Biological Assessment and Monitoring of Anadromous Fish at Summer Bay Lake, Unalaska Island, Alaska, 1999: Juvenile and Adult Fish Production Two Years Following the *M/V Kuroshima* Oil Spill

By

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ABSTRACT

Fisheries studies continued at Summer Bay Lake, Dutch Harbor, Alaska in 1999, to monitor fishery production trends that may be influenced by the *M/V Kuroshima* oil spill. These studies included: 1) monitoring the abundance, size, and age of emigrating juvenile sockeye *Oncorhynchus nerka*, pink *O. gorbuscha*, and coho *O. kisutch* salmon and abundance of Dolly Varden char *Salvelinus malma*, and other anadromous species and 2) determining the adult salmon and Dolly Varden escapement into Summer Bay Lake. In addition, salmon escapement age structure and size were assessed.

At least 5,468 age 0. pink salmon fry emigrated from 30 May through 9 September and the peak emigration occurring on 5 June. Of 46,268 sockeye salmon smolt that emigrated, 29,585 (63.9%) were age 1. and 16,688 (36.1%) were age 2. fish. The majority (80.2%) of the sockeye smolt emigrated in July. Only 1,980 coho salmon smolt emigrated in 1999, of which 15.9% (314 fish) were age 1. and 82.5% (1,634 fish) were age 2. Dolly Varden (2,091 fish) emigrated throughout the summer; however, most emigrated in June.

Adult escapements through 9 September into Summer Bay Lake included: 3,375 sockeye, 20 coho, and 2,250 pink salmon, and 1,636 Dolly Varden. Peak escapements occurred for sockeye salmon on 4 July (392), for coho salmon on 9 September (4), and pink salmon on 29 August (279), and for Dolly Varden on 31 July (182). The majority of the sockeye salmon were ages 1.2 (21.1%) and 1.3 (65.7%). The average size of adult sockeye salmon was 530 mm and the sex ratio was 53.9% female: 46.1% male. Sockeye salmon were distributed throughout the shoal areas of Summer Bay Lake in July, with some entering the main inlet tributary from mid to late August. The majority of sockeye salmon appear to spawn in shoal areas on the west side of the lake. Pink salmon entered the inlet tributary in late August through early September with peak numbers observed on 5 September. The majority of the pink salmon spawned in the inlet tributary; none were observed utilizing shoal areas of the lake.

The wide distribution and the characteristics of the oil spilled in Summer Bay Lake and the early freshwater life histories of endemic fish suggest a high probability of direct exposure to hydrocarbons, as well as a potential for indirect impacts to primary and secondary producers. There are sufficient similarities to the *Exxon Valdez* oil spill (EVOS) and other spills in subarctic climates that relevant research should be considered when assessing damage to Summer Bay Lake. The impacts of the *M/V Kuroshima* oil spill on Summer Bay Lake fish will not be known until several years of additional juvenile and adult production data are collected to provide brood year survival information.

INTRODUCTION

On November 26, 1997, the *M/V Kuroshima* went aground in Summer Bay just outside the city of Unalaska/Dutch Harbor (Figure 1), spilling approximately 39,000 gallons of heavy bunker C fuel oil (Group V oil) into the water (Appendix A). Storm conditions, along with high tides, washed oil onto the coastline and eventually into Summer Bay Lake.

Identifying the source of the petroleum relies on special chemical characteristics of the spilled oil to distinguish it from other potential sources in the area of the spill and from background hydrocarbons (Stein et al. 1998). Determining the environmental fate of petroleum is dependent on a number of factors, such as the type of petroleum, weather, oceanographic conditions, and the geography of the spill site.

Group V fuel oils (bunker fuel) have an API gravity less than 10° at 60°F, meaning that the specific gravity is less than or equal to 1.00 mg/l, the same as fresh water (NOAA 1994). There is no clear break in the Group V fuel oil properties at an API = 10°. Group V oils pose significantly greater risks to natural resources compared to floating oil spills because the oil can float, be neutrally buoyant, or sink in water, depending on the properties of the specific oil and the salinity of the receiving waters. Group V fuel oils are different from other types of Group V oils, such as asphalt, asphalt cutter stock, and very heavy crude oils. Group V fuel oils are also likely to be chemically different than conventional crude oils, because of market-driven changes in source and production. Spilled oil may separate into components that can float, suspend, and sink simultaneously, depending upon chemical properties. Group V fuel oil is much more likely to sink in freshwater due to the incorporation of sand. If only the water-soluble fraction of the oil is considered, bunker fuel is rated as toxic as diesel (Markarian et al. 1993). Thus, even though heavy residual oils (bunker fuel) are not usually considered to be acutely toxic to fish, spills that mix into the water column without first weathering (by evaporation) on the water surface may increase the amount of oil that dissolves and may promote acute toxicity to fish.

Several factors need to be considered to determine the deleterious effects on natural resources from an oil spill. These include identification of which species are at risk of elevated exposure; which species present are reproductively active or present in sensitive larval or juvenile stages; and which species near an oil spill have populations that are depleted (Stein et al. 1998). The primary emphasis of the investigation of ecological effects is on determining the exposure of natural resources to and the toxic effects from the petroleum. The exposure of fish to aromatic hydrocarbons can result in a variety of adverse biological effects, many of which are associated with formation of reactive metabolites that exert their toxicity by binding to cellular macromolecules (Varanasi et al. 1989).

Crude oil contamination in Prince William Sound (PWS) from the *Exxon Valdez* Oil Spill (EVOS) resulted in sub lethal effects to herring and salmon stocks (Hose et al. 1996; Weidmer et al. 1996; Marty et al. 1997). Adult and juvenile pink salmon (*Oncorhynchus gorbuscha*) were vulnerable to oil exposure due to their extensive use of intertidal spawning areas and nearshore marine rearing areas, respectively (Bue et al. 1998). Pink salmon embryo mortality was significantly greater in oiled versus reference streams (Bue et al. 1996; 1998) and similar results were observed in laboratory tests (Heintz et al. 1995; Marty et al. 1997). Observations of polynuclear aromatic hydrocarbons (PAH) concentrations in PWS pink salmon stream sediments were consistent with the minimum concentrations required to impart both short and long-term damage in the laboratory (Heintz et al. 1995). Development of pink salmon incubating in gravel contaminated with weathered Prudhoe Bay crude oil was retarded at concentrations as low as 55.1 ug oil/g gravel, and several other oil-related changes were indicative of premature emergence (Marty et al. 1997). In addition, past research indicated that pink salmon embryos absorb PAHs (Moles et al. 1987) and that these compounds were capable of inducing chromosomal lesions (McBee and Bickham 1988) and influence endocrine function (Thomas and Budiantara 1995). Potentially, this genetic or physiological damage to one brood year would be expressed two years later in pink salmon since they have two genetically isolated lineages (odd and even years; Heard 1991).

There has been very little research on anadromous fish in the Alaska Peninsula or Aleutian Islands, with the exception of escapement and harvest estimates. The earliest commercial harvest records for the Alaska Peninsula date back to 1906 and 1911 in the Aleutian Islands Management Area (Shaul and Dinnocenzo 2000). There are an estimated 535 salmon systems in the Aleutian Islands Area of which an estimated 75 support sockeye (*O. nerka*) salmon runs and 119 have coho (*O. kisutch*) salmon runs (McCullough *in press*). Nearly all of these systems have pink and/or chum (*O. keta*) salmon runs.

Several lakes on the Alaska Peninsula in the vicinity of Cold Bay were recently evaluated for potential sockeye salmon production or rearing capacity using limnological characteristics (Kyle et al. 1993). The limnology of these lakes as a group was unique in terms of sockeye salmon habitat in that some were very shallow, brackish or saline, and the zooplankton community was dominated by various marine taxa. Research was expanded in 1993 through 1995 to other watersheds that support salmon on the Alaska Peninsula and Aleutian area, including Summer Bay Lake on Unalaska Island (Honnold et al. 1996).

Summer Bay Lake is located on the northwest side of Unalaska Island, approximately 6.8 km northeast of the city of Unalaska (Figure 1). The lake drains into Summer Bay (part of the larger Unalaska Bay) by way of Summer Bay Lake Creek. Other than low sockeye salmon escapements (450 average from 1986-1995) little was known about juvenile and adult fishery production limitations prior to recent research (Honnold et al. 1996). The lake was identified as oligotrophic (nutrient poor) and indicated rearing habitat limitations. Modeling of the lake's surface area estimated potential sockeye salmon production to be 1,100 fish. Low zooplankton biomass suggested that the lake was a poor candidate for fry stocking. Presmolt stocking in late fall was recommended as a suitable stocking strategy. Although phosphorous and chlorophyll were somewhat deficient, levels were not within the established criteria for lake enrichment (Honnold et al. 1996). A suitable hatchery fry or presmolt delivery system for sockeye and/or coho salmon did not exist and the recommendations for enhancement were not implemented. Further baseline limnology data were not collected after 1994 at Summer Bay Lake and baseline fishery data were limited to aerial survey indices of pink and sockeye salmon escapements.

Several fishery investigations were initiated in 1998 at the Summer Bay Lake system by the lead federal administrative trustee, the National Atmospheric and Oceanic Administration (NOAA).

Various federal and state agencies and local native groups proposed investigations to determine the effects of the *M/V Kuroshima* oil spill on the surrounding environment. NOAA proposed that funding for these studies would come from the U.S. Coast Guard (USCG) Oil Spill Liability Trust Fund. The Alaska Department of Fish and Game (ADF&G) proposed juvenile and adult salmon enumeration projects to collect baseline data for assessing the status of Summer Bay Lake salmonid productivity (ADF&G 1998). Juvenile salmon migrations from the lake (to the ocean) have not been documented in the past. Juvenile migration and adult escapement data, as well as an improved understanding of the biological attributes of each stock were considered essential to assist with any future restoration planning.

The goal of the project was to assess the abundance and biological attributes of juvenile and adult anadromous fish and to monitor the potential effects of the oil spill at Summer Bay Lake. Project objectives included: (1) estimating the number and timing of juvenile salmon, Dolly Varden char (*Salvelinus malma*), and other fish species emigrating from the lake, (2) estimating the average age composition, size, and condition factor of the sockeye and coho salmon smolt emigration and the average condition of the pink salmon fry emigration, (3) collecting juvenile salmon samples for use in additional analyses as determined by the resource trustees, (4) estimating adult salmon escapement, distribution, and age structure by species, and (5) summarizing all project activities in a written report.

In 1999, the USCG again funded ADF&G Summer Bay Lake juvenile and adult fish studies for assessing potential damage caused by the *M/V Kuroshima* oil spill (Murphy and McCullough 1999). The purpose of this report is to chronicle the 1999 data collection efforts conducted on the Summer Bay Lake system and to assess the 1998 and 1999 fish runs.

Description of Study Area

Summer Bay Lake (53° 53' N. lat., 166° 24' W. long.) is 0.4 km long by 0.25 km wide with a surface area of 0.2 km^2 (Honnold et al. 1996). The mean and maximum depth of the lake is 5.8 m and 11.3 m, respectively. The Summer Bay Lake peak fish counts (live fish) from 1988-1997 aerial and/or foot surveys averaged 311 sockeye salmon, 1,248 pink salmon, and 9 coho salmon (ADF&G database, Kodiak, AK). The pink salmon odd-year and even-year averages were 69 and 1,720 fish, respectively. Escapement estimates of salmon species have been difficult to ascertain on a consistent basis due to limitations associated with aerial survey techniques. Limnological investigations were conducted on the lake in 1994 (Honnold et al. 1996). The estimated production based on the lake's surface area is 1,100 adult sockeye salmon. Fish known to inhabit Summer Bay Lake are sockeye, pink, and coho salmon, Dolly Varden char, threespine stickleback *Gasterosteus aculeatus*, and freshwater sculpin *Cottus aleuticus*. In addition, starry flounder *Platichthys stellatus* have been observed in the lake.

METHODS

Juvenile Fish Assessment and Monitoring

Weir and Trap Description, Installation, and Operation

A juvenile fish trapping system, consisting of a diversion weir and one incline plane trap with attached collection tank, was installed in the Summer Bay Lake outlet stream just below the bridge on 30 May and removed on 10 September (Figure 2). The weir was placed in the river in a "V" shaped configuration with the two wings leading from adjacent stream banks to the incline plane smolt trap positioned in midchannel (Appendix B). A perforated plywood live holding box was anchored downstream of the weir to contain juvenile fish for sampling purposes. An adult salmon holding pen of welded aluminum piping was anchored upstream of the weir to contain fish for sampling purposes.

In 1999, a pipe frame structure was erected (1.5 m legs and 2.4 m cross members of 5 cm diameter pipe and NU-RAIL fittings) to support perforated sheets of aluminum for the weir. Between the perforated sheets and the pipe frame, 5.1 cm by 10.2 cm by 3.1 m lumber was also used to support the perforated sheets. Several ropes were placed from the bridge piling to the smolt trap and frame structure for additional support. The face of the weir was comprised of 1.2 m by 2.4 m sheets of aluminum perforated plate ~3 mm thick with 3 mm diameter holes on 1.1 cm staggered centers. The base of each perforated plate sheet was positioned in the stream bed substrate. Sandbags were installed where the weir met the stream banks and along the entire base of the weir. Sandbags and large rocks were placed behind each frame leg. Polypropylene (lortex) material was used as needed along the ends and base of the weir and the fish trap to prevent fish injury and escapement. The incline plane trap comprised structural aluminum angle framing and cross bracing of the following dimensions: 1.0 m wide by 2.4 m long by 0.8 m high. Thus, the entrance of the trap was 1.0 m by 0.8 m and the base of the inside of the trap (incline portion) tapered for approximately 2.0 m from a height of ~0 m to 0.8 m. A hinged aluminum plate (0.3 m by 1.0 m) was attached downstream of the incline for adjusting the water flow through the trap and the attached fish collection box. The sides and base of the trap were covered with ~3 mm thick aluminum perforated plate with 1 cm diameter holes on 1.1 cm staggered centers.

The weir and trap were monitored at least every two hours from 2200 to 0600 hours and at least every four hours during daylight periods. Monitoring was increased during heavy emigrations. When monitoring the trapping system, the wings of the weir were cleaned of debris and the trap was adjusted to provide optimal flow (measured subjectively, based on the movement of fish) and to minimize mortality. The weir was also cleaned of all oil and oily debris when necessary. When significant oiling of the apparatus occurred, the time, location of oil, amount of oil, and any associated mortality were recorded. The weir, trapping system, and live hold boxes remained in the same location during the entire project.

Emigration Counts

All juvenile salmonids were dip-netted from the inclined plane trap, counted individually and released or placed in the holding box for sampling. In addition, emigrating starry flounder, freshwater sculpin, and threespine stickleback were tallied. A single counting day was the 24-hour period from noon to noon and identified by the calendar date corresponding to the first noon.

The trapping system fished at less that 100% efficiency intermittently during the season because of high water. Missed juvenile emigrations were not estimated because these events were infrequent and did not last long. It was estimated that the trap efficiency was 100% except on 5 and 19 June when the efficiency was 95%, on 8 and 20 June when the efficiency was 98%, and on 23 June between 2000 and 2300 hours when efficiency was 0%.

When the weir was removed on 10 September, adult pink salmon and Dolly Varden were holding downstream of the weir; most of these fish entered the lake within a few hours and their numbers were estimated.

Salmon Age and Size

A portion of captured sockeye and coho salmon smolt were sampled for age-weight-length (AWL) information. Fish were held for sampling in a live box (1.0 m by 1.0 m by 1.0 m) placed in the river below the weir. Approximately 40 sockeye salmon smolt were sampled daily for five days per week. Although AWL data were desired from 40 coho salmon smolt per day for three days per week, the fish were seldom available.

Each AWL sample was taken from a single day's catch. A single sampling day was the 24-hour period from noon to noon, identified by the calendar date corresponding to the first noon. Smolt and fry were anesthetized in a tricaine methanesulfonate (MS-222) solution, measured to the nearest 1.0 millimeter (mm), and weighed to the nearest 0.1 gram (g). The ponderal index (condition coefficient K) was calculated (Bagenal 1978) using:

$$\hat{K} = \frac{W}{L^3} 10^5 \qquad (1)$$

where:
K=smolt condition factor
W=smolt weight in grams (g)
L=smolt length in millimeters (mm)

In addition, a scale smear was taken from the preferred area (INPFC 1963) of each sockeye and coho smolt, placed on a glass slide, and ages were determined using a microfiche projector (Murphy and McCullough 1999). The fish were revived in fresh water and released downstream of the weir.

Salmon Stomach Content Analysis

Thirty sockeye salmon smolt were collected via the incline plane trap and anesthetized with MS-222 to prevent regurgitation of stomach contents. Each fish was measured for length (nearest mm), weight (nearest 0.1 g), and scales collected for age analysis, and frozen whole. Five sockeye salmon smolt were collected 20 June, ten on 25 July, and the remainder on an unknown date. The smolt were thawed in January 2000 and their stomachs removed. Stomachs were visually determined to be either empty, mostly empty, 1/4 full, 1/2 full, or full. Stomach contents were placed in a petri dish and examined under magnification with reflected light. All contents were identified to the lowest possible taxon (McCafferty 1983). The percentage by volume of each taxon per stomach was estimated and pooled by family.

Adult Fish Assessment and Monitoring

Weir Description and Installation

The juvenile fish-trapping configuration dually served as an adult counting weir from 30 May to 10 September when the project was terminated. An adult holding pen was attached to the upstream side of the weir to hold adult fish for sampling.

Weir Operation and Escapement Counts

Immigrating salmonids were counted by species as they passed upstream through the weir. Salmon would not approach the juvenile/adult weir during daylight hours due to shallow water. It was undesirable to open the gate and pass adults at night, because opening the gate would compromise the trapping efficiency for juveniles. Therefore, all adult fish were dip-netted at a schooling hole ~50 feet downstream of the weir and were immediately released upstream of the weir or held in a pen at night, enumerated and sampled for biological information the following day, and released. Due to the relatively small run strength, this was an acceptable procedure for the entire run.

Escapement Age, Size, and Sex Ratio

Age, length, and sex (ALS) data were collected from a portion of the sockeye salmon escapement (Murphy and McCullough 1999). Scales were collected from the preferred area of the fish as outlined in INPFC (1963). Scales were mounted on gum cards and impressions were made on cellulose acetate (Clutter and Whitesel 1956). Methods utilized for age designation followed rules outlined in Koo (1962). Fish ages were classified by examining scales for annual growth using a microfiche reader (Mosher 1968). Age designation followed the European notation where a decimal separates the freshwater age from the saltwater age. Fish lengths were measured from mid-eye to fork-of-tail to the nearest millimeter. Length composition data were summarized by age and sex representing the fish sampled (Nelson and Swanton 1996). Sex was determined by visual examination of morphological characteristics. Sampling was random and distributed throughout the escapement period for each species.

Escapement Distribution

Escapement distribution surveys in the Summer Bay Lake system were conducted from July through November at the primary tributary (inlet) creek, the outlet creek and the lake shoals (Figure 3). Tributary and outlet surveys were conducted on foot by walking upstream until fish were not observed. Surveys were replicated by walking back downstream. Lake shoals were surveyed by walking along the lakeshore. All live and dead adult fish were enumerated by species.

Climatological Measurements

Water temperature (^{0}C), air temperature (^{0}C), cloud cover, ceiling, visibility, wind direction (N-S), wind velocity (kn), and relative stream depth (cm) were measured daily from 31 May to 9 September at Summer Bay Lake Creek. A standard Celsius thermometer was used to measure temperature, a meter rule attached to a bridge piling was used to measure relative stream depth, and a windsock was used to measure wind direction and velocity.

