FALLS, GUT BAY, AND KUTLAKU LAKES SUBSISTENCE SOCKEYE SALMON PROJECT 2002 ANNUAL REPORT

by

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This report has been prepared to assess project progress. Review comments have not been addressed in this report, but will be incorporated into the final report for this project.

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1 The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

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PROJECT SPONSORSHIP

The Federal Subsistence Board, managed by U.S. Fish and Wildlife Service Office of Subsistence Management, approved the Falls Lake Sockeye Salmon Stock Assessment Project (Study Number FIS00-044) and the Gut, Kook, and Hoktaheen Sockeye Salmon Stock Assessment Project (Study Number FIS01-125). The projects were funded by the U.S. Forest Service, and are cooperative projects between the U.S. Forest Service (USFS), the Alaska Department of Fish and Game (ADF&G), and the Organized Village of Kake. This annual report partially fulfills contract obligations for Sikes Act Contract (53-0109-2-6110, 53-0109-2-61200, and 43-0109-0-0174).

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ABSTRACT

Sockeye salmon (*Oncorhynchus nerka*) returning to Falls, Gut Bay, and Kutlaku Lakes are important traditional resources for the people of Kake. In 2002, Falls, Gut Bay, and Kutlaku Lakes were combined as the Kake Subsistence Sockeye Salmon Project to address concerns about increasing fishing pressure in these systems in the traditional areas around Kake. The project evaluates returning adult sockeye salmon populations to each lake along with the productivity of the freshwater environments and rearing juvenile sockeye salmon within them. This annual report summarizes the results of work conducted in 2002, the second field season at Falls and Gut Bay Lakes, and the first full field season at Kutlaku Lake.

In 2002, the return of adult sockeye salmon to Falls Lake was estimated for the second consecutive year through subsistence and sport harvest surveys, weir counts verified with a mark-recapture study, and an independent, spawning-grounds mark-recapture study. A portion of the escapement of adult sockeye salmon to Kutlaku Lake, specifically the part of the population spawning in the main inlet stream, was estimated through a mark-recapture study on the spawning grounds. In Gut Bay Lake, only visual counts of adult sockeye salmon were conducted. Age, length, and sex composition of the escapement in Falls and Kutlaku Lakes were estimated. Sockeye fry populations were estimated in all three lakes using hydroacoustic and trawl sampling. Light, temperature, and dissolved oxygen profiles were measured and zooplankton populations and species distributions were estimated in all three lakes. About 3,700 adult sockeye salmon returned to Falls Lake in 2002; 2,600 of these were harvested in subsistence fishing, leaving an escapement of about 1,100. Compared with 2001, the total return was smaller and the subsistence harvest higher in 2002, resulting in an escapement of only about 40% of the previous year's number. Sockeye adults with two ocean years dominated the 2002 Falls Lake escapement with 46% of the sample at age-1.2 and 23% at age-2.2, contrasting with the 2001 escapement where almost 90% were age-1.3. About 1,350 sockeye salmon spawned in the main inlet stream of Kutlaku Lake, constituting an unknown portion of the total escapement. Age-1.2 sockeye salmon comprised 75% of the Kutlaku Lake escapement sample. At Falls Lake, the estimated sockeye salmon fry density of about 0.02 fry·m^{-2} was low compared with other Southeast Alaska lakes sampled, and lower than in 2001 (Conitz et al. 2002). Both Gut Bay and Kutlaku Lakes had among the highest sockeye fry densities of lakes sampled in Southeast Alaska in 2002, with about 0.25 fry·m^{-2}, and, relative to the same group of Southeast Alaska lakes sampled in 2001, their fry densities remained about the same in 2001 and 2002. Falls, Gut Bay, and Kutlaku Lakes each had a mean euphotic zone depth between 8 – 9.5 m, developed a summer thermocline, and had adequate levels of dissolved oxygen at least in the upper half of the water column. Zooplankton levels were very low in Falls and Gut Bay Lakes, with total seasonal mean biomass of 50 mg·m^{-2} and 30 mg·m^{-2}, respectively, at the main sampling station, and even lower at the second station. Copepods *Diaptomus* sp. and *Cyclops* sp. were dominant in Falls Lake, while the cladoceran *Bosmina* sp. was dominant in Gut Bay Lake. Zooplankton biomass was 3-4 times greater in Kutlaku Lake, with total seasonal mean about 130 mg·m^{-2} at both sampling stations. The cladocerans *Bosmina* sp. and *Daphnia longiremis* together constituted over 50% of biomass, but the *Daphnia* were small at 0.5-0.7 mm length.

The work performed in 2002 yielded a second year of successful harvest and escapement estimates at Falls Lake, and of lake productivity estimates at all three lakes. These results bring us one step closer to the long-term goal of setting scientifically based, sustainable harvest limits and escapement goals.

INTRODUCTION

The Kake Subsistence Sockeye Salmon Project is a combination of two federally funded, cooperative projects between ADF&G, the Organized Village of Kake (OVK), and the U.S. Forest Service. The Falls Lake Subsistence Sockeye Salmon Project (FIS 00-044) was initiated in 2000, and data collection began in the 2001 field season. The Kake "trilogy" Subsistence Sockeye Salmon Project (FIS 01-125) was initiated in the 2001 field season. Gut Bay, Kook, and Hoktaheen Lakes originally comprised the Kake trilogy, but the project was reorganized prior to the 2002 field season to include only lakes within the traditional fishing areas surrounding Kake. Kook Lake is now in the Angoon subsistence sockeye salmon project, and Hoktaheen Lake is in the Hoonah subsistence sockeye salmon project. Falls Lake (ADF&G stream no. 109-20-013/014), Gut Bay Lake (ADF&G stream no. 109-20-007/008), and Kutlaku Lake (ADF&G stream no. 109-52-035) produce sockeye salmon (*Oncorhynchus nerka*) runs traditionally and currently important to subsistence users from the village of Kake (Figure 1).

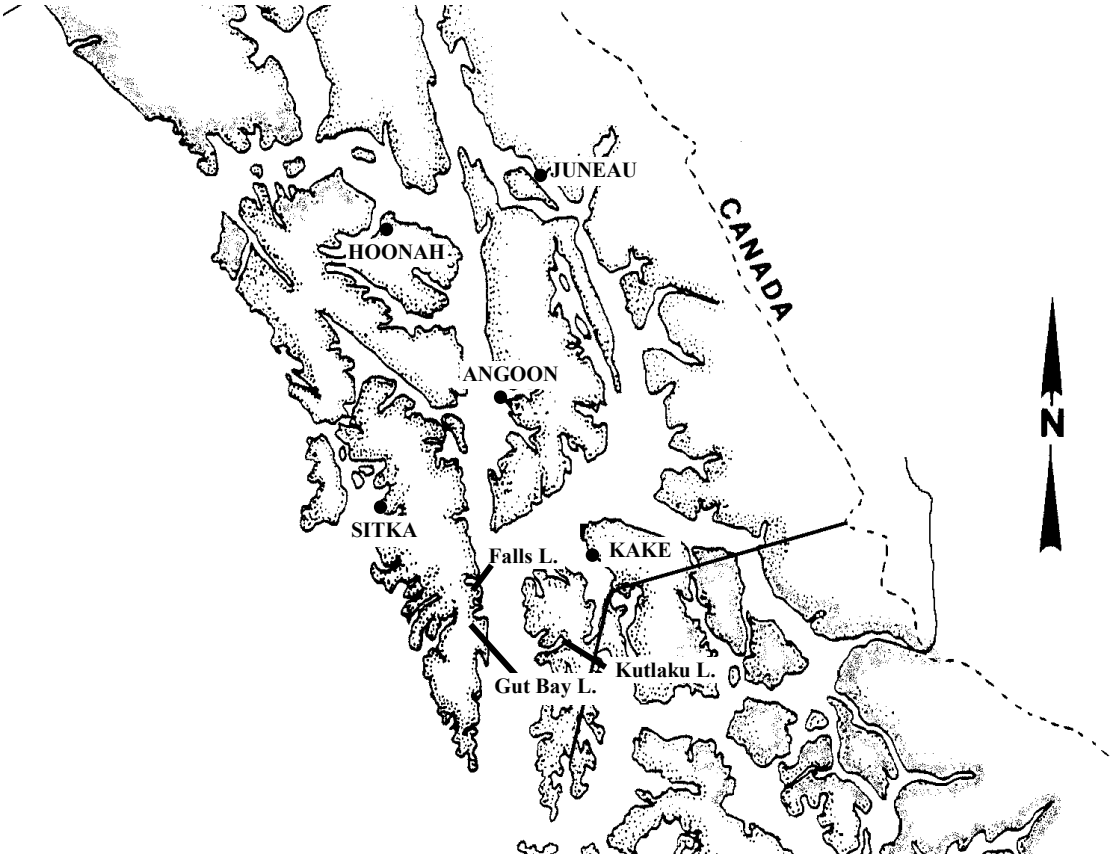

Figure 1. Map of Southeast Alaska showing location of Falls, Gut Bay, and Kutlaku Lakes, and the village of Kake.

Cultural and Subsistence Fishing History

Falls Lake and Gut Bay, along with other areas along the east coast of Baranof Island between Red Bluff Bay and Cape Ommaney, were in traditional territory shared by the Kake and Angoon people. The Bay of Pillars and other areas of Kuiu Island were part of the traditional territory of the Kake people. Until a government school, with compulsory attendance, was opened in the early 1900s at the present-day Kake village site, the Kake people occupied many village sites spread out among Kuiu, Kupreanof, Baranof and Admiralty Islands and the mainland. Many Tlingit villages in southeast Alaska are centered prominently around productive sockeye systems, and property rights surrounding sockeye lakes lent clans with stewardship claims to these areas increased recognition. Old village sites in the Bay of Pillars area indicate a long history of use and dependence on Kutlaku Lake sockeye salmon (M. Jackson OVK, personal communication 2001). Small settlements or fishing camps were also located in proximity to the sockeye streams at Falls and Gut Bay (Goldschmidt et al. 1998). In 1914 the Kake people requested that the U.S. government create a reserve for their exclusive use, in order to protect their land and subsistence rights. However, when the government proposed a smaller reserve, the Kake people declined, saying it would not be large enough to do them any good. Meanwhile, the village of Kake had become a self-governing town by the 1920s and incorporated as a first class city in 1952 (Firman and Bosworth 1990).

Since the beginning of the commercial fishing period, Kake people have incorporated seasonal fish-processing work and commercial fishing into their seasonal subsistence activities. The first cannery built within Kake territory was in the Bay of Pillars in 1890. Kake people living at Port Camden walked overland to the head of the Bay of Pillars where they kept skiffs they used to get to the cannery to work. The first cannery burned down after only two years of operation, but another cannery, saltery, and herring reduction plant was built in the Bay and operated through the 1940s (Firman and Bosworth 1990). From the early 1920s through the 1940s, many Kake residents engaged in commercial trolling and fished the waters of Chatham Strait. Some Kake people sold fish at Port Alexander and owned houses there, while others worked out of trolling camps located in the bays of Kuiu and Admiralty Islands and sold to fish packers from the cannery at Tyee on Admiralty Island. The Kake fishing fleet became more centralized after 1950, when the village purchased the Kake cannery, while the smaller and more isolated canneries along the Chatham coast began closing due to changing market conditions. In an effort to keep fishing opportunities within the community, the Kake IRA Council owned or financed the purchase of larger boats, especially seiners, and after the limited entry system was initiated in 1975, Kake Tribal Corporation financed the purchase of limited entry permits (Firman and Bosworth 1990).

Participation in commercial fisheries has influenced the subsistence fishing patterns of Kake people throughout this historical period. During the early commercial period, people continued their aboriginal patterns of subsistence fishing, while supplementing their livelihoods by fishing for or working in the canneries. Later, when they owned commercial fishing boats, Kake residents used them to access and harvest subsistence resources from various traditional fishing and hunting areas along both sides of Chatham. With the centralization and recent decline in commercial fisheries, Kake residents no longer have convenient access to distant subsistence fishing and hunting areas. Many also have jobs in the timber industry or other employment,

which restricts the time they have available for subsistence activities. People must now travel the substantial distances from Kake and cross or travel along the rough waters of Chatham Strait in skiffs or small cabin cruisers, on single day or overnight trips. Nevertheless, because Falls Lake, Gut Bay, and Kutlaku Lake are among just a handful of sockeye producing systems in Kake's traditional area, they continue to be important subsistence fishing areas. In a 1985 survey, over 50% of Kake households reported using these three areas for subsistence fishing. In 1985 and 1986, when subsistence-fishing permits were required for individual systems, the large majority of permits were requested for Gut Bay and Bay of Pillars. Out of 253 permits issued in 1985, 107 and 85 were for Gut Bay and Bay of Pillars, respectively, and in 1986, out of 242 total, 115 and 81 permits, respectively, were issued for those areas. Nearly all the reported sockeye catch was from those two systems (Firman and Bosworth 1990).

Salmon is the most important subsistence resource for Kake residents and is shared widely within the community. ADF&G Division of Subsistence household surveys show that almost all Kake households use subsistence salmon. Other households give salmon to households that are unable to harvest their own salmon; about 60% of Kake households participate in subsistence salmon harvesting (Table 1). Sockeye salmon comprises at least half of all subsistence salmon used in Kake (ADF&G Div. of Subsistence, Community Profile Database 2003). Information on subsistence use of salmon and other resources in Kake has been further documented and updated during the winter of 2002 in a cooperative project between the ADF&G Division of Subsistence and the Organized Village of Kake, funded by the Federal Subsistence Fisheries Resource Monitoring Program (Larson 2001). The report from this project will be finished in the summer of 2003 (M. Turek ADF&G, personal communication 2003).

Table 1. Community survey data for Kake households using and harvesting subsistence salmon (ADF&G Div. of Subsistence, Community Profile Database 2003).

	Sockeye Salmon		**All Salmon**	
Year	Households Using (%)	Households Harvesting (%)	Households Using (%)	Households Harvesting (%)
1985	41.4	34.3	87.1	61.4
1987	50.3	31.7	87.7	55.6
1996	95.9	41.1	98.6	61.6

Subsistence fishing permits are issued by ADF&G Division of Commercial Fisheries; permit holders are required to report their harvest, and the division compiles effort and harvest data in its regional database. In the past decade, reported subsistence sockeye salmon harvest and effort have increased dramatically at Falls Lake, fluctuated widely with slight increases at Gut Bay, and declined at the Bay of Pillars/Kutlaku (Table 2). There are many factors, which may contribute to these trends, including improved reporting in recent years, a decrease in the amount of subsistence salmon taken in the commercial fisheries, and the use of larger outboard motors to access the areas. However, it is widely acknowledged that the permit reporting system routinely underestimates total subsistence harvest.

Table 2. Harvest and effort for sockeye salmon at Falls, Gut Bay, and Kutlaku, reported on subsistence permits from 1985-2001 (ADF&G Div. of Commercial Fisheries database 2003).

System	Year	Number of Permits	Total Sockeye Harvested	Average Sockeye per Permit
Falls Ck	1985	2	17	9
	1986	3	30	10
	1987	3	30	10
	1988	24	338	14
	1989	26	390	15
	1990	16	149	9
	1991	10	122	12
	1992	34	550	16
	1993	51	1012	20
	1994	51	911	18
	1995	56	976	17
	1996	70	1229	18
	1997	68	977	14
	1998	62	1101	18
	1999	75	1020	14
	2000	59	798	14
	2001	84	1290	15
Average, all 17 yrs:		41	644	14
Average, since 1992:		61	986	16
Gut Bay	1985	37	339	9
	1986	59	572	10
	1987	22	211	10
	1988	39	419	11
	1989	29	649	22
	1990	16	182	11
	1991	12	128	11
	1992	46	765	17
	1993	52	795	15
	1994	32	432	14
	1995	38	490	13
	1996	41	488	12
	1997	23	287	12
	1998	53	732	14
	1999	26	272	10
	2000	37	419	11
	2001	47	577	12
Average, all 17 yrs:		36	456	13
Average, since 1992:		40	526	13
Kutlaku	1985	38	812	21
	1986	32	750	23
	1987	50	1312	26
	1988	48	969	20
	1989	36	784	22
	1990	27	593	22
	1991	37	813	22
	1992	63	1375	22
	1993	23	516	22
	1994	24	629	26
	1995	11	238	22
	1996	33	842	26
	1997	33	648	20
	1998	33	791	24
	1999	46	984	21
	2000	15	200	13
	2001	7	105	15
Average, all 17 yrs:		33	727	22
Average, since 1992:		29	633	21

Commercial and Sport Fisheries

Commercial fisheries were established in Chatham Straits by 1889, with the building of canneries at Pavlof Harbor and Redfish Bay. After relocating from Pavlof Harbor in 1890, the Pillar Bay cannery was destroyed by fire just two years later, leaving the Redfish Bay cannery as the sole buyer in the Chatham district until about 1900 (Rich and Ball 1933). Red (sockeye) salmon was the main species targeted in the early years. A primitive hatchery operation was started in the Kutlaku Lake outlet stream in 1892. About one million sockeye eggs were fertilized and incubated, but were washed out after hatching by an extreme high tide. The hatchery was not rebuilt. Both the hatchery and the commercial fishing operations used picket and net barriers across the outlet stream (Roppel 1982). After 1900, several salteries were opened in the Chatham district including one in the Bay of Pillars, and subsequently, more canneries were built. During this period, other species of salmon began to equal or exceed sockeye salmon in commercial importance. At the peak of the early commercial period, there were 13 canneries operating in the Chatham district, and at least as many more in other districts were taking salmon from Chatham. During this period of expansion, the bays and terminal areas were fished largely by Native fishermen with hand seines, while fish traps owned by the canneries were used in the open waters of Chatham Strait (Rich and Ball 1933).

Commercial harvest records show that most of the Chatham sockeye runs were small and irregular; however, the streams along the east side of the Strait, especially along Kuiu Island, were apparently more productive than those along Chichagof and Baranof Islands on the west side. A fairly regular harvest of 10,000 or more sockeye salmon was taken annually from the Bay of Pillars during most of the 35-year period between 1890 and 1924 (Table 3; Rich and Ball 1933). The records do not specify whether the catches came from around Kutlaku Creek in the south arm of Bay of Pillars, or from Pillar Bay Stream in the north arm; however, most of the commercial activity seems to have been in the south arm. Records from Gut Bay show an irregular pattern of harvest, with peak landings of 10,000 to 20,000 sockeye salmon in a few years, and no more than a few thousand in most years. Again, this harvest may have included sockeye salmon bound for other streams. The Falls Lake sockeye run was one of the smaller runs along Chatham Strait; commercial exploitation started later and was less intense than in other nearby areas. Progress in fisheries legislation in 1924 made it possible to implement conservation closures in the most severely over-fished bays in Chatham starting in 1925, including the south arm (Kutlaku drainage) of Bay of Pillars, Gut Bay, Falls Creek, and Red Bluff Bay (Rich and Ball 1933).

Table 3. Historic records of commercial sockeye salmon harvest from Bay of Pillars, Gut Bay, and Falls Lake (Rich and Ball 1933).

	Total Sockeye Harvest		
Year	**Bay of Pillars**	**Gut Bay**	**Falls Lake**
1892	9,842	1,673	-
1893	2,605	2,766	-
1894	8,740	630	-
1895	14,572	6,716	-
1896	15,834	2,326	-
1897	11,709	-	-
1898	10,000	-	-
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1904	14,500	20,000	-
1905	15,000	7,000	-
1906	30,000	2,500	-
1907	12,000	-	-
1908	17,000	1,302	-
1909	3,700	2,703	-
1910	19,400	4,905	-
1911	12,000	4,371	-
1912	7,037	100	-
1913	2,278	1,723	1,279
1914	15,045	1,777	2,479
1915	12,089	3,234	3,586
1916	13,267	12,009	-
1917	8,790	1,057	-
1918	8,854	1,500	-
1919	4,160	22,572	9,615
1920	3,645	10,402	3,717
1921	4,070	7,120	1,810
1922	6,331	4,514	3,214
1923	12,000	215	-
1924	11,023	10,551	-
1925	70	-	-
1926	13	-	-
1927	20	-	-

Although there are no longer directed commercial fisheries in the bays and streams along Chatham Strait, the present-day purse seine fleet is now the largest harvester of sockeye salmon in Chatham Strait. Commercial fishery data from recent years show a dramatic increase in the total sockeye harvest in districts on both sides of southern Chatham Strait, including subdistricts adjacent to the Bay of Pillars, Falls Lake, and Gut Bay (Figure 2). The great increase is attributed to increased fishing opportunities and greater overall catches that have resulted from high hatchery chum production (Larson 2001). Subdistricts contributing the most to the total harvest,

in all years since 1960, were 109-51 (east side, Kingsmill Point to Washington Bay) at 42% of the total, 109-20 (west side, Baranof Warm Springs to Patterson Point, including the areas adjacent to Falls Lake and Gut Bay) at 22%, and 109-61 (east side, from Pt. Ellis to Coronation Is.) at 18%. Since 1989, the combined relative contributions of the main east Chatham districts, 109-51 and 109-61, have increased to nearly 70% of the total catch, while the relative contribution of subdistrict 109-20 has decreased slightly to less than 20% of the total. The highest annual harvests from subdistrict 109-20 were in 1979, 1993, and 1994; between 10,500 and 11,000 sockeye salmon were landed in each of those years (ADF&G Alexander database, 2003). These landings include sockeye salmon from different origins, and it is impossible to estimate the contribution of any specific system. In particular, many sockeye salmon in the largest contributing subdistrict (109-51) are not local runs but are passing through on their way into Frederick Sound (Rich and Ball 1933).

