely better off as a unified Service than would be the case if these two operations were divided.

Nevertheless, the commercial fisheries and wildlife programs were officially separated on 1 July 1955 and these two groups later became known as the U.S. Bureau of Commercial Fisheries and the U.S. Bureau of Sport Fisheries and Wildlife. Whether or not Shuman's or Dufresne's report had anything to do with this split is moot.

Following Shuman's 1947 Moraine Creek study were several subsequent bear predation on sockeye investigations at Karluk Lake (Table 10-2), which we describe below.

Moraine and Halfway Creeks: 1948

Shuman and Nelson conducted a second study of bear predation at Karluk Lake in 1948. Observations on Moraine Creek were made in essentially the same manner as in 1947. However, at Halfway Creek, another lateral stream of Karluk Lake, the sample of fish examined included not only carcasses that floated onto the weir, but also carcasses in the stream and on the stream banks. This latter group of carcasses was examined and removed from the area every five days.

The first manuscript summarizing the 1948 data was written by Shuman and Nelson in 1950. Like Shuman's 1950 paper, this report also had a stormy history because the FWS did not want a replay of the problems generated by the earlier paper. Many revisions were required and other authors and studies became involved, as did both FWS branches.

In 1954 Shuman died in an airplane accident, and Nelson assumed senior authorship and transferred to

[3] 1) Letter (20 June 1951) from R. F. Shuman, Fishery Management Supervisor, FWS, Juneau, AK, to Regional Director, FWS, Juneau, AK.
2) Letter (12 July 1951) from R. F. Shuman, Fishery Management Supervisor, FWS, Juneau, AK, to Regional Director, FWS, Juneau, AK. Both located at NARA, Anchorage, AK.

Washington, DC. Administrations changed and at least 50 letters and memoranda were exchanged concerning the study. Finally, in 1961 an acceptable manuscript was produced ("Brown bear predation on spawning salmon, 1948–1953, Kodiak Island, Alaska") and authored by Nelson, Shuman, Clark, and Hoffman. The manuscript was issued as a Manuscript Report of the Auke Bay Laboratory Library in 1963. Important information in the manuscript included the findings that 26.3% and 11% of the carcasses examined at Moraine Creek and Halfway Creek, respectively, were unspawned and bear-killed (Table 10-2). Also included were data from other Kodiak Island streams and a discussion of experimental errors.

Moraine Creek: 1952

In 1952, FWS Kodiak National Wildlife Refuge personnel conducted a third bear predation study on Moraine Creek to determine if the installation of an electric fence around part of the creek would reduce bear predation on sockeye salmon (Clark, 1959). Methods were the same as in earlier years, except that an electric fence was installed around the lower four-fifths of the spawning area, dead fish in the stream and along the stream banks were enumerated, and a second weir was constructed at the upper end of the fence. This upper weir was designed to catch most dead fish that drifted from the spawning area above while permitting live fish to pass in either direction. Results were that above the fence 73.5% of the sample were bear-killed whereas within the electric fence only 2.5% were bear-killed (Table 10-2). Percentages of unspawned bear-killed fish above and within the fence were 20.4% and 0.6%, respectively. Clearly, bear predation on salmon within the fenced area was greatly reduced.

Halfway Creek: 1953

A somewhat different type of bear predation investigation was conducted by FWS Kodiak National Wildlife Refuge personnel on Halfway Creek in 1953 (Grogan, 1969). Near the mouth of the creek, a small island divided the creek into two parts. This permitted the installation of a weir on one side of the island and an escape pond on the other side. The escape pond extended into the lake where a fence prevented sockeye salmon from returning to the main body of the lake. The purpose of the pond was to create a relatively deep, safe haven into which spawning salmon in the stream could flee to escape a pursuing bear. Both pond and weir were surrounded by an electric fence. Once each day fish were counted through the weir and carcasses were collected from the weir face and from the escape pond, assessed as in 1948, and removed from the stream bank. Every seven days, all dead fish in the stream and on the stream banks were examined and removed from the area.