Two Onset StowAwayTM thermographs capable of recording temperatures between –5°C and +37°C were used at the Summer Bay Lake Creek to record air and water temperatures. The thermographs recorded data about every two hours. The thermographs were housed in plastic pipes with numerous holes to allow free passage of air and water. One logger was attached in the shade under the bridge by means of a wire cable to collect air temperatures; the other was attached underwater with cable to a bridge piling to collect water temperatures. Both were installed on 1 June 1999. Rocks were added to the interior of the water temperature pipe so that the entire unit would sink to the streambed. The thermograph data were downloaded in the field using a small shuttle device on 24 June 2000.

RESULTS

Juvenile Salmon Emigration and Run Timing

Near record snowfalls at Dutch Harbor delayed the opening of the Summer Bay road until 24 May and the weir was not installed until 30 May. Due to the late weir installation, sockeye smolt, coho smolt and juveniles, pink salmon juveniles, and Dolly Varden, sculpin, stickleback, and flounder emigrants were immediately captured (Tables 1-3).

Sockeye Salmon

Few sockeye salmon smolt emigrated from Summer Bay Lake, until late June (Table 1; Figure 4A). There was a substantial increase in the emigration during the last week of June, several separate peaks occurred throughout July, and a rapid decline occurred in August. The last observed sockeye salmon smolt to emigrate was on 9 September. A total of 46,268 sockeye smolt and 3,893 juvenile sockeye salmon emigrated (Table 1). In 1999, an additional 3,932 smolt emigrants were counted as compared to 1998 counts (Honnold et al. 1999). The run timing of the

1999 sockeye smolt was similar to the timing observed in 1998 (Figure 4B). Approximately 63.9% (29,585) of the overall sockeye salmon smolt emigration were age 1. fish and 36.1 % (16,688) were age 2. fish (Table 1). Age 2. fish emigrated somewhat earlier than age 1. fish (Figure 5A). The emigration by age class was also noticeable in the 1998 smolt migration (Figure 5B).

Coho Salmon

Only 1,980 coho salmon smolt emigrated from Summer Bay Lake in 1999 (Table 2). More than half emigrated in June (55%) and 34% in July (Figure 6A). The peak emigration was on 29 June (153 fish) and the last observed smolt emigrated on 9 September (Table 2; Figure 6A). The majority (82.5%) of emigrating coho salmon smolt were age 2. fish (1,634); age 1. fish accounted for 15.9% (314) of the emigration. Smolt emigration timing was earlier than in 1998 (Figure 6B; Honnold et al. 1999). In 1999, an additional 1,655 smolt emigrants were counted as compared to 1998 counts (Honnold et al. 1999). Juvenile coho salmon accounted for an additional 547 migrants (Table 2). Emigration timing by age class varied; age 2. fish tended to emigrate somewhat earlier than age 1. fish (Figure 7A). It is possible that the early portion of the coho emigration was missed due to the late project start date in 1999 as compared to 1998 (Figure 7B).

Pink Salmon

Pink salmon fry (age 0.) are normally the first juveniles to emigrate from Summer Bay Lake (Honnold et al. 1999). In 1999, it is likely that the early portion of the run was missed given the relatively large emigration count of 648 fish on 30 May when the weir was first installed (Table 3). The 1999 pink salmon emigration peaked on 5 June (2,424 fry) and none were captured after 6 August (Figure 8A). A total of 5,468 pink salmon fry were counted and most emigrated in early June (Table 3). The run timing of pink fry occurs in the narrowest time period of all emigrating juvenile salmon with most of the run occurring in a two-week period (Figure 8B).

When the weir and fry trap are operating at 100% efficiency it is probably capturing all of the systems emerging pink salmon fry. Although limited pink salmon spawning occurs in the outlet stream (Honnold et al. 1999) fry survival below the weir (Appendix B) is likely nonexistent. Fall storms deposit tons of sand, kelp, and other material into the inlet stream and subsequent storms scour this material out into the bay which appears to annually change the outlet stream channel below the bridge (K. Bouwens, ADF&G, Division of Commercial Fisheries, Kodiak, personal communication).

Dolly Varden, Sculpin, Stickleback, and Flounder Emigration and Run Timing

Dolly Varden

The emigration of Dolly Varden began similarly to pink salmon fry on 30 May (Table 4). Undoubtedly some were missed because the 30 May count, the first day that the weir was installed, totaled 101 fish. Due to the difficulty of distinguishing juvenile from adult Dolly

Varden, all emigrants were combined. The emigration peaked on 7 June (243 fish) but fish were still occasionally exiting the lake on 9 September (Figure 9A). In 1999, 2,091 Dolly Varden were observed emigrating from the lake, about 280 less than in 1998 (Honnold et al. 1999). If the entire 1999 run had been counted the run timing would probably have been similar to the timing observed in 1998 (Figure 9B).

Sculpin

In 1999, 10,059 sculpins emigrated from Summer Bay Lake (Table 3). Similarly to other counts of fish exiting the lake, some were likely missed since in 1998 weir counts on 9 May noted their presence (Honnold et al. 1999). The 1999 emigration peaked on 14 June with 379 fish and the run continued throughout the duration of the project with 19 fish counted on 9 September (Figure 10A). If the entire 1999 run had been counted, the run timing would probably have been similar to the timing observed in 1998 (Figure 10B). Emigrating sculpins were second to only sockeye smolt in abundance of fish observed exiting the lake.

Stickleback

In 1999, 5,528 sticklebacks emigrated from Summer Bay Lake (Table 3). Similarly to other counts of fish exiting the lake, some were likely missed since in 1998 weir counts on 9 May noted their presence (Honnold et al. 1999). The 1999 emigration peaked on 19 August with 481 fish and the run continued throughout the duration of the project with 15 fish counted on 9 September (Figure 11A). If the entire 1999 run had been counted, the run timing would probably have been similar to the timing observed in 1998 (Figure 11B).

Flounder

In 1999, 120 flounder emigrated from Summer Bay Lake (Table 3). Similarly to other counts of fish exiting the lake, some were likely missed since in 1998 weir counts on 9 May noted their presence (Honnold et al. 1999). The 1999 emigration peaked on 31 May with 12 fish and the run continued through 9 August (Figure 12A). The 1999 run tended to be more evenly spaced in time than the 1998 run (Figure 12B).

Juvenile Salmon Age and Size Data

Sockeye Salmon

The age composition of the 2,030 sockeye salmon smolt sampled from the Summer Bay Lake emigration from weeks ending 6 June through 8 August was 59.5% age 1. and 40.5% age 2 (Table 5). There was a higher proportion of age 1. smolt during peak emigrations, which resulted in larger overall percentage (63.9%) of this age class in the total emigration (Table 1). There were twice as many age 2. smolt in the 1999 emigration than in the 1998 emigration (Table 6).

The average sizes of emigrating sockeye salmon were 9.0 g and 97.1 mm for age 1. smolt and 12.4 g and 108.4 mm for age 2. smolt (Table 7; Figures 13A and 13B). The condition factor (K) for all sockeye salmon smolt age classes exceeded 0.90 (Figure 13C). Although the smolt for both age classes were somewhat shorter than in 1998 and age 2. smolt weighed less than in 1998, the condition factor was greater in 1999 (Figure 13C).

Coho Salmon

The age composition of the 605 coho salmon smolt sampled from the Summer Bay Lake emigration from weeks ending 6 June through 12 September was 0.5% age 0. fish, 27.9% age 1. fish, 70.4% age 2. fish, and 1.2% age 3. fish (Table 8). There was a higher proportion of age 2. smolt during peak emigrations, which resulted in more overall (82.5%) fish of this age class in the total emigration (Table 2). There were nearly twice as many age 2. smolt in the 1999 emigration as compared to the 1998 emigration (Table 9).

The average sizes of emigrating coho salmon were 4.8 g and 69.7 mm for age 0. smolt, 14.4 g and 101.0 mm for age 1. smolt, 42.4 g and 157.7 mm for age 2. smolt, and 45.5 g and 164.7 mm for age 3. smolt (Table 10). Condition factors (K) for coho salmon smolt exceeded 0.95 and were highest for younger smolt. In contrast to 1998 coho smolt, the 1999 smolt were longer, weighed more, and were in better condition for each age class (Figures 14A, B, and C.)

Juvenile Salmon Stomach Contents

Thirty juvenile sockeye salmon stomachs were analyzed (Table 11). Nine (30%) were empty and six (20%) were mostly empty. The remaining 15 stomachs were at least 1/4 full or fuller. Most fish were consuming aquatic life stage insects.

Adult Fish Escapement and Run Timing

Sockeye Salmon

The 1999 total sockeye salmon escapement into Summer Bay Lake of 3,375 fish was 734 more than in 1998 (Table 12; Honnold et al. 1999). Of the 3,375 fish, 100 were sacrificed to aid in the development of a Pacific Ocean sockeye salmon genetic database. After the genetic tissue samples were collected the carcasses were iced and given to the Dutch Harbor Pioneer Home.

The escapement was primarily age 1.2 (21.1%) and age 1.3 (65.7%) fish (Table 12). There were also lesser numbers of age 0.3 (9.6%), age 2.2 (0.7%), age 2.3 (1.4%), and other age classes (1.5%) of sockeye salmon in the escapement.

Sockeye salmon moved into the lake slowly, beginning on 2 June, with a mean passage rate of ~10-50 fish/day until 20 June; the peak escapement of 392 fish occurred on 4 July (Figure 15A). After this peak, additional sockeye salmon moved into the lake at a low rate through 10 September when the weir was removed. The peak weekly escapement was 157 age 1.2 and 510 age 1.3 fish for a total of 769 sockeye salmon for the week ending 4 July (Table 13). In 1999, the entry of salmon into the lake was more uniform than during 1998 (Figure 15B).

Coho Salmon

From 1990 through 1994 a Dutch Harbor fisheries biologist observed that the Summer Bay Lake coho salmon run extended through at least late October and perhaps into early November (D. Tracy, ADF&G, Division of Sport Fish, Kodiak, personal communication). The biologist noted that bright fish could be caught in the lake through late October and water marked fish through late November. The biologist also said that the coho run seemed to be weaker, fewer individual fish, after 1993 or 1994.

Only 20 coho salmon were counted into Summer Bay Lake in 1999 (Table 12; Figure 16A). The first salmon entered the lake on 16 August and the last observed fish was on 9 September after which the weir was removed. The 20 fish count is likely low since 41% of the 1998 observed coho escapement occurred from 9-23 September (Figure 16B; Honnold et al. 1999).

Although the 1999 coho weir escapement counts may have been low due to the weir being removed in early September, foot surveys of the lake and primary tributary also indicated a weak run. Foot surveys of the lake and its major tributary revealed only one coho salmon carcass on a 7 September survey and none on a 27 November survey (Table 14). Due to the low coho salmon escapement numbers, the entire Summer Bay Lake drainage was closed to sport fishing from 22 September through 31 December 1999 (L. Schwarz, ADF&G, Division of Sport Fish, Kodiak, personal communication). No adult age data were collected in 1999.

Pink Salmon

The total pink salmon escapement into Summer Bay Lake was 2,250 fish (Table 12), about one-third of last year's escapement (Honnold et al. 1999). Aleutian Islands pink salmon runs tend to be much larger during even numbered years (Holmes 1997). Two hundred pink salmon were holding below the weir and within a day of the weir removal moved upstream into the lake. Subsequently, some of the pink salmon returned to the outlet stream and spawned (T. Spencer, ADF&G, Division of Sport Fish, Dutch Harbor, personal communication).

The pink salmon escapement began on 27 July, but very few fish returned until 25 August when 102 fish immigrated; the peak escapement occurred on 29 August (Figure 17A). The last observed escapement (35 fish) occurred on 9 September after which the weir was removed. The run timing was about a week different between the odd and even year runs with the smaller odd year run (1999) about a week later than the larger even year run (1998; Figure 17B). This run timing difference between the even and odd year pink salmon runs is expressed in most Alaska Peninsula and Aleutian Islands pink streams (McCullough *in press*).

Dolly Varden

Almost six times as many Dolly Varden entered the lake in 1999 (1,636) as compared to 1998 (Table 4; Honnold et al. 1999). Dolly Varden began entering the lake on 27 June and on 10 September, after the weir was removed, an estimated 275 fish that had been holding below the weir migrated into the lake (Figure 18A). The peak weir count occurred on 31 July (182 fish). In both 1998 and 1999 the August escapement was comparatively flat (Figure 18B).

Other Fish Counts

A single chum salmon migrated into Summer Bay Lake on 23 August. One possible chum/pink hybrid was also observed entering the lake.

One male steelhead *O. mykiss* passed upstream through the weir on 10 June and one female moved out to sea on 6 August.

Adult Sockeye Salmon Age and Size Data

Sockeye salmon escapement age samples (n=652) indicate that the 1999 Summer Bay Lake sockeye run was primarily composed of fish having spent one winter in freshwater as juveniles and two or three winters in the ocean as adults (Table 15). The dominant ages were 1.2 (21.1%) and 1.3 (65.7%) fish which, combined equal about 87% of the total run. In 1999 the run had a larger percentage of age 0.3 and 1.3 fish and a correspondingly lesser percentage of age 1.2 fish as compared to the 1998 return (Figure 19).

The sample proportions by sex were 53.9% female and 46.1% male sockeye salmon (Table 16). As in many salmon populations, the males tended to enter the lake before the females.

Adult sockeye salmon averaged 530 mm in length (females 517 mm and males 546 mm) and size increased with ocean residence from 317 mm for age 1.1 fish to 533 mm of age 0.3 and 550 mm for age 2.3 fish (Table 17).

Adult Salmon Escapement Distribution

Stream and lake surveys were conducted at the Summer Bay Lake system, as well as other area anadromous fish systems, in the summer and fall of 1999 to enumerate adult fish distributions over time (Table 14). The initial survey of the Summer Bay Lake system was conducted on 28 July. Few salmon were observed in the lake and none in the inlet tributary. Thirty-six sockeye salmon were observed in the southwest portion of the lake on 6 August and 4 in the inlet stream. The peak observation of sockeye salmon in the drainage (359) was on 27 August, as well as the first observation of pink salmon (250). One coho salmon carcass was observed on 7 September in the inlet stream. Dolly Varden were observed in the inlet stream beginning 31 July through 27 November. The earliest Dolly Varden spawning activity was observed on 11 August in the inlet tributary.

Summer Bay Lake has both lake and tributary sockeye spawning stocks. Most lake spawners used the western side of Summer Bay Lake, where springs and runoff creeks enter the lake (Figure 3; Table 14). Most of the tributary spawning activity occurred in the lower portion of the primary inlet stream at the south end of the lake; the gravel in the lower 200 m of the stream appeared to be excellent spawning substrate. The upper reaches of the stream consisted of ~50-60% useable spawning gravel. Sockeye salmon spawning in the inlet stream used the lower 100-200 m of habitat. Spawning pink salmon used the upper portion of the inlet stream above the canyon and none were observed spawning in the lake. A small number of pink salmon (~100-200) spawned in the outlet stream.

Air and Water Temperature, Stream Height, and Wind Velocity

Water temperature was about 6^{0}C in early June, warming to a maximum of 16^{0}C by late July through mid August and cooling in December to 0°C (Figure 20A; Appendix C). Air and water temperatures were within a few degrees of each other throughout most of the field season (Figures 20A and B). Air temperatures were below zero and water temperatures were near zero from late November 1999 to early April 2000, increasing slowly that spring. Stream height fluctuated widely in June then decreased to a low level in mid August (Figure 21A). The winds came mostly from the south (Figure 21B).

DISCUSSION

The original spill and continued persistence of oil in the lake (T. Cappiello, ADF&G, Division of Commercial Fisheries, Kodiak, personal communication) may have implications for future fish production.).

The number of fish rearing in Summer Bay Lake were unknown at the time of the *M/V Kuroshima* oil spill and juvenile production data had not been previously collected at this system. Fishery professionals often extrapolate adult escapements to estimate juvenile recruitment, based upon system-specific production parameters or production parameters gleaned from the literature. For example, knowing the average sex ratio, fecundity, potential egg deposition, and survival to emergence would enable estimating juvenile recruitment from a known escapement. Recruitment estimates of this type are, however, predicated on reliable escapement estimates that were not available until 1998 and 1999 when a weir was utilized to count the escapement.

Aerial surveys and limited foot surveys were the only methods employed to estimate Summer Bay Lake sockeye and pink salmon escapements in years prior to the spill (Honnold et al. 1996). Surveys of coho salmon abundance were sparse and typically conducted during poor survey conditions. Previous salmon escapement estimates at Summer Bay Lake were considered indices, rather than actual escapements. What are considered as peak counts are often used to index salmon escapements at Summer Bay Lake, as well as other area salmonid systems (Shaul and Dinnocenzo 2000). Peak counts generally represent only a portion of the estimated total escapement (Cousens et al. 1982), and are not comparable to other peak counts (Johnson and Barrett 1988). Counting biases have been widely documented and almost always result in surveys that underestimate total escapements (Symons and Waldichuk 1984; Tshaplinski and Hyatt 1991; Jones et al. 1998). As a result, many fishery managers use multipliers to account for fish not present in the escapement at the time of the peak count and others not seen or counted (Barrett et al. 1990; Swanton and Nelson 1994; Jones et al. 1998). Peak counts of Summer Bay

Lake salmon escapements have not been expanded to estimate total escapements (Shaul and Dinnocenzo 2000) except in Honnold et al. (1999).

The juvenile age classes of each species must also be assessed when extrapolating from total escapements to estimate lake residence at a given time. The results of juvenile emigration estimates indicate three age classes of both sockeye and coho salmon rearing in Summer Bay Lake. Pink salmon do not rear in lakes for extended periods (Heard 1991). In Summer Bay Lake, the majority of pink fry pass through the lake as they emigrate from their emergence site (the primary inlet creek at south end of the lake) to the ocean.

Dolly Varden, sculpins, sticklebacks, and flounder also utilize the lake for spawning, rearing, and/or overwintering but their life cycles and dependence upon Summer Bay Lake are poorly understood.

Care must be taken when applying conclusions from the *Exxon Valdez* Oil Spill (EVOS), as well as other studies (Appendix D), to the *M/V Kuroshima* oil spill since the type of oil, severity of oiling, lake habitat, and affected species differ in most cases. There are sufficient similarities; however, to suggest that the EVOS research is relevant and should be considered (D. Helton, NOAA, Anchorage, personal communication). For example, both spills occurred in subarctic climates, both spills involved persistent oils, both spills affected pink salmon, and both spills affected spawning and rearing habitat.

Juvenile and adult fishery data collected in 1998-1999 and the timing and extent of the *M/V Kuroshima* oil spill at Summer Bay Lake provide information for supposition of potential damage to fish species residing in the lake at the time of the spill and in the interim. The full extent of the oil spill, however, will not be known until several years of juvenile and adult data are collected and some indication of brood year survivals can be established. Lastly, if fish survivals decline, PAH analyses of juvenile fish collected in 1998 will be essential to determine if oil contamination was the reason for reductions in production.

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Table 1. Daily and cumulative juvenile sockeye salmon emigrants by age class from Summer Bay Lake, 1999.