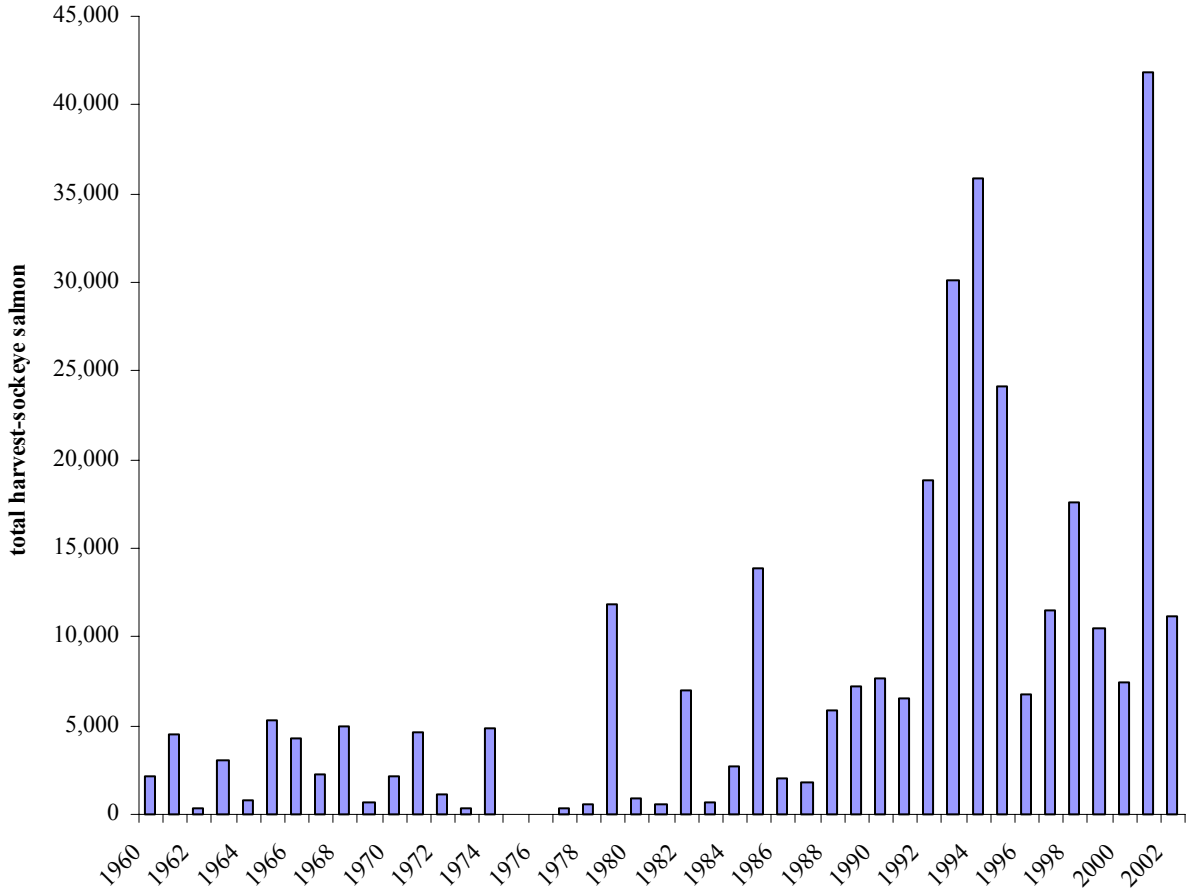

Figure 2. Commercial purse seine landings of sockeye salmon in the combined lower Chatham Strait subdistricts (109-10, -11, -13, -20, -51, -52, -61, -62, and -63) from 1960-2002. The largest contributions from sub-district 109-20, adjacent to Falls Lake and Gut Bay, were in 1979, 1993, and 1994, with about 10,500 sockeye salmon harvested in each of those years. (ADF&G Division of Commercial Fisheries database 2003).

Very limited data are available on sockeye harvest in the sport and charter fisheries. Prior to the on-site harvest monitoring in the current study at Falls Lake, effort and harvest were estimated mainly from voluntary responses to ADF&G Sport Fish mail surveys. For the entire Chatham Strait area, estimates were generated from an average of 24 responses each year from 1990-1999. The target salmon species were chinook and coho; sockeye salmon catches were only reported for four years during this time period (Table 4). Some sport fishing also occurs in the freshwater and estuarine areas at Falls, Gut Bay, and Kutlaku Lakes. Between 1987 and 2001, there were averages of 28 anglers and 57 fishing days annually at Falls Lake. In 1989, the only year with any reported sockeye catch at Falls Lake; the estimated catch was 89 fish. There are no records in the ADF&G statewide harvest survey database from Gut Bay or Gut Bay Lake. There was somewhat more sport fishing activity at the Kutlaku Lake outlet and the Bay of Pillars, where an average of 46 anglers spent an average of 115 days fishing each year. Catches of 67, 225, and 21 sockeye salmon were estimated in 1990, 1993, and 2000, respectively. Out of these fish, only 9 were reported caught in freshwater, with the remainder from saltwater areas in the Bay of Pillars. The estimates for these specific systems are based on fewer than 12 responses each, so the Division of Sport Fish advises that they should only be used to document that fishing occurred (ADF&G Div. of Sport Fish database).

Table 4. Sport fishing effort and catch in Chatham Strait estimated from statewide harvest survey responses, saltwater fishing by boat, 1990-1999 (ADF&G Division of Sport Fish database 2003).

			Total Catch by Species		
Year	**Number of anglers**	**No. Days fished**	**Chinook**	**Coho**	**Sockeye**
1990	392	2532	361	723	0
1992	410	1086	359	154	0
1993	473	1549	447	617	35
1994	1099	2137	327	1748	0
1995	505	1451	227	113	0
1996	477	970	226	841	84
1997	570	1583	280	1478	11
1998	512	1486	200	864	198
1999	481	1099	396	832	0
Average	547	1544	314	819	36

Ecological and Salmon Escapement Information

Falls Lake was considered for enhancement by ADF&G in the late 1970's (Koenings et al. 1983), and the lake was fertilized from 1983-1985. Data on sockeye fry and smolt populations, lake zooplankton populations, and lake water physical and chemical characteristics were collected during the pre-fertilization and fertilization studies. A fishpass was constructed in 1986

by the U.S. Forest Service to aid salmon migration. Escapements of sockeye and coho adults were monitored at a weir on the lake outlet stream from 1981-89 (Conitz et al. 2002).

The only data available for Gut Bay Lake prior to the current project are from occasional aerial surveys conducted by ADF&G fishery managers. The counts since 1980 are very low, as were the boat survey counts conducted for the current project in 2001 (Conitz and Cartwright 2002).

No escapement estimates for Kutlaku Lake were attempted prior to this project; some visual counts by aerial and foot surveys were conducted by ADF&G since 1960, and by U.S. Fish & Wildlife Service in a few years prior to 1960 (Appendix A.1). The range of the peak escapement counts from 1955-1999 was 70 to 5,000 sockeye salmon, with an average count of 1,434. Visual survey data is subject to unpredictable variation in fish visibility, run timing, water levels, and observer bias, and so does not generally provide a reliable index of escapement (Jones et al. 1998; Jones and McPherson 1997). Adult sockeye age and length compositions in Kutlaku Lake escapements have been consistently estimated in most years since 1982 on samples ranging from about 130 to 550 fish each year by ADF&G (Appendix A.2a-b). Age-1.3 was the dominant age class, on average, from 1982-2001, but age-1.2 was the dominant age class in six of those years. A high proportion of jacks (age-1.1) were observed in several years, most notably in 1990 when they comprised 74% of the sample. The average length of Kutlaku sockeye salmon across all age classes and years, but excluding jacks, was 509 mm.

With the exception of a single water chemistry analysis in 1979, limnological data has not been collected at Kutlaku Lake. However, zooplankton samples and some physical data were collected in 2001. The lake had a euphotic zone depth of 9.2 m. in June and 5.6 m in October. In early October the temperature was nearly uniform in the water column at about 9°C, while the relative dissolved oxygen content decreased gradually with depth from 97% near surface to about 85% at 20 m (Appendix A.3). Small, (average length 0.3 mm) *Bosmina* sp. dominated the zooplankton community numerically, but *Holopedium* sp. (average length 0.6 mm) contributed the largest proportion of the biomass. There were smaller numbers of the larger cladoceran *Daphnia* (average length 0.7 mm), a preferred prey species for sockeye fry (Appendix A.4, A.6). Since the lake was only sampled on two dates during 2001, it is not possible to observe seasonal trend; however, the density of *Cyclops* sp., *Bosmina* sp., and *Daphnia longiremis* increased by five-fold or greater between mid-June and early Oct. In contrast, *Holopedium* sp. decreased from very high numbers in June to near zero in early October (Appendix A.5). Within taxa, there was little body size difference, on average, between sampling dates (Appendix A.6). Hydroacoustic and mid-water trawl sampling were also conducted in 2001, with a resulting population estimate of 102,000 sockeye fry (Appendix A.6).

Lake ecology data including light intensity, temperature and dissolved oxygen profiles, juvenile population, age and size distribution estimates, and adult sockeye escapement and harvest estimates were compiled under the current project in 2001 for Falls Lake (Conitz et al. 2002). Lake ecology data, juvenile sockeye salmon estimates, and boat survey counts of sockeye spawners were also compiled for Gut Bay Lake in 2001 (Conitz and Cartwright 2001).

Issues and Concerns

All three systems have federal and state Customary and Traditional (C&T) use designation. The Organized Village of Kake and the City of Kake submitted regulatory Proposal FP01-31 to the Regional Advisory Council in 2000, which requested that the Kutlaku Lake/Pillar Bay drainage, along with the Gut Bay and Falls Lake drainages, be closed to non-federally qualified subsistence users. The Federal Subsistence Board adopted this proposal into regulation, which states: "Only Federally qualified subsistence users may harvest sockeye salmon in streams draining into Falls Lake, Gut Bay, or Pillar Bay." (Federal Register 2001)

The Alaska Department of Fish and Game sought to rescind this regulation for Kutlaku/Pillar Bay, based on insufficient evidence of a conservation concern there (Larson 2001). However, the Federal Subsistence Board let the regulation stand (R. Larson USFS, personal communication 2002).

The Organized Village of Kake has informed the Southeast Alaska Regional Advisory Council that sport fishing at Bay of Pillars, as well as at Gut Bay and Falls Creek, is negatively affecting subsistence users in Kake. Kake residents report that increasing numbers of sport fishing vessels are present in these locations, anchoring in the most productive fishing locations and interfering with normal subsistence activities. There is consensus among Kake residents that there is over-harvest of the stocks in these systems, considering the sum total of all fishing activity (Larson 2001). While there appears to be no immediate conservation concern for the Bay of Pillars/Kutlaku sockeye run, OVK members anticipate that subsistence use will increase there if harvest opportunities are restricted at Falls Lake and Gut Bay due to conservation concerns there (R. Larson USFS, personal communication 2002).

This report covers the second year of a three-year project. Data collection in 2002 again included an assessment of each lake's physical characteristics, and zooplankton species composition, density, and biomass. Fry density, size, and age were estimated to provide indicators of sockeye salmon response to conditions within each lake. Smolt size and age were estimated at Falls Lake. Adult escapements were estimated using mark-recapture methods and visual surveys, and a weir at Falls Lake, with additional estimates of age, sex, and length composition. Subsistence and sport fishing harvest of sockeye salmon was estimated in the Falls Lake terminal area by direct observation and interviews of fishers.

These results support the long-term objective of setting escapement goals that incorporate lake productivity modeling. If extended over a 5-10 year time period, this type of data collection effort will provide fisheries managers with the quantitative information they need to set escapement goals and ensure that these important salmon resources continue to provide sustainable fishing opportunities into the future. Given the possible conservation concerns expressed by residents of Kake and ADF&G fishery managers, the early subsistence and sport closures at Falls Lake in 2002 and management actions in the commercial purse seine fishery following those closures, and the actions taken by the federal Regional Advisory Council and Subsistence Board, it is critical to continue to accurately document sockeye escapements and related information in these systems.

OBJECTIVES

1. Estimate the escapement of sockeye salmon into Falls Lake at the weir and on the spawning grounds so that the estimated coefficient of variation is less than 10% for the weir estimate and less than 15% for the spawning grounds estimate.
2. Estimate the annual sockeye escapement into Kutlaku Lake, using mark-recapture methods and observer counts on the spawning grounds, so that the estimated coefficient of variation is less than 15%. Obtain observer counts of sockeye salmon throughout the spawning season in Gut Bay Lake.
3. Estimate the subsistence harvest of sockeye salmon from Falls Lake Creek so that the estimated coefficient of variation is less than 15%.
4. Estimate the age, length, and sex composition of the sockeye salmon in the escapement at Falls and Kutlaku Lakes, so that the estimated coefficient of variation is less than 5%.
5. At Falls Lake, compare the spawning grounds survey/mark-recapture estimates and the total estimated escapement of sockeye salmon from the weir and weir mark-recapture study.
6. Estimate the productivity of each lake using established ADF&G limnological sampling procedures.
7. Estimate the sockeye fry rearing density within each lake so that the estimated coefficient of variation is less than 10%.
8. Estimate the age, sex, and size composition of outmigrant sockeye smolt at Falls Lake so that the estimated coefficient of variation is less than 10%.

A 95% confidence interval will be reported for these population estimates, where appropriate.

METHODS

Study Sites

Falls Lake

Falls Lake (N 56°49.5', W 134°42.2') is located on the east side of Baranof Island just south of Red Bluff Bay, within the central Baranof metasediments subsection (Nowacki et al. 2001). It lies in a steep mountain cirque basin at an elevation of about 20 m, and drains a watershed area of about 16.5 km^2. The continental ice sheets of the Pleistocene Ice Age never overrode the upper elevations of the steep angular mountains in this area, but abundant precipitation caused the formation of smaller alpine glaciers, which have carved the landscape and persist today. Frequent landslides, debris torrents, and avalanches sweep down off the steep slopes and have deposited colluvial and alluvial fans around the bases of the mountains (Nowacki et al. 2001). Falls Lake's two main inlet streams, originating in hanging glaciers and steep mountain falls, have formed large alluvial fans at their lower ends, supporting productive old-growth spruce forest and willow and alder thickets. Salmon spawn in the lower reaches of the southwestern inlet, and at the mouth of the adjacent stream entering the west-southwest corner of the lake. Both streams have partial or complete migration barriers a short distance upstream from the lake.

The southwest inlet stream is frequently cloudy with glacial silt, while the west-southwest inlet stream is usually clear. The lake is organically stained. It has a surface area of about 95 ha, an average depth of 32 m, and a maximum depth of 75 m (Figure 3). There is one large main basin in the center of the lake, separated by a shallow sill from a much smaller basin near the outlet. A very short outlet stream plunges over two falls directly into Chatham Strait. Sockeye (*Oncorhychus nerka*) and coho (*O. kisutch*) salmon ascend the falls and spawn in the lake or inlet streams. Pink salmon (*O. gorbuscha*) spawn in lower section of the outlet stream, but most eggs are probably washed out due to lack of suitable gravel and high discharges; a very small number of pink salmon ascend the falls. The lake supports resident and anadromous populations of Dolly Varden char (*Salvelinus malma*), as well as sticklebacks (*Gasterosteus aculeatus*) and a few sculpins (*Cottus cognatus*).

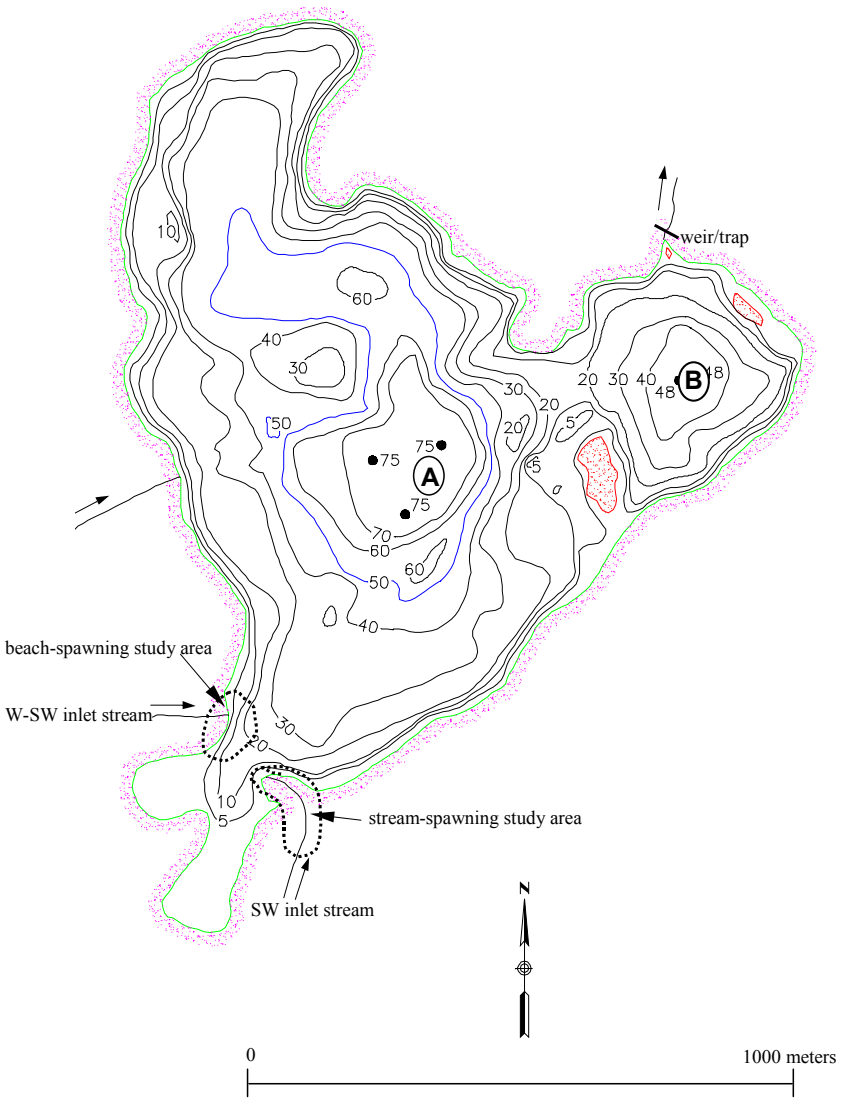

Figure 3. Bathymetric map of Falls Lake, showing 10 m depth contours, location of weir and trap at top of fishpass on the lake outlet, mark-recapture study areas, and two permanent limnology-sampling stations (A and B).

Gut Bay Lake

Gut Bay is a fiord on the east side of Baranof Island; its entrance on Chatham Strait is about 12 km south of Falls Lake and its head is about 9 km to the southwest of the entrance. Gut Bay Lake (N 56°42.97', W 134°42.15') and its 2 km outlet stream lie in a steep valley to the southwest of the bay, which forms a pass through to the Great Arm of Whale Bay on the west side of Baranof Island. The lake drains a watershed area of about 17 km^2 and is at 18 m in elevation. Sharing the same steep, angular mountain topography as Falls Lake, outer Gut Bay is also in the central Baranof metasediments ecological subsection, while the head of the bay and the lake extend into the Necker Bay granitics subsection (Nowacki et al. 2001). The head of the fiord and the lake are surrounded by extremely steep, bare rock walls, broken by waterfall and stream channels with brushy willow and alder thickets growing from the alluvial fans at their bases. The main inlet stream to the lake flows through a steep alluvial fan of light-colored cobbles, and sockeye salmon spawn in the lake around its base. The lake has a surface area of 36 hectares, a mean depth of about 16 m, and a maximum depth of about 25 m (Figure 4). In addition to sockeye salmon, the lake and outlet stream also support minor runs of pink, coho, and chum salmon (*O. keta*).