Bear predation was minimal as only 1.5% of the carcasses examined were killed unspawned by bears (Table 10-2). Although the bear population in the Karluk Lake basin was about the same as in 1952, bears apparently did not feed on salmon in the Karluk tributaries as heavily as in earlier years. Grogan (1969) attributed this to an early, bumper crop of elderberries, *Sambucus recemosus pubens*. When elderberries were available, bears preferred these to sockeye salmon. Elderberries apparently had flourished because of a warm, dry spring and early summer.

Halfway Creek: 1955

Design of the 1955 investigation was similar to that employed in 1953 except that a sample of sockeye salmon was seined and tagged at the mouth of the stream and their spawning status was checked daily by dip-netting them at their spawning location (Clark, 1965). Results were that 25% of the carcasses examined had been killed by bears, but the bear take of unspawned fish was only 1.5%, the same as in 1953 (Table 10-2). Bears appeared on the stream late in the season, probably the result of a late-ripening elderberry crop, which kept them browsing on the slopes later than usual. The tagging experiment indicated that: 1) both sexes of sockeye salmon remained in the lake off the stream mouth until they became ripe, 2) after they entered the stream, spawning started immediately, 3) within 24 hours a female may have deposited 50% or more of its eggs, 4) netting of fish was difficult when they were fresh, but became easier after spawning was completed, and 5) they returned to the safety of the lake when molested by bears or humans. Because of these behavioral traits Clark (1965) concluded that bears have little chance to take wholly unspawned salmon in small streams.

Halfway Creek: 1956

Methods in 1956 were the same as those used in 1955 (Clark, 1959). Total bear-take of the sockeye salmon sample was 66.0% and unspawned bear-take was 13.0% (Table 10-2). Both figures were the highest obtained during four years of study. Higher bear predation in 1956 was probably due to the lowest escapement on record (138,000 at Karluk River weir and 665 at Halfway Creek weir) and to the fact that several unspawned fish were caught by bears in the escape pen before the electric fence was installed. It appeared that the escape pen was ineffective in 1956.

Bear-killed sockeye salmon, Karluk Lake tributary, 1965. (Benson Drucker, Reston, VA)

Grassy Point Creek: 1964 and 1965

Data for 1964 and 1965 are treated together because they constitute one study. In 1964 Grassy Point Creek, a lateral stream, was unfenced while in 1965 it was completely surrounded by an electric fence. Gard (1971) conducted this investigation following methods used in earlier studies described by Clark (1959) with the differences noted below. The sex of the sockeye salmon escapement and of the sample of carcasses was determined. Carcasses were collected from the weir, stream, and stream banks twice each day and were deposited in the lake after they were examined for spawning status. Spawning status was determined for intact female carcasses only; eggs were counted in individuals of questionable status. In 1964 a downstream escape pen designed to enable salmon to evade bears was attached to the weir, but it was removed because bears tore off the cover and killed the trapped salmon. Three lots of 100 fish each were tagged at the weir (1964 only) and their longevity determined during twice-daily stream surveys. Loss of eggs to bear predation was calculated from potential egg deposition, actual egg deposition, and information collected at the weir and during the carcass assessments. (see Gard, 1971 for details).

Results of the investigation follow. Percentages of the sockeye salmon escapements examined on the spawning grounds were 80 in 1964 and 86 in 1965, the highest reported in any predation study (Table 10-2). High recoveries were probably due to more frequent stream cleanups than in earlier studies. Bears were efficient predators in Grassy Point Creek, killing up to 74% of the salmon in 1964; however, only 9.6% of a sample of bear-killed females were unspawned. The maximum estimate of sockeye salmon eggs lost to bear predation in 1964 was about 1,000,000 compared to a total loss from all causes of 8,000,000 potential eggs. The ratio of males to females in each year's escapement approached 1:1, whereas the ratio among bear kills was about 3:2. Thus, males acted as a buffer against predation of females. The electric fencing reduced bear predation by two-thirds in Grassy Point Creek.

Grassy Point and Halfway Creeks: 1966, 1967, 1968

This bear predation study by Benson Drucker[4] included the 1964 data and methods reported by Gard (1971), except that the streams were unfenced, salmon escapements into Grassy Point Creek in 1967 and 1968 were restricted, and eggs were counted in each female carcass found during the 1967–68 stream surveys. Additionally, Drucker calculated sockeye salmon mortality rates from the rate of disappearance of tagged spawners in 1964, 1966, and 1968 and attributed all mortality during spawning to bear predation. He then compared the mortality rates found by the two methods, using 1) carcass recovery and 2) rate of disappearance of tagged spawners.