	Sockeye Smolt			Daily Sockeye Smolt By Age Class		Sockeye Juvenile			Total Sockeye		
Date	Daily[a]	Cum. #	Cum. %	1.	2.	Daily[a]	Cum. #	Cum. %	Daily[a]	Cum. #	Cum. %
30-May	27	27	0	13	14	0	0	0	27	27	0
31-May	32	59	0	15	17	0	0	0	32	59	0
1-Jun	28	87	0	13	15	0	0	0	28	87	0
2-Jun	20	107	0	9	11	1	1	0	21	108	0
3-Jun	27	134	0	13	14	0	1	0	27	135	0
4-Jun	20	154	0	9	11	0	1	0	20	155	0
5-Jun	8	162	0	4	4	1	2	0	9	164	0
6-Jun	9	171	0	4	5	0	2	0	9	173	0
7-Jun	34	205	0	15	19	0	2	0	34	207	0
8-Jun	18	223	0	8	10	0	2	0	18	225	0
9-Jun	15	238	1	7	8	0	2	0	15	240	0
10-Jun	14	252	1	6	8	0	2	0	14	254	1
11-Jun	36	288	1	16	20	0	2	0	36	290	1
12-Jun	29	317	1	13	16	0	2	0	29	319	1
13-Jun	39	356	1	17	22	0	2	0	39	358	1
14-Jun	54	410	1	5	49	0	2	0	54	412	1
15-Jun	86	496	1	7	79	0	2	0	86	498	1
16-Jun	43	539	1	4	39	0	2	0	43	541	1
17-Jun	16	555	1	1	15	0	2	0	16	557	1
18-Jun	59	614	1	5	54	0	2	0	59	616	1
19-Jun	62	676	1	5	57	0	2	0	62	678	1
20-Jun	81	757	2	7	74	0	2	0	81	759	2

-Continued-

Table 1. (page 2 of 5)

	Sockeye Smolt			Daily Sockeye Smolt By Age Class		Sockeye Juvenile			Total Sockeye		
Date	Daily[a]	Cum. #	Cum. %	1.	2.	Daily[a]	Cum. #	Cum. %	Daily[a]	Cum. #	Cum. %
21-Jun	92	849	2	6	86	0	2	0	92	851	2
22-Jun	461	1,310	3	32	429	0	2	0	461	1,312	3
23-Jun	635	1,945	4	44	591	0	2	0	635	1,947	4
24-Jun	143	2,088	5	10	133	0	2	0	143	2,090	4
25-Jun	86	2,174	5	6	80	0	2	0	86	2,176	4
26-Jun	359	2,533	5	25	334	0	2	0	359	2,535	5
27-Jun	603	3,136	7	42	561	0	2	0	603	3,138	6
28-Jun	407	3,543	8	150	257	0	2	0	407	3,545	7
29-Jun	1,716	5,259	11	631	1,085	0	2	0	1,716	5,261	10
30-Jun	914	6,173	13	336	578	0	2	0	914	6,175	12
1-Jul	817	6,990	15	301	516	0	2	0	817	6,992	14
2-Jul	1,646	8,636	19	606	1,040	0	2	0	1,646	8,638	17
3-Jul	2,286	10,922	24	841	1,445	0	2	0	2,286	10,924	22
4-Jul	484	11,406	25	178	306	0	2	0	484	11,408	23
5-Jul	2,095	13,501	29	1,523	572	1	3	0	2,096	13,504	27
6-Jul	3,268	16,769	36	2,376	892	0	3	0	3,268	16,772	33
7-Jul	780	17,549	38	567	213	0	3	0	780	17,552	35
8-Jul	1,410	18,959	41	1,025	385	0	3	0	1,410	18,962	38
9-Jul	546	19,505	42	397	149	0	3	0	546	19,508	39
10-Jul	446	19,951	43	324	122	0	3	0	446	19,954	40
11-Jul	899	20,850	45	654	245	0	3	0	899	20,853	42
12-Jul	1,780	22,630	49	1,285	495	1	4	0	1,781	22,634	45

-Continued-

Table 1. (page 3 of 5)

	Sockeye Smolt			Daily Sockeye Smolt By Age Class		Sockeye Juvenile			Total Sockeye		
Date	Daily[a]	Cum. #	Cum. %	1.	2.	Daily[a]	Cum. #	Cum. %	Daily[a]	Cum. #	Cum. %
13-Jul	2,547	25,177	54	1,839	708	0	4	0	2,547	25,181	50
14-Jul	1,273	26,450	57	919	354	1	5	0	1,274	26,455	53
15-Jul	310	26,760	58	224	86	6	11	0	316	26,771	53
16-Jul	142	26,902	58	103	39	1	12	0	143	26,914	54
17-Jul	261	27,163	59	188	73	3	15	0	264	27,178	54
18-Jul	827	27,990	60	597	230	0	15	0	827	28,005	56
19-Jul	703	28,693	62	514	189	1	16	0	704	28,709	57
20-Jul	1,447	30,140	65	1,058	389	4	20	1	1,451	30,160	60
21-Jul	1,384	31,524	68	1,012	372	0	20	1	1,384	31,544	63
22-Jul	1,396	32,920	71	1,020	376	0	20	1	1,396	32,940	66
23-Jul	2,208	35,128	76	1,614	594	0	20	1	2,208	35,148	70
24-Jul	501	35,629	77	366	135	2	22	1	503	35,651	71
25-Jul	1,430	37,059	80	1,045	385	0	22	1	1,430	37,081	74
26-Jul	1,097	38,156	82	901	196	0	22	1	1,097	38,178	76
27-Jul	1,379	39,535	85	1,132	247	1	23	1	1,380	39,558	79
28-Jul	934	40,469	87	767	167	0	23	1	934	40,492	81
29-Jul	1,158	41,627	90	951	207	1	24	1	1,159	41,651	83
30-Jul	690	42,317	91	566	124	4	28	1	694	42,345	84
31-Jul	964	43,281	94	791	173	1	29	1	965	43,310	86
1-Aug	707	43,988	95	580	127	18	47	1	725	44,035	88
2-Aug	520	44,508	96	420	100	44	91	2	564	44,599	89
3-Aug	286	44,794	97	231	55	18	109	3	304	44,903	90

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Table 1. (page 4 of 5)

Date	Sockeye Smolt			Daily Sockeye Smolt By Age Class		Sockeye Juvenile			Total Sockeye		
	Daily[a]	Cum. #	Cum. %	1.	2.	Daily[a]	Cum. #	Cum. %	Daily[a]	Cum. #	Cum. %
4-Aug	142	44,936	97	115	27	30	139	4	172	45,075	90
5-Aug	278	45,214	98	224	54	138	277	7	416	45,491	91
6-Aug	113	45,327	98	91	22	117	394	10	230	45,721	91
7-Aug	86	45,413	98	69	17	108	502	13	194	45,915	92
8-Aug	165	45,578	99	133	32	58	560	14	223	46,138	92
9-Aug	179	45,757	99	144	35	160	720	18	339	46,477	93
10-Aug	104	45,861	99	84	20	165	885	23	269	46,746	93
11-Aug	53	45,914	99	43	10	281	1,166	30	334	47,080	94
12-Aug	50	45,964	99	40	10	300	1,466	38	350	47,430	95
13-Aug	95	46,059	100	77	18	205	1,671	43	300	47,730	95
14-Aug	9	46,068	100	7	2	223	1,894	49	232	47,962	96
15-Aug	17	46,085	100	14	3	586	2,480	64	603	48,565	97
16-Aug	36	46,121	100	29	7	317	2,797	72	353	48,918	98
17-Aug	13	46,134	100	10	3	202	2,999	77	215	49,133	98
18-Aug	42	46,176	100	34	8	87	3,086	79	129	49,262	98
19-Aug	19	46,195	100	15	4	98	3,184	82	117	49,379	98
20-Aug	11	46,206	100	9	2	99	3,283	84	110	49,489	99
21-Aug	13	46,219	100	10	3	74	3,357	86	87	49,576	99
22-Aug	11	46,230	100	9	2	82	3,439	88	93	49,669	99
23-Aug	5	46,235	100	4	1	84	3,523	90	89	49,758	99
24-Aug	3	46,238	100	2	1	38	3,561	91	41	49,799	99
25-Aug	2	46,240	100	2	0	11	3,572	92	13	49,812	99

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Table 1. (page 5 of 5)

Date	Sockeye Smolt			Daily Sockeye Smolt By Age Class		Sockeye Juvenile			Total Sockeye		
	Daily[a]	Cum. #	Cum. %	1.	2.	Daily[a]	Cum. #	Cum. %	Daily[a]	Cum. #	Cum. %
26-Aug	2	46,242	100	2	0	14	3,586	92	16	49,828	99
27-Aug	2	46,244	100	2	0	7	3,593	92	9	49,837	99
28-Aug	5	46,249	100	4	1	3	3,596	92	8	49,845	99
29-Aug	4	46,253	100	3	1	19	3,615	93	23	49,868	99
30-Aug	0	46,253	100	0	0	28	3,643	94	28	49,896	99
31-Aug	0	46,253	100	0	0	10	3,653	94	10	49,906	99
1-Sep	0	46,253	100	0	0	6	3,659	94	6	49,912	100
2-Sep	2	46,255	100	2	0	6	3,665	94	8	49,920	100
3-Sep	3	46,258	100	2	1	10	3,675	94	13	49,933	100
4-Sep	0	46,258	100	0	0	15	3,690	95	15	49,948	100
5-Sep	0	46,258	100	0	0	21	3,711	95	21	49,969	100
6-Sep	2	46,260	100	2	0	16	3,727	96	18	49,987	100
7-Sep	3	46,263	100	2	1	51	3,778	97	54	50,041	100
8-Sep	1	46,264	100	1	0	68	3,846	99	69	50,110	100
9-Sep	4	46,268	100	3	1	47	3,893	100	51	50,161	100
Total	46,268			29,583	16,685	3,893			50,161		
Percent				63.9	36.1						

[a] No estimates were made of emigrating fish when the trap efficiency was < 100%.

Each date is a 24-hour period extending from noon to noon. Date identifies the first noon of the 24-hour period.
Weir was fish-tight ~1800 hours 30 May through 0230 hours 10 September.

Table 2. Daily and cumulative juvenile coho salmon emigrants by age class from Summer Bay Lake, 1999.

	Coho Smolt			Daily Coho Smolt By Age Class[a]				Coho Juvenile			Total Coho		
Date	Daily	Cum. #	Cum. %	0.	1.	2.	3.	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
30-May	4	4	0	0	2	2	0	2	2	0	6	6	0
31-May	9	13	1	0	5	4	0	7	9	2	16	22	1
1-Jun	9	22	1	0	5	4	0	1	10	2	10	32	1
2-Jun	5	27	1	0	3	2	0	0	10	2	5	37	1
3-Jun	4	31	2	0	2	2	0	0	10	2	4	41	2
4-Jun	6	37	2	0	3	3	0	2	12	2	8	49	2
5-Jun	1	38	2	0	1	0	0	1	13	2	2	51	2
6-Jun	4	42	2	0	2	2	0	1	14	3	5	56	2
7-Jun	3	45	2	0	0	3	0	1	15	3	4	60	2
8-Jun	5	50	3	0	0	5	0	4	19	3	9	69	3
9-Jun	8	58	3	0	0	7	1	3	22	4	11	80	3
10-Jun	4	62	3	0	0	4	0	1	23	4	5	85	3
11-Jun	11	73	4	0	0	10	1	0	23	4	11	96	4
12-Jun	11	84	4	0	0	10	1	0	23	4	11	107	4
13-Jun	9	93	5	0	0	8	1	0	23	4	9	116	5
14-Jun	16	109	6	0	1	14	0	0	23	4	16	132	5
15-Jun	14	123	6	0	1	13	0	0	23	4	14	146	6
16-Jun	36	159	8	0	3	32	1	0	23	4	36	182	7
17-Jun	22	181	9	0	2	20	0	2	25	5	24	206	8
18-Jun	33	214	11	0	3	30	1	0	25	5	33	239	9
19-Jun	22	236	12	0	2	20	0	1	26	5	23	262	10
20-Jun	78	314	16	0	6	70	2	0	26	5	78	340	13
21-Jun	87	401	20	0	2	82	2	0	26	5	87	427	17

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Table 2. (page 2 of 5)

	Coho Smolt			Daily Coho Smolt By Age Class[a]				Coho Juvenile			Total Coho		
Date	Daily	Cum. #	Cum. %	0.	1.	2.	3.	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
22-Jun	112	513	26	0	3	106	3	0	26	5	112	539	21
23-Jun	86	599	30	0	2	81	2	2	28	5	88	627	25
24-Jun	82	681	34	0	2	78	2	4	32	6	86	713	28
25-Jun	65	746	38	0	2	61	2	0	32	6	65	778	31
26-Jun	35	781	39	0	1	33	1	0	32	6	35	813	32
27-Jun	61	842	43	0	2	58	2	0	32	6	61	874	35
28-Jun	62	904	46	0	3	58	1	0	32	6	62	936	37
29-Jun	153	1,057	53	0	8	143	2	0	32	6	153	1,089	43
30-Jun	46	1,103	56	0	3	43	1	1	33	6	47	1,136	45
1-Jul	66	1,169	59	0	4	62	1	0	33	6	66	1,202	48
2-Jul	66	1,235	62	0	4	62	1	0	33	6	66	1,268	50
3-Jul	104	1,339	68	0	6	97	1	0	33	6	104	1,372	54
4-Jul	45	1,384	70	0	2	42	0	0	33	6	45	1,417	56
5-Jul	43	1,427	72	1	7	36	0	0	33	6	43	1,460	58
6-Jul	43	1,470	74	1	7	36	0	0	33	6	43	1,503	59
7-Jul	15	1,485	75	0	2	12	0	0	33	6	15	1,518	60
8-Jul	43	1,528	77	1	7	36	0	34	67	12	77	1,595	63
9-Jul	20	1,548	78	0	3	17	0	0	67	12	20	1,615	64
10-Jul	17	1,565	79	0	3	14	0	0	67	12	17	1,632	65
11-Jul	25	1,590	80	0	4	21	0	1	68	12	26	1,658	66
12-Jul	42	1,632	82	0	9	33	1	44	112	20	86	1,744	69
13-Jul	45	1,677	85	0	9	35	1	33	145	27	78	1,822	72
14-Jul	16	1,693	86	0	3	12	0	45	190	35	61	1,883	75

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Table 2. (page 3 of 5)

	Coho Smolt			Daily Coho Smolt By Age Class[a]				Coho Juvenile			Total Coho		
Date	Daily	Cum. #	Cum. %	0.	1.	2.	3.	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
15-Jul	7	1,700	86	0	1	5	0	21	211	39	28	1,911	76
16-Jul	3	1,703	86	0	1	2	0	11	222	41	14	1,925	76
17-Jul	5	1,708	86	0	1	4	0	8	230	42	13	1,938	77
18-Jul	3	1,711	86	0	1	2	0	8	238	44	11	1,949	77
19-Jul	5	1,716	87	0	2	3	0	5	243	44	10	1,959	78
20-Jul	5	1,721	87	0	2	3	0	2	245	45	7	1,966	78
21-Jul	8	1,729	87	0	2	6	0	3	248	45	11	1,977	78
22-Jul	7	1,736	88	0	2	5	0	0	248	45	7	1,984	79
23-Jul	8	1,744	88	0	2	6	0	0	248	45	8	1,992	79
24-Jul	5	1,749	88	0	2	3	0	0	248	45	5	1,997	79
25-Jul	9	1,758	89	0	3	6	0	1	249	46	10	2,007	79
26-Jul	5	1,763	89	0	3	2	0	0	249	46	5	2,012	80
27-Jul	4	1,767	89	0	2	2	0	0	249	46	4	2,016	80
28-Jul	4	1,771	89	0	2	2	0	3	252	46	7	2,023	80
29-Jul	6	1,777	90	0	4	2	0	3	255	47	9	2,032	80
30-Jul	6	1,783	90	0	4	2	0	3	258	47	9	2,041	81
31-Jul	6	1,789	90	0	4	2	0	3	261	48	9	2,050	81
1-Aug	8	1,797	91	0	5	3	0	7	268	49	15	2,065	82
2-Aug	6	1,803	91	0	4	2	0	5	273	50	11	2,076	82
3-Aug	7	1,810	91	0	5	2	0	15	288	53	22	2,098	83
4-Aug	9	1,819	92	0	6	3	0	6	294	54	15	2,113	84
5-Aug	4	1,823	92	0	3	1	0	4	298	54	8	2,121	84
6-Aug	2	1,825	92	0	1	1	0	9	307	56	11	2,132	84

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Table 2. (page 4 of 5)

Date	Coho Smolt			Daily Coho Smolt By Age Class[a]				Coho Juvenile			Total Coho		
	Daily	Cum. #	Cum. %	0.	1.	2.	3.	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
7-Aug	4	1,829	92	0	3	1	0	4	311	57	8	2,140	85
8-Aug	3	1,832	93	0	2	1	0	9	320	59	12	2,152	85
9-Aug	9	1,841	93	0	6	3	0	1	321	59	10	2,162	86
10-Aug	2	1,843	93	0	1	1	0	7	328	60	9	2,171	86
11-Aug	2	1,845	93	0	1	1	0	7	335	61	9	2,180	86
12-Aug	9	1,854	94	0	6	3	0	25	360	66	34	2,214	88
13-Aug	4	1,858	94	0	3	1	0	10	370	68	14	2,228	88
14-Aug	2	1,860	94	0	1	1	0	10	380	69	12	2,240	89
15-Aug	3	1,863	94	0	2	1	0	5	385	70	8	2,248	89
16-Aug	3	1,866	94	0	2	1	0	2	387	71	5	2,253	89
17-Aug	4	1,870	94	0	3	1	0	9	396	72	13	2,266	90
18-Aug	12	1,882	95	1	9	2	0	5	401	73	17	2,283	90
19-Aug	12	1,894	96	1	9	2	0	7	408	75	19	2,302	91
20-Aug	6	1,900	96	0	5	1	0	5	413	76	11	2,313	92
21-Aug	0	1,900	96	0	0	0	0	3	416	76	3	2,316	92
22-Aug	2	1,902	96	0	2	0	0	1	417	76	3	2,319	92
23-Aug	6	1,908	96	0	5	1	0	11	428	78	17	2,336	92
24-Aug	6	1,914	97	0	5	1	0	6	434	79	12	2,348	93
25-Aug	1	1,915	97	0	1	0	0	6	440	80	7	2,355	93
26-Aug	0	1,915	97	0	0	0	0	7	447	82	7	2,362	93
27-Aug	2	1,917	97	0	2	0	0	2	449	82	4	2,366	94
28-Aug	0	1,917	97	0	0	0	0	1	450	82	1	2,367	94
29-Aug	9	1,926	97	0	7	2	0	1	451	82	10	2,377	94

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Table 2. (page 5 of 5)

	Coho Smolt			Daily Coho Smolt By Age Class[a]				Coho Juvenile			Total Coho		
Date	Daily	Cum. #	Cum. %	0.	1.	2.	3.	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
30-Aug	5	1,931	98	0	4	1	0	10	461	84	15	2,392	95
31-Aug	5	1,936	98	0	4	1	0	8	469	86	13	2,405	95
1-Sep	3	1,939	98	0	2	1	0	13	482	88	16	2,421	96
2-Sep	7	1,946	98	0	6	1	0	6	488	89	13	2,434	96
3-Sep	5	1,951	99	0	4	1	0	1	489	89	6	2,440	97
4-Sep	11	1,962	99	0	9	2	0	6	495	90	17	2,457	97
5-Sep	6	1,968	99	0	5	1	0	5	500	91	11	2,468	98
6-Sep	0	1,968	99	0	0	0	0	5	505	92	5	2,473	98
7-Sep	3	1,971	100	0	1	2	0	4	509	93	7	2,480	98
8-Sep	7	1,978	100	0	2	5	0	18	527	96	25	2,505	99
9-Sep	2	1,980	100	0	1	1	0	20	547	100	22	2,527	100
Total	1,980			5	314	1,634	33	547			2,527		
Percent				0.2	15.9	82.5	1.7						

[b] Numbers may not total exactly due to rounding errors.