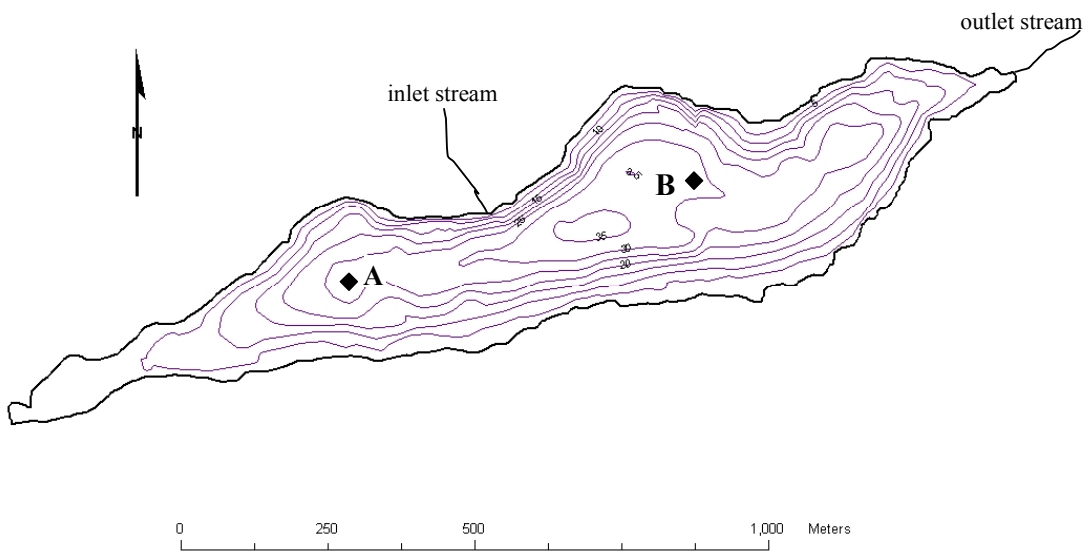

Figure 4. Bathymetric map of Gut Bay Lake, showing 5 m depth contours and two permanent limnology sampling stations (A and B).

Kutlaku Lake

Kutlaku Lake (N 56°37.00', W 134°7.54') is located on the west side of Kuiu Island, about 45 km from Kake, and drains into the southeast arm at the head of Bay of Pillars. Kutlaku Lake and the Bay of Pillars are within the Rowan sediments subsection. The rounded mountains in this area are a result of heavy erosion and scouring by the continental ice sheets. In some areas, deep

residual silty or loamy soils have built up, supporting highly productive hemlock-spruce forests, while in other areas, bogs and muskegs have formed over glacial till with poorly drained organic soils (Nowacki et al. 2001). Kutlaku Lake is situated at an elevation of about 25 m, with a 0.7 km outlet stream exiting the northeast corner of the lake; it lies in a steep-sided, heavily forested valley, with intermittent patches of windfall, muskeg, and beaver-dammed streams (Figure 5). The main inlet stream on the south side of the lake has been dammed repeatedly by beavers, forming a large delta area. The lake surface area is about 78 hectares, and the maximum depth is about 22 m. Sockeye, coho, pink, and chum salmon all spawn in the lake and inlet streams. There are also large numbers of anadromous or resident Dolly Varden char and cutthroat trout (*O. clarki*). Rough-skinned newts (*Taricha granulosa*) are common in the shallow water around the lake outlet.

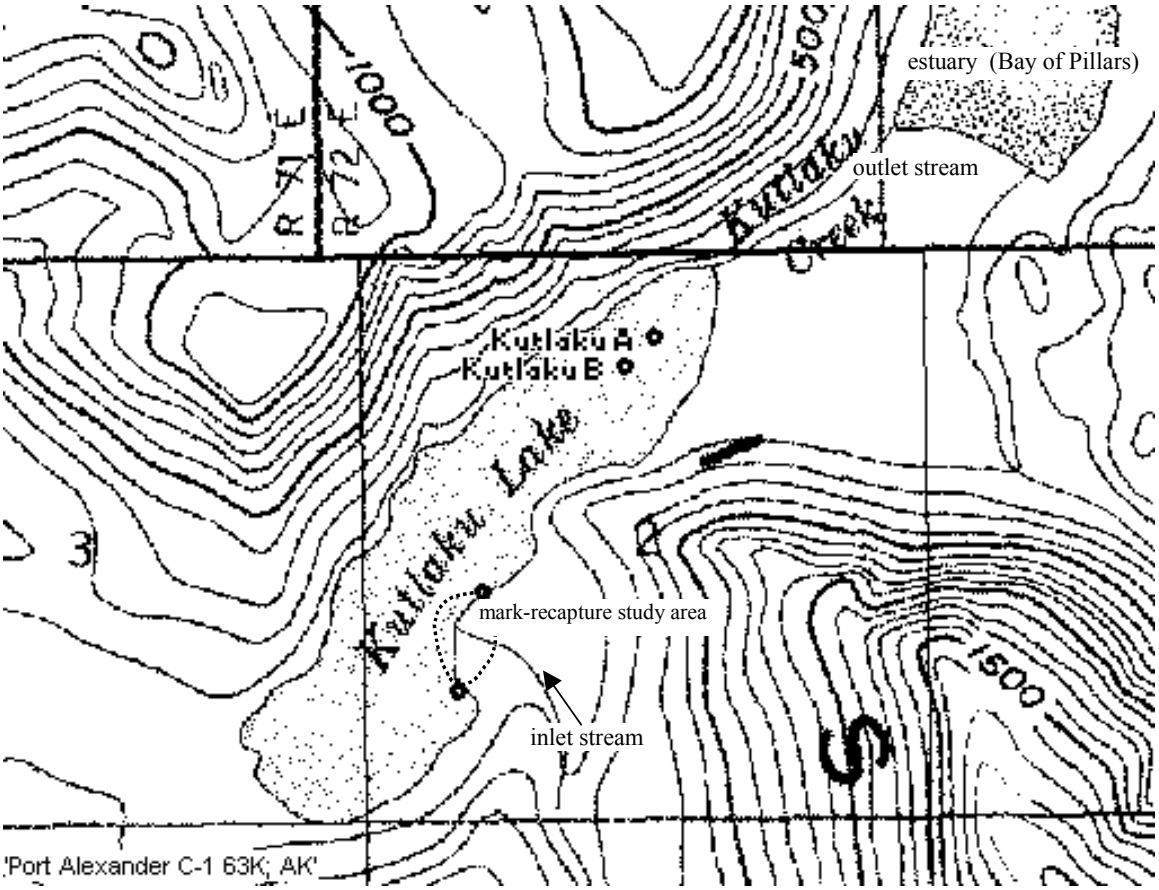

Figure 5. Topographic map of Kutlaku Lake, showing two permanent limnology sampling stations (Kutlaku A, B) and mark-recapture study area.

Juvenile Sockeye Population Assessment

Smolt Estimates

Sockeye and coho smolt were sampled during their migration out of Falls Lake in May and June. A small fyke net was placed in the riffle area between the upper and lower falls, on the north bank of the stream. The cod-end of the net was attached to a live box for holding fish for sampling. Smolts caught in the trap were anaesthetized with a clove oil solution (Anderson et al. 1997), and were weighed to the nearest 0.1 g, measured to the nearest mm, and scale sampled. Smolts were aged by analyzing the scale patterns in the laboratory. The target sample size was 600, enough to distinguish proportions in two or three age classes to a precision of 95% (Thompson 1992, p. 39). The fyke net was fished from approximately 8:00 pm to midnight each evening, with a daily target sample of 20-40 smolts. Sampling occurred nightly from May 14 through June 18.

Fry Estimates

Hydroacoustic and mid-water trawl sampling were used to estimate the distribution and abundance of sockeye salmon fry in Falls, Gut Bay, and Kutlaku Lakes. Prior to conducting the 2002 lake survey, each lake was divided into sections based on lake area and shape. Falls Lake had five sections, Gut Bay had six sections, and Kutlaku Lake had four sections. Ten evenly spaced orthogonal transects were identified within each section and two of these were randomly selected to be surveyed. Transects selected in 2002 became permanent and will be repeated during future surveys. The decision to keep the transects fixed each year reflects a decision to emphasize year-to-year changes in population size in our estimates.

Hydroacoustic Survey

During the acquisition of acoustic targets, we surveyed each selected transect from shore to shore, beginning and ending the sampling at the depth of 10 m. Sampling was conducted during the darkest part of the night. A constant boat speed of about 2.0 m · sec^{-1} was attempted for all transects. The acoustic equipment consisted of a Biosonics[2] DT-4000™ scientific echosounder (420 kHz, 6° single beam transducer). Biosonics Visual Acquisition© version 4.0.2 software was used to collect and record the data. Ping rate was set at 5 pings · sec^{-1} and pulse width at 0.4 ms. Only target strengths ranging from –40 dB to –68 dB were recorded because this range represented fish within the size range of juvenile sockeye salmon and other small pelagic fish.

Trawl Sampling

Midwater trawl sampling was conducted in conjunction with the hydroacoustic surveys to determine the species composition of pelagic fish and the age distribution of sockeye fry. A 2 m x 2 m elongated beam-trawl net with a cod-end was used for the trawl sampling. Trawl sampling was conducted in the area of the lake with the highest concentration of fish, identified during the hydroacoustic survey. An exploratory surface tow was conducted to determine if there were fish on the surface not detected by the down-looking hydroacoustic gear. A surface tow was conducted on clear and stained lakes and will not be repeated in future surveys if no fish were

caught. The surface tow was conducted by attaching floats to the top of the tow net so that it floated just beneath the lake surface 30 m back from the boat. Additional tows were conducted at two depths also identified during the hydroacoustic survey in the same area of highest fish concentration. Two replicate tows were conducted at each depth. The second tow at a given depth was started at the termination point of the first tow. The direction of the second tow for each depth was selected such that it did not sample the same area as the first tow. The trawl duration ranged from 15 to 30 minutes, depending on fish density and lake size and morphology. If warranted, a second complete set of tows was conducted in a morphologically distinct section of the lake or in a second area of high fish densities.

All adult fish caught in the midwater trawl were identified, counted, and released. All small fish from the trawl net were euthanized with MS 222. Fish were preserved with 90% alcohol. Samples from each tow were preserved in separate bottles. The bottle was labeled with the date, lake name, tow number, tow depth, time of tow, and initials of collectors. Fish captured in the tow samples were analyzed at the laboratory to determine species composition and ages of sockeye juveniles. The species composition of the midwater trawl samples was pooled and applied to the total target estimate to calculate each species-specific population estimate. The sockeye fry density and age composition was also calculated using the sockeye fry trawl sample data.

In the laboratory, fish were soaked in water for 60 minutes before sampling to re-hydrate the samples. All fish were identified and the snout-fork length (to the nearest millimeter) and weight (to the nearest 0.1 gram) were measured on each fish. All sockeye salmon fry under 50 mm were assumed to be age-0. Scales were collected from sockeye fry over 50 mm and mounted onto a microscope slide for age determination. Sockeye fry scales were examined through a Carton microscope with a video monitor and aged using methods outlined in Mosher (1968). Two trained technicians independently aged each sample. The results of each independent scale ageing were compared. In instances of discrepancy between the two age determinations, a third independent examination was conducted. A proportion of each age class of sockeye fry is used to allocate the hydroacoustic sockeye fry estimates by age. Data was recorded onto a form and then entered into an MS Excel spreadsheet.

Data Analysis

Data were analyzed using Biosonics Visual Analyzer© version 4.0.2 software. Echo integration was used to generate a fish density (targets $\cdot$ m^{-2}) for each of the sample sections (MacLennand and Simmonds 1992). The target density for each section was estimated as the mean of these two replicate target densities, with their sample variance. The mean target density for the whole lake was estimated as the average of target density estimates for each section weighted by surface area of each section. A target population for each sample section was estimated as the product of mean target density and surface area for each section. The total target population for the lake was estimated as the sum of target population estimates for each section. Because each section was sampled independently from other sections, the estimated sampling variance for the whole lake target population estimate was simply the sum of the variances for each section, and was reported as a coefficient of variation (CV; Sokal and Rohlf 1987). If the CV for an estimate was

greater than 10% for any of the lakes, more sample sections will be added in that lake in future years.

The apportionment of targets into species composition categories allowed us to get a rough estimate of sockeye fry abundance in those lakes where we had adequate trawl data. An obvious way to estimate the sockeye fry abundance in the entire lake is to simply pool all fish caught in all trawl samples (except the surface tow) into one sample, calculate the proportion of sockeye fry in the pooled sample, and then use this proportion to adjust the estimate of total sonar targets in the lake to an estimate of total sockeye fry. Although this approach should give a reasonable and very usable estimate of the number of sockeye juveniles present in the lake, unfortunately, this approach leaves us without a means to estimate the sampling error in the estimate.

We first assumed that sockeye fry are completely randomly distributed within the lake, and therefore within the multiple trawl samples. If so, we reasoned that the estimate of sampling error could be based on an approximation to the binomial distribution, which is well studied, and formulas for confidence intervals or standard errors can be found in any elementary statistical textbook. We began by developing rules for sample size requirements and using chi-squared tests for heterogeneity to test for similarity among trawl samples. We reasoned that if we had greater than 30 fish targets per trawl sample, if the assumptions of the chi-squared test we met (greater than 5 expected counts per cell and a fairly uniform distribution), that small observed chi-squared statistics would mean that the binomial approximation would be a usable assumption. However, we found that we had inadequate sample sizes to compare trawls at the same depth with these chi-squared tests. When we pooled the samples into one or more depth categories, in general we got small chi-squared statistics with small sample sizes and lager chi-squared statistics with larger sample sizes. In the end, we concluded that a simple, defendable estimate of the variance associated with the estimate of the proportion of sockeye fry is not possible because of the non-uniform distribution of sockeye fry in the lake, the clustering of sockeye fry within the samples and the small sample sizes. If we assume that the distribution is clumped, a negative binomial distribution to account for the clusters could be used if we had adequate trawl samples at each depth.

Adult Escapement Estimates

Weir/Trap

Migrating fish ascending the Falls Lake fishpass were channeled into a 1.25 m x 1.25 m x 2.5 m box frame trap (Conitz et al. 2002). A weir across the remaining portion of the Falls Lake outlet, just upstream of the upper falls, diverted fish not using the fishpass into a second trap. All fish that entered the trap were counted by species and passed upstream. About 50% of the sockeye salmon were marked with finclips for a mark-recapture study to verify the weir count. Sockeye and coho salmon were sampled at the weir for sex, length, and scales, with a sampling goal of 600 sockeye salmon distributed through the run, sampled systematically on a daily basis (e.g. sample every fifth fish).

The weir/trap system was operated continuously between from June 21 through August 30. Historically, most or all spawning sockeye salmon have entered Falls Lake during this time period. A full count of coho escapement was not possible since their run continued into the fall after the weir was removed.

We used a stratified, two-sample mark-recapture study design to estimate sockeye salmon escapement into Falls Lake, and a comparison was made between the estimate and the count to test the integrity of the weir/trap system. Sockeye salmon passed through the trap were marked with fin clips, with marking stratified by time (Arnason et al. 1995). The target daily marking rate at the weir was 50% of all sockeye salmon, with systematic selection (e.g. every other fish is marked); the daily rate varied somewhat and the cumulative marking rate was 51%. Two, rather than three marking strata were designated, since the run was small. The primary mark was an adipose clip, to indicate that the fish was marked and should be checked for a secondary mark The secondary marks indicated the strata as follows: stratum 1 – left axillary, June 21 through August 6, and stratum 2 – left ventral, August 7-30.

Recapture events were conducted on the spawning grounds during the spawning period at approximately bi-weekly intervals. Fish were captured and examined for marks in all spawning areas, and marked with a secondary mark to prevent duplicate sampling. Darroch, maximum-likelihood, Schaefer population, and "pooled Petersen" estimates were calculated with the Stratified Population Analysis System (SPAS) software (Arnason et al. 1995). The pooled Petersen estimate was used because it had the lowest variance and was free of calculation errors. A 95% confidence interval for the pooled Petersen estimate was constructed by pooling the data from all marking and all recapture strata and treating the pooled data as for a single estimate.

Let K denote the number of fish marked in a random sample of a population of size N. Let C denote the number of fish examined for marks at a later time, and let R denote the number of fish in the second sample with a mark. Then the estimated number of fish in the entire population, $\hat{N}$, is given by

$$\hat{N} = \frac{(K+1)(C+1)}{(R+1)} - 1. \qquad (1)$$

In this equation, R is a random variable, and it can be assumed to follow a Poisson, binomial, or hypergeometric distribution, depending on the circumstances of the sampling. Moreover, when R is large compared with the size of the second sample, C, its distribution can be assumed to be approximately normal (a practical check is to ensure R is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of the proportion of marked fish in the population such that $\hat{p} = \frac{R}{C}$. We used approximate confidence interval bounds for $\hat{p}$ based on the assumption that R follows a hypergeometric distribution. We defined the confidence bounds for $\hat{p}$ as ($a_{0.025}$, $a_{0.975}$). Then the 95% confidence interval bounds for the Petersen population estimate, N^*, were

found by taking reciprocals of the confidence interval bounds for $\hat{p}$, and multiplying by K. That is, the confidence bounds for the Petersen estimate are given by ($K * 1/a_{0.975}$, $K * 1/a_{0.025}$).

Sample size criteria are given in Seber (1982, p. 63). If $\hat{p} \geq 0.1$, and the size of the second sample C is at least the minimum given in Table 5, a 95% confidence interval for $\hat{p}$ is given by

$$\hat{p} \pm \left[1.96\sqrt{\left(1 - \frac{C}{\hat{N}}\right) * \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C} \right], \text{ (Seber 1982, eq. 3.4).} \qquad (2)$$

Table 5. Sample size criteria for using Seber's (1982) eq. 3.4 to find 95% confidence interval for $\hat{p}$. For given $\hat{p}$, minimum sizes for the second sample C are indicated.

$\hat{p}$ (or 1- $\hat{p}$)	0.5	0.4	0.3	0.2	0.1
minimum C	30	50	80	200	600

Seber's (1982) eq. 3.4 was also used when $\hat{p} < 0.1$ if $R > 50$. If these criteria were not met, the confidence interval bounds for $\hat{p}$ were found from Table 41 in Pearson and Hartley (1966).

Adult Population Age and Size Distribution

Scales, matched with sex and length data, were collected from adult sockeye salmon at the Falls Lake weir and on the spawning grounds in Kutlaku Lake to describe the age and size structure of each population. The sampling goal for each lake was 600 fish. At the Falls Lake weir, fish were selected systematically (e.g. every fifth fish) to prevent selection bias, through the entire run; at Kutlaku Lake, all unmarked sockeye salmon were sampled on the first day of each sampling trip, until the trip goal of 200 samples was reached. Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age and length data were paired for each fish sample. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g. 1.3 denotes 1-year freshwater and 3-years saltwater) (Koo 1962). Brood year tables were compiled by sex and brood year to describe the age structure of the returning adult sockeye salmon population. The length of each fish was measured from mid-eye to tail fork to the nearest millimeter (mm).

After the scales were aged, the scale samples were stratified by age and by sex. Let n be the total number of samples aged, n_k be the number of samples in stratum k, and N be the estimated escapement. The proportion of each stratum k was calculated by

$$\hat{p}_k = \frac{n_k}{n} . \tag{3}$$

The estimated standard error was derived from the binomial formula with correction for finite population size (Thompson 1992, p. 35-36):

$$SE(\hat{p}_k) = \sqrt{\left(1 - \frac{n}{N}\right)\frac{\hat{p}_k(1-\hat{p}_k)}{n-1}} \tag{4}$$

The estimated mean length and associated standard error for stratum k were calculated as the sample mean of a simple random sample (Thompson 1992, p. 42-43):

$$\bar{y}_k = \frac{1}{n_k}\sum_{i=1}^{n_k} y_{ki} \text{ , and } SE(\bar{y}_k) = \sqrt{\frac{1}{n_k}}\sqrt{\left(\frac{1}{n_k - 1}\right)\sum_{i=1}^{n_k}(y_{ki} - \bar{y}_i)^2} . \tag{5}$$

Spawning Grounds Mark-Recapture and Visual Survey

Mark-recapture studies on the spawning grounds were used to provide independent estimates of a portion of sockeye escapement at Falls and Kutlaku Lakes. At Falls Lake, the spawning grounds estimate was compared with the weir-based estimate; at Kutlaku Lake it provided the only estimate of escapement.

We have observed distinct patterns of beach spawning and inlet stream spawning in Falls Lake sockeye salmon; we assumed that there was no exchange between these two spawning populations. Therefore, separate series of four mark-recapture events were conducted in the beach spawning and inlet stream spawning areas, accompanied by visual surveys of the lakeshore and inlet streams. At Kutlaku Lake, the main spawning area is the inlet stream that enters the southeast side of the lake. There are several other areas where sockeye salmon spawn along the shoreline of the lake. In 2002, mark-recapture events were conducted only in the inlet stream. Surveys were conducted in the inlet stream and around the lakeshore. At Gut Bay Lake, dispersed and deep water spawning made capture of adequate samples of sockeye salmon very difficult, so only visual surveys were conducted, around the lakeshore.