Results were substantially different depending on the method used. In the carcass recovery method, unspawned, bear-killed female sockeye salmon ranged from 1.1% to 11.2% in Grassy Point and Halfway Creeks, which indicated low to moderate predation when compared to other studies (Table 10-2). However, in the disappearance of tagged spawners method, unspawned

[4] Drucker, Benson. 1973. Determining the effect of bear predation on spawning sockeye salmon on the basis of rate of disappearance of tagged salmon. BCF, ABL, Auke Bay. Unpubl. report. 46 p. Copy in the personal papers of Richard Gard, Juneau, AK.

bear-killed females ranged from 39% to 79% in Grassy Point Creek, with the highest predation rate occurring in 1968.

Another indicator of extreme predation in 1968 was that average number of eggs in the females examined was almost four times greater than in 1967. Presumably nearly constant harassment by bears interrupted the spawning act. Calculated number of eggs lost to bear predation for the entire stream in 1964 was 4 or 5 million depending on whether spawning was completed in 2 or 3 days, whereas Gard (1971) calculated eggs lost to bears in 1964 to be only 1 million by the carcass recovery method. In the 1968 carcass samples the ratio of females to males killed by bears was significantly higher at Halfway Creek than was expected from the sex ratio at the weir, but there was no difference at Grassy Point Creek. However, Gard (1971) found that bears selected males at Grassy Point Creek in 1964–65.

Drucker believed that the disappearance of tagged spawners method produced more realistic estimates of the effects of bear predation on sockeye salmon than did the carcass recovery method because eggs were often lost when a ripe female was struggling in the jaws of a bear. Such fish might have been classified as spawned out, but in reality were unspawned at the time of capture. This did happen in an unknown number of cases and the numbers of unspawned, bear-killed females determined from samples of carcasses may have been lower than they really were.

It was equally true that there were errors associated with the disappearance of tagged spawners method. Firstly, the assumption was made that all disappearances of tagged fish were due to bear predation. However, there were other reasons for tagged fish to disappear, including loss of tags, increased mortality caused by the presence of tags, and predation by other animals. Red foxes killed 1% of the carcasses inspected at Grassy Point Creek in 1965 (Gard, 1971). Also, bald eagles, river otters, and various species of gulls may have taken sockeye salmon. Clark (1965) found four sockeye salmon in six bald eagle nests he inspected, but did not comment on the spawning status. Secondly, the assumption was made that all salmon females required 2 or 3 days to establish a redd site and spawn. Because Clark (1965) and Owen[5] reported that many sockeye salmon females were spawned out after only 24 hours in Grassy Point and Cottonwood Creeks, respectively, the 2- or 3-day spawning periods assumed by Drucker were unrealistically long.

Summary and Conclusions

Many animals preyed on adult sockeye salmon in the Karluk River system, but the brown bear was easily the most important. Other predators included red foxes, river otters, bald eagles, and various species of gulls. None of these other predator species was by itself significant, but the total impact of all these species might have been appreciable. Information on these predators was scarce and largely anecdotal.

Perhaps the most significant information revealed by the bear predation on sockeye salmon studies was that predation rates varied greatly between lateral streams during one year or between years for one stream. For example, in unfenced streams there was about a 2-fold difference in bear-take of unspawned fish between streams in 1948 and 1968 and a 10-fold difference between 1967 and 1968 at Grassy Point Creek (Table 10-2). These results emphasize the fallacy of extrapolating from data collected from only one stream or year. Once again, the wide diversity of biological responses in space and time are evident for the Karluk Lake ecosystem.