No estimates were made of emigrating fish when the trap efficiency was < 100%.
Each date is a 24-hour period extending from noon to noon. Date identifies the first noon of the 24-hour period.
Weir was fish-tight ~1800 hours 30 May through 0230 hours 10 September.

Table 3. Daily and cumulative juvenile pink salmon, sculpins, sticklebacks, and flounder emigrants from Summer Bay Lake, 1999.

	Pink Juvenile			Sculpin			Stickleback			Flounder		
Date	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
30-May	648	648	12	43	43	0	18	18	0	0	0	0
31-May	460	1,108	20	85	128	1	11	29	1	12	12	10
1-Jun	104	1,212	22	64	192	2	4	33	1	10	22	18
2-Jun	99	1,311	24	75	267	3	15	48	1	0	22	18
3-Jun	103	1,414	26	82	349	3	12	60	1	1	23	19
4-Jun	148	1,562	29	45	394	4	10	70	1	1	24	20
5-Jun	2,424	3,986	73	23	417	4	10	80	1	3	27	23
6-Jun	90	4,076	75	43	460	5	2	82	1	2	29	24
7-Jun	118	4,194	77	168	628	6	3	85	2	2	31	26
8-Jun	209	4,403	81	138	766	8	10	95	2	9	40	33
9-Jun	277	4,680	86	121	887	9	13	108	2	10	50	42
10-Jun	103	4,783	87	184	1,071	11	6	114	2	0	50	42
11-Jun	4	4,787	88	231	1,302	13	23	137	2	0	50	42
12-Jun	24	4,811	88	152	1,454	14	10	147	3	2	52	43
13-Jun	5	4,816	88	189	1,643	16	4	151	3	0	52	43
14-Jun	5	4,821	88	379	2,022	20	7	158	3	0	52	43
15-Jun	4	4,825	88	205	2,227	22	7	165	3	0	52	43
16-Jun	0	4,825	88	224	2,451	24	5	170	3	0	52	43
17-Jun	181	5,006	92	268	2,719	27	35	205	4	9	61	51
18-Jun	210	5,216	95	170	2,889	29	11	216	4	7	68	57
19-Jun	89	5,305	97	178	3,067	30	13	229	4	6	74	62
20-Jun	3	5,308	97	165	3,232	32	2	231	4	2	76	63
21-Jun	4	5,312	97	121	3,353	33	9	240	4	1	77	64

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Table 3. (page 2 of 5)

	Pink Juvenile			Sculpin			Stickleback			Flounder		
Date	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
22-Jun	8	5,320	97	153	3,506	35	25	265	5	2	79	66
23-Jun	29	5,349	98	110	3,616	36	14	279	5	5	84	70
24-Jun	8	5,357	98	94	3,710	37	28	307	6	3	87	73
25-Jun	6	5,363	98	141	3,851	38	23	330	6	2	89	74
26-Jun	1	5,364	98	228	4,079	41	4	334	6	0	89	74
27-Jun	4	5,368	98	218	4,297	43	20	354	6	2	91	76
28-Jun	2	5,370	98	233	4,530	45	11	365	7	0	91	76
29-Jun	1	5,371	98	217	4,747	47	11	376	7	2	93	78
30-Jun	0	5,371	98	228	4,975	49	23	399	7	0	93	78
1-Jul	5	5,376	98	286	5,261	52	15	414	7	1	94	78
2-Jul	13	5,389	99	264	5,525	55	102	516	9	8	102	85
3-Jul	8	5,397	99	225	5,750	57	37	553	10	2	104	87
4-Jul	1	5,398	99	279	6,029	60	5	558	10	0	104	87
5-Jul	0	5,398	99	133	6,162	61	27	585	11	0	104	87
6-Jul	0	5,398	99	204	6,366	63	31	616	11	0	104	87
7-Jul	6	5,404	99	165	6,531	65	34	650	12	0	104	87
8-Jul	6	5,410	99	160	6,691	67	80	730	13	3	107	89
9-Jul	0	5,410	99	155	6,846	68	31	761	14	1	108	90
10-Jul	10	5,420	99	179	7,025	70	20	781	14	0	108	90
11-Jul	13	5,433	99	150	7,175	71	42	823	15	1	109	91
12-Jul	14	5,447	100	124	7,299	73	78	901	16	3	112	93
13-Jul	0	5,447	100	93	7,392	73	60	961	17	1	113	94
14-Jul	1	5,448	100	54	7,446	74	41	1,002	18	1	114	95

-Continued-

Table 3. (page 3 of 5)

	Pink Juvenile			Sculpin			Stickleback			Flounder		
Date	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
15-Jul	6	5,454	100	145	7,591	75	48	1,050	19	1	115	96
16-Jul	0	5,454	100	136	7,727	77	55	1,105	20	0	115	96
17-Jul	0	5,454	100	105	7,832	78	55	1,160	21	0	115	96
18-Jul	8	5,462	100	73	7,905	79	35	1,195	22	2	117	98
19-Jul	1	5,463	100	182	8,087	80	22	1,217	22	0	117	98
20-Jul	0	5,463	100	153	8,240	82	14	1,231	22	0	117	98
21-Jul	1	5,464	100	100	8,340	83	36	1,267	23	0	117	98
22-Jul	1	5,465	100	79	8,419	84	60	1,327	24	0	117	98
23-Jul	0	5,465	100	68	8,487	84	24	1,351	24	0	117	98
24-Jul	0	5,465	100	37	8,524	85	43	1,394	25	0	117	98
25-Jul	0	5,465	100	83	8,607	86	8	1,402	25	0	117	98
26-Jul	0	5,465	100	37	8,644	86	16	1,418	26	0	117	98
27-Jul	0	5,465	100	49	8,693	86	21	1,439	26	2	119	99
28-Jul	0	5,465	100	54	8,747	87	34	1,473	27	0	119	99
29-Jul	0	5,465	100	18	8,765	87	37	1,510	27	0	119	99
30-Jul	0	5,465	100	12	8,777	87	65	1,575	28	0	119	99
31-Jul	0	5,465	100	43	8,820	88	43	1,618	29	0	119	99
1-Aug	0	5,465	100	75	8,895	88	78	1,696	31	0	119	99
2-Aug	0	5,465	100	11	8,906	89	85	1,781	32	0	119	99
3-Aug	0	5,465	100	46	8,952	89	65	1,846	33	0	119	99
4-Aug	0	5,465	100	13	8,965	89	64	1,910	35	0	119	99
5-Aug	2	5,467	100	38	9,003	90	51	1,961	35	0	119	99
6-Aug	1	5,468	100	13	9,016	90	55	2,016	36	0	119	99

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Table 3. (page 4 of 5)

Date	Pink Juvenile			Sculpin			Stickleback			Flounder		
	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
7-Aug	0	5,468	100	21	9,037	90	56	2,072	37	0	119	99
8-Aug	0	5,468	100	33	9,070	90	67	2,139	39	0	119	99
9-Aug	0	5,468	100	65	9,135	91	126	2,265	41	1	120	100
10-Aug	0	5,468	100	20	9,155	91	116	2,381	43	0	120	100
11-Aug	0	5,468	100	34	9,189	91	73	2,454	44	0	120	100
12-Aug	0	5,468	100	41	9,230	92	101	2,555	46	0	120	100
13-Aug	0	5,468	100	26	9,256	92	210	2,765	50	0	120	100
14-Aug	0	5,468	100	17	9,273	92	110	2,875	52	0	120	100
15-Aug	0	5,468	100	36	9,309	93	174	3,049	55	0	120	100
16-Aug	0	5,468	100	36	9,345	93	264	3,313	60	0	120	100
17-Aug	0	5,468	100	54	9,399	93	104	3,417	62	0	120	100
18-Aug	0	5,468	100	54	9,453	94	298	3,715	67	0	120	100
19-Aug	0	5,468	100	38	9,491	94	481	4,196	76	0	120	100
20-Aug	0	5,468	100	47	9,538	95	154	4,350	79	0	120	100
21-Aug	0	5,468	100	26	9,564	95	73	4,423	80	0	120	100
22-Aug	0	5,468	100	48	9,612	96	213	4,636	84	0	120	100
23-Aug	0	5,468	100	40	9,652	96	145	4,781	86	0	120	100
24-Aug	0	5,468	100	53	9,705	96	137	4,918	89	0	120	100
25-Aug	0	5,468	100	14	9,719	97	38	4,956	90	0	120	100
26-Aug	0	5,468	100	14	9,733	97	53	5,009	91	0	120	100
27-Aug	0	5,468	100	24	9,757	97	79	5,088	92	0	120	100
28-Aug	0	5,468	100	16	9,773	97	30	5,118	93	0	120	100
29-Aug	0	5,468	100	35	9,808	98	109	5,227	95	0	120	100

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Table 3. (page 5 of 5)

	Pink Juvenile			Sculpin			Stickleback			Flounder		
Date	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
30-Aug	0	5,468	100	30	9,838	98	87	5,314	96	0	120	100
31-Aug	0	5,468	100	44	9,882	98	85	5,399	98	0	120	100
1-Sep	0	5,468	100	40	9,922	99	33	5,432	98	0	120	100
2-Sep	0	5,468	100	12	9,934	99	6	5,438	98	0	120	100
3-Sep	0	5,468	100	10	9,944	99	4	5,442	98	0	120	100
4-Sep	0	5,468	100	15	9,959	99	5	5,447	99	0	120	100
5-Sep	0	5,468	100	14	9,973	99	4	5,451	99	0	120	100
6-Sep	0	5,468	100	22	9,995	99	10	5,461	99	0	120	100
7-Sep	0	5,468	100	23	10,018	100	21	5,482	99	0	120	100
8-Sep	0	5,468	100	22	10,040	100	31	5,513	100	0	120	100
9-Sep	0	5,468	100	19	10,059	100	15	5,528	100	0	120	100
Total	5,468			10,059			5,528			120		

Each date is a 24-hour period extending from noon to noon. Date identifies the first noon of the 24-hour period.
Weir was fish-tight ~1800 hours 30 May through 0230 hours 10 September.

Table 4. Daily and cumulative Dolly Varden migrations, Summer Bay Lake, 1999.

	Dolly Varden Downstream			Dolly Varden Upstream		
Date	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
30-May	101	101	5	0	0	0
31-May	58	159	8	0	0	0
1-Jun	83	242	12	0	0	0
2-Jun	49	291	14	0	0	0
3-Jun	10	301	14	0	0	0
4-Jun	96	397	19	0	0	0
5-Jun	88	485	23	0	0	0
6-Jun	59	544	26	0	0	0
7-Jun	243	787	38	0	0	0
8-Jun	139	926	44	0	0	0
9-Jun	131	1,057	51	0	0	0
10-Jun	43	1,100	53	0	0	0
11-Jun	85	1,185	57	0	0	0
12-Jun	48	1,233	59	0	0	0
13-Jun	58	1,291	62	0	0	0
14-Jun	26	1,317	63	0	0	0
15-Jun	61	1,378	66	0	0	0
16-Jun	32	1,410	67	0	0	0
17-Jun	32	1,442	69	0	0	0
18-Jun	53	1,495	71	0	0	0
19-Jun	62	1,557	74	0	0	0
20-Jun	103	1,660	79	0	0	0
21-Jun	28	1,688	81	0	0	0
22-Jun	57	1,745	83	0	0	0
23-Jun	22	1,767	85	0	0	0
24-Jun	21	1,788	86	0	0	0
25-Jun	36	1,824	87	0	0	0
26-Jun	13	1,837	88	0	0	0
27-Jun	13	1,850	88	1	1	0
28-Jun	21	1,871	89	2	3	0
29-Jun	15	1,886	90	3	6	0
30-Jun	39	1,925	92	5	11	1
1-Jul	14	1,939	93	16	27	2
2-Jul	19	1,958	94	0	27	2

-Continued-

Table 4. (page 2 of 4)

	Dolly Varden Downstream			Dolly Varden Upstream		
Date	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
3-Jul	22	1,980	95	2	29	2
4-Jul	3	1,983	95	7	36	2
5-Jul	15	1,998	96	28	64	4
6-Jul	6	2,004	96	24	88	5
7-Jul	5	2,009	96	83	171	10
8-Jul	6	2,015	96	20	191	12
9-Jul	0	2,015	96	2	193	12
10-Jul	7	2,022	97	17	210	13
11-Jul	8	2,030	97	13	223	14
12-Jul	17	2,047	98	9	232	14
13-Jul	4	2,051	98	32	264	16
14-Jul	5	2,056	98	3	267	16
15-Jul	1	2,057	98	6	273	17
16-Jul	1	2,058	98	2	275	17
17-Jul	0	2,058	98	5	280	17
18-Jul	2	2,060	99	4	284	17
19-Jul	0	2,060	99	1	285	17
20-Jul	0	2,060	99	15	300	18
21-Jul	0	2,060	99	15	315	19
22-Jul	0	2,060	99	12	327	20
23-Jul	0	2,060	99	6	333	20
24-Jul	2	2,062	99	17	350	21
25-Jul	0	2,062	99	3	353	22
26-Jul	0	2,062	99	6	359	22
27-Jul	3	2,065	99	101	460	28
28-Jul	1	2,066	99	5	465	28
29-Jul	0	2,066	99	104	569	35
30-Jul	0	2,066	99	2	571	35
31-Jul	2	2,068	99	182	753	46
1-Aug	1	2,069	99	13	766	47
2-Aug	3	2,072	99	42	808	49
3-Aug	2	2,074	99	29	837	51
4-Aug	0	2,074	99	6	843	52
5-Aug	0	2,074	99	0	843	52

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Table 4. (page 3 of 4)

	Dolly Varden Downstream			Dolly Varden Upstream		
Date	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
6-Aug	0	2,074	99	1	844	52
7-Aug	1	2,075	99	4	848	52
8-Aug	0	2,075	99	6	854	52
9-Aug	1	2,076	99	1	855	52
10-Aug	0	2,076	99	6	861	53
11-Aug	0	2,076	99	5	866	53
12-Aug	0	2,076	99	14	880	54
13-Aug	1	2,077	99	9	889	54
14-Aug	0	2,077	99	14	903	55
15-Aug	0	2,077	99	3	906	55
16-Aug	1	2,078	99	1	907	55
17-Aug	0	2,078	99	4	911	56
18-Aug	1	2,079	99	4	915	56
19-Aug	1	2,080	99	4	919	56
20-Aug	2	2,082	100	13	932	57
21-Aug	1	2,083	100	11	943	58
22-Aug	0	2,083	100	4	947	58
23-Aug	1	2,084	100	4	951	58
24-Aug	1	2,085	100	8	959	59
25-Aug	0	2,085	100	2	961	59
26-Aug	0	2,085	100	2	963	59
27-Aug	0	2,085	100	7	970	59
28-Aug	0	2,085	100	77	1,047	64
29-Aug	1	2,086	100	117	1,164	71
30-Aug	0	2,086	100	1	1,165	71
31-Aug	0	2,086	100	38	1,203	74
1-Sep	0	2,086	100	50	1,253	77
2-Sep	0	2,086	100	10	1,263	77
3-Sep	0	2,086	100	16	1,279	78
4-Sep	0	2,086	100	24	1,303	80
5-Sep	0	2,086	100	15	1,318	81
6-Sep	1	2,087	100	10	1,328	81
7-Sep	2	2,089	100	4	1,332	81
8-Sep	0	2,089	100	27	1,359	83

-Continued-

Table 4. (page 4 of 4)

	Dolly Varden Downstream			Dolly Varden Upstream		
Date	Daily	Cum. #	Cum. %	Daily	Cum. #	Cum. %
9-Sep	2	2,091	100	2	1,361	83
Post Weir				275	1,636	100
Total	2,091			1,636		

Weir was fish-tight ~1800 hours 30 May through 0230 hours 10 September.
Post Weir count includes 275 fish that moved into the lake after the weir was removed.

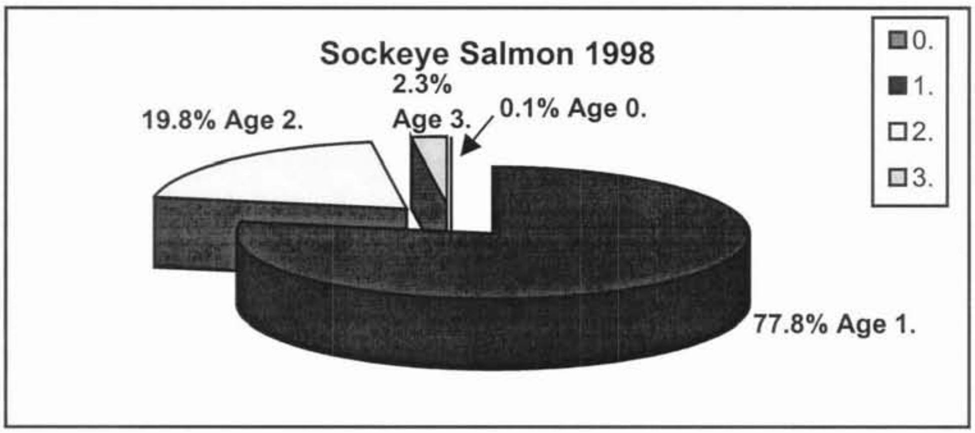
Table 5. Age composition of Summer Bay Lake sockeye salmon smolt, 1999.

Statistical Week	Calendar Dates	Sample Size		Age Composition 0.	1.	2.	3.	Total
23	5/31-6/06	83	Percent	0.0	47.0	53.0	0.0	100.0
			Numbers	0	39	44	0	83
24	6/07-6/13	34	Percent	0.0	44.1	55.9	0.0	100.0
			Numbers	0	15	19	0	34
25	6/14-6/20	94	Percent	0.0	8.5	91.5	0.0	100.0
			Numbers	0	8	86	0	94
26	6/21-6/27	217	Percent	0.0	6.9	93.1	0.0	100.0
			Numbers	0	15	202	0	217
27	6/28-7/04	234	Percent	0.0	36.8	63.2	0.0	100.0
			Numbers	0	86	148	0	234
28	7/05-7/11	278	Percent	0.0	72.7	27.3	0.0	100.0
			Numbers	0	202	76	0	278
29	7/12-7/18	273	Percent	0.0	72.2	27.8	0.0	100.0
			Numbers	0	197	76	0	273
30	7/19-7/25	234	Percent	0.0	73.1	26.9	0.0	100.0
			Numbers	0	171	63	0	234
31	7/26-8/01	313	Percent	0.0	82.1	17.9	0.0	100.0
			Numbers	0	257	56	0	313
32	8/02-8/08	270	Percent	0.0	80.7	19.3	0.0	100.0
			Numbers	0	218	52	0	270
Total		2,030	Percent	0.0	59.5	40.5	0.0	100.0
			Numbers	0	1,208	822	0	2,030

Note: There were 54 fish sampled where the age could not be determined.

Table 6. Age composition of Summer Bay Lake sockeye salmon smolt, 1998-1999.