ADF&G biologists have modified the methods described in Schwarz et al. (1993) for estimating salmon escapements in beach spawning systems (Cook 1998). Specifically, we used a two-sample Petersen estimate for each trip and a multiple-trip estimate using a modified Jolly-Seber method to estimate the number of spawners returning across all trips (Seber 1982; Schwarz et al. 1993; Cook 1998; J. Blick former ADF&G, personal communication 1998).

Visual Survey Counts of Sockeye Spawners

Prior to each mark-recapture event, visual counts of sockeye spawners were made by each crewmember in defined strata around the entire lakeshore and in any inlet stream where spawners were present. A separate count was made within the "study area" or areas designated for the mark-recapture study. Any inlet stream with sockeye spawners present was defined as a separate stratum, and as a "study area" if mark-recapture sampling was conducted in the stream. We attempted to have at least three observers for each survey. Each crewmember recorded their individual counts separately. The counts gave a rough indication of the proportion of sockeye spawners within the defined study area at each sampling event.

Beach Spawning Populations

In Falls Lake, the mark-recapture study area selected in 2001 was the beach area off the mouth of the inlet stream entering the west-southwest corner of the lake (Figure 3). In 2002, the stream had changed course at its lower end and the main flow entered the lake at a different point on the delta, so some of the beach seining was conducted in this new area. Seine sets were made along all parts of the stream delta where sockeye spawners were concentrated. The mark-recapture events or trips were timed about two weeks apart, beginning on August 20 and ending on September 30. Sampling on the second trip (September 3) was incomplete, so data from that trip were pooled with sampling data from the third trip (September 19).

In Kutlaku Lake, beach spawning was observed at the mouth of a small, secondary inlet stream that enters the northeast corner of the lake near its outlet, and also along the northwest side near the ADF&G campsite and at the southwest end of the lake (Figure 5). A beach spawning study area was not designated in 2002, the first year of study, due to time constraints and uncertainty about the sockeye spawning pattern there. However, a beach spawning mark-recapture study will be conducted in 2003 and subsequent years if adequate numbers of spawners are present. The preferred location is near the secondary inlet stream at the northeast end of the lake.

The study design for beach-spawning populations consisted of two stages: 1) a two-sample Petersen estimate for each trip (Seber 1982) and 2) a multiple-trip estimate using a modified form of the Jolly-Seber method for multiple mark-recaptures in an open population (Seber 1982; Schwarz et al. 1993; Cook 1998). In the first stage, fish were marked on one day and examined for marks the next day. In the second stage, fish caught on both days of a given trip were given a unique mark for that trip. Then on subsequent trips recaptures of these marks were recorded. In the second stage we used the number of recaptures from each previous trip, together with the first-stage Petersen estimates of abundance from each trip, to generate an estimate fish that spawned within the study area over the entire season.

A 20 m long x 4 m deep beach seine was used to surround sockeye salmon, pulled by a small skiff with outboard motor and crewmembers on foot. All sockeye salmon caught were first inspected for previous marks, then marked with an opercular punch or pattern of punches indicating the trip and day number, and released with a minimum of stress. The total sample size, the number of new fish marked, and the number of recaptured fish with each type of mark were recorded. Sampling in these small populations continued until the number of same-day

recaptures exceeded the number of new fish caught. Right opercular punches were the primary mark for each trip as follows: trip 1 – round, trip 2 – triangle, trip 3 – square, trip 4 – two round. A left opercular punch (any shape) was given each fish caught on the second day of each trip to indicate the fish had already been caught and should not be recounted on that trip.

Stream Spawning Population

At Falls Lake, stream-spawning sockeye salmon school around the gravel bar at the mouth of the inlet stream at the southwest corner of the lake, before going a short distance up the stream to spawn (Figure 3). All or nearly all spawning takes place below a small partial-barrier falls about 0.8 km upstream. At Kutlaku Lake, stream-spawning sockeye salmon school around the gravel bar at the mouth of the stream entering about midway along the southeast side (Figure 5). The delta area of this small stream has been substantially altered by the activity of beavers, and the channel depends also on water level, which can be very low during dry weather. Most spawning occurs within the lower 100 m of the stream.

A stratified, two-sample mark-recapture procedure was used to estimate escapement (Arnason et al. 1995). In both lakes, sockeye salmon were caught and marked as they schooled up around the mouth of the inlet prior to going upstream to spawn (first samples). As soon as sockeye salmon were observed spawning within the inlet stream, samples were taken in the stream (second samples) using a small barrier net and/or dipnets. All parts of the stream were sampled as evenly as possible.

The marking samples were stratified by time, using a distinct opercular punch shape to distinguish between strata as follows: stratum 1 – round, stratum 2 – triangle, stratum 3 – square, stratum 4 – 2 round. The primary mark was put in the left operculum at Falls Lake to distinguish fish from this stream area from those marked in the beach spawning area. In the recapture phase, fish caught upstream were examined for marks; carcasses were also examined for marks. Numbers of marked fish from each stratum and the number of unmarked fish were recorded. A secondary mark was given all live fish and carcasses in the second samples to prevent re-counting. Sample sizes were as large as practical while avoiding multiple same-day recaptures. There were three marking and three recapture strata at Falls Lake, and four marking and four recapture strata at Kutlaku Lake. The first trip coincided with the time that sockeye salmon were beginning to school off the stream mouth but before they entered the stream, beginning on August 19 at Falls Lake and August 14 at Kutlaku Lake. Only the marking phase was conducted on the first trip. On subsequent trips, spaced about two weeks apart, both the marking and recapture phases were conducted, until there were no more sockeye spawners at the mouth of the stream. On the last trip, only the recapture phase was conducted; the last trip occurred when most of the spawners were dead or dying.

Data Analysis

The first-stage estimates for beach-spawning populations, or the "instantaneous" Petersen estimates within the study area, are formed using the method described in the Weir/Trap section above. This method is also used for pooled Petersen estimates of stream-spawning populations.

In the second-stage estimation process for beach-spawning populations, the first-stage Petersen estimates are used to estimate the total spawning population within the study area, N^*. Given s sampling occasions, we let $\hat{N}_i$ denote the first-stage Petersen population estimate from each sampling occasion i. The $\hat{N}_i$ values were used in place of the Jolly-Seber-derived parameter estimates of the number of animals alive in the system at each sampling occasion (J. Blick ADF&G, personal communication 1998; Cook 1998). We let n_i represent the number of unmarked fish and fish marked on previous trips, caught at sampling occasion i, and we let m_i represent the number of fish marked on previous trips, caught at sampling occasion i.

We also defined the following parameters (Schwarz et al. 1993; J. Blick ADF&G, personal communication, 1998; Cook 1998):

M_i = number of marked fish alive at time i,
ϕ_i = probability that a fish alive at time i is also alive at time i+1 (*i.e.* the survival rate)
B_i = number of fish that enter the system after occasion i and are still alive at time i+1 (*i.e.* immigration).
B_i^* = number of fish that enter the system after occasion i, but before occasion i+1,
N^* = total number of animals that enter the system before the last sampling occasion.

M_i was estimated as $\hat{M}_i = m_i \hat{N}_i / n_i$, for $i = 1,\ldots,s$;
ϕ_i was estimated as $\hat{\phi}_i = \hat{M}_{i+1} / (\hat{M}_i - m_i + n_i)$, for $i = 1,\ldots,s$-1;
B_i was estimated as $\hat{B}_i = \hat{N}_{i+1} - \hat{\phi}_i \hat{N}_i$, for $i = 1,\ldots,s$-1;
B_i^* was estimated as $\hat{B}_i^* = \hat{B}_i \log(\hat{\phi}) / (\hat{\phi} - 1)$, for i = 2,…..,s-1, and
N^* was estimated as $\hat{N}^* = \sum_{i=0}^{s-1} \hat{B}_i^*$.

Recruitment and mortality were assumed to be uniform between times i and i+1. Because B_0^* and B_1^* are not uniquely estimable, $\hat{B}_0^* + \hat{B}_1^*$ was estimated by $\hat{N}_2 \log(\hat{\phi}) / (\hat{\phi} - 1)$.

A parametric bootstrap method (Buckland 1985 and 1984) was used to construct confidence intervals for the parameter estimates in both stages. Let each bootstrap step be indexed by j (j=1,...G; for our purposes G=1,000). The parametric bootstrap distribution for $\hat{N}_i$ was developed by drawing G bootstrap observations of a hypergeometrically distributed random variable (that is, r_i) using parameters based on the observed values of C_i, K_i, and $\hat{N}_i$ at each sampling event i. At each step $\hat{N}_i(j)$ is developed as previously described. Denote each bootstrap observation in the first estimation stage as the pair of $r_i(j)$ and $\hat{N}_i(j)$, for j = 1,...G. Before proceeding on to the simulation of the second stage (the Jolly-Seber portion), the variance of the number of recaptures across all bootstrap replicates was calculated and denoted sb_i, for each trip i (*i.e.*, $\mathrm{Var}_j(r_i(j)) = sb_i$). Note that this standard deviation is calculated from the bootstrap distribution of just the recaptures from the previous-day's marking event. To simulate the Jolly-Seber portion, for each bootstrap step, a bootstrap observation, $m_i(j)$, was drawn from a normal distribution with the mean determined from the actual observed value of m_i, and the standard

deviation given by sb_i. Because this standard deviation is based on the simulated variability in just the previous-day's marking, it may tend to understate the sampling variability of m_i, which is the number of recaptures from all previous marking events. Even so, this assumption should provide a sensible approximation. We condition on the sample size, which we assume to be fixed and not a random variable, so that $n_i = n_i(j)$, for all j bootstrap observations. We then estimate $\hat{M}_i(j)$, $\hat{\phi}_i(j)$, and so on, as previously described, for all $j = 1, ...G$. The confidence interval for each parameter estimate is found from the quantiles of the bootstrap distribution (Rice 1995) for that estimate.

For the stream spawning population, data from the three or four marking and recapture strata were analyzed using Darroch, maximum-likelihood, Schaefer population, and "pooled Petersen" estimates, calculated with the Stratified Population Analysis System (SPAS) software (Arnason et al. 1995). The pooled Petersen estimate was selected because it had lowest variance and was free of errors such as out-of-bounds estimates that occurred with the other methods. A 95% confidence interval was constructed for the pooled Petersen estimate as given in the weir/trap section above. Since the inlet stream spawning areas in both Falls and Kutlaku Lakes were short, the entire stream area was sampled and the estimate applies to the entire stream spawning population.

Subsistence Harvest Estimate

A one-stage stratified sampling design was used to estimate sockeye salmon harvest and fishing effort (Cochran 1977) at Falls Lake from June 1 through July 23, after which the sport and subsistence fisheries were closed by ADF&G emergency order. The primary sampling units were boat-parties within days. This design was appropriate because participating boats could be accurately counted and most could be interviewed after they completed fishing. The design was stratified by angler type. Sport fishers (using hook and line) were one stratum, subsistence fishers using gillnets were a second stratum, and subsistence fishers using seines were a third stratum. Given the very low number of participants in the fishery, the sampling day was all day-light hours, the crew was up and able to monitor the fishery, seven days a week. Experience in 2001 suggested that samplers could interview nearly all participating groups during this time period, and this was true in 2002. The exception was those boat parties that chose to leave the area without completing an interview. This happened several times despite the crew contacting them at least once to initiate an interview. These instances were recorded as missed interviews; if the sampler was able to estimate a catch from observation or third person reporting, that was noted in the comments.

As a fishing boat entered the area, the sampler contacted the group by radio or by motoring out, gave a short explanation of the creel survey, determined the group's sport or subsistence gear use, and requested that the boat party contact the samplers as they prepared to leave the area so the interview could be completed. Data collected during each interview included angler effort (rod or net hours), gear type used, and harvest by species. If the technician was unable to interview a party because two or more boats were leaving at the same time, one boat was randomly selected using a coin toss. Samplers maintained a view of the fishing area during the entire sampling period. Boat parties that left the fishery without being interviewed were counted

according to their previously identified sport or subsistence gear use, along with any other known information.

Data Analysis

Equations for estimation of harvest, catch, and effort in each creel survey were those for a 1-stage direct expansion (access point, completed-trip interview) survey, as found in Cochran (1977) (Conitz et al. 2002). We let h_j = harvest on boat j using gear g, m_g = number of boat parties interviewed using gear g, and M_g = number of boat-parties counted using gear g. The harvest (by species and gear group g) was estimated as:

$$\hat{H}_g = \frac{M_g}{m_g} \sum_{j=1}^{m_g} h_{gj} \ . \tag{6}$$

Letting $\bar{h}_g$ denote the mean harvest per boat for the gth gear group, the variance of the harvest by stratum was estimated as:

$$var\left[\hat{H}_g\right] = (1 - \frac{m_g}{M_g}) M_g^{\ 2} \frac{\sum_{j=1}^{m_g} (\hat{h}_{gj} - \bar{h}_g)^2}{m_g (m_g - 1)} \ . \tag{7}$$

If all boat parties in a gear group were interviewed, the estimated harvest by species was simply the sum of the harvest on individual boats.

Effort was estimated similarly, substituting E for H in the equations above. Subsistence total harvest for the season was the sum of harvests for the gillnet and seine groups.

Limnology Sampling

Limnology sampling began in late May due to late ice cover in 2002, and was repeated at approximately six-week intervals through early October, for a total of four sampling dates. Two stations were sampled in each lake (Conitz et al. 2002; Conitz and Cartwright 2002). Physical data were taken only at Station A (the main lake basin). Zooplankton samples were collected from both stations on each sampling date.

Light, Temperature, and Dissolved Oxygen Profiles

Underwater light intensity was recorded from just below the surface to the depth where measured intensity was one percent of the surface light reading, at 0.5 m intervals, using an electronic light sensor and meter (Protomatic). The vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (natural log of percent subsurface light) versus depth. The euphotic zone depth (EZD) was defined as the depth to which one percent of the subsurface light [photosynthetically available radiation (400-700nm)] penetrates the lake surface (Schindler 1971), and is calculated from the equation: EZD = 4.6205/ K_d (Kirk 1994). The euphotic zone depth defines the part of the lake where photosynthesis is possible.

Temperature and dissolved oxygen (DO) profiles were measured with a Yellow Springs Instruments (YSI) Model 58 DO meter and probe, in relative (%) and absolute (mg L^{-1}) values for DO and in ºC for temperature. Measurements were made at 1 m intervals to the first 10 m or the lower boundary of the thermocline (defined as the depth at which the change in temperature decreased to less than 1ºC per meter), and thereafter at 5 m intervals to within 2 m of the bottom (or 50 m). The dissolved oxygen meter reading at 1 m was calibrated at the beginning of a sampling trip using the value from a 60 ml Winkler field titration (Koenings et al. 1987). The DO profile was measured only on the first sampling trip in May, except at Gut Bay Lake where logistics and weather delayed measurement until August.

Secondary Production

Zooplankton samples were collected at two stations using a 0.5 m diameter, 153 um mesh, 1:3 conical net. Vertical zooplankton tows were pulled from a maximum depth of 50 m, or 2 m from the bottom of the lake if shallower than 50 m, at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed at the ADF&G Commercial Fisheries Limnology Laboratory in Soldotna, Alaska. Identification to genus or species, enumeration, and density and biomass estimates were performed as in 2001 (Conitz et al. 2002; Koenings et al. 1987). Zooplankton density (individuals per m^2 surface area) and biomass (weight per m^2 surface area) were estimated by species and by the sum of all species (referred to as total zooplankton density or biomass).

RESULTS

Juvenile Sockeye Population Assessment

Smolt Estimates

Total samples of 727 sockeye smolts and 148 coho smolts were taken in the Falls Lake outlet stream between May 14 and June 18 (Figure 6). Other fish collected in the fyke net were Dolly Varden char, sculpins, and sticklebacks, but there were fewer than 10 of each. Age-1 smolt constituted the largest age class in the sampled sockeye smolt, at about 84% (Table 6). No age-3 smolts were identified. About 3% of the sampled smolt were not ageable. Age-2 smolts were larger, on average, by about 9 mm in length and about 1 g in weight than age-1 smolts.

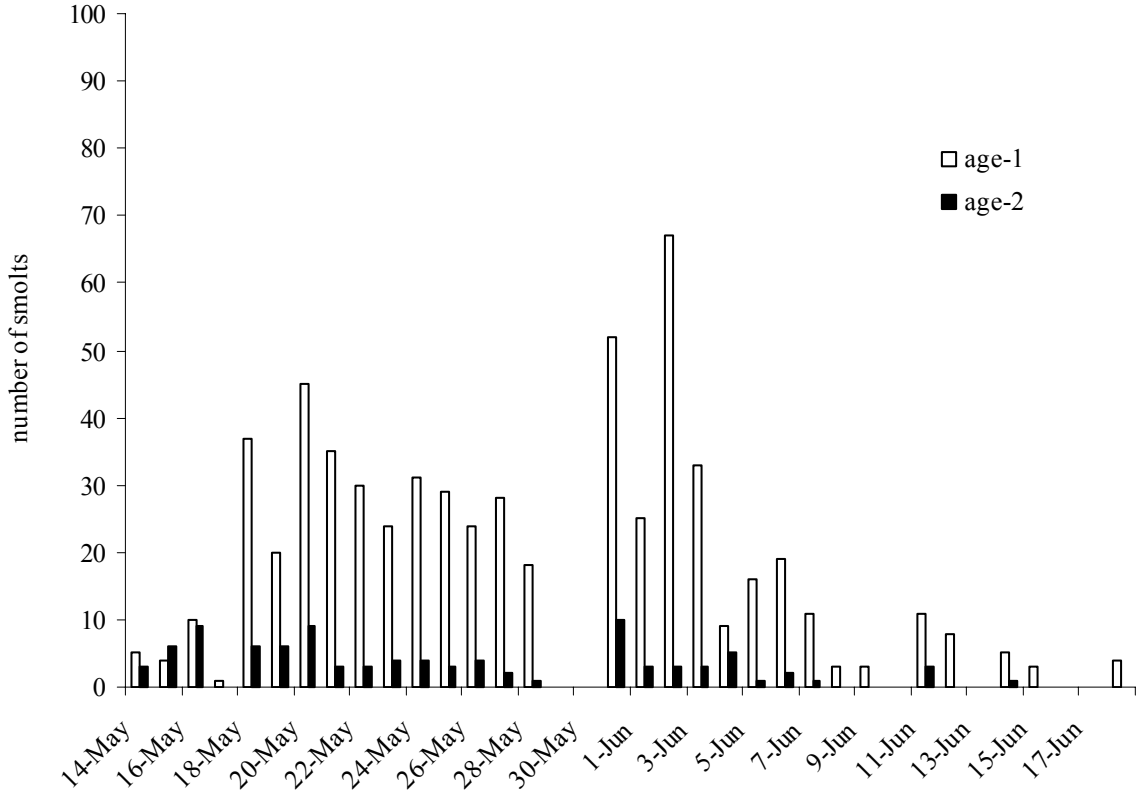

Figure 6. Numbers of sockeye and coho smolts sampled at Falls Creek, May 14-June 18, 2002. Sampling occurred between 7:00 pm and midnight on most evenings.

Table 6. Age, weight, and length composition of sockeye salmon smolt sampled at the Falls Lake outlet in May-June 2002.

	Age 1	Age 2	No Scale	Regenerated Scale	All Ages
Av. Length ± Std. Dev. (mm)	74.2 ± 5.1	83.6 ± 4.0	78.2 ± 6.9	77.0 ± 6.1	75.5 ± 5.9
Av. Weight ± Std. Dev. (g)	2.99 ± 0.68	4.13 ± 0.67	3.52 ± 0.70	3.08 ± 0.80	3.15 ± 0.78
Count	610	95	5	17	727
Percent of Total	83.9%	13.1%	0.7%	2.3%	100%

Fry Estimates

Falls Lake

Hydroacoustic and trawl surveys were completed in Falls Lake on August 24. The total hydroacoustic target estimate was 30,482 fish (CV 11%). Three mid-water trawl tows were conducted, two at 8 m depth and one at 10 m, and each lasting 15 minutes. Of 23 fish caught, 14 were sockeye fry and 9 were sticklebacks (Table 7). Five sockeye fry were larger than 50 mm, but were determined to be age-0. Species apportionment for the hydroacoustic targets was assumed to be 61% age-0 sockeye fry and 39% sticklebacks, based on these limited samples. The estimated total population of sockeye fry was about 18,500, and the estimated density of sockeye fry in the lake was 0.02 fry · m^{-2} (Table 10).

Table 7. Results of individual trawl tows for small pelagic fish in Falls Lake, August 24, 2002.