The most important variable influencing the effect of bear predation probably was the size of the sockeye salmon population. During the years of study, sockeye salmon escapements to Karluk Lake varied greatly from 138,000 in 1956 to 754,000 in 1948, while estimates of the bear populations varied moderately from 115 in 1953 (Clark, 1959) to 156 in 1962.[6] In years with low escapements a relatively constant number of bears could have had a substantial effect on the sockeye salmon population, but in years of large escapements the effect of predation would have been insignificant or even beneficial. In 1947 there was a relatively small escapement to Moraine Creek of 14,826 fish and the unspawned bear-take was 31.3%, whereas in 1948 the escapement was 61,160 and the unspawned bear-take dropped to 26.3% (Table 10-2). Also in 1956 when the escapement to Halfway Creek was only 665 (the smallest on record) the unspawned bear-take was a relatively high 13.0%, whereas in 1955 with an escapement of 2,845 the unspawned bear-take was only 1.5%. Rounsefell (1958) demonstrated that the Karluk sockeye salmon reproduction curve was of the "Ricker type" and suggested

[5] Letter (13 July 1957) from John B. Owen, Fishery Research Biologist, to W. F. Royce, FWS, Juneau, AK. Located at NARA, Anchorage, AK.

[6] See footnote 1.

that when the escapement was large enough for the expected return to fall along the right limb of the curve, some bear predation could have increased the return.

During the peak of the spawning run sockeye salmon were often the preferred food of brown bears, but at other times bears ate a variety of plant foods. Elderberries were of special interest because bears apparently preferred them to salmon, even when the latter were readily available. In 1953 there was an abundant, early elderberry crop and bears left Halfway Creek early to feast on the berries, with the result that the bear-take of unspawned fish was only 1.5% (Grogan, 1969). Due to a late vegetative season in 1955, bears apparently grazed on the high slopes later in the summer than usual and stayed on to browse on the late-ripening elderberry crop (Clark, 1965). The result was that bears spent little time on Halfway Creek that year and the bear-take of unspawned fish was again only 1.5%. Berns et al. (1980) and Barnes (1990) also mentioned the importance of elderberries in the diet of brown bears during August and September.

Sockeye salmon have evolved several behavioral traits that permitted them to flourish in the shallow lateral streams of Karluk Lake despite bear predation. These behaviors included: 1) remaining in the lake until ripe, 2) quickly building a redd and spawning, often depositing over half their eggs within 24 hours following stream entry, and 3) returning to the safety of the lake each afternoon or if disturbed by bears.

Electric fences were installed around all or part of the three test streams to determine if they would reduce bear predation on sockeye. Percentages of unspawned bear-take in these streams were 0.6, 1.5 (twice), 3.1, and 13.0, with an average of 4.8. The 13% figure was for Halfway Creek in 1956 when the escapement was at an all time low. Comparable percentages for unfenced streams ranged from 1.1 to 31.3, with an average of 12.7 (Table 10-2). Therefore, electric fences usually restricted bear predation on sockeye salmon to very low levels and were the least damaging and least expensive method to protect sockeye salmon in small streams when escapements were low. However, regular fence maintenance was required during the spawning period because bears occasionally broke the fences to reach the streams.

There was no consistent pattern of differential predation by bears on male or female sockeye salmon. In 1964 and 1965 male sockeye salmon were selected by bears at Grassy Point Creek. In 1968 neither sex was selected at Grassy Point Creek, but females were selected at Halfway Creek. Therefore, there was no justification for permitting a differential harvest of either sex in the Karluk commercial fishery.

Escape pens were constructed at the stream mouths during four studies to provide safe havens to which spawning salmon could have retreated during bear harassment. In two studies the results were inconclusive because few bears visited the streams and in the other two studies bears got into the pens and probably killed more salmon than they would have had there been no pens.

In the opening paragraph of this chapter the question was posed as to whether or not control of brown bears, as was suggested by Shuman (1950) and the Alaska Territorial Legislature (1949, 1951), would result in an increased number of sockeye salmon. We may never know for certain the answer to that question when directed toward the situation existing at Karluk Lake in the 1940s and early 1950s because control measures were never put into effect. What we do know is that during the late 1940s sockeye salmon escapements were falling and that bear numbers were high due to lack of hunters and bear migrations during World War II. We also know that bear populations remained fairly steady after 1951 and that sockeye salmon escapements oscillated around 400,000 through 1984, but in recent years approached 1 million fish (Fig. 1-3). This resurgence came without any control of bears. Further, we know that most of the studies in the 1950s and 1960s found bear-take of unspawned fish to be low to moderate. Therefore, we conclude that bear predation usually has little effect on sockeye populations at Karluk Lake and that control of bears by means other than sport hunting would not be justified and, in fact, could be detrimental in years of high sockeye salmon escapements.