	Sample	Sample		Age Composition				
Year	Dates	Size		0.	1.	2.	3.	Total
1998	05/09-08/0	1,592	Percent	0.1	77.8	19.8	2.3	100.0
			Numbers	2	1,238	315	37	1,592
1999	05/31-08/0	2,030	Percent	0.0	59.5	40.5	0.0	100.0
			Numbers	0	1,208	822	0	2,030
Total		3,622	Percent	0.1	67.5	31.4	1.0	100.0
			Numbers	2	2,446	1,137	37	3,622



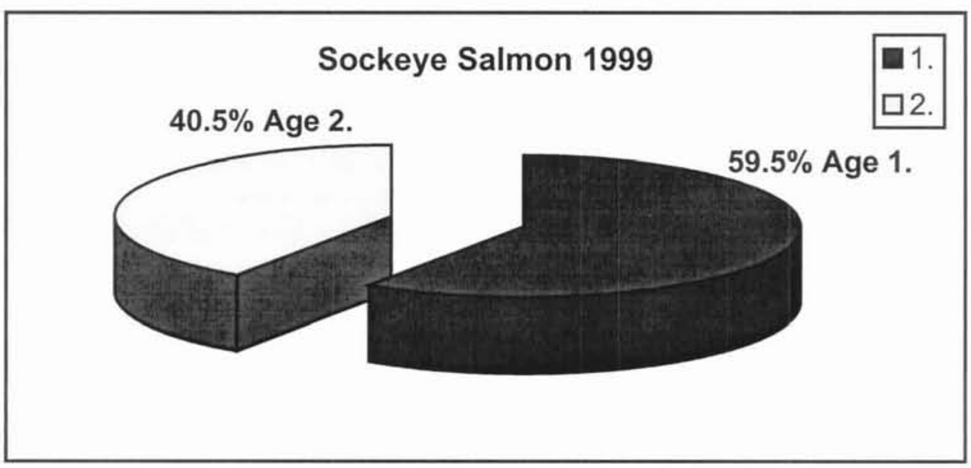


Table 7. Length, weight, and condition of Summer Bay Lake sockeye salmon smolt, 1999.

			Length			Weight			Condition		
Age	Statistical Week	Calendar Dates	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error
1	23	5/31-6/06	39	85.6	1.20	38	5.2	0.23	38	0.82	0.02
1	24	6/07-6/13	15	91.9	3.86	15	7.5	0.91	15	0.93	0.03
1	25	6/14-6/20	8	95.3	5.02	8	8.7	1.31	8	0.95	0.03
1	26	6/21-6/27	15	104.9	2.07	12	10.7	0.52	12	0.91	0.01
1	27	6/28-7/04	86	98.2	0.77	86	9.1	0.19	86	0.95	0.01
1	28	7/05-7/11	201	93.9	0.51	202	8.1	0.13	201	0.98	0.01
1	29	7/12-7/18	197	96.9	0.56	197	9.0	0.15	197	0.98	0.01
1	30	7/19-7/25	171	98.2	0.51	171	9.5	0.14	171	1.00	0.01
1	31	7/26-8/01	257	98.4	0.40	257	9.5	0.11	257	0.99	0.01
1	32	8/02-8/08	218	99.3	0.49	217	9.7	0.13	217	0.98	0.01
Total			1,207	97.1	0.23	1,203	9.0	0.06	1,202	0.97	0.00
2	23	5/31-6/06	44	96.8	0.98	43	7.4	0.23	43	0.82	0.01
2	24	6/07-6/13	19	105.7	3.33	19	11.1	1.18	19	0.89	0.02
2	25	6/14-6/20	86	120.9	1.11	86	16.5	0.45	86	0.92	0.01
2	26	6/21-6/27	202	117.6	0.59	186	15.8	0.25	186	0.95	0.01
2	27	6/28-7/04	148	108.7	0.75	147	12.2	0.24	147	0.94	0.01
2	28	7/05-7/11	76	100.2	0.97	76	9.9	0.31	76	0.96	0.01
2	29	7/12-7/18	76	100.4	0.97	76	10.0	0.27	76	0.98	0.01
2	30	7/19-7/25	63	100.8	0.99	63	10.4	0.37	63	1.00	0.01
2	31	7/26-8/01	56	101.3	0.99	56	10.2	0.32	56	0.97	0.01
2	32	8/02-8/08	52	102.4	1.13	52	10.3	0.34	52	0.95	0.01
Total			822	108.4	0.42	804	12.4	0.15	804	0.95	0.00

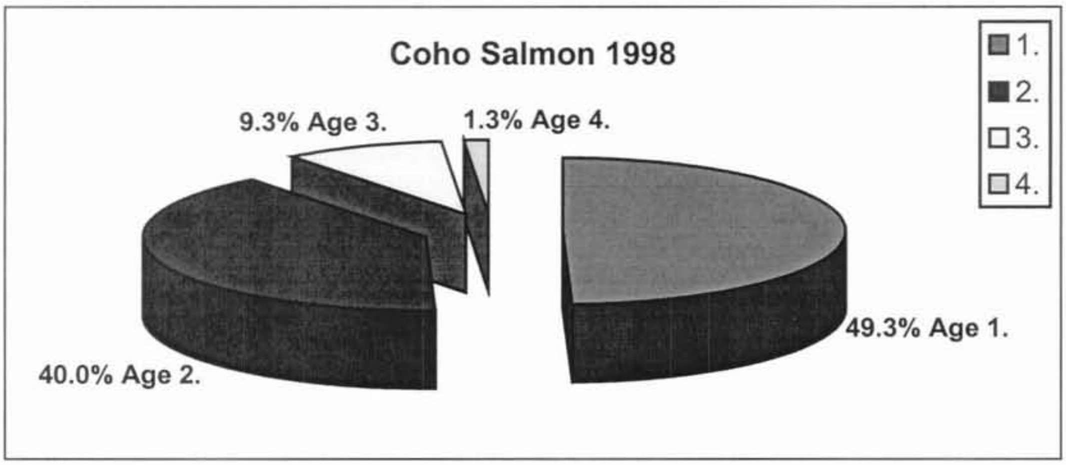
Table 8. Age composition of Summer Bay Lake coho salmon smolt, 1999.

Statistical Week	Calendar Dates	Sample Size		Age Composition 0.	1.	2.	3.	Total
23	5/31-6/06	9	Percent	0	55.6	44.4	0	100
			Numbers	0	5	4	0	9
24	6/07-6/13	15	Percent	0	0	93.3	6.7	100
			Numbers	0	0	14	1	15
25	6/14-6/20	51	Percent	0	7.8	90.2	2	100
			Numbers	0	4	46	1	51
26	6/21-6/27	111	Percent	0	2.7	94.6	2.7	100
			Numbers	0	3	105	3	111
27	6/28-7/04	91	Percent	0	5.5	93.4	1.1	100
			Numbers	0	5	85	1	91
28	7/05-7/11	82	Percent	1.2	15.9	82.9	0	100
			Numbers	1	13	68	0	82
29	7/12-7/18	53	Percent	0	20.8	77.4	1.9	100
			Numbers	0	11	41	1	53
30	7/19-7/25	29	Percent	0	31	69	0	100
			Numbers	0	9	20	0	29
31	7/26-8/01	23	Percent	0	60.9	39.1	0	100
			Numbers	0	14	9	0	23
32	8/02-8/08	23	Percent	0	65.2	34.8	0	100
			Numbers	0	15	8	0	23
33	8/09-8/15	24	Percent	0	70.8	29.2	0	100
			Numbers	0	17	7	0	24
34	8/16-8/22	37	Percent	5.4	75.7	18.9	0	100
			Numbers	2	28	7	0	37
35	8/23-8/29	21	Percent	0	81	19	0	100
			Numbers	0	17	4	0	21
36	8/30-9/05	33	Percent	0	81.8	18.2	0	100
			Numbers	0	27	6	0	33
37	9/06-9/12	3	Percent	0	33.3	66.7	0	100
			Numbers	0	1	2	0	3
Total		605	Percent	0.5	27.9	70.4	1.2	100
			Numbers	3	169	426	7	605

Note: There were 64 fish sampled where the age could not be determined.

Table 9. Age composition of Summer Bay Lake coho salmon smolt, 1998-1999.

Year	Sample Date	Sample Size		Age Composition 0.	1.	2.	3.	4.	Total
1998	5/10-09/0	75	Percent	0.0	49.3	40.0	9.3	1.3	100.0
			Numbers	0	37	30	7	1	75
1999	5/31-09/0	605	Percent	0.5	27.9	70.4	1.2	0.0	100.0
			Numbers	3	169	426	7	0	605
Total		680	Percent	0.4	30.3	67.1	2.1	0.1	100.0
			Numbers	3	206	456	14	1	680



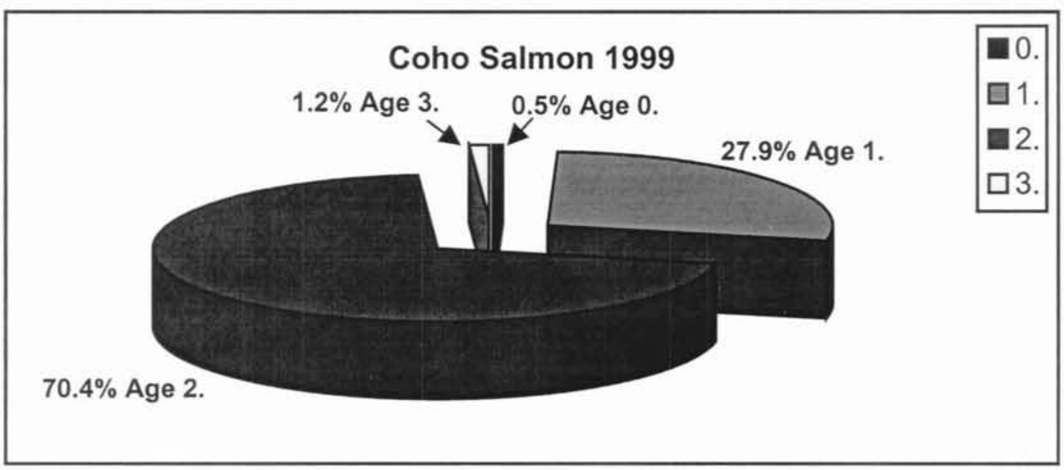


Table 10. Length, weight, and condition of Summer Bay Lake coho salmon smolt, 1999.

			Length			Weight			Condition		
Age	Statistical Week	Calendar Dates	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error
0	28	7/05-7/11	1	84.0	0.00	1	7.4	0.00	1	1.25	0.00
0	34	8/16-8/22	2	62.5	7.50	2	3.5	0.65	2	1.48	0.26
Total			3	69.7	8.37	3	4.8	1.34	3	1.41	0.17
1	23	5/31-6/06	5	80.8	3.60	5	5.5	0.71	5	1.02	0.04
1	25	6/14-6/20	4	93.3	10.90	4	9.3	2.96	4	1.07	0.08
1	26	6/21-6/27	3	113.7	14.05	3	18.2	6.35	3	1.14	0.06
1	27	6/28-7/04	5	136.0	16.19	5	29.2	8.56	5	1.05	0.07
1	28	7/05-7/11	13	116.6	8.83	13	19.6	3.48	13	1.11	0.04
1	29	7/12-7/18	11	135.2	7.14	11	27.7	2.91	11	1.07	0.04
1	30	7/19-7/25	9	122.4	11.95	9	23.5	4.54	9	1.14	0.06
1	31	7/26-8/01	14	101.0	8.04	14	14.0	3.45	14	1.14	0.04
1	32	8/02-8/08	15	80.6	2.82	15	6.8	0.54	15	1.29	0.07
1	33	8/09-8/15	17	105.1	9.18	17	17.9	4.18	17	1.19	0.03
1	34	8/16-8/22	28	84.7	3.93	28	8.9	2.41	28	1.20	0.03
1	35	8/23-8/29	17	95.0	6.58	17	12.7	4.30	17	1.17	0.04
1	36	8/30-9/05	27	98.8	4.16	26	11.9	2.51	26	1.12	0.02
1	37	9/06-9/12	1	102.0	0.00	1	11.3	0.00	1	1.06	0.00
Total			169	101.0	2.31	168	14.4	1.09	168	1.15	0.01
2	23	5/31-6/06	4	111.5	13.19	4	15.6	6.98	4	0.92	0.10
2	24	6/07-6/13	14	165.6	6.61	14	49.6	5.50	14	1.03	0.03
2	25	6/14-6/20	46	171.0	2.43	46	52.8	2.36	46	1.03	0.01
2	26	6/21-6/27	105	159.5	1.45	99	42.9	1.25	99	1.03	0.01
2	27	6/28-7/04	85	157.2	1.56	85	39.9	1.13	85	1.01	0.01
2	28	7/05-7/11	68	149.7	2.43	68	36.0	1.68	68	1.02	0.01
2	29	7/12-7/18	40	155.5	2.24	40	39.1	1.77	40	1.01	0.01
2	30	7/19-7/25	20	162.6	2.60	19	46.5	2.26	19	1.06	0.01
2	31	7/26-8/01	9	156.1	9.26	9	45.0	7.04	9	1.10	0.04
2	32	8/02-8/08	8	168.5	3.07	8	52.4	3.38	8	1.08	0.02
2	33	8/09-8/15	7	175.6	4.47	7	60.5	4.65	7	1.11	0.02
2	34	8/16-8/22	7	171.4	15.69	7	70.1	13.65	7	1.21	0.03
2	35	8/23-8/29	4	142.0	20.91	4	32.9	12.16	4	0.98	0.03
2	36	8/30-9/05	6	120.5	13.53	6	23.3	9.55	6	1.10	0.03
2	37	9/06-9/12	2	88.0	12.00	2	7.9	2.30	2	1.15	0.13
Total			425	157.7	0.99	418	42.4	0.78	418	1.03	0.00
3	24	6/07-6/13	1	150.0	0.00	1	30.2	0.00	1	0.89	0.00
3	25	6/14-6/20	1	146.0	0.00	1	28.6	0.00	1	0.92	0.00
3	26	6/21-6/27	3	175.3	16.01	3	57.6	15.24	3	1.02	0.02
3	27	6/28-7/04	1	180.0	0.00	1	52.4	0.00	1	0.90	0.00
3	29	7/12-7/18	1	151.0	0.00	1	34.6	0.00	1	1.00	0.00
Total			7	164.7	8.26	7	45.5	7.74	7	0.97	0.02

Table 11. Summer Bay Lake sockeye salmon smolt stomach analysis, 1999.

Sample Date	Length(mm)	Weight (gm)	Stomach Fullness	Stomach Contents
6/20/99	110	16	full	Ceratopogonidae 95%, Simuliidae 5%
6/20/99	105	12	1/2 full	Ceratopogonidae 99%, Hydracarina < 1%,
6/20/99	95	9.4	1/2 full	Ceratopogonidae 100%
6/20/99	90	6.6	1/4 full	Unidentifiable fry 80%, Empididae 15%, Ceratopogonidae 5%
6/20/99	81	5.5	1/4 full	Ceratopogonidae 100%
7/25/99	71	3.6	empty	
7/25/99	40	0.9	mostly empty	Diptera parts
7/25/99	40	0.9	1/4 full	Ceratopogonidae 95%, Simuliidae 5%
7/25/99	40	0.8	1/4 full	Ceratopogonidae 100%
7/25/99	49	1.2	1/4 full	Ceratopogonidae 100%
7/25/99	39	0.7	full	Copepoda 60%, Ceratopogonidae 35%, Hydracarina 5%
7/25/99	44	1	1/2 full	Ceratopogonidae 100%
7/25/99	44	0.9	full	Ceratopogonidae 80%, Simuliidae
7/25/99	45	1.2	1/2 full	Simuliidae 80%, Ceratopogonidae20%
7/25/99	43	0.9	mostly empty	some copepoda
no date	38	0.6	mostly empty	Copepoda 60%, Diptera pieces 40%
no date	38	0.8	mostly empty	Ceratopogonidae
no date	34	0.5	empty	
no date	44	0.9	empty	
no date	34	0.5	1/4 full	Ceratopogonidae 100%
no date	32	0.4	mostly empty	Diptera parts
no date	50	1.5	empty	
no date	47	1.2	full	Trichoptera 95%, Diptera 5%
no date	44	1	empty	
no date	45	1.1	empty	
no date	45	0.9	mostly empty	Ostracoda
no date	44	0.7	1/2 full	Trichoptera 100%
no date	50	1.3	empty	
no date	39	0.6	empty	
no date	42	0.8	empty	

Table 12. Daily and cumulative adult salmon escapement by age class and species into Summer Bay, 1999.

	Sockeye			Sockeye By Age Class[a]						Coho			Pink		
Date	Daily	Cum. #	Cum. %	0.3	1.2	1.3	2.2	2.3	Other	Daily	Cum. #	Cum. %	Daily	Cum.	Cum. %
30-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-Jun	9	9	0	2	2	6	0	0	0	0	0	0	0	0	0
3-Jun	2	11	0	0	0	1	0	0	0	0	0	0	0	0	0
4-Jun	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0
5-Jun	12	23	1	2	2	8	0	0	0	0	0	0	0	0	0
6-Jun	13	36	1	2	2	8	0	0	0	0	0	0	0	0	0
7-Jun	14	50	1	2	2	9	0	0	0	0	0	0	0	0	0
8-Jun	2	52	2	0	0	1	0	0	0	0	0	0	0	0	0
9-Jun	17	69	2	3	3	11	0	0	0	0	0	0	0	0	0
10-Jun	46	115	3	8	8	30	0	0	0	0	0	0	0	0	0
11-Jun	13	128	4	2	2	9	0	0	0	0	0	0	0	0	0
12-Jun	15	143	4	3	3	10	0	0	0	0	0	0	0	0	0
13-Jun	10	153	5	2	2	7	0	0	0	0	0	0	0	0	0
14-Jun	13	166	5	1	2	10	0	0	0	0	0	0	0	0	0
15-Jun	16	182	5	2	2	12	0	0	0	0	0	0	0	0	0
16-Jun	6	188	6	1	1	5	0	0	0	0	0	0	0	0	0
17-Jun	14	202	6	1	2	11	0	0	0	0	0	0	0	0	0
18-Jun	10	212	6	1	1	8	0	0	0	0	0	0	0	0	0
19-Jun	6	218	6	1	1	5	0	0	0	0	0	0	0	0	0
20-Jun	58	276	8	6	7	45	0	0	0	0	0	0	0	0	0
21-Jun	23	299	9	2	4	17	0	0	0	0	0	0	0	0	0

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Table 12. (page 2 of 5)

	Sockeye			Sockeye By Age Class[a]						Coho			Pink		
Date	Daily	Cum. #	Cum. %	0.3	1.2	1.3	2.2	2.3	Other	Daily	Cum. #	Cum. %	Daily	Cum.	Cum. %
22-Jun	12	311	9	1	2	9	0	0	0	0	0	0	0	0	0
23-Jun	32	343	10	3	5	24	0	0	0	0	0	0	0	0	0
24-Jun	85	428	13	8	13	64	0	0	0	0	0	0	0	0	0
25-Jun	66	494	15	6	10	50	0	0	0	0	0	0	0	0	0
26-Jun	45	539	16	4	7	34	0	0	0	0	0	0	0	0	0
27-Jun	77	616	18	7	12	58	0	0	0	0	0	0	0	0	0
28-Jun	38	654	19	4	8	25	0	1	0	0	0	0	0	0	0
29-Jun	111	765	23	12	23	74	0	3	1	0	0	0	0	0	0
30-Jun	40	805	24	4	8	27	0	1	0	0	0	0	0	0	0
1-Jul	138	943	28	14	28	91	0	3	1	0	0	0	0	0	0
2-Jul	13	956	28	1	3	9	0	0	0	0	0	0	0	0	0
3-Jul	37	993	29	4	8	25	0	1	0	0	0	0	0	0	0
4-Jul	392	1,385	41	41	80	260	0	9	2	0	0	0	0	0	0
5-Jul	25	1,410	42	2	6	16	0	0	0	0	0	0	0	0	0
6-Jul	45	1,455	43	4	10	29	0	1	1	0	0	0	0	0	0
7-Jul	191	1,646	49	15	44	125	1	3	3	0	0	0	0	0	0
8-Jul	104	1,750	52	8	24	68	0	2	2	0	0	0	0	0	0
9-Jul	129	1,879	56	10	30	84	1	2	2	0	0	0	0	0	0
10-Jul	88	1,967	58	7	20	57	0	1	2	0	0	0	0	0	0
11-Jul	141	2,108	62	11	33	92	1	2	3	0	0	0	0	0	0
12-Jul	20	2,128	63	2	5	12	1	0	0	0	0	0	0	0	0
13-Jul	135	2,263	67	14	32	83	3	1	2	0	0	0	0	0	0
14-Jul	52	2,315	69	5	12	32	1	0	1	0	0	0	0	0	0