Tow	Depth (m)	Time (min)	Species	No. of Fish
1	8	15	Sockeye age 0	1
			Stickleback	9
2	8	15	Sockeye age 0	5
3	10	20	Sockeye age 0	8

Gut Bay Lake

Hydroacoustic and trawl surveys were completed in Gut Bay Lake on August 23. The total hydroacoustic target estimate was 73,359 fish (CV 5%). One surface tow and four midwater tows were conducted (Table 8). Of 42 fish caught, 40 were sockeye fry and 2 were coho fry. All but one of the sockeye fry were 50 mm or less in length and assumed to be age-0, and the individual larger than 50 mm was also age-0 (Figure 7). Species apportionment for the hydroacoustic targets was assumed to be 95% age-0 sockeye fry and 5% coho fry, based on these limited samples. The estimated total population of sockeye fry was about 69,800, and the estimated density of sockeye fry in the lake was 0.25 fry · m^{-2} (Table 10).

Table 8. Results of individual trawl tows for small pelagic fish in Gut Bay Lake, August 23, 2002.

Tow	Depth (m)	Time (min)	Species	No. of Fish
1	Surface	15	Sockeye age 0	1
2	9	15	Sockeye age 0	3
3	9	15	Sockeye age 0	8
			Coho	1
4	11	15	Sockeye age 0	18
5	11	20	Sockeye age 0	10
			Coho	1

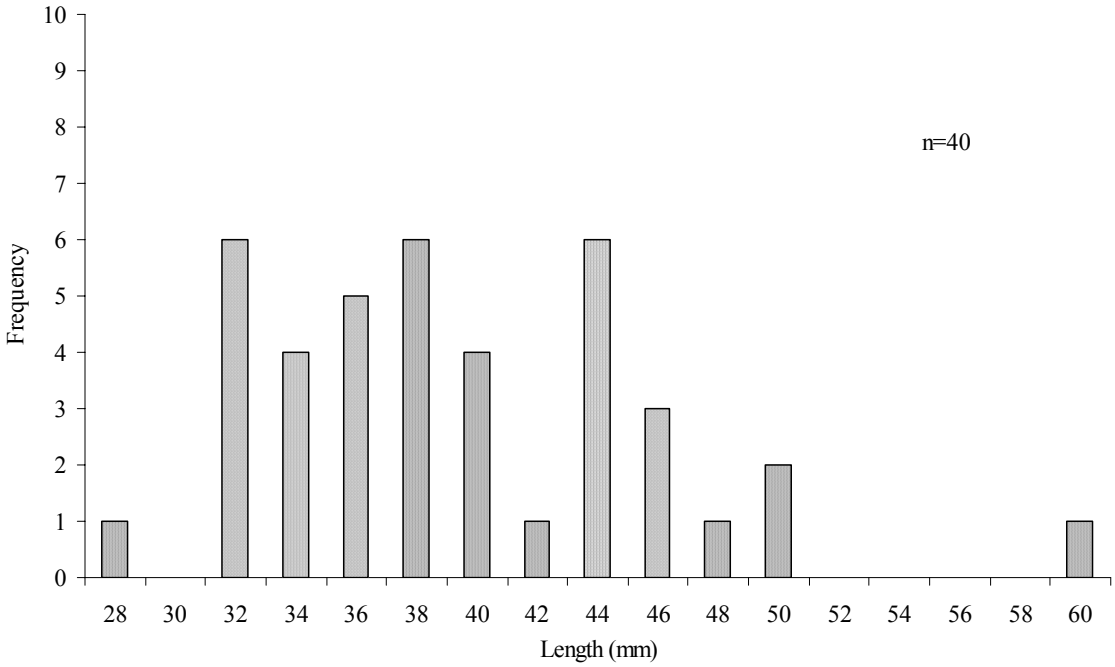

Figure 7. Length frequency distribution of sockeye salmon fry in Gut Bay Lake, 2002. Scale analysis showed the single fry over 50 mm in length was age-0.

Kutlaku Lake

Hydroacoustic and trawl surveys were completed in Kutlaku Lake on August 9. The total hydroacoustic target estimate was 114,881 fish (CV 11%). Five trawl tows were conducted, one at the surface, two at 8 m. and two at 10 m. In a total trawl sample of 167 fish, 164 were sockeye fry and 3 were sticklebacks (Table 9). Of 51 sockeye fry that were greater than 50 mm in length, 4 were age-1, and the remaining 47 were age-0, and the 113 sockeye fry less than 50 mm were also assumed to be age-0 (Figure 8). Species and age apportionment for the hydroacoustic targets was assumed to be 96% age-0 sockeye fry, 2% age-1 sockeye fry, and 2% sticklebacks, based on

these samples. The estimated total population of sockeye fry was about 112,800 (CV 11%), and the estimated density of sockeye fry in the lake was 0.41 fry · m^{-2} (Table 10).

Table 9. Results of individual trawl tows for small pelagic fish in Kutlaku Lake, August 9, 2002.

Tow	Depth (m)	Time (min)	Species	No. of Fish
1	Surface	15	Sockeye age 0	1
2	8	15	Sockeye age 0	17
3	8	15	Sockeye age 0	9
4	10	15	Sockeye age 0	89
			Sockeye age 1	4
5	10	15	Sockeye age 0	44
			Stickleback	3

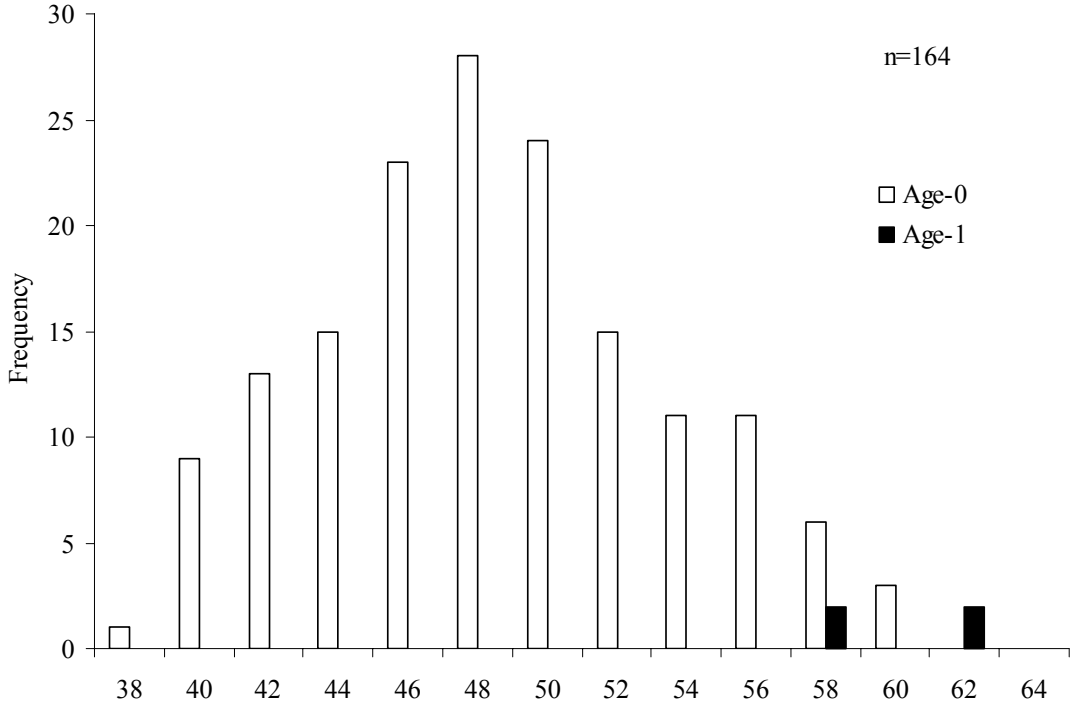

Figure 8. Length frequency distribution of sockeye salmon fry in Kutlaku Lake, 2002.

Table 10. Size and age distribution of sockeye salmon fry and other small pelagic fish estimated from midwater trawl samples; population estimates based on hydroacoustic surveys with species and age apportionment based on trawl samples, for Falls, Gut Bay, and Kutlaku Lakes, 2002. Sample standard deviation (stdev) is indicated with mean length and weight.

Lake	Species	Age	Sample size	Proportion of total	Mean length (mm) ± stdev	Mean weight (g) ± stdev	Total Population Est. by Species, Age
Falls	Sockeye	0	14	61%	44.7± 10.3	0.73 ± 0.52	18,554
	Stickleback	na	9	39%	45.9 ± 9.6	0.88 ± 0.40	11,928
Gut Bay	Sockeye	0	40	95%	39.0± 6.3	0.53 ± 0.31	69,866
	Coho	2	2	5%	108 ± 1.4	12.45 ± 2.19	3,493
Kutlaku	Sockeye	0	160	96%	48.2± 5.0	1.05 ± 0.34	110,066
	Sockeye	1	4	2%	60.3 ± 2.6	1.98 ± 0.24	2,752
	Stickleback	na	3	2%	48± 3.6	1.07 ± 0.15	2,064

Adult Escapement Estimates

Weir/Trap

Between July 13 and August 30, 774 sockeye salmon were counted through the Falls Lake weir. The weir was in place from June 21 through August 30, but no sockeye salmon passed through it before July 13. By August 30, the daily sockeye count had been 5 or fewer for over a week, with counts of zero on two of those days. Peak escapement was 104 sockeye salmon on August 6; this coincided with the end of a low water period lasting about 2 weeks at maximum summer air and water temperatures (Appendix B). Between August 5-30, 167 coho salmon were counted through the Falls Lake weir. The only other fish counted at the weir were 2 pink salmon and 4 Dolly Varden char.

Although the daily marking rate fluctuated somewhat, the cumulative marking rate remained near 50% during most of the run and was 51% overall. Because the run was small, only two marking strata were used. A total of 227 sockeye salmon were marked in the first stratum, ending August 6, and 167 sockeye salmon were marked in the second stratum from August 7-30 (Table 11). Recapture events were conducted on the spawning grounds between August 19 and October 1, approximately 2 weeks apart; each event constituted one recapture stratum. Eventually all marking and all recapture strata were pooled, since the "pooled Petersen" estimate yielded the smallest confidence interval, and no errors, in the SPAS program (Arnason et al. 1995). The sockeye salmon escapement estimated by the mark-recapture experiment was 1,090, with a 95% confidence interval of 968-1,257. Since this estimate, including the lower bound of the confidence interval, is higher than the weir count, it indicates that some fish escaped through the weir without being counted.

Table 11. Weir mark and recapture sample sizes and number of marked fish caught in recapture samples in Falls Lake, 2002. Sockeye salmon were marked as they were passed through the weir/trap at the lake outlet. Recapture sampling was conducted in all spawning areas of the lake and its inlet streams throughout the spawning period.

Phase	Stratum	Dates	Sample Size	Number Marked	Number recaptured with Marks Stratum 1	Number recaptured with Marks Stratum 2
Marking	1	7/13-8/6	443	227		
	2	8/7-30	331	167		
Total marked:				394		
Recapture	1	8/19-21	140		35	16
	2	9/3-4	107		29	12
	3	9/19	40		9	7
	4	9/30-10/1	24		0	4
		Total sampled:	311		73	39
		Total recaps (all strata):	112			

Adult Sockeye Population Age and Size Distribution

Falls Lake

At Falls Lake, 431 sockeye salmon were sampled, of which 204 were males and 227 were females (Table 12). Age could not be determined in 36 samples. The largest class was age-1.2, representing about 46% of the sampled fish. Age-2.2 and -2.3 fish together comprised about 43% of the sample, with the remainder being age-1.3 and two additional age-2.3 jacks.

Table 12. Age composition of adult sockeye salmon in the Falls Lake escapement by sex, July 13 - August 30, 2002.

Brood year:	1998	1998	1997	1997	1996	
Age:	1.2	2.1	1.3	2.2	2.3	Total
Male						
Sample size	76	2	32	35	41	186
Percent	19.2	0.5	8.1	8.9	10.4	47.1
Std. Error	2	0.4	1.4	1.4	1.5	2.5
Female						
Sample size	104		13	55	37	209
Percent	26.3		3.3	13.9	9.4	52.9
Std. Error	2.2		0.9	1.7	1.5	2.5
All Fish						
Sample size	180	2	45	90	78	395
Percent	45.6	0.5	11.4	22.8	19.7	100
Std. Error	2.5	0.4	1.6	2.1	2	

The overall average mid-eye to fork length of 510 mm reflected the large proportion of age-1.2 fish, whose average length was just under 490 mm (Table 13). Age-2.2 fish were only slightly larger, at 494 mm average length. Age-1.3 and age-2.3 fish likewise had similar average lengths at 551 mm and 558 mm, respectively.

Table 13. Mean fork length (mm) of adult sockeye salmon in the Falls Lake escapement by sex and age class, July 13 - August 30, 2002.

Brood Year:	**1998**	**1997**	**1998**	**1997**	**1996**		
Age:	**1.2**	**1.3**	**2.1**	**2.2**	**2.3**	**Not aged**	**All Fish**
Male							
Av. Length	487	555	351	499	560	520	516
SE (av. length)	2.4	5.5	25.0	4.0	3.6	8.0	3.0
Sample Size	76	32	2	35	40	18	203
Female							
Av. Length	489	541		491	556	504	504
SE (av. length)	2.0	3.8		2.9	4.3	9.4	2.3
Sample Size	104	13		55	35	18	225
All Fish							
Av. Length	488	551	351	494	558	512	510
SE (av. length)	1.5	4.1	25.0	2.4	2.8	6.2	1.9
Sample Size	180	45	2	90	75	36	428

Kutlaku Lake

At Kutlaku Lake, 442 sockeye salmon were sampled, of which 263 were male and 177 were female. Sex was not recorded for two fish, and age could not be determined in 128 of the sampled fish. The dominant class for both sexes was age-1.2, representing 75% of the sampled fish (Table 14). Age-1.3 fish made up another 12% of the sampled fish, and age-2.2 and age-2.3 fish were 11% of the total sample. There were a few jacks.

Table 14. Age composition of adult sockeye salmon in the Kutlaku Lake escapement by sex and brood year, August 11 - October 26, 2002.

Brood year:	**1999**	**1998**	**1998**	**1997**	**1997**	**1996**	
Age:	**1.1**	**1.2**	**2.1**	**1.3**	**2.2**	**2.3**	**Total**
Male							
Sample size	3	140	1	22	9	9	184
Percent	1	44.9	0.3	7.1	2.9	2.9	59
Std. Error	0.5	2.8	0.3	1.4	0.9	0.9	2.8
Female							
Sample size		95		16	13	4	128
Percent		30.4		5.1	4.2	1.3	41
Std. Error		2.6		1.2	1.1	0.6	2.8

Table 14. Page 2 of 2

Brood year:	1999	1998	1998	1997	1997	1996	
Age:	1.1	1.2	2.1	1.3	2.2	2.3	Total
All Fish							
Sample size	3	236	1	38	22	13	313
Percent	1	75.4	0.3	12.1	7	4.2	100
Std. Error	0.5	2.4	0.3	1.8	1.4	1.1	

The sockeye adults sampled at Kutlaku Lake were small, with an overall average length of 490 mm (Table 15). The average mid-eye to fork length of age-1.2 fish was 476 mm. The one fish that was not aged or sexed was probably a jack, as its length was <400 mm.

Table 15. Mean fork length (mm) of adult sockeye salmon in the Kutlaku Lake escapement by sex, brood year, and age, August 11 - October 26, 2002.

Brood Year:	1999	1998	1997	1998	1997	1996		
Age Class:	1.1	1.2	1.3	2.1	2.2	2.3	Not aged	All Fish
Male								
Av. Length	372	478	553	388	504	557	500	493
SE (av. length)	29.3	2.7	2.7		12.3	6.0	5.2	2.8
Sample Size	3	140	22	1	9	9	79	263
Female								
Av. Length		473	530		493	541	496	487
SE (av. length)		2.9	5.1		10.0	10.2	5.7	2.8
Sample Size		95	16		13	4	49	177
Not Sexed								
Av. Length		451					373	412
SE (av. length)								1.0
Sample Size		1					1	2
All Fish								
Av. Length	372	476	543	388	497	552	497	490
SE (av. length)	29.3	2.0	3.2		7.7	5.4	4.0	2.0
Sample Size	3	236	38	1	22	13	129	442

Mark-Recapture and Visual Survey Escapement Estimates

Falls Lake

Mark-recapture sampling in the beach and inlet stream spawning areas and visual survey counts of sockeye spawners in Falls Lake were accomplished in four trips between August 19 and October 1 (Tables 16-18). Very few sockeye salmon were spawning in the beach study area in 2002, so sample sizes were small. On the second trip, the recapture sampling in the beach spawning area was not conducted due to weather and few fish present. The sample and recapture numbers for the second and third trip were therefore combined in the analysis. A total of 177 (95% CI 157 - 204) sockeye salmon were estimated in the study area, and the estimate met our

objective for precision with a coefficient of variation (cv) of 6.8%. The estimate of sockeye salmon spawning in the SW inlet stream was 707 (95% CI 470 - 1,175), with a cv of 18.1%. Summing the estimate of beach spawners within the study area and the estimate of stream spawners yields a minimum escapement estimate for Falls Lake of 884 (range 627 - 1,379). This estimate is somewhat lower than the weir mark-recapture estimate of 1,090, at least in part because we estimated only that portion of the beach spawning sockeye population present within the study area (Table 14).

Table 16. Sample sizes and numbers of recaptured fish in the main beach spawning area at Falls Lake, designated as the study area. In the first stage sampling, fish were marked on one day and examined for marks the following day, assuming the population to be closed over this short time period. In the second stage sampling, fish caught on both days of an event were given a unique mark for that event, and were also examined for marks given on previous events. The second stage allowed for an open population estimate.

	First Stage			
Event Dates	**No. Marked (day 1)**	**No. Sampled (day 2)**	**No. Recaps from day 1**	**Petersen estimate (95% CI)**
8/20-21	33	43	18	78 (56 - 150)
9/3-4	12	Sampling incomplete; no recapture sample		
9/19-20	47	44	28	73 (60 - 100)
9/30-10/1	17	14	12	20 (17 - 30)

	Second Stage				
	No. Marked	**Recaps from event:**	**1**	**2**	**3**
8/20-21	58		-	-	-
9/3-4	12		5	-	-
9/19-20	63		6	3	-
9/30-10/1	19		0	0	10

Table 17. Visual counts of sockeye spawners in Falls Lake, listed individually by date and observer (2 - 4 observers). Counts were made in the SW inlet stream on foot, and kept separate from the shoreline area counts. Shoreline areas were surveyed by boat. The study area count was a designated stratum within the total lake shoreline count.

	Sockeye Counts		
Date	**SW Inlet Stream**	**Beach Study Area**	**Entire Lake Shore**
8/19	2, 2, 0, 2	93, 62, 68, 75	174, 93, 129, 100
9/1	258, 255, 283	65, 83, 78	73, 109, 114
9/19	208, 199, 188	47, 49, 46	69, 72, 67
9/30	48, 48	23, 22	45, 44

Table 18. Sample sizes in mark and recapture strata and numbers of marked fish caught in recapture strata in southwest inlet stream to Falls Lake, 2002. Marking was conducted at the mouth of the stream; recapture sampling was conducted in the stream. All mark and recapture strata were pooled for analysis since the sample sizes in the later strata were very small.

Phase	Stratum	Dates	Number marked			
Marking	1	8/19	76			
	2	9/4	8			
	3	9/19	10			
Total marked:			94			
				Recaptured fish by stratum:		
			Sample size	**1**	**2**	**3**
Recapture	1	9/4	89	13	-	-
	2	9/20	53	4	1	-
	3	10/1	6	0	0	1
		Total sampled:	148	17	1	1
		Total recaps (all strata):	19			

Kutlaku Lake

Mark-recapture sampling and visual survey counts of sockeye spawners in Kutlaku Lake were conducted between August 14 and October 25 (Tables 19-20). Early in the season, most sockeye spawners were concentrated around the main inlet stream on the SE side of the lake, and we decided to use the stream spawning sampling design. Total stream-spawning escapement was estimated at 1,354 (95% CI 1,156 - 1,658), with a cv of 7.6%. Later, many more spawners began to appear in beach areas all around the lake, but they were not obviously concentrated in one area and the crew did not initiate a second mark-recapture study. Therefore, only part of the spawning escapement in Kutlaku Lake was estimated, specifically, that part spawning in the inlet stream. In addition to sockeye salmon, several hundred cutthroat trout, Dolly Varden char, and pink salmon were observed in Kutlaku Lake early in the season, and a few chum and up to 150 coho salmon were observed later in the season.

Table 19. Visual counts of sockeye spawners in Kutlaku Lake, listed individually by date and observer (2 - 3 observers). Counts were made in the main inlet stream on foot; counts along all shoreline areas of the lake were made by boat.