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Table 12. (page 3 of 5)

Date	Sockeye			Sockeye By Age Class[a]						Coho			Pink		
	Daily	Cum. #	Cum. %	0.3	1.2	1.3	2.2	2.3	Other	Daily	Cum. #	Cum. %	Daily	Cum.	Cum. %
15-Jul	53	2,368	70	5	12	33	1	0	1	0	0	0	0	0	0
16-Jul	35	2,403	71	4	8	22	1	0	1	0	0	0	0	0	0
17-Jul	53	2,456	73	5	12	33	1	0	1	0	0	0	0	0	0
18-Jul	97	2,553	76	10	23	60	2	1	2	0	0	0	0	0	0
19-Jul	33	2,586	77	3	7	21	1	1	1	0	0	0	0	0	0
20-Jul	77	2,663	79	7	16	49	2	2	1	0	0	0	0	0	0
21-Jul	93	2,756	82	9	19	59	2	2	2	0	0	0	0	0	0
22-Jul	39	2,795	83	4	8	25	1	1	1	0	0	0	0	0	0
23-Jul	44	2,839	84	4	9	28	1	1	1	0	0	0	0	0	0
24-Jul	46	2,885	85	4	10	29	1	1	1	0	0	0	0	0	0
25-Jul	23	2,908	86	2	5	15	1	0	0	0	0	0	0	0	0
26-Jul	27	2,935	87	3	4	18	0	0	1	0	0	0	0	0	0
27-Jul	41	2,976	88	4	6	27	1	1	2	0	0	0	2	2	0
28-Jul	14	2,990	89	1	2	9	0	0	1	0	0	0	0	2	0
29-Jul	49	3,039	90	5	8	32	1	1	2	0	0	0	1	3	0
30-Jul	26	3,065	91	3	4	17	0	0	1	0	0	0	1	4	0
31-Jul	37	3,102	92	4	6	24	0	1	2	0	0	0	7	11	0
1-Aug	4	3,106	92	0	1	3	0	0	0	0	0	0	0	11	0
2-Aug	13	3,119	92	1	3	8	0	0	0	0	0	0	1	12	1
3-Aug	45	3,164	94	4	10	29	0	1	1	0	0	0	1	13	1
4-Aug	10	3,174	94	1	2	6	0	0	0	0	0	0	0	13	1
5-Aug	0	3,174	94	0	0	0	0	0	0	0	0	0	0	13	1
6-Aug	16	3,190	95	2	3	10	0	0	0	0	0	0	2	15	1

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Table 12. (page 4 of 5)

	Sockeye			Sockeye By Age Class[a]						Coho			Pink		
Date	Daily	Cum. #	Cum. %	0.3	1.2	1.3	2.2	2.3	Other	Daily	Cum. #	Cum. %	Daily	Cum.	Cum. %
7-Aug	29	3,219	95	3	6	19	0	1	1	0	0	0	0	15	1
8-Aug	17	3,236	96	2	4	11	0	0	0	0	0	0	2	17	1
9-Aug	20	3,256	96	1	8	10	0	0	1	0	0	0	0	17	1
10-Aug	10	3,266	97	0	4	5	0	0	0	0	0	0	3	20	1
11-Aug	9	3,275	97	0	4	5	0	0	0	0	0	0	2	22	1
12-Aug	11	3,286	97	0	4	6	0	0	0	0	0	0	6	28	1
13-Aug	11	3,297	98	0	4	6	0	0	0	0	0	0	1	29	1
14-Aug	3	3,300	98	0	1	2	0	0	0	0	0	0	1	30	1
15-Aug	7	3,307	98	0	3	4	0	0	0	0	0	0	4	34	2
16-Aug	4	3,311	98	0	2	2	0	0	0	1	1	5	3	37	2
17-Aug	13	3,324	98	0	5	7	0	0	0	0	1	5	8	45	2
18-Aug	6	3,330	99	0	3	3	0	0	0	0	1	5	20	65	3
19-Aug	2	3,332	99	0	1	1	0	0	0	0	1	5	17	82	4
20-Aug	7	3,339	99	0	3	4	0	0	0	1	2	10	39	121	5
21-Aug	0	3,339	99	0	0	0	0	0	0	0	2	10	29	150	7
22-Aug	1	3,340	99	0	0	1	0	0	0	0	2	10	23	173	8
23-Aug	2	3,342	99	0	1	1	0	0	0	1	3	15	56	229	10
24-Aug	8	3,350	99	0	3	4	0	0	0	3	6	30	60	289	13
25-Aug	1	3,351	99	0	0	1	0	0	0	0	6	30	102	391	17
26-Aug	1	3,352	99	0	0	1	0	0	0	2	8	40	169	560	25
27-Aug	2	3,354	99	0	1	1	0	0	0	1	9	45	51	611	27
28-Aug	2	3,356	99	0	1	1	0	0	0	2	11	55	263	874	39
29-Aug	3	3,359	100	0	1	2	0	0	0	0	11	55	279	1,153	51

-Continued-

Table 12. (page 5 of 5)

	Sockeye			Sockeye By Age Class[a]						Coho			Pink		
Date	Daily	Cum. #	Cum. %	0.3	1.2	1.3	2.2	2.3	Other	Daily	Cum. #	Cum. %	Daily	Cum.	Cum. %
30-Aug	3	3,362	100	0	1	2	0	0	0	2	13	65	9	1,162	52
31-Aug	0	3,362	100	0	0	0	0	0	0	0	13	65	173	1,335	59
1-Sep	1	3,363	100	0	0	1	0	0	0	0	13	65	139	1,474	66
2-Sep	3	3,366	100	0	1	2	0	0	0	0	13	65	86	1,560	69
3-Sep	0	3,366	100	0	0	0	0	0	0	1	14	70	142	1,702	76
4-Sep	2	3,368	100	0	1	1	0	0	0	2	16	80	79	1,781	79
5-Sep	0	3,368	100	0	0	0	0	0	0	0	16	80	50	1,831	81
6-Sep	3	3,371	100	0	1	2	0	0	0	0	16	80	95	1,926	86
7-Sep	3	3,374	100	0	1	2	0	0	0	0	16	80	36	1,962	87
8-Sep	0	3,374	100	0	0	0	0	0	0	0	16	80	53	2,015	90
9-Sep	1	3,375	100	0	0	1	0	0	0	4	20	100	35	2,050	91
Post Weir Estimate													200	2,250	100
Total	3,375			325	715	2,220	29	54	50	20			2,250		
Percent				9.6	21.1	65.7	0.7	1.4	1.5						

[a] Sockeye by age class may not total to exact daily count due to rounding errors.

Post weir estimate includes 200 fish that moved into the lake after the weir was removed.

Table 13. Age composition of Summer Bay Lake sockeye salmon escapement by week, 1999.

Statistical Week	Sample Size		Age Composition 0.2	1.1	0.3	1.2	1.3	2.2	2.3	3.3	Total
23	0	Percent	0	0	17.9	17.9	64.3	0	0	0	100
5/31-6/06		Number	0	0	6	6	23	0	0	0	36
24	28	Percent	0	0	17.2	17.2	65.6	0	0	0	100
6/07-6/13		Number	0	0	20	20	77	0	0	0	117
25	31	Percent	0	0	10.6	11.6	77.8	0	0	0	100
6/14-6/20		Number	0	0	13	14	96	0	0	0	123
26	81	Percent	0	0	9.1	15.7	75.0	0	0.3	0	100
6/21-6/27		Number	0	0	31	53	255	0	1	0	340
27	75	Percent	0.5	0	10.5	20.5	66.3	0	2.3	0	100
6/28-7/04		Number	4	0	81	157	510	0	18	0	769
28	103	Percent	1.8	0	7.8	23.1	65.2	0.4	1.7	0	100
7/05-7/11		Number	13	0	56	167	471	3	12	0	723
29	101	Percent	1.8	0	10.1	23.4	61.6	2.5	0.6	0	100
7/12-7/18		Number	8	0	45	104	274	11	3	0	445
30	88	Percent	1.4	0.4	9.4	20.7	63.9	2.2	2.0	0	100
7/19-7/25		Number	5	1	33	74	227	8	7	0	355
31	69	Percent	2.7	2.4	10.1	15.8	66.2	1.3	1.6	0	100
7/26-8/01		Number	5	5	20	31	131	3	3	0	198
32	50	Percent	2.1	0.6	9.8	21.2	64.0	0.3	1.8	0.2	100
8/02-8/08		Number	3	1	13	28	83	0	2	0	130
33	26	Percent	0.2	0	4.4	40.4	51.3	0	0.2	3.5	100
8/09-8/15		Number	0	0	3	29	36	0	0	2	71
34	0	Percent	0	0	3.8	42.3	50.0	0	0	3.8	100
8/16-8/22		Number	0	0	1	14	17	0	0	1	33
35	0	Percent	0	0	3.8	42.3	50.0	0	0	3.8	100
8/23-8/29		Number	0	0	1	8	10	0	0	1	19
36	0	Percent	0	0	3.8	42.3	50.0	0	0	3.8	100
8/30-9/05		Number	0	0	0	4	5	0	0	0	9
37	0	Percent	0	0	3.8	42.3	50.0	0	0	3.8	100
9/06-9/12		Number	0	0	0	3	4	0	0	0	7
Total	652	Percent	1.1	0.2	9.6	21.1	65.7	0.7	1.4	0.1	100.0
		Number	38	7	323	712	2,219	25	46	4	3,375

Percentages may not total to exactly 100% due to rounding errors.

Table 14. Summer Bay Lake and inlet streams escapement distrubution by date and species, 1999.

			Number of Fish by Species				
Date	Section/Area	Visibility	Sockeye	Coho	Pink	Dolly Varden	Comments
28-Jul	Entire System	Fair	0	0	0	0	Visibility fair due to wind. Several jumpers in the lake.
31-Jul	NW & SW Lake	Poor	0	0	0	0	Light ripple on the water.
	and Inlet Stream		0	0	0	20	Dolly Varden observed in the inlet stream.
6-Aug	Lake northwest	Good	0	0	0	0	Partly cloudy with NW wind.
	Lake east	Good	2	0	0	0	Salmon were milling in lake at inlet streams.
	Lake southwest	Good	36	0	0	0	
	Lake inlet	Good	4	0	0	0	
11-Aug	Lake northeast	Good	5	0	0	0	Cloudy with 5k W wind.
	Lake inlet	Good	67	0	0	150	Some of the Dolly Varden were actively spawning in inlet stream.
14-Aug	Lake inlet	Good	51	0	0	0	Lake was too choppy to survey. Ten sockeye were at the confluence of the lake and stream the remainder were upstream of the stream canyon.
16-Aug	Lake west	Good	94	0	0	0	Light chop on lake reduced visibility. S shore counts include lower
	Lake south & inlet	Good	57	0	0	0	portion of the inlet stream.
24-Aug	Lake west	Good	177	0	0	0	Overcast. Count includes one dead sockeye. Nothing in SE lake.
	Lake east	Good	23	0	0	0	
27-Aug	inlet stream	Good	359	0	250		Surveyed from 1/4 mile above the canyon to the lake. Dolly Varden numerous throughout the stream. Pinks above the canyon, sockeye from canyon to the lake. Highest sockeye concentration near stream mouth. A few Dolly Varden in tributary to the SE of lake, these appear to be spawning.

-Continued-

Table 14. (page 2 of 2)

Date	Section/Area	Visibility	Number of Fish by Species				Comments
			Sockeye	Coho	Pink	Dolly Varden	
2-Sep	Lake west	Good	134	0	0	0	Partly cloudy with winds picking up during later portion of the survey.
	Lake east	Good	39	0	0	0	Dead fish were not counted.
5-Sep	Inlet stream	Poor	177		864		Surveyed from 1/2 mile above canyon to the lake. Additional 10 sockeye carcasses. Very many Dolly Varden.
7-Sep	Lake west	Poor	193	0	0	0	Additional 20 sockeye carcasses.
	Lake east	Poor	63	0	0	0	Includes 50 sockeye at the inlet stream mouth.
	Lake south	Poor	36	0	0	0	
7-Sep	Inlet stream	Good	0	0	0	56	Additional 1 coho and 8 pink carcasses.
27-Nov	Inlet stream	Good	0	0	0	3	

Table 15. Age composition of Summer Bay Lake sockeye salmon escapement, 1998-1999.

Year	Sample Dates	Sample Size		Age Composition								Total
				0.2	1.1	0.3	1.2	1.3	2.2	2.3	3.3	
1998	6/07-9/15	705	Percent	0.3	0.3	0.3	58.3	35.9	2.3	2.7	0.0	100.0
			Numbers	7	7	7	1,540	948	60	71	0	2,641
1999	6/07-8/15	652	Percent	1.1	0.2	9.6	21.1	65.7	0.7	1.4	0.1	100.0
			Numbers	38	7	323	712	2,219	25	46	4	3,375

Table 16. Estimated sex composition of the Summer Bay Lake sockeye salmon escapement by week, 1999.

Statistical		Sample			Escapement				
					Percent		Number		
Week	Dates	Females	Males	Total	Females	Males	Females	Males	Total
23	5/31-6/06	0	0	0	36.1	63.9	13	23	36
24	6/07-6/13	14	26	40	35.9	64.1	42	75	117
25	6/14-6/20	22	21	43	48.8	51.2	60	63	123
26	6/21-6/27	47	49	96	50.0	50.0	170	170	340
27	6/28-7/04	55	41	96	57.1	42.9	439	330	769
28	7/05-7/11	75	52	127	58.2	41.8	421	302	723
29	7/12-7/18	68	57	125	54.2	45.8	241	204	445
30	7/19-7/25	53	53	106	49.9	50.1	177	178	355
31	7/26-8/01	41	45	86	47.5	52.5	94	104	198
32	8/02-8/08	28	34	62	46.9	53.1	61	69	130
33	8/09-8/15	28	10	38	70.4	29.6	50	21	71
34	8/16-8/22	0	0	0	72.7	27.3	24	9	33
35	8/23-8/29	0	0	0	73.7	26.3	14	5	19
36	8/30-9/05	0	0	0	77.8	22.2	7	2	9
37	9/06-9/12	0	0	0	71.4	28.6	5	2	7
Total		431	388	819	53.9	46.1	1,819	1,556	3,375

Table 17. Length composition of the Summer Bay Lake sockeye salmon escapement samples by age and sex, 31 May through 12 September, 1999.

	Age Composition								
	0.2	0.3	1.1	1.2	1.3	2.2	2.3	3.3	Total
Females									
Mean Length	473	519	0	481	531	503	543	505	517
SE	25	4	-	3	2	22	3	-	2
Range	425-545	445-575	0-0	420-575	460-575	465-540	535-550	505-505	420-575
Sample Size	4	38	0	84	210	3	4	1	344
Males									
Mean Length	437	553	317	498	561	513	556	0	546
SE	15	3	3	3	1	9	20	-	2
Range	390-480	525-580	315-320	465-545	465-620	500-530	505-600	0-0	315-620
Sample Size	5	25	2	51	219	3	4	0	309
All Fish									
Mean Length	453	533	317	487	546	508	550	505	530
SE	15	3	3	2	1	11	10	-	1
Range	390-545	445-580	315-320	420-575	460-620	465-540	505-600	505-505	315-620
Sample Size	9	63	2	135	429	6	8	1	653

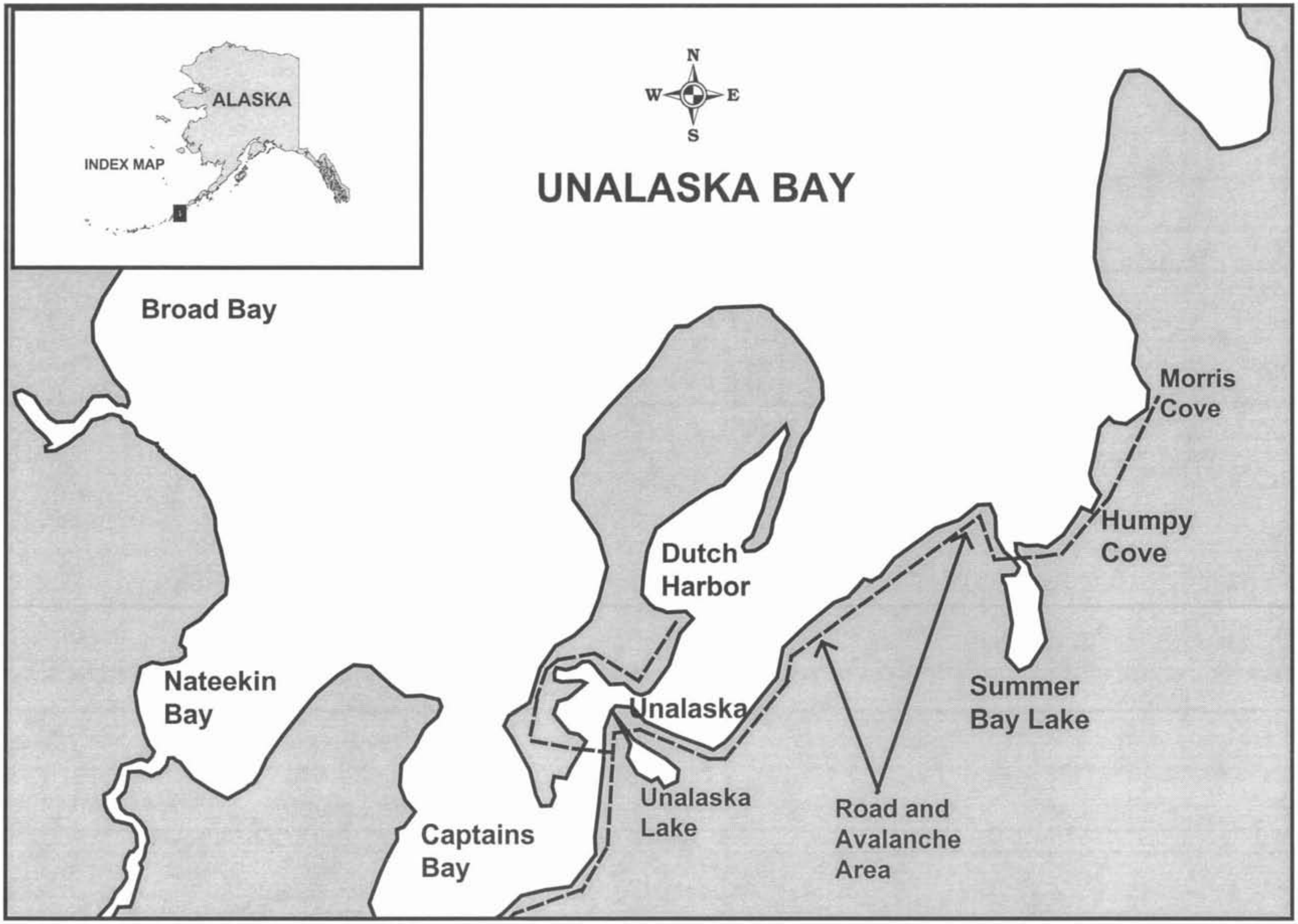


Figure 1. Map of Unalaska Bay and surrounding coastal area showing the relative location of Summer Bay Lake.

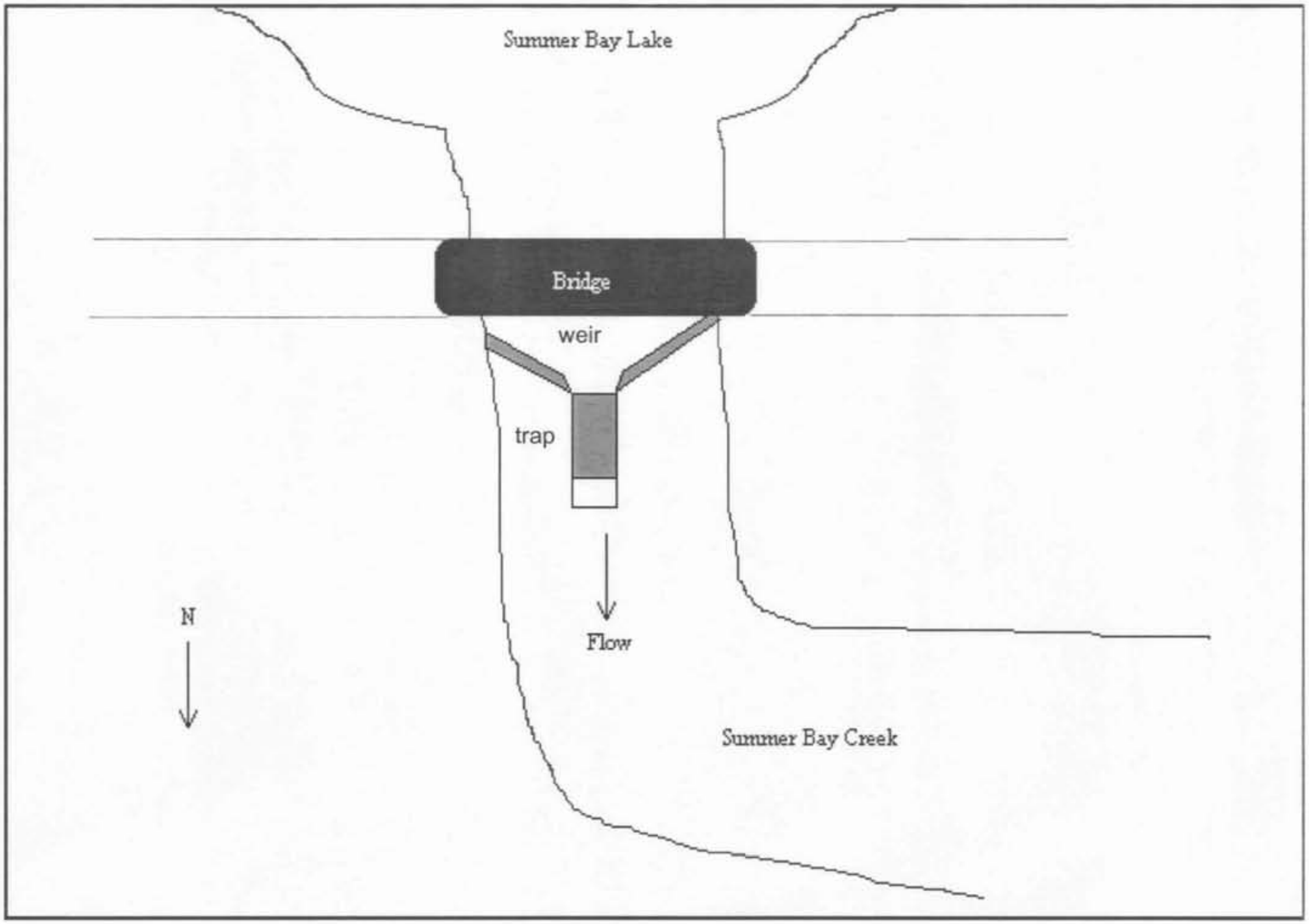


Figure 2. Diagrammatic representation of Summer Bay Creek and the relative locations of the bridge, weir, and lake.

The bridge is located at 53.9° N. lat., 166.5° W. long.

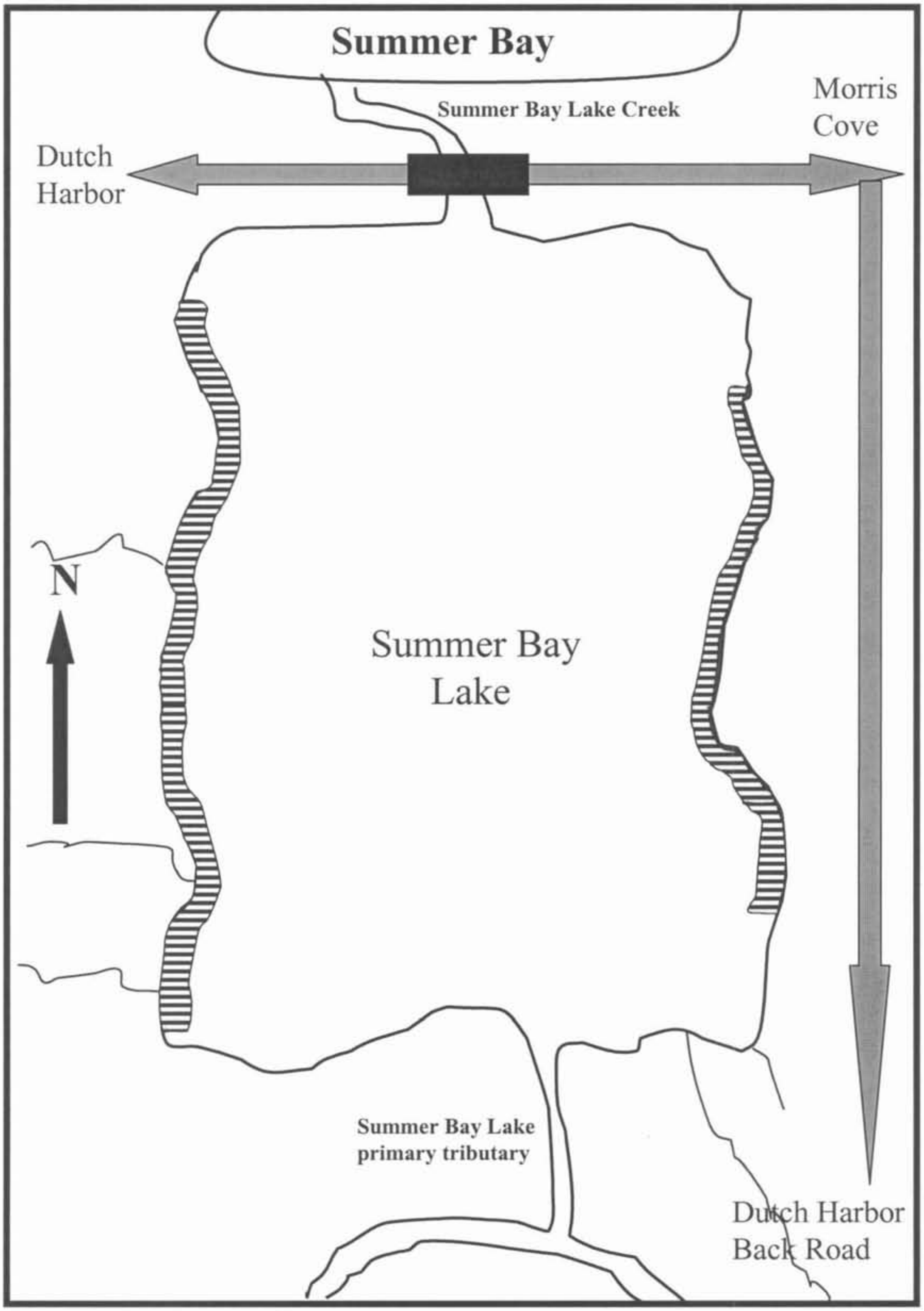


Figure 3. Summer Bay Lake showing bridge (black rectangle), primary tributary, outlet creek, and salmon spawning lake shoal locations (shaded bar areas).

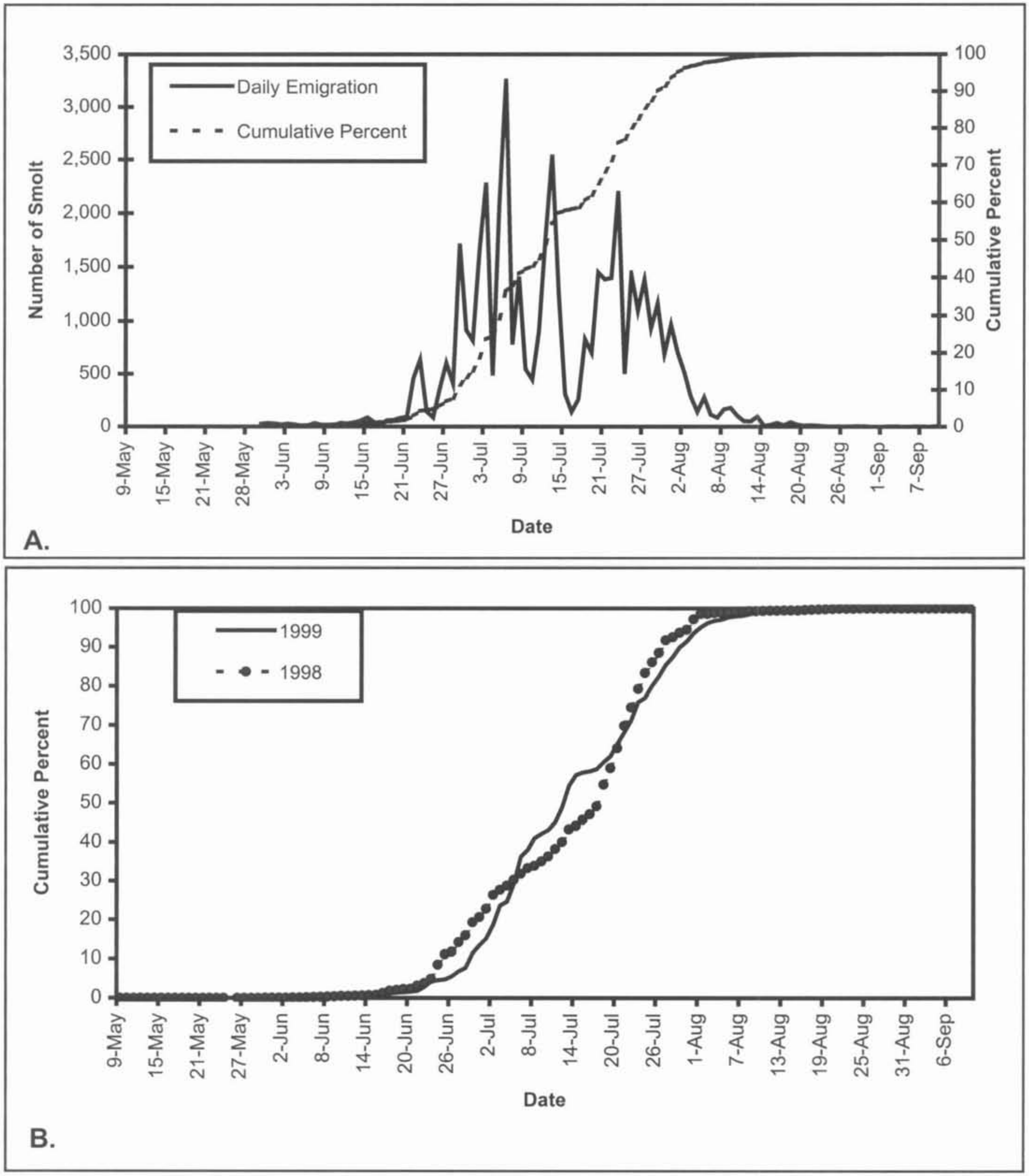


Figure 4. Daily and cumulative percent of sockeye salmon smolt emigration from Summer Bay Lake, 1999 (A); Cumulative percent of sockeye salmon smolt emigration from Summer Bay Lake, 1998-1999 (B).

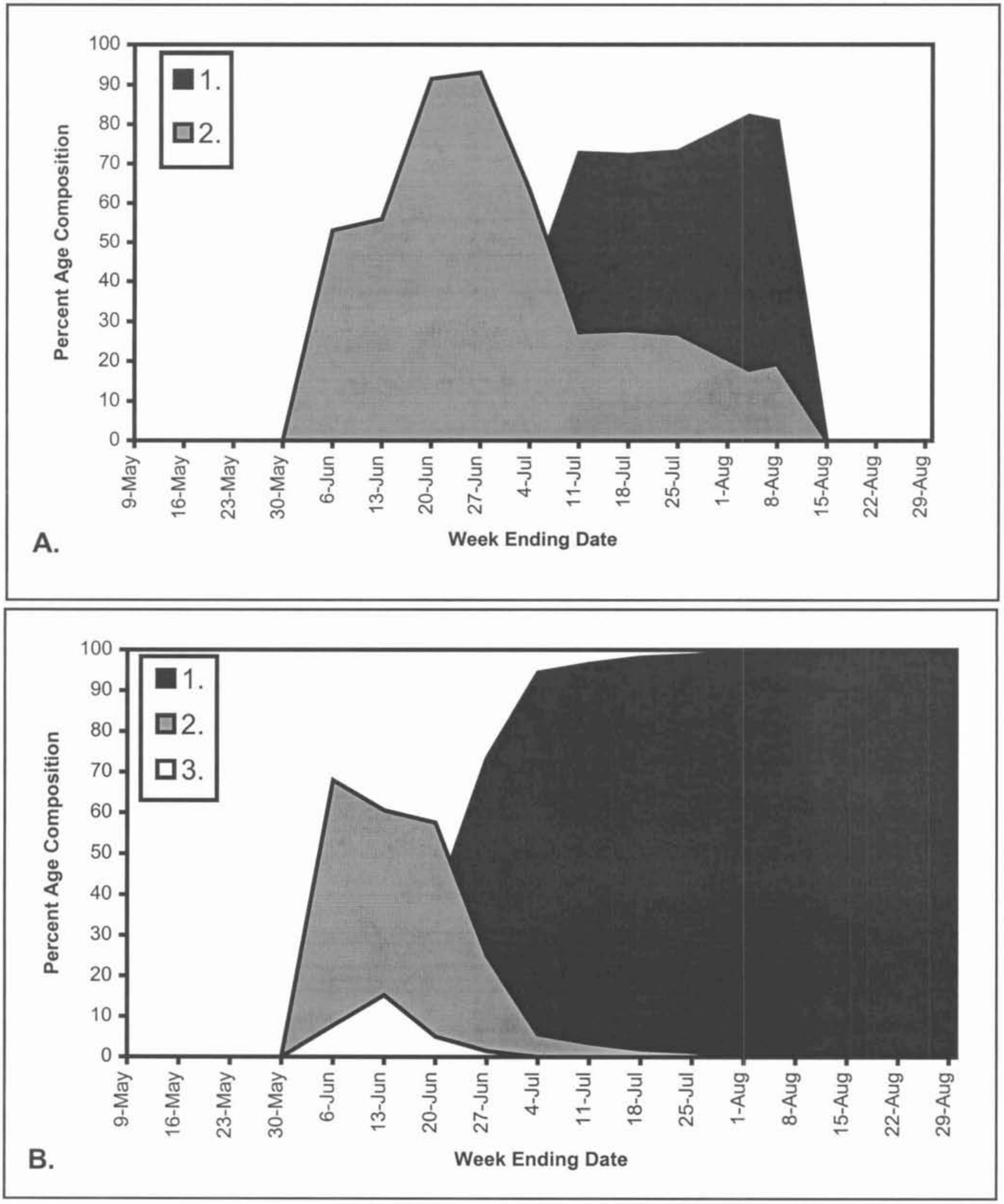


Figure 5. Sockeye smolt percent age composition, Summer Bay Lake, 1999 (A); Sockeye smolt percent age composition, Summer Bay Lake, 1998 (B).