	Average Sockeye Count	
Date	**Inlet Stream**	**Lake Shore**
8/19	25, 13, 20	2, 0, 4
8/31	140, 120	465, 472
9/16	256, 241	418, 331
9/28	20, 18	842, 805
10/11	12, 9	902, 831
10/25	2, 0	370, 357

Table 20. Sample sizes in mark and recapture strata and numbers of marked fish caught in recapture strata in Kutlaku Lake inlet stream, 2002. Marking was conducted at the mouth of the stream; recapture sampling was conducted in the stream. All mark and recapture strata were pooled for analysis.

Phase	Stratum	Dates	Number marked				
Marking	1	8/14	35				
	2	8/30	129				
	3	9/16	42				
	4	9/29	29				
Total marked:			235				
				Recaptured fish by stratum:			
			Sample size	**1**	**2**	**3**	**4**
Recapture	1	8/31	229	7	31		
	2	9/17	215	12	5	10	
	3	9/29	57	2	5	15	
	4	10/11	9	0	0	0	1
		Total sampled:	510	21	41	25	1
		Total recaps (all strata):	88				

Gut Bay Lake

Only visual survey counts of sockeye spawners were attempted in Gut Bay Lake in 2002. However, weather and hazardous flying conditions once again prevented us from following the planned sampling schedule. The survey dates were too far apart, and did not extend late enough to detect a peak spawning count (Table 21).

Table 21. Observer counts of sockeye spawners in Gut Bay Lake. Counts were made along all shoreline areas of the lake, by 2 - 3 observers.

Date	Sockeye Counts
8/17	74, 71, 90
9/19	54, 58, 32
10/2	153, 163

Subsistence Harvest Estimate

With the exception of one subsistence boat and one sport boat early in June, fishing effort began at the Falls Lake terminal area on June 27 and ended when the sport and subsistence seasons were closed by emergency order on July 23 (Figure 9). The crew counted all fishing boats in the Falls Lake terminal area from June 1 through July 23. They were unable to complete interviews with nine boats, mainly because those fishers did not comply with requests to notify the crew when they were leaving. A total of 55 boats fished in the marine waters near Falls Lake. Of

those, 13 were sport boats and 42 were subsistence boats. A total harvest of 2,574 sockeye salmon was estimated, with a small bycatch, about 140 each, of chum and pink salmon (Table 19). The majority of the sockeye harvest, about 1,600 fish, was caught with seine gear, while the estimated harvest with gillnets was about 800 fish. The crew failed to record the gear type used by 5 of the subsistence boats; these boats caught about 200 sockeye salmon. Only 6 sockeye salmon (less than 0.5% of the total), and no other species, were caught with sport gear.

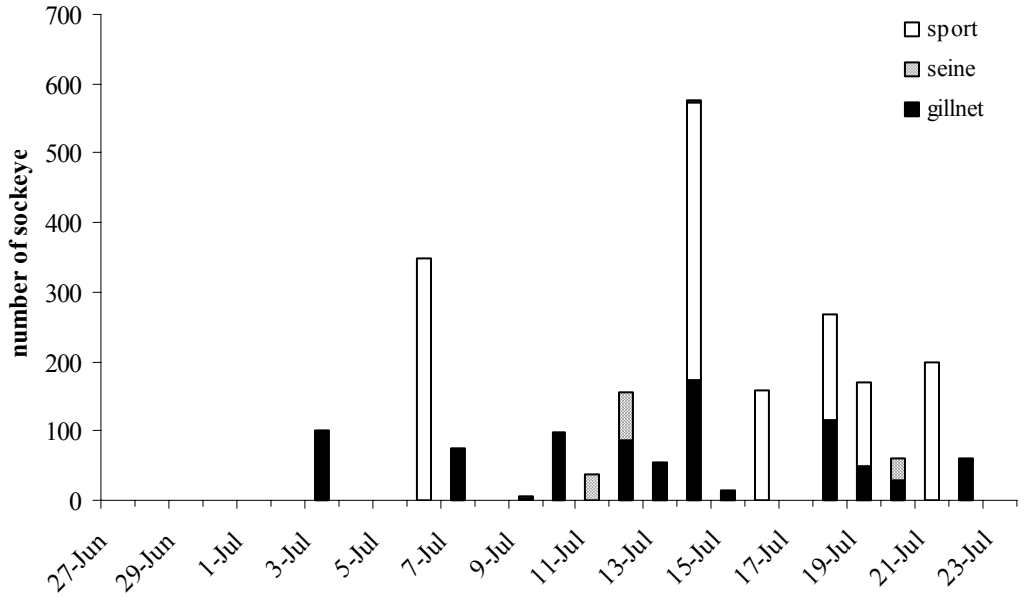

Figure 9. Daily subsistence and sport harvests of sockeye salmon in the Falls Lake terminal area during the 2002 season. Although the season opened on June 1, there was virtually no effort before the end of June. Sport and subsistence fishing were closed by ADF&G emergency order on July 23.

Table 22. Estimated number of salmon, ± standard error, caught in the Falls Lake sport and subsistence fisheries during 2002.

Gear Type	Number Counted	Number Sampled	Sockeye[a]	Coho	Chum	Pink	Chinook
Gillnet	22	16	810 ± 113	1 ± 1	114 ± 34	91 ± 24	3 ± 1
Seine	15	13	1,543 ± 180	0	18 ± 8	48 ± 15	0
Unknown Subsistence	5	4	215 ± 85	0	3 ± 2	9 ± 3	0
Sport	13	13	6	0	0	0	0
Totals	55	46	2,574 ± 229	1 ± 1	135 ± 35	148 ± 28	3 ± 1

[a] At least 130 more sockeye salmon were caught than were reported.

By far the highest sockeye harvest of about 1,300 fish occurred during the week of July 14-20. At least 400-450 sockeye salmon were caught in each of the two preceding weeks. Most of the boats fished during the weeks of July 7-13 (20 boats) and July 14-20 (21 boats). Rough estimates of catch-per-unit effort (CPUE) were made by comparing the numbers of sockeye salmon caught by gear type or by week with the number of hours fished with each unit of gear (one rod or one net; Table 23). A maximum CPUE of 25 sockeye salmon per gear-hour occurred during the last two days of the fishery, July 21-22, seine gear accounted for most of this catch. The average CPUE for seine gear was about 18 sockeye salmon per gear-hour; for gillnet gear the CPUE was about 7.5 sockeye salmon per gear-hour. Sport gear had by far the lowest CPUE, at only 0.2 sockeye salmon per gear hour. Overall, the greatest fishing effort was with gillnets, with at least 106 hours for the 2002 season, followed by seines with at least 77 hours, and another 14 hours with unknown subsistence gear type. Total sport fishing effort was about 30 hours.

Table 23. Catch-per-unit-effort (CPUE) and hours of effort (gear-hours fished) for sockeye salmon in the subsistence and sport fisheries at the Falls Lake terminal area, 2002. Gear-hours are hours fished per unit of gear (net or rod-and-reel); CPUE is number of sockeye salmon caught per gear-hour.

	CPUE (Gear-hours Fished) by Gear Type				
Week	**Gillnet**	**Unknown Subs.**	**Seine**	**Sport**	**All Gear Types**
Before June 29	(0)	0 (1)	(0)	0 (16)	0 (17)
June 30 - July 6	7 (14)	0 (1)	32 (11)	0 (1)	17 (27)
July 7-13	5 (52)	3 (6)	5 (21)	0 (6)	5 (85)
July 14-20	10 (41)	63 (3)	17 (42)	1 (5)	14 (90)
July 21-22	(0)	15 (4)	62 (3)	0 (3)	25 (10)
All Weeks	7 (106)	17 (14)	18 (77)	0 (31)	11 (228)

Limnology Sampling

Light, Temperature, and Dissolved Oxygen Profiles

The mean euphotic zone depths (EZD) in 2002 were 10.34 m at Falls Lake, 10.18 m at Gut Bay Lake, and 8.14 m at Kutlaku Lake (Table 24). Minimum depths for the season at all three lakes occurred in October, coinciding with heavy rainfall and maximum sediment input. The July sampling date was missed at Gut Bay Lake due to hazardous flying conditions into the lake.

Table 24. Euphotic zone depths in Falls, Gut Bay, and Kutlaku Lakes, 2002.

Lake	Sample date	EZD (m)
Falls	29-May	9.66
	17-Jul	11.30
	18-Aug	11.11
	30-Sep	9.27
	Seasonal mean	10.34
Gut Bay	30-May	12.09
	16-Aug	10.23
	3-Oct	8.22
	Seasonal mean	10.18
Kutlaku	30-May	8.98
	16-Jul	9.57
	15-Aug	7.91
	29-Sep	6.09
	Seasonal mean	8.14

All three lakes were nearly isothermic on the first sampling date in May, and became thermally stratified during summer months (Figure 10). Although the July sampling date was missed at Gut Bay and Kutlaku Lakes, the thermocline persisted through the August sampling date. By early October the thermocline had nearly disappeared in all three lakes. Maximum epilimnetic temperatures in August were 13.3 ^{o}C in Falls Lake, 13.8^{o}C in Gut Bay Lake, and 14.9^{o}C in Kutlaku Lake. The minimum temperature in the hypolimnion was 3.8^{o}C in Falls Lake, 4.3^{o}C in Gut Bay Lake, and 6.4^{o}C in Kutlaku Lake, probably in inverse relationship to maximum lake depth. Dissolved oxygen (DO) levels were above 90% saturation at all depths in Falls Lake and in depths to 16 m in Kutlaku Lake in late May (Table 25). The minimum DO level in Kutlaku Lake was 80.5% at 20 m, near the bottom of the lake. Dissolved oxygen measurements were not made in Gut Bay Lake until mid-August. At that time, a steep decline was observed, from 95.5% saturation at 10 m to 58.4% at 25 m near the lake bottom. However, these readings were not taken at the deepest part of the lake, but instead were near the west end of the lake, away from the main inlet streams and the lake outlet; water circulation was probably minimal at that location.

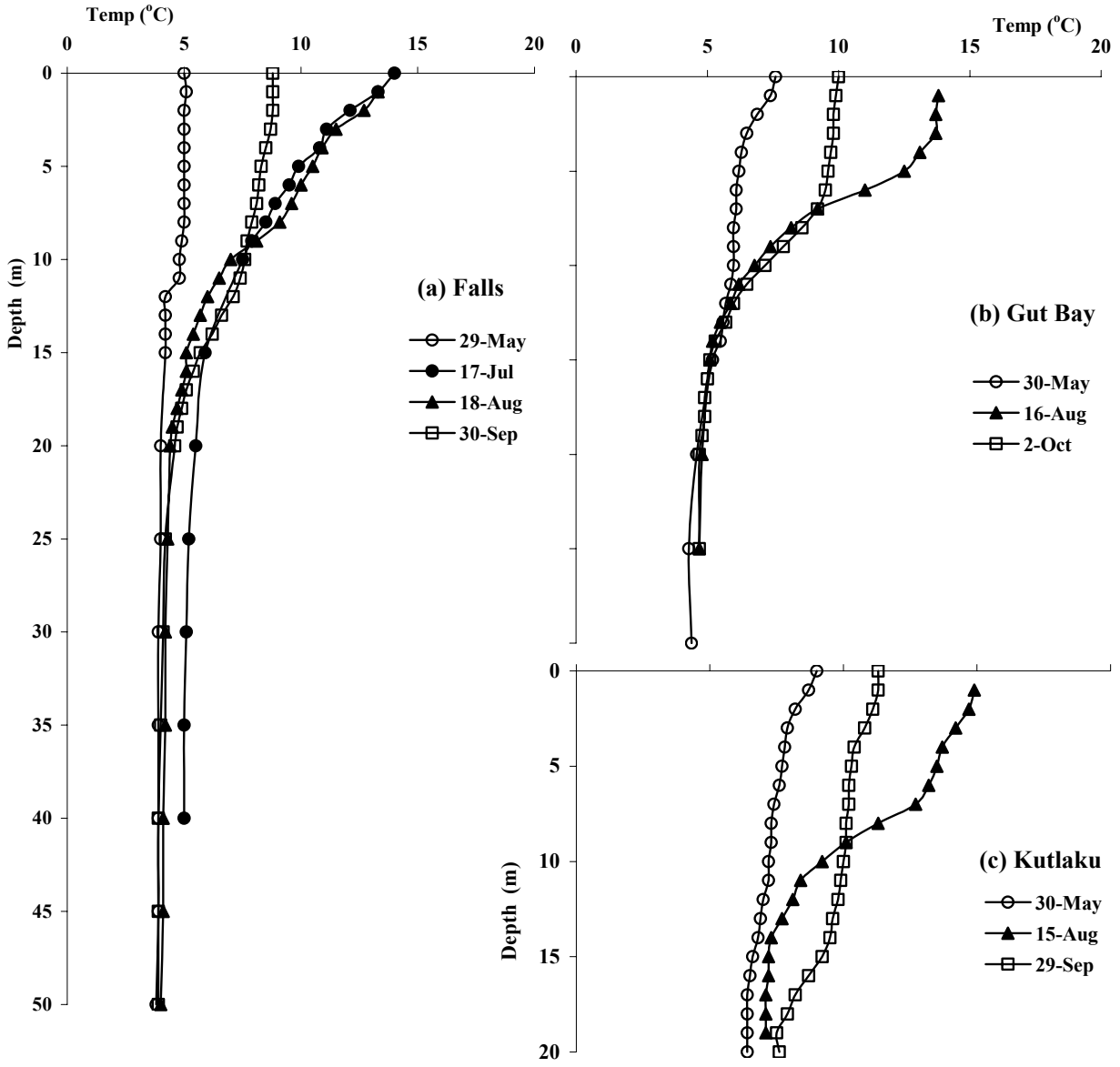

Figure 10. Temperature profiles from (a) Falls, (b) Gut Bay, and (c) Kutlaku Lakes, Station A, in 2002.

Table 25. Dissolved oxygen (DO) profiles from Falls, Gut Bay, and Kutlaku Lakes, Station A, in 2002, as % O_2 saturation. DO was measured in Falls Lake on May 29, in Kutlaku Lake on May 30, and in Gut Bay Lake on August 16.

	Dissolved O_2 (% Saturation)		
Depth (m)	**Falls**	**Gut Bay**	**Kutlaku**
0	96.6		99.8
1	96.7	101.5	99.6
2	96.2	103.9	98.6
3	96.0	104.7	98.4
4	96.0	105.3	98.2
5	95.8	105.1	98.0
6	95.7	108.1	97.6
7	95.6	111.8	97.7
8	95.5	109.3	97.6
9	95.3	104.5	97.5
10	95.0	95.5	97.7
11	94.6	89.0	97.5
12	93.4	85.0	97.0
13	93.3	79.7	95.0
14	93.2	75.7	94.1
15	93.1	74.2	93.1
20	91.0	66.0	80.5
25	90.8	58.4	
30	90.6		
35	90.5		
40	90.2		
45	90.1		
50	90.4		

Secondary Production

Major taxa of macro-zooplankton identified in water samples from Falls, Gut Bay, and Kutlaku Lakes were cladocerans *Bosmina* sp., *Daphnia longiremus*, and *Holopedium* sp., and copepod *Cyclops* sp.; additionally, the copepod *Diaptomus franciscanus* was present in Falls Lake samples. Among the three project lakes, Gut Bay had the lowest zooplankton density and biomass and Kutlaku had the highest.

Falls Lake

Zooplankton abundance was low at Falls Lake; with total seasonal mean biomass at main station A of 50 $mg \cdot m^{-2}$ and only 6 $mg \cdot m^{-2}$ at secondary station B (Table 26). The total seasonal mean density was 19,000 and 5,000 zooplankters $\cdot m^{-2}$ at stations A and B, respectively (Table 27). The two-copepod taxa comprised over 90% of the biomass at main station A, and over 75% of the abundance numerically. *Diaptomus franciscanus* were the largest zooplankters in the samples, with average lengths of 0.5-1.4 mm, and contributed the largest proportion of the biomass. The somewhat smaller *Cyclops vernalis* were the most abundant numerically, although the seasonal

mean density of the small cladoceran *Bosmina* sp. was slightly higher at station B. Small but measurable proportions of the large cladoceran *Daphnia longiremis* (average length 0.6-0.8 mm) were present in samples from both stations.

Table 26. Size and biomass of macrozooplankton in Falls Lake, 2002. Mean lengths are weighted by density (numbers · m^{-2}) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

	Average Length (mm)						
Station A	**May 29**	**Jul 19**	**Aug 18**	**Sep 30**	**Weighted Mean Length (mm)**	**Seasonal Mean Biomass ($mg \cdot m^{-2}$)**	**% of Total Biomass**
Diaptomus franciscanus	0.59	0.88	1.20	1.39	1.01	29.5	58.9%
Ovig. D. franciscanus			1.51	1.54	1.53	0.4	0.7%
Cyclops vernalis	0.92	0.74	0.85	1.07	0.76	15.5	31.0%
Ovig. C. vernalis				1.14	1.14	0.3	0.6%
Bosmina sp.	0.47	0.38	0.36	0.35	0.35	3.3	6.7%
Ovig. Bosmina sp.	0.60			0.37	0.38	0.4	0.8%
Daphnia longiremis	0.68		0.78	0.77	0.74	0.5	0.9%
Ovig. D. longiremis	1.03		0.86	0.80	0.89	0.2	0.4%
Holopedium gibberum							
Ovig. H. gibberum			0.56			0.0	0.0%
			Total Seasonal Mean Biomass			**50**	
Station B							
Diaptomus franciscanus	0.54	0.73	0.83	0.72	0.75	1.7	28.3%
Ovig. D. franciscanus							
Cyclops vernalis	0.85	0.58	0.62	0.59	0.59	1.4	23.2%
Ovig. C. vernalis							
Bosmina sp.	0.34	0.32	0.35	0.32	0.33	1.9	32.0%
Ovig. Bosmina sp.	0.62		0.35	0.36	0.36	0.2	3.4%
Daphnia longiremis	0.73	0.61	0.64	0.59	0.64	0.4	7.3%
Ovig. D. longiremis	0.82	0.82	0.86	0.56	0.85	0.3	5.6%
Holopedium gibberum		0.83	0.61		0.83	0.7	12.2%
Ovig. H. gibberum							
			Total Seasonal Mean Biomass			**6**	

Table 27. Density (number · m^{-2}) of macrozooplankton by taxon in Falls Lake, 2002.

	Density (number · m^{-2})					
Station A	**May 29**	**Jul 19**	**Aug 18**	**Sep 30**	**Seasonal Mean**	**% of Total Numbers**
Diaptomus franciscanus	932	15,690	7,981	2,275	6,720	34.4%
Ovig. D. franciscanus	0	0	34	68	25	0.1%
Cyclops vernalis	127	27,509	3,192	475	7,826	40.0%
Ovig. C. vernalis	0	0	0	272	68	0.4%
Bosmina sp.	285	0	4,007	7,370	2,916	14.9%
Ovig. Bosmina sp.	41	0	0	1,087	282	1.4%
Daphnia longiremis	306	0	306	170	195	1.0%
Ovig. D. longiremis	56	0	136	34	56	0.3%
Holopedium gibberum	0	0	0	0	0	
Ovig. H. gibberum	0	0	34	0	8	0.04%
Copepod nauplii	5,364	0	509	0	1,468	7.5%
	Seasonal Mean Density, All Taxa				**19,565**	
Station B						
Diaptomus franciscanus	107	2,649	764	20	885	16.2%
Ovig. D. franciscanus						
Cyclops vernalis	19	3,974	713	61	1,192	21.8%
Ovig. C. vernalis						
Bosmina sp.	151	1,783	2,089	3,729	1,938	35.4%
Ovig. Bosmina sp.	2	0	0	708	177	3.2%
Daphnia longiremis	59	306	611	36	253	4.6%
Ovig. D. longiremis	2	51	357	5	104	1.9%
Holopedium gibberum	0	408	0	0	102	1.9%
Ovig. H. gibberum						
Copepod nauplii	927	2,140	153	87	827	15.1%
	Seasonal Mean Density, All Taxa				**5,477**	

Gut Bay Lake

Zooplankton abundance was very low in Gut Bay Lake, with total seasonal mean biomass of 11-30 mg·m^{-2} (Table 28) and total seasonal mean density of 16,000-32,000 zooplankters·m^{-2} (Table 29). The small cladoceran *Bosmina* sp. (average length 0.3 mm) was the dominant taxon, representing 76% of the total seasonal mean biomass and 80% of seasonal mean abundance numerically at main station A. Small but measurable proportions of the larger cladoceran Daphnia *longiremus* (average length 0.6-0.7 mm) were present in samples from both stations. Copepods were represented in Gut Bay Lake samples only by *Cyclops* sp. and high numbers of unidentified nauplii larvae.

Table 28. Size and biomass of macrozooplankton in Gut Bay Lake, 2002. Mean lengths are weighted by density (numbers · m^{-2}) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

	Average Length (mm)					
Station A	**May 30**	**Aug 16**	**Oct 2**	**Weighted Mean Length (mm)**	**Weighted Biomass ($mg \cdot m^{-2}$)**	**% of Total Biomass**
Diaptomus						
Cyclops	0.51	0.54	0.56	0.55	1.3	4.2%
Bosmina	0.35	0.30	0.31	0.31	20.9	69.5%
Ovig. Bosmina	0.41	0.27	0.34	0.34	2.0	6.6%
Daphnia l.	0.59	0.57	0.68	0.64	1.0	3.2%
Ovig. Daphnia l.	0.74	0.75	0.85	0.80	0.5	1.7%
Holopedium	0.41	0.48	0.58	0.56	3.1	10.3%
Ovig. Holopedium	0.60	0.48	0.62	0.57	1.4	4.6%
			Total Seasonal Mean Biomass		**30**	
Station B						
Diaptomus						
Cyclops	0.51	0.56	0.56	0.55	1.07	9.7%
Bosmina	0.32	0.28	0.32	0.31	6.1	54.8%
Ovig. Bosmina	0.38	0.31	0.37	0.37	1.7	15.1%
Daphnia l.	0.56	0.59	0.59	0.58	0.5	4.4%
Ovig. Daphnia l.	0.74	0.78	0.83	0.78	0.3	2.8%
Holopedium	0.40	0.52	0.57	0.51	0.9	8.3%
Ovig. Holopedium		0.54	0.60	0.57	0.5	4.8%
			Total Seasonal Mean Biomass		**11**	

Table 29. Density (number · m^{-2}) of macrozooplankton by taxon in Gut Bay Lake, 2002.

	Density (number · m^{-2})				
Station A	**May 30**	**Aug 16**	**Oct 2**	**Seasonal Mean**	**% of Total Numbers**
Diaptomus	0	0	0	0	0%
Cyclops	204	849	2,649	1,234	4%
Bosmina	645	5,332	66,021	24,000	74%
Ovig. Bosmina	102	102	5,434	1,879	6%
Daphnia l.	374	408	883	555	2%
Ovig. Daphnia l.	136	136	272	181	1%
Holopedium	340	238	2,785	1,121	3%
Ovig. Holopedium	0	442	951	464	1%
Copepod nauplii	3,023	1,596	3,872	2,830	9%
	Seasonal Mean Density, All Taxa			**32,264**	
Station B					
Diaptomus	0	0	0	0	0%
Cyclops	543	484	2,174	1,067	7%
Bosmina	340	3,999	16,845	7,061	44%
Ovig. Bosmina	170	102	3,838	1,370	9%
Daphnia l.	374	102	577	351	2%
Ovig. Daphnia l.	136	76	136	116	1%
Holopedium	306	306	611	408	3%
Ovig. Holopedium	0	280	272	184	1%
Copepod nauplii	10,188	3,999	2,038	5,408	34%
	Seasonal Mean Density, All Taxa			**15,965**	

Kutlaku Lake

Zooplankton abundance in Kutlaku Lake was moderate; with total seasonal mean biomass of 123-136 mg·m^{-2} (Table 30) and seasonal mean density of 67,000-94,000 zooplankters·m^{-2} (Table 31). Cladoceran taxa comprised almost all of the biomass, with *Holopedium* sp. representing the largest proportion, 38-58%, overall, of the biomass. *Daphnia longiremus* made up 23-30% of the biomass, but were small in size with a seasonal mean length of about 0.5 mm. *Bosmina* sp. dominated the Kutlaku Lake zooplankton numerically, at 35-50% of the total seasonal mean, but *Daphnia* also represented a major proportion at 32-35%.

Table 30. Size and biomass of macrozooplankton in Kutlaku Lake, 2002. Mean lengths are weighted by density (numbers · m^{-2}) at each sampling date and seasonal mean biomass is based on the weighted mean length. Ovigorous (egg-bearing) individuals in each taxa were measured separately.

	Average Length (mm)						
Station A	**May 30**	**Jul 16**	**Aug 15**	**Sep 29**	**Weighted Mean Length (mm)**	**Weighted Biomass ($mg \cdot m^{-2}$)**	**% of Total Biomass**
Diaptomus							
Cyclops	0.56	0.66		0.46	0.55	1.1	0.8%
Bosmina	0.30	0.32	0.35	0.31	0.32	40.9	30.0%
Ovig. Bosmina	0.39		0.39	0.33	0.36	1.8	1.4%
Daphnia l.	0.47	0.60	0.56	0.50	0.52	27.4	20.1%
Ovig. Daphnia l.	0.76	0.74	0.78	0.66	0.73	13.1	9.6%
Holopedium	0.58	0.83			0.74	42.3	31.0%
Ovig.	0.70				0.69		7.1%
Holopedium						9.7	
				Total Seasonal Mean Biomass		**136**	
Station B							
Diaptomus							
Cyclops	0.55	0.65	0.59	0.52	0.56	1.2	1.0%
Bosmina	0.31	0.33	0.34	0.30	0.32	20.5	16.7%
Ovig. Bosmina	0.39	0.38	0.38	0.37	0.38	1.6	1.3%
Daphnia l.	0.49	0.57	0.47	0.50	0.50	19.6	15.9%
Ovig. Daphnia l.	0.78	0.74	0.69	0.64	0.70	8.8	7.2%
Holopedium	0.52	0.77	0.64	0.54	0.73	66.4	53.8%
Ovig.	0.74	0.86			0.77		4.2%
Holopedium						5.2	
				Total Seasonal Mean Biomass		**123**	

Table 31. Density (number · m^{-2}) of macrozooplankton by taxon in Kutlaku Lake, 2002.

Station A	May 30	Jul 16	Aug 15	Sep 29	Seasonal Mean	% of Total Numbers
Diaptomus						
Cyclops	3,057	425	0	1,019	1,125	1.2%
Bosmina	3,226	6,707	37,188	136,356	45,869	48.7%
Ovig. Bosmina	3,226	0	306	2,547	1,520	1.6%
Daphnia l.	4,755	7,896	25,369	58,584	24,151	25.6%
Ovig. Daphnia l.	3,566	1,783	8,966	8,321	5,659	6.0%
Holopedium	11,547	19,613	0	0	7,790	8.3%
Ovig. Holopedium	8,321	85	0	0	2,101	2.2%
Copepod nauplii	21,226	2,972	0	0	6,049	6.4%
		Seasonal Mean Density, All Taxa			**94,265**	
Station B						
Diaptomus						
Cyclops	2,445	543	136	1,630	1,189	1.8%
Bosmina	2,989	12,090	30,294	43,607	22,245	32.9%
Ovig. Bosmina	2,649	136	136	1,766	1,172	1.7%
Daphnia l.	4,755	6,928	24,724	41,297	19,426	28.8%
Ovig. Daphnia l.	1,970	2,445	9,373	2,989	4,194	6.2%
Holopedium	6,521	42,656	204	136	12,379	18.3%
Ovig. Holopedium	2,853	679	0	0	883	1.3%
Copepod nauplii	6,928	4,619	0	12,634	6,045	9.0%
		Seasonal Mean Density, All Taxa			**67,533**	

DISCUSSION

We accomplished all project objectives in 2002, with minor exceptions. At Kutlaku Lake, we only obtained a partial estimate of sockeye escapement since the distribution and timing of spawning was not known prior to this year's fieldwork. At Gut Bay Lake, not all scheduled trips to survey the sockeye spawner population could be accomplished, due to weather and hazardous flying conditions; in particular, the peak of spawning was not determined since we could not get into the lake in the late season. In estimating fry populations, the hydroacoustic results were successful and met our objective for precision, but we encountered difficulty in reliably estimating species apportionments based on the trawl samples.

The Falls Lake subsistence sockeye harvest was about 2,600 fish, larger than in 2001 by about 600 fish, and the escapement of about 1,100 sockeye salmon was smaller than the 2001 escapement by around 1,600 fish. The escapement estimated in 2002 was smaller than any of the weir counts from 1981-85 and 1987-89, and much smaller than the average count for those years of about 2,500 sockeye salmon (Conitz et al. 2002, Appendix B.1). The total estimated return of sockeye salmon to Falls Lake was about 4,600 in 2001 and about 3,700 in 2002. About 40% of returning sockeye salmon were harvested in 2001, contrasted with about 70% in 2002. There was concern in 2001 about the distribution of the sockeye harvest in relation to run timing, because there was no escapement until after the close of subsistence fishing on July 20. Although it is possible that this timing was due to environmental conditions as well as fishing, ADF&G managers decided to increase the size of the no-fishing area around the mouth of the stream to provide a refuge for some of the sockeye salmon staging in the terminal area below the falls. Between July 13 and the close of the subsistence fishing season on July 23, 27 sockeye salmon entered Falls Lake. Although this was 27 fish more than in the 2001 escapement prior to the fishery closure, is was nevertheless a very small fraction of the total escapement and relatively late compared with run timing data from the 1980s (Conitz et al. 2002).

The 2002 weir count of sockeye salmon at Falls Lake, about 770 fish, was substantially lower than the weir-based mark-recapture estimate of around 1,100 fish. Inspection of the weir at the end of the season revealed two places where holes or bypasses had developed, and so it is evident that the weir count was low and the weir mark-recapture estimate should be considered the best estimate of escapement.

Independent mark-recapture studies on the spawning grounds were successful at Falls and Kutlaku Lakes. We met our objective for precision (cv < 15%) in two out of three estimates: the beach spawning estimate at Falls Lake had a coefficient of variation of about 7%, and the stream spawning estimate at Kutlaku Lake had a cv of 8%. The stream-spawning estimate at Falls Lake had a cv of 18%; although not meeting the objective for precision, the estimate of about 700 fish appears to be reasonable when compared with visual counts and the weir-based estimate. The low numbers of beach spawning sockeye salmon at Falls Lake resulted in small sample sizes, but made it possible to mark a high proportion of those fish present and recapture substantial numbers of marked fish. The escapement estimate within the study area was very low, only about 180 fish. An estimate of the proportion of total beach spawning escapement found within the study area can be obtained by using the averages of observer counts (Table 17) to determine

the proportion of beach spawners within the study area at each sampling occasion, then taking an average proportion over all sampling occasions, weighted by estimated escapement at each occasion (Table 16). Expanding the study area escapement of 177 fish by the inverse of this proportion (1/.63) yields a total beach-spawning escapement of about 280 fish. Adding estimates of stream spawners and beach spawners yields a rough estimate of total escapement of about 980 fish for Falls Lake, which is within the 95% confidence interval for the weir-based estimate.

We were not able to estimate escapement of beach spawners at Kutlaku Lake, because the locations of spawning areas were not apparent until the second or third trip. By late September, we could see that spawning was dispersed throughout many shallow areas around the lake, and some of these areas could be difficult to sample effectively. Spawning in or around the main inlet stream at Kutlaku Lake had been noted in previous years by ADF&G sampling crews, and we observed spawning activity there in 2002 earlier than in other areas of the lake. Mark-recapture sampling was started at this inlet stream on the first trip, and sampling was continued consistently there through the spawning season. We estimated a moderate escapement of about 1,300 sockeye salmon in the inlet stream, which appeared to represent substantially less than 50% of total escapement in this system. The peak observer count of sockeye spawners in the inlet was about 240 in mid-September while the peak count for shoreline areas was just under 900 in early October. In 2003, we plan to conduct mark-recapture sampling in a portion of the beach spawning areas in Kutlaku Lake, in addition to the inlet stream.

Our inability to access Gut Bay Lake for spawner surveys was again disappointing. Over four weeks passed between the first survey in mid-August and the second in mid-September, and fewer than 100 sockeye salmon were counted each of those trips. The sockeye count increased in early October, after which no more trips to the lake were possible, so we were unable to determine the peak spawning period. In 2001, with similar difficulties in access to Gut Bay Lake, the highest sockeye count was on the last trip, in late October. Although there is concern about the apparent very small sockeye escapement into Gut Bay Lake, efforts to estimate escapement so far have been unsuccessful. If additional funds become available, placing a weir on the Gut Bay outlet stream on near the mouth would allow us to get an estimate of escapement to determine the magnitude of this run compared to the visual counts. This would also alleviate the need to fly into the lake, which is a safety concern due to the weather, winds and small lake surface area.

The age composition of the Falls Lake 2002 escapement was distributed between age-1.2 (45% of sample), age-2.2 (23%), age-2.3 (20%), and age-1.3 (11%), a strong shift away from the dominant age-1.3 class (89% of sample) in 2001. This represents relatively strong returns from the 1996 brood year in 2001, and moderate returns from the 1998 brood year in 2002. In 1982-89 Falls Lake sockeye escapements alternated between age-1.2 and age-1.3 dominant classes, but in 1984 and 1985, age-2.3 was the dominant class. The sockeye escapement at Kutlaku Lake was dominated by the age-1.2 class, at 75% of sampled fish. Sockeye escapements in Kutlaku Lake have been sampled for age, length, and sex in all but two years since 1982. During this time period, the run alternated between age-1.2 and age-1.3 dominant classes (Appendix A.2). Sockeye salmon with 2 freshwater years represented a very small proportion of the escapement in all years of sampling at Kutlaku Lake. In some years, the samples contained very high proportions of jacks (e.g. 74% in 1990), but this may be a sampling artifact (M. Olsen ADF&G,

personal communication 2003). Sample sizes for age and length determination were low in both lakes, well below the goal of 600. At Falls Lake, the designated sampling rate of 50% at the weir was too low to get a full sample, given the very small run; however, samples were evenly distributed throughout the run and probably represent the escapement reasonably well. At Kutlaku Lake, most of the samples came from fish caught in mark-recapture samples, whose total numbers were less than 600, and these fish were exclusively those spawning in the inlet stream. Some additional samples were taken late in the season from some of the shoreline spawning areas, but given the small overall sample size and the uneven distribution of samples among all the spawning groups in the lake, the results should be interpreted cautiously.

However, the total hydroacoustic target estimates met our objective for precision in Sitkoh and Kook Lakes, and because only sockeye fry were present in the Kook Lake tow net samples, the total target estimate can be assumed to be a good estimate of sockeye fry. Sockeye fry sampling was completed in all three lakes in 2002. Because of the highly clumped distribution of fry in the lakes, we were unable to make formal estimates of species apportionment. However, the total hydroacoustic target estimates for Gut Bay Lake met our objective for precision, while those for Falls and Kutlaku Lakes fell slightly outside our objective, both having cv's of 11%. For Kutlaku Lake, larger trawl sample sizes, and the fact that 98% of these samples were sockeye fry, indicate that the total sockeye fry estimate is probably similar in size and precision to the total target estimate. In fry densities, Gut Bay and Kutlaku Lakes ranked among the highest of those lakes sampled in Southeast Alaska in 2002, while Falls Lake ranked among the lowest (Table 32). The estimates for 2002 are not directly comparable with the 2001 estimates, because we reviewed and changed the sampling design in 2002, to use replicate transects within each lake section instead of a repeated measure on the same transect. Nevertheless, sockeye fry densities in all three lakes retained approximately the same relative positions compared with other sockeye-producing lakes sampled in 2001 and 2002 (Conitz et al. 2002; Conitz and Cartwright 2002).

With the exception of Kutlaku Lake, the trawl sample sizes were very low. Small sample sizes, combined with clumped distribution of fry in the lake, made it impossible to obtain reliable estimates of species apportionment, particularly in Falls Lake. No age-1 fry appeared in the samples from Falls or Gut Bay Lake, and there were just four age-1 fry in a sample of 163 fish from Kutlaku Lake. The trawl gear is known to select against older fry. In Falls and Kutlaku Lakes, adult sockeye salmon with two freshwater years were present in significant proportions in the escapement samples. Smolt age distributions at Falls Lake are probably more representative of the true age distribution of juveniles, because the in-stream fyke net used to sample them does not have the selection bias against the older and larger fish that the tow net has. Among the three lakes, Falls Lake appeared to have the highest proportion (40%) of sticklebacks, a potential competitor with sockeye fry for zooplankton prey. Age-0 fry from Kutlaku Lake had the highest average weight, at over 1.0 g, and those from Gut Bay Lake had the lowest, at about 0.5 g, a possible indicator of food supply and rearing conditions within each lake.

Table 32. Sockeye fry densities in Southeast Alaska lakes producing important subsistence runs, 2002. Total population estimates of small pelagic fish were based on hydroacoustic surveys of each lake, and sockeye populations were estimated from the proportions of sockeye fry in tow net samples. Fry density estimates are the total sockeye population divided by the estimated surface area for each lake.

Lake	Date Sampled	Fry·100 m^{-2}
Hetta	Jul 18	44
Gut	Aug 23	25
Kutlaku	Aug 9	25
Klag	Aug 25	24
Luck	Jul 22	23
Chilkoot	Oct 9	20
Hoktaheen	Oct 13	18
Salmon (Sitka)	Aug 22	12
Sitkoh	Aug 13	11
Salmon Bay	Sep 22	4
Klawock	Jul 17	4
Chilkat	Oct 10	3
Kanalku	Aug 10	3
Klawock II	Oct 2	3
Kook	Aug 11	2
Virginia	Sep 20	2
Falls	Aug 24	2
Mahoney	Aug 1	0

Smolt sampling at Falls Lake provides some additional information on rearing habitat productivity. The strong dominance of age-1 smolt (87% of aged samples) contrasted with sampling results from 1981-1982, when age-2 smolt were dominant (72% average, 1981-85). Better growth during the first year may account, at least in part, for the difference. The average weights of age-1 and age-2 smolt sampled in 2002 were higher than in samples from 1981-85. Average weight of age-1 smolt in 2002 was 3.0 g, compared with the 2.6 g average for 1981-85, and average weight of age-2 smolt in 2002 was 4.1 g, compared with the 3.4 g average for 1981-85. The 2002 average weights were also higher than those in any single year from 1981-85 except 1984, which followed the first year of lake fertilization (Conitz et al. 2002). Some ecological characteristics in Falls Lake may have changed since the 1980s. Sockeye fry density was lower, at 2 fry·100 m^{-2} in 2002, than in 1983-85, when the estimates were 4, 13, and 7 fry ·100 m^{-2}, respectively. The euphotic zone depth in 2002 was deeper by 1.5 m than the average depth of 8.8 m from 1981-85. Lake temperature profiles appear to be similar. Overall zooplankton abundance and biomass remained similar to what they were between 1981-86, but the *Daphnia* population appears to have decreased substantially. Average seasonal mean *Daphnia* biomass from 1981-86 was 4.0 mg·m^{-2}, compared with the 2002 seasonal mean biomass of about 0.7 mg·m^{-2}. Similarly, average seasonal mean density of *Daphnia* was 1,700·m^{-2}, compared with the 2002 seasonal mean density of about 300·m^{-2}. With very limited historical data on juvenile sockeye populations and ecology characteristics, it is difficult to draw any conclusions about trends in juvenile growth and production. However, Falls Lake smolt weights are below an average smolt weight of 3.9 g (std. error 0.4) obtained from nine organically stained

lakes in Alaska over a total of 34 lake years (Edmundson and Mazumder 2001). Smolt weights at Falls Lake are also lower than those in Klawock Lake (Lewis and Cartwright 2003).

Zooplankton sampling in both Falls and Gut Bay Lakes revealed very low prey populations for sockeye fry. The total seasonal mean zooplankton biomass in these two lakes was among the lowest of 15 Southeast Alaska sockeye rearing lakes sampled in 2002 (Table 30). These zooplankton biomass levels (29 $mg \cdot m^{-2}$ in Falls Lake and 21 $mg \cdot m^{-2}$ in Gut Bay Lake) are well below a possible starvation threshold of 100 $mg \cdot m^{-2}$ for typical Alaska sockeye rearing lakes (Edmundson and Mazumder 2001). An even more important measure of prey availability in sockeye rearing lakes may be abundance and biomass of the cladoceran *Daphnia* sp., which is preferred by sockeye fry due to its larger body size and slower movement (A. Mazumder University of Victoria, personal communication 2002). While each lake had some *Daphnia*, both the mean *Daphnia* biomass and its percentage of species composition were very low in each lake compared with other Southeast Alaska lakes sampled in 2002 (Table 33), and average body sizes were small. By contrast, total seasonal mean zooplankton biomass in Kutlaku Lake was moderate, although still below the median of the 15 lakes sampled (Table 30). A healthy proportion of the species composition, about 27% overall, was *Daphnia*, but individual body sizes were small, averaging only about 0.5 mm. The smaller size could be a response to heavy predation.

Table 33. Comparison of zooplankton biomass in 2002 between 15 sockeye rearing lakes in Southeast Alaska that produce important subsistence runs. Biomass was estimated from body length measurements and numbers of individuals in a sample expanded to number per m^2 of lake surface area; seasonal mean biomass was the mean of four samples taken between May and October, 2002, at two sampling stations per lake.