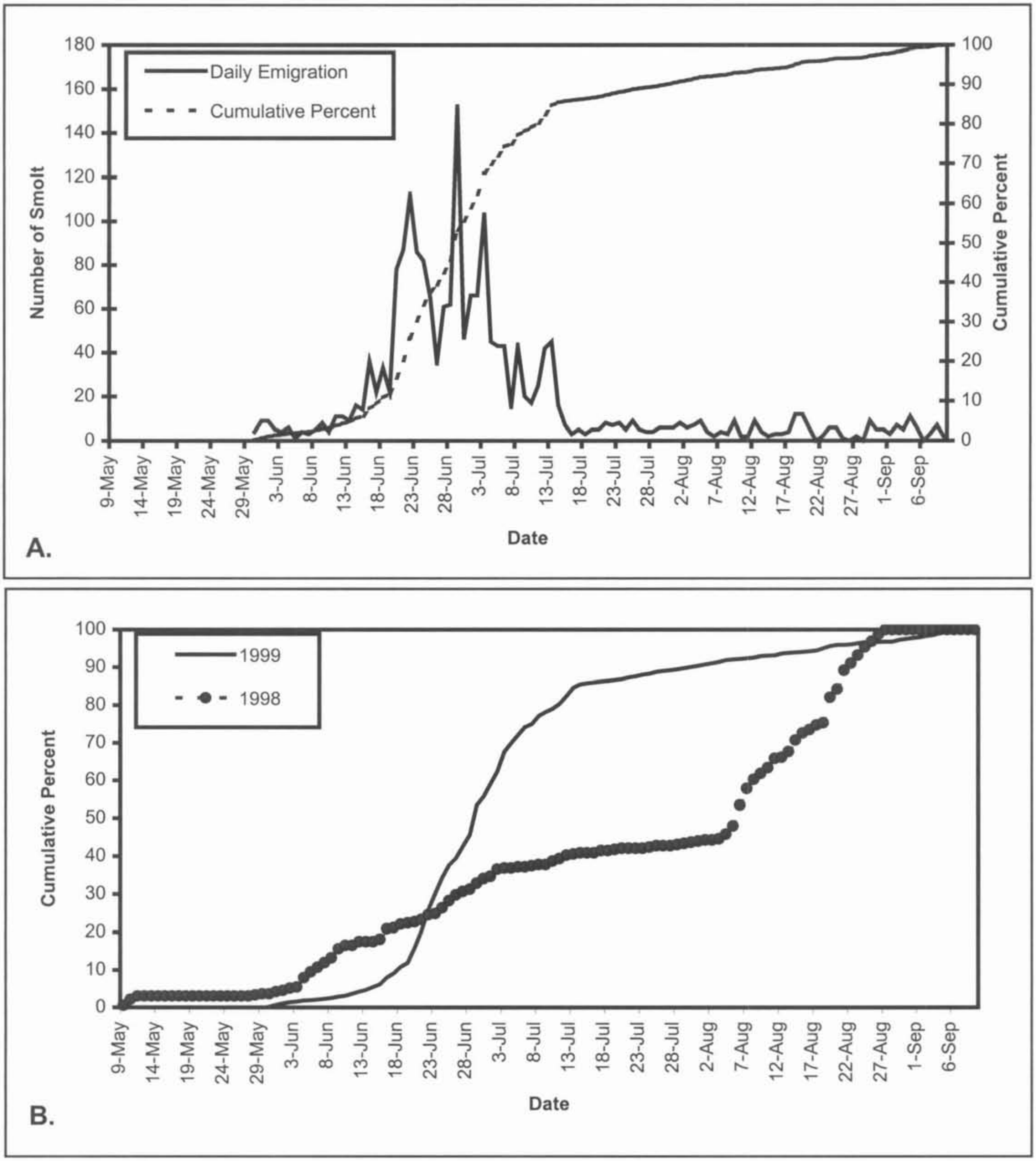
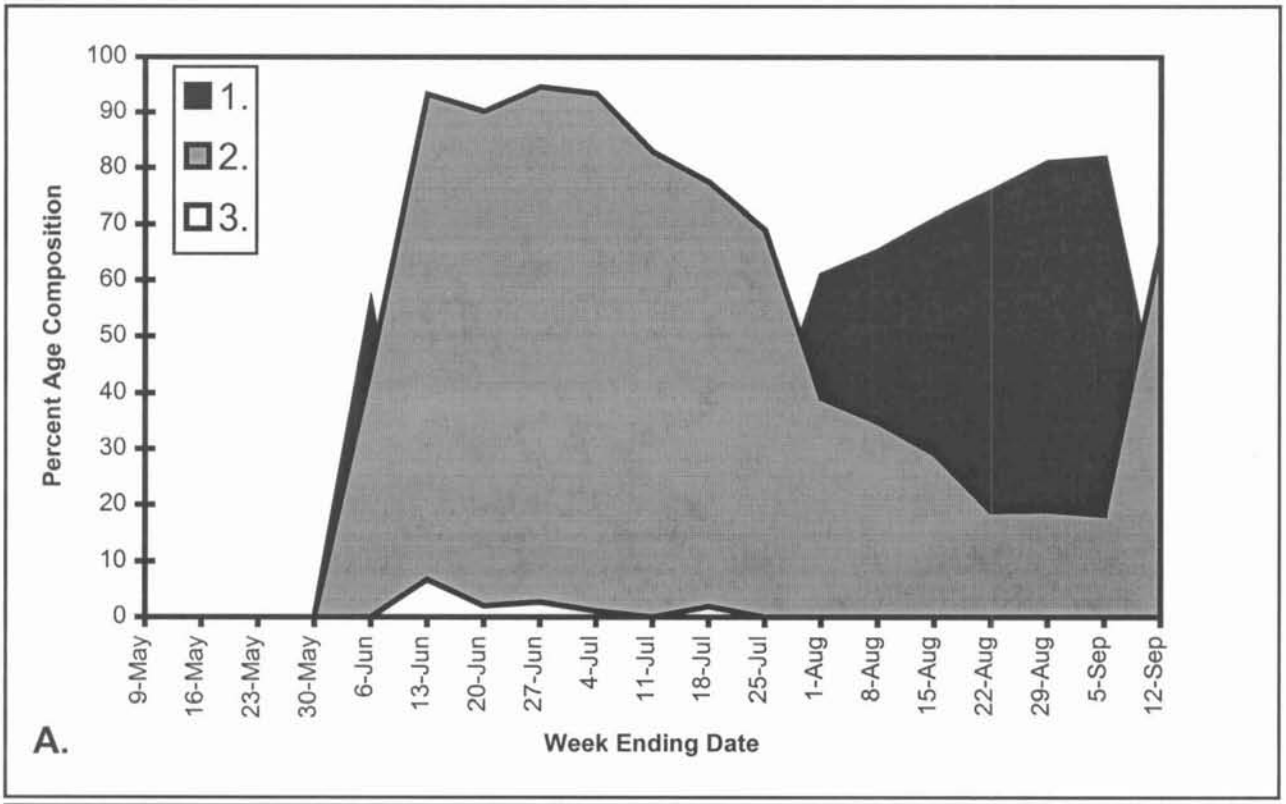


Figure 6. Daily and cumulative percent of coho salmon smolt emigration from Summer Bay Lake, 1999 (A); Cumulative percent of coho salmon smolt emigration from Summer Bay Lake, 1998-1999 (B).



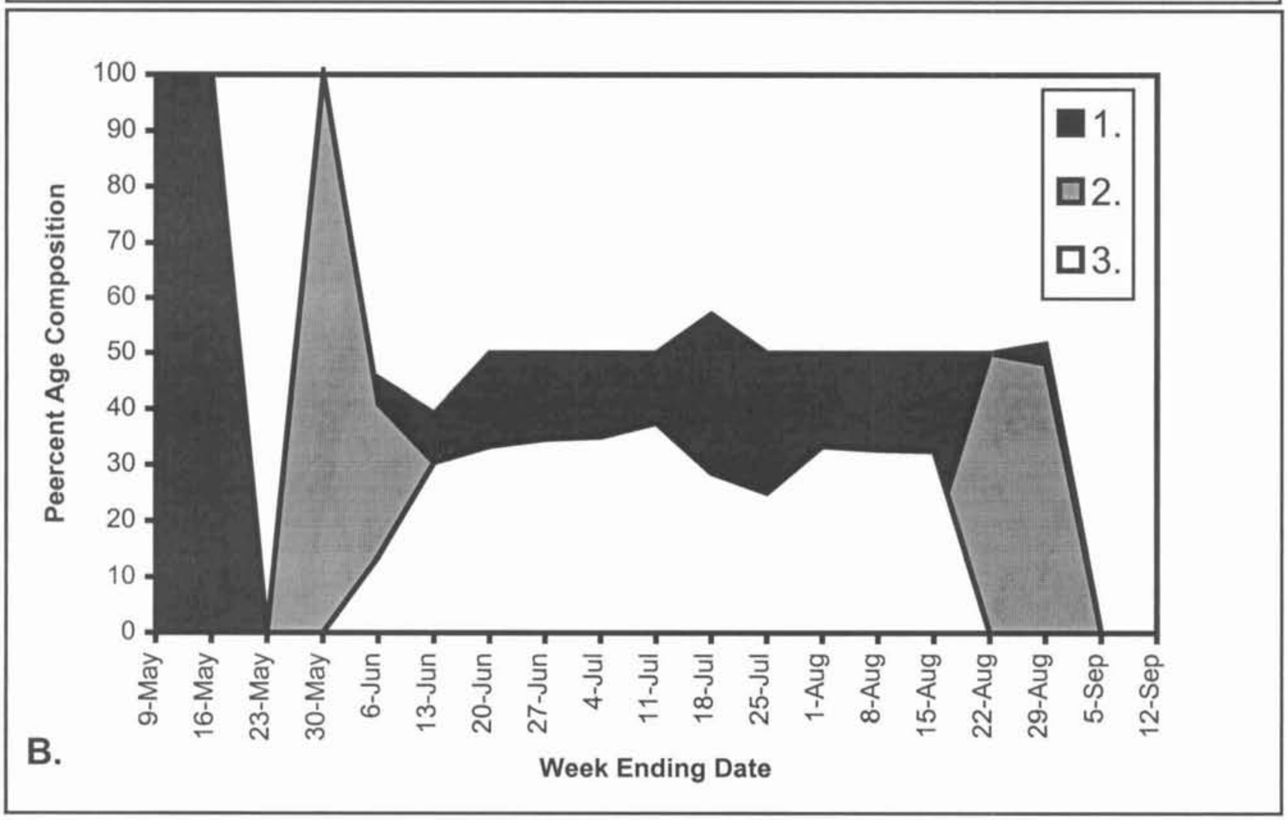


Figure 7. Coho smolt percent age composition, Summer Bay Lake, 1999 (A); Coho smolt percent age composition, Summer Bay Lake, 1998 (B).

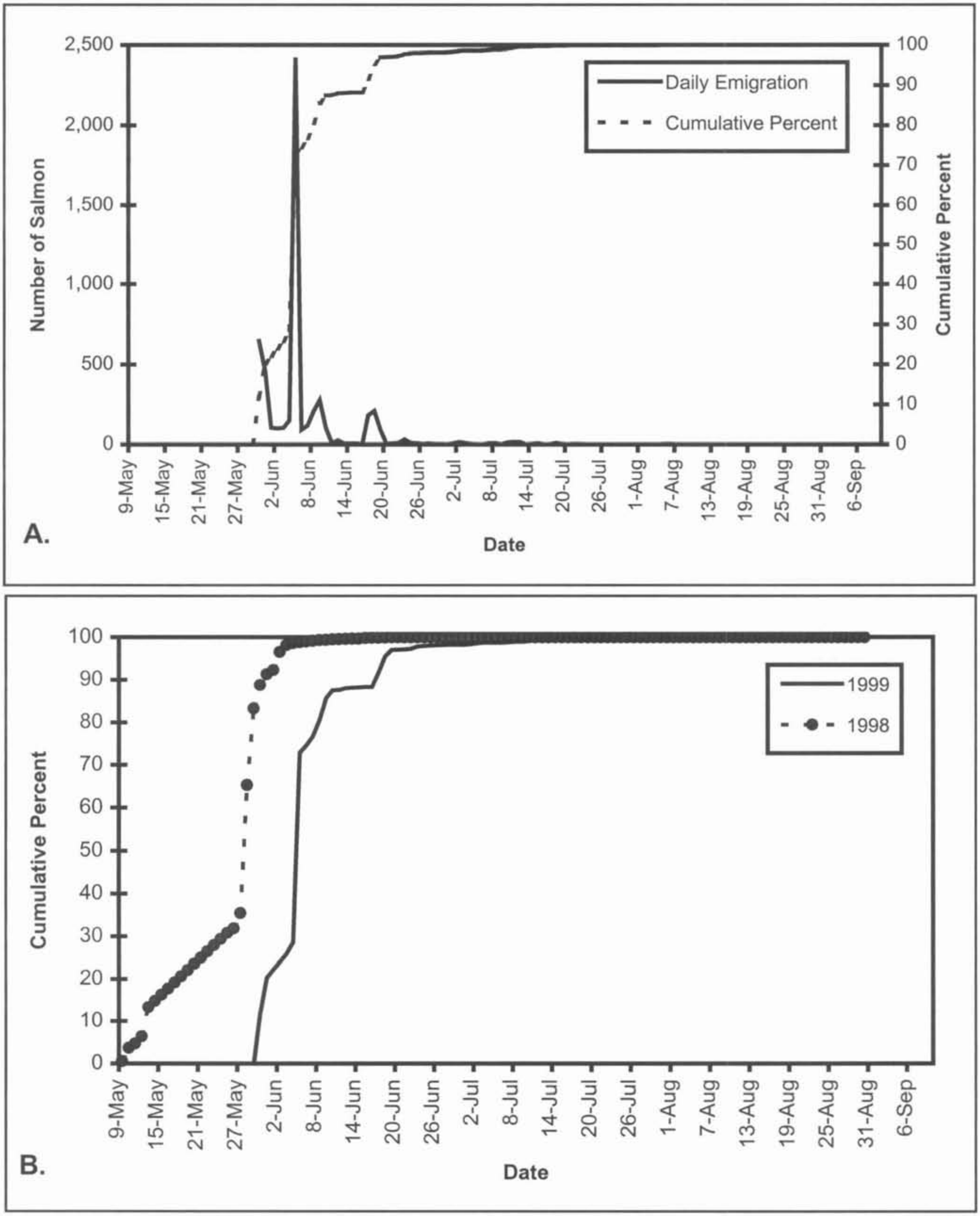


Figure 8. Daily and cumulative percent of juvenile pink salmon emigrating from Summer Bay Lake, 1999 (A); Cumulative percent of juvenile pink salmon emigration from Summer Bay Lake, 1998-1999 (B).

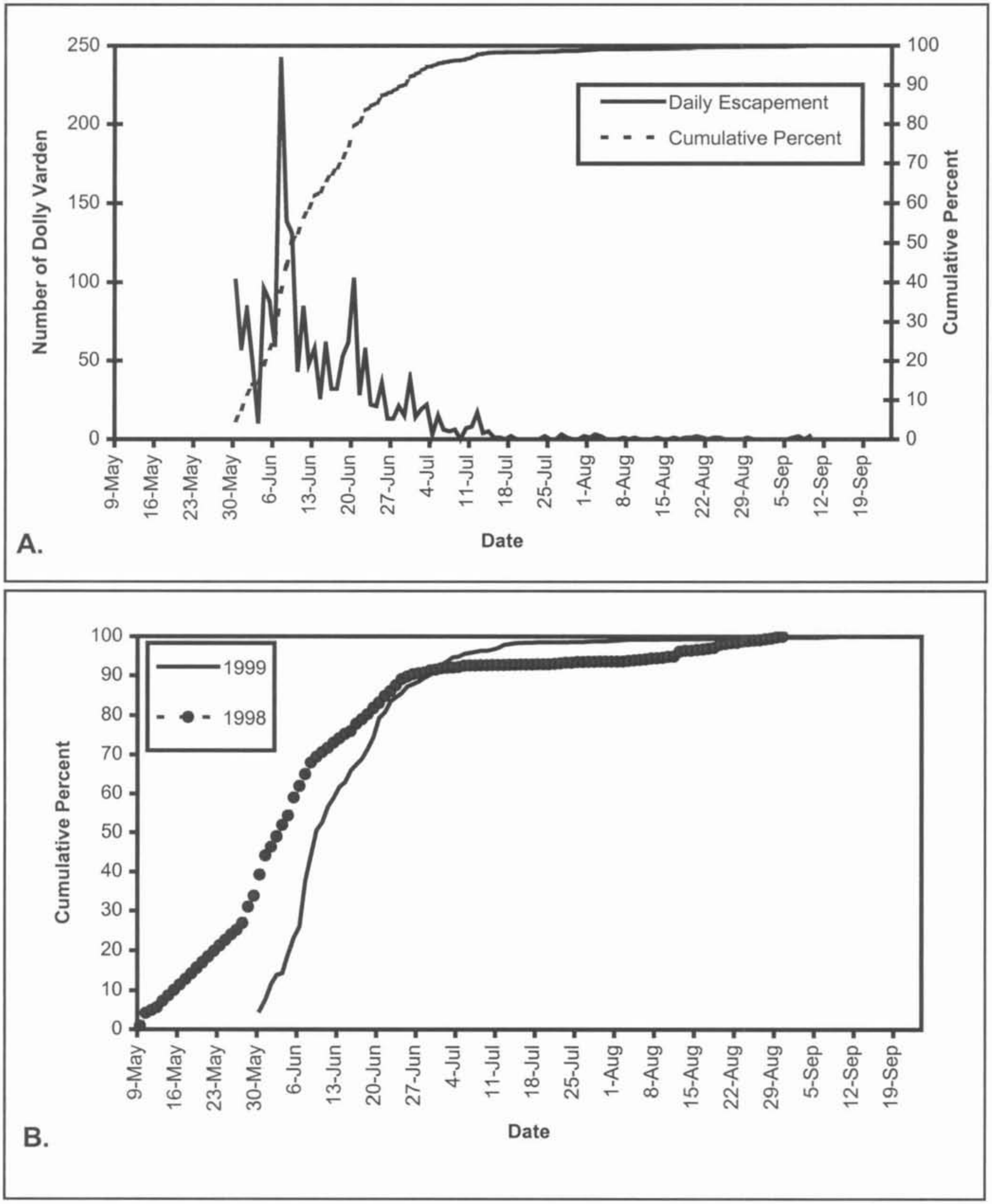


Figure 9. Downstream Dolly Varden migrants from Summer Bay Lake, 1999 (A); Cumulative percent of downstream Dolly Varden migrants from Summer Bay Lake, 1998-1999 (B).

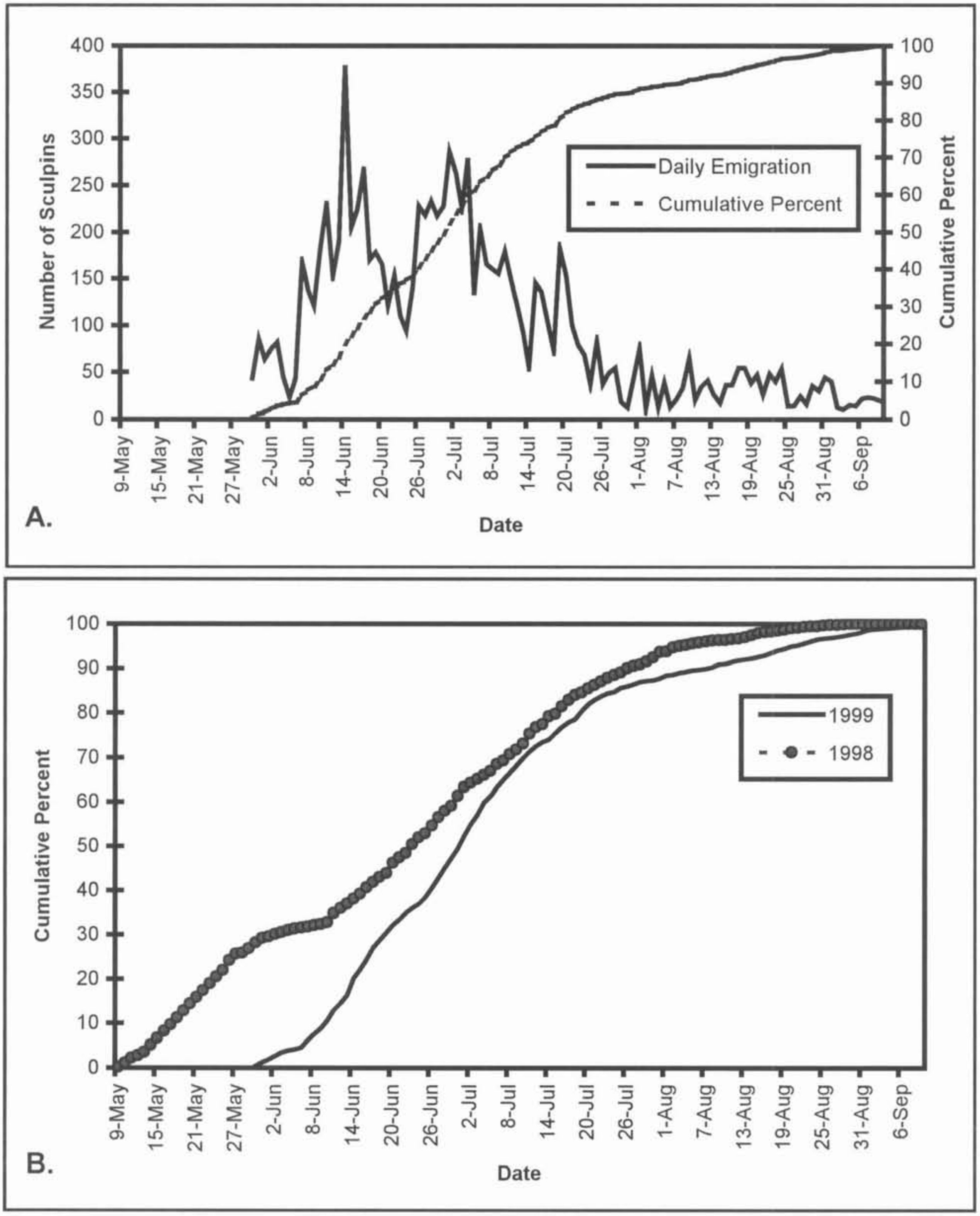


Figure 10. Daily and