Lake	**Seasonal Mean Biomass, All Species ($mg \cdot m^{-2}$)**	***Daphnia* as % of Total Biomass**
Hoktaheen	618	3
Sitkoh	569	33
Neva	476	75
Tumakof	454	0
Kanalku	419	33
Luck	312	6
Kook	311	16
Klag	222	2
Salmon Bay	195	8
Kutlaku	130	27
Thoms	119	6
Hetta	47	10
Falls	29	2
Gut Bay	21	6
Pavlof	1	5

The very low numbers of both sockeye fry and their prey in Falls Lake suggest an unproductive system. The system could be limited by light and temperature, since the lake is surrounded by

high mountains and does not receive full irradiance during all daylight hours, even in mid-summer. The possibility of nutrient limitation was discussed in the Falls Lake pre-fertilization study and was the basis for the fertilization program there from 1983-85 (Koenings et al. 1983). Limnology data from the pre-fertilization and fertilization studies need to be thoroughly analyzed and compared with current data, as well as data from other Alaskan lakes, to gain a better understanding of habitat conditions within this lake. The low zooplankton populations in Gut Bay Lake could be a result of heavy predation by the apparently large sockeye fry population. However, evidence of a large sockeye salmon population in this lake is not supported by what little escapement and harvest data we have. If this lake does indeed produce a very large juvenile sockeye population, then either we have so far been unable to observe most of the harvest or escapement that occurs, or there is a very high fry-to-adult mortality rate in this population. Kutlaku Lake appears to be more typical of other small, island-based sockeye systems in Southeast Alaska. It is moderately productive and supports a healthy sockeye population as well as several other salmonid species. Although two years' worth of data do not provide conclusive evidence, they suggest an adequate food supply for juvenile sockeye salmon, with normal response by the zooplankton population to this predation.

The relationship between sockeye harvest and escapement at Falls Lake, in both numbers and timing, continues to be a matter of concern to both subsistence users and biologists, based on data from two seasons. Collecting harvest and escapement data for a longer period of consecutive years will be very important to establish this relationship and develop sustainable harvest levels and escapement goals. Sockeye salmon runs into Kutlaku Lake appear, with only one full year of supporting data, to be healthy, and although harvest data was not collected, anecdotal information and permit data suggest that these runs are not heavily fished. The amount of information we have been able to collect about sockeye harvest and escapement at Gut Bay Lake, to date, has been insufficient to draw even speculative conclusions. The high sockeye fry abundance in Gut Bay Lake remains a puzzle in relation to very small numbers of returning adults observed in harvest and visual survey data.

Data collection in these systems needs to be extended over a 5-10 year time period to provide fisheries managers with the quantitative information they need to set escapement goals and ensure that these important salmon resources continue to provide sustainable fishing opportunities into the future. Given the possible conservation concerns expressed by residents of Kake and ADF&G fishery managers, and the actions taken by the federal Regional Advisory Council and Subsistence Board, it is critical to continue to accurately document sockeye escapements and related information in these systems.

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APPENDICES

Appendix A. Sockeye adult escapement, limnology, and sockeye fry data collected at Kutlaku Lake prior to 2002.

Appendix A.1. Peak counts from visual surveys at Kutlaku Lake and mouth of outlet stream, 1955-1999 (ADF&G database).

Year	Date	Sockeye Peak Count	No. Surveys	Survey Type
1955	07/17	150	4	FOOT
1957	07/16	200	4	FOOT
1958	07/12	2,000	8	
-	-	-	-	-
1960	08/29	4,000	2	AERIAL
1961	08/25	2,500	2	AERIAL
1962	08/29	2,000	2	AERIAL
1965	09/09	700	1	HELICOPTER
1966	09/01	600	1	HELICOPTER
1967	08/14	5,000	2	AERIAL
1967	08/16	5,000	2	AERIAL
1968	08/27	2,000	1	AERIAL
1971	08/30	500	1	HELICOPTER
1972	08/09	500	3	AERIAL
1973	07/25	3,000	4	AERIAL
1974	09/14	3,000	4	AERIAL
1975	08/29	200	3	AERIAL
1976	08/24	80	1	AERIAL
1977	07/19	350	2	AERIAL
1978	09/06	70	2	AERIAL
1980	09/17	700	2	AERIAL
1981	07/13	80	1	AERIAL
1982	09/21	750	4	FOOT
1983	09/08	1,535	2	FOOT
1984	09/01	1,400	1	FOOT
1985	09/08	2,260	2	BOAT
1986	08/25	450	4	AERIAL
1987	09/01	1,575	4	FOOT
1988	09/08	1,000	6	FOOT
1989	07/26	1,200	5	AERIAL
1990	07/24	900	3	AERIAL
1992	09/04	1,830	4	FOOT
1993	08/30	1,800	3	AERIAL
1994	09/03	1,200	2	FOOT
1995	08/15	885	1	FOOT
1998	08/18	200	1	AERIAL
1999	09/13	2,000	1	FOOT

Appendix A.2a. Summary of historical age compositions of adult sockeye salmon sampled in the Kutlaku Lake escapements from 1982-2001, by return year.

	% of Sample by Age Class											
Return year	**0.1**	**0.2**	**0.3**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**2.1**	**2.2**	**2.3**	**Sample size**
1982	0	0	0	10.5	38.1	48.5	0	0.3	0.3	1.2	1.2	344
1983	0	0	0	12.9	28.4	56.1	0.2	0	0.4	1.3	0.7	458
1984	0	0.2	0.2	20.9	54.1	24	0	0	0.4	0	0.2	492
1985	0	0	0	21.1	41.4	33.2	0	0	2.2	2.2	0	413
1986	0	0	0	1.4	48.3	43.9	0.2	0	0.2	5.7	0.2	424
1987	0.2	0	0	14.6	18.1	64.7	0	0.2	0.4	0.2	1.6	493
1988	0	0	0	2.9	70.7	25.7	0	0	0	0.7	0	276
1989	0	0	0	15.8	34.5	46.8	0	0	0	2.3	0.6	171
1990 - 1992	0	0	0	74.1	11.3	10.9	0.2	0	0.8	0.8	1.9	478
1992 - 1994	0	0	0	4.3	23.6	70.3	0	0	0.2	0.9	0.7	539
1994	0	0	0	35	4.9	57.4	0	0	1.3	1.5	0	551
1995	0	0	0	0	14.6	77.4	2.2	0	0.7	0.7	4.4	137
1996	0	0	0	2.4	32.5	59	0	0	0.7	3.3	2.2	459
1997	0	0	0	7.2	35.7	53.3	0	0	0.2	2.5	1.1	552
1998	0	0	0	2.3	43.2	39.2	0	0	6.3	2.3	6.8	176
1999	0	0	0	0.2	7.4	71.7	0	0	1.1	15.4	4.2	527
2000	0	0	0	5	43.3	21.4	0	0	1.7	16.4	12.2	238
2001	0	0	0	25.9	9	43.4	0	0	0.9	5.8	15	433
Average	0	0	0	15.4	30.9	46.5	0.1	0	0.8	3.6	2.6	
Se	0	0	0	0.4	0.5	0.6	0	0	0.1	0.2	0.2	

Appendix A.2b. Summary of historical length compositions of adult sockeye salmon sampled in the Kutlaku Lake escapements from 1982-2001.

	Average Length (mm) by Age Class											
Return year	**0.1**	**0.2**	**0.3**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**2.1**	**2.2**	**2.3**	**Sample size**
1982	0	0	0	306	458	525	0	482	318	465	523	343
1983	0	0	0	317	451	523	550	0	315	475	515	458
1984	0	445	530	331	453	523	0	0	370	0	500	484
1985	0	0	0	332	460	519	0	0	331	463	0	408
1986	0	0	0	322	471	541	510	0	365	473	535	423
1987	320	0	0	339	457	542	0	550	357	505	540	493
1988	0	0	0	364	465	528	0	0	0	460	0	274
1989	0	0	0	317	461	513	0	0	0	473	530	171
1990	0	0	0	313	454	530	555	0	328	467	534	478
	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	343	464	515	0	0	414	464	498	539
	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	330	452	510	0	0	337	438	0	551
1995	0	0	0	0	478	532	546	0	362	462	525	137
1996	0	0	0	341	488	537	0	0	316	477	524	458
1997	0	0	0	344	500	536	0	0	361	485	533	549
1998	0	0	0	366	450	519	0	0	352	481	521	174
1999	0	0	0	325	464	519	0	0	347	472	525	526
2000	0	0	0	324	473	557	0	0	348	493	556	238
2001	0	0	0	326	451	521	0	0	355	468	521	432
Average	320	445	530	325	466	526	542	516	344	474	527	
Se	0	0	0	0.7	0.7	0.4	11.2	34	3.6	1.9	1.8	

Appendix A.3. Temperature, and dissolved oxygen profiles in October for Kutlaku Lake, 2001.

	2 Oct.	
Depth (m)	**Temp (^{o}C)**	**DO (%)**
0.1		
0.5		
1.0	9.8	97.6
2.0	9.8	97.1
3.0	9.8	99.5
4.0	9.8	99.8
5.0	9.8	97.7
6.0	9.7	96.7
7.0	9.7	96.2
8.0	9.6	96.2
9.0	9.6	96.1
10.0	9.6	95.7
12.0	9.5	95.1
14.0	9.3	92.5
16.0	9.2	90.3
18.0	9.1	88.6
20.0	9.0	85.2

Appendix A.4. Species distributions of macro-zooplankton in Kutlaku Lake, 2001. Zooplankton densities (number · m^{-2}) and mean weighted biomass (mg · m^{-2}) are seasonal mean values from two samples, collected on 14 June and 2 Oct., at two permanent sampling stations. Ovigorous (egg-bearing) individuals in dominant taxon were enumerated separately.

Station A	**Density (no. · m^{-2})**	**Percent of Total Numbers**	**Weighted Biomass (mg · m^{-2})**	**Percent of Total Biomass**
Diaptomus	0			
Cyclops	1,087	0.92%	1	0.6%
Bosmina	45,305	38.28%	38	19.6%
Ovig. Bosmina	34,879	29.47%	32	16.3%
Daphnia l.	6,708	5.67%	11	5.6%
Ovig. Daphnia l.	221	0.19%	0.45	0.2%
Holopedium	19,630	16.59%	57	29.2%
Ovig. Holopedium	8,151	6.89%	56	28.5%
Copepod nauplii	2,361	1.99%		0.0%
Total	118,340		195	
Station B				
Diaptomus	0			
Cyclops	4,585	3.94%	4	2.6%
Bosmina	47,249	40.61%	37	23.7%
Ovig. Bosmina	15,092	12.97%	15	9.4%
Daphnia l.	20,059	17.24%	34	21.4%
Ovig. Daphnia l.	2,038	1.75%	4	2.5%
Holopedium	14,391	12.37%	38	24.2%
Ovig. Holopedium	3,248	2.79%	26	16.3%
Copepod nauplii	9,679	8.32%		
Total	116,339		158	

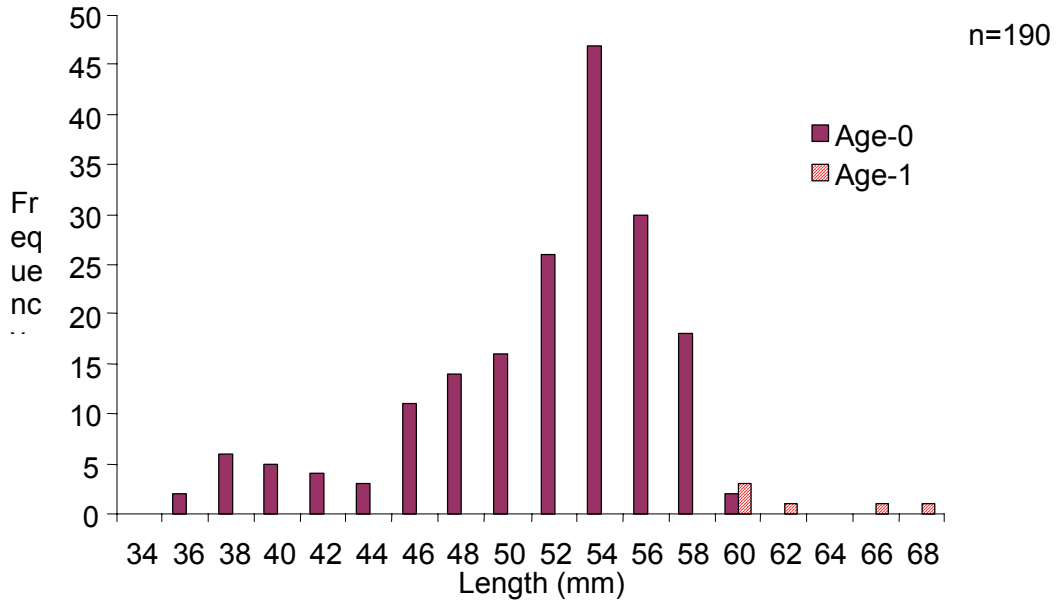
Appendix A.5. Zooplankton density by species and sampling date in Kutlaku Lake, 2001.

	Macrozooplankton Density ($no \cdot m^{-2}$)		Seasonal Mean ($no \cdot m^{-2}$)
Station A	**14-Jun**	**2-Oct**	
Diaptomus			0
Cyclops	340	1,834	1,087
Bosmina	14,603	76,006	45,305
Ovig. Bosmina	6,283	63,474	34,879
Daphnia l.	3,736	9,679	6,708
Ovig. Daphnia l.	340	102	221
Holopedium	39,056	204	19,630
Ovig. Holopedium	16,302	0	8,151
Copepod nauplii	2,887	1,834	2,361
Total			118,340
Station B			
Diaptomus			0
Cyclops	1,019	8,151	4,585
Bosmina	22,797	71,701	47,249
Ovig. Bosmina	9,679	20,504	15,092
Daphnia l.	891	39,226	20,059
Ovig. Daphnia l.	127	3,948	2,038
Holopedium	28,782		14,391
Ovig. Holopedium	6,495		3,248
Copepod nauplii	3,566	15,792	9,679
Total			116,339

Appendix A.6. Zooplankton size by sampling date and biomass in Kutlaku Lake, 2001.

	Body Size (mm)		Seasonal Means			
	Jun 14	**Oct 2**	**Mean Length (mm)**	**Weighted Length (mm)**	**Biomass ($mg \cdot m^{-2}$)**	**Weighted Biomass ($mg \cdot m^{-2}$)**
Station A						
Diaptomus						
Cyclops	0.58	0.59	0.59	0.59	1	1
Bosmina	0.29	0.31	0.30	0.31	36	38
Ovig. Bosmina	0.40	0.31	0.36	0.32	40	32
Daphnia l.	0.64	0.61	0.63	0.62	11	11
Ovig. Daphnia l.	0.68	0.72	0.70	0.69	0.47	0.45
Daphnia g.						
Holopedium	0.57	0.68	0.63	0.57	71	57
Ovig. Holopedium	0.81	0.92	0.87	0.81	65	56
Copepod nauplii						
				Total	226	195
Station B						
Diaptomus						
Cyclops	0.56	0.52	0.54	0.52	4	4
Bosmina	0.32	0.29	0.31	0.30	39	37
Ovig. Bosmina	0.39	0.30	0.35	0.33	16	15
Daphnia l.	0.56	0.63	0.60	0.63	30	34
Ovig. Daphnia l.	0.73	0.67	0.70	0.67	4	4
Daphnia g.						
Holopedium	0.55		0.55	0.55	38	38
Ovig. Holopedium	0.86		0.86	0.86	26	26
Copepod nauplii						
				Total	158	158

Appendix A.7. Sockeye salmon fry length distributions by age class in samples taken from Kutlaku Lake, Aug. 2001.



Appendix B. Daily and cumulative counts of adult salmon at Falls Lake weir/trap and associated water levels and water and air temperatures for 2002.

	Sockeye Salmon		Coho Salmon*		Physical Data		
Date	Daily	Cumulative	Daily	Cumulative	Water level (m)	Water temp (^oC)	Air temp (^oC)
20-Jun	weir complete and functioning as of June 21				0.27		
21-Jun	0	0	0	0	0.28	12.0	
22-Jun	0	0	0	0	0.27	11.0	
23-Jun	0	0	0	0	0.30	13.0	
24-Jun	0	0	0	0	0.43	11.5	
25-Jun	0	0	0	0	0.64	9.0	
26-Jun	0	0	0	0	0.41		
27-Jun	0	0	0	0	0.40	10.0	
28-Jun	0	0	0	0	0.35	10.5	
29-Jun	0	0	0	0	0.00	11.0	
30-Jun	0	0	0	0	0.30	11.5	
1-Jul	0	0	0	0	0.39	10.0	
2-Jul	0	0	0	0	0.33	10.0	
3-Jul	0	0	0	0	0.29	9.3	
4-Jul	0	0	0	0	0.27	10.5	
5-Jul	0	0	0	0	0.28	12.0	
6-Jul	0	0	0	0	0.27	11.0	
7-Jul	0	0	0	0	0.26	12.0	
8-Jul	0	0	0	0	0.26	10.5	
9-Jul	0	0	0	0	0.26	12.0	
10-Jul	0	0	0	0	0.30	13.0	
11-Jul	0	0	0	0	0.30	13.0	
12-Jul	0	0	0	0	0.28	13.5	
13-Jul	1	1	0	0	0.27	13.5	
14-Jul	0	1	0	0	0.27	12.5	
15-Jul	0	1	0	0	0.27	13.0	13.0
16-Jul	9	10	0	0	0.30	13.0	12.0
17-Jul	14	24	0	0	0.44	12.0	12.0
18-Jul	1	25	0	0	0.38	11.5	12.0
19-Jul	0	25	0	0	0.30	13.0	13.0
20-Jul	0	25	0	0	0.27	12.0	12.0
21-Jul	0	25	0	0	0.26	12.0	13.0
22-Jul	2	27	0	0	0.29	11.5	12.5
23-Jul	8	35	0	0	0.30	12.0	12.5
24-Jul	8	43	0	0	0.35	13.5	15.0
25-Jul	9	52	0	0	0.30	13.0	13.5
26-Jul	17	69	0	0	0.28	12.5	13.5
27-Jul	25	94	0	0	0.25	13.5	14.0
28-Jul	58	152	0	0	0.27	13.0	13.0
29-Jul	38	190	0	0	0.25	13.0	13.5
30-Jul	16	206	0	0	0.23	13.0	13.5
31-Jul	8	214	0	0	0.22	13.5	13.0
1-Aug	14	228	0	0	0.22	13.0	15.0
2-Aug	27	255	0	0	0.22	14.0	17.5
3-Aug	6	261	0	0	0.22	13.0	15.0
4-Aug	19	280	0	0	0.21	14.5	17.0
5-Aug	59	339	1	1	0.20	15.0	12.0
6-Aug	104	443	0	1	0.21	16.0	14.5
7-Aug	22	465	0	1	0.25	13.0	14.0
8-Aug	53	518	14	15	0.38	13.4	14.0

Appendix B. Page 2 of 2

	Sockeye Salmon		Coho Salmon*		Physical Data		
Date	Daily	Cumulative	Daily	Cumulative	Water level (m)	Water temp (^{o}C)	Air temp (^{o}C)
9-Aug	50	568	5	20	0.36	13.5	13.5
10-Aug	45	613	7	27	0.30	13.0	13.5
11-Aug	29	642	4	31	0.29	13.5	13.0
12-Aug	12	654	3	34	0.30	14.0	14.0
13-Aug	22	676	16	50	0.49	12.0	13.0
14-Aug	19	695	10	60	0.32	13.0	13.0
15-Aug	23	718	13	73	0.28	13.5	14.0
16-Aug	5	723	3	76	0.27	13.5	14.0
17-Aug	9	732	2	78	0.24	13.0	11.0
18-Aug	3	735	1	79	0.20	13.5	14.0
19-Aug	2	737	0	79	0.20	13.5	13.0
20-Aug	2	739	0	79	0.18	13.8	13.0
21-Aug	6	745	6	85	0.31	13.0	13.5
22-Aug	8	753	17	102	0.39	13.5	13.0
23-Aug	3	756	12	114	0.47	12.0	13.0
24-Aug	5	761	13	127	0.35	12.5	11.0
25-Aug	0	761	0	127	0.55	11.5	11.0
26-Aug	3	764	5	132	0.48	11.0	12.0
27-Aug	2	766	15	147	0.42	12.0	13.5
28-Aug	4	770	0	147	0.48	11.5	13.0
29-Aug	3	773	11	158	0.30	12.0	12.0
30-Aug	1	774	9	167	0.30	12.5	13.0
31-Aug	weir opened 31 Aug. and removed						

*Other species: pink salmon – 2 (1 on 8/14, 1 on 8/15); Dolly Varden char – 4 (1 on 7/25, 1 on 8/14, 1 on 8/15)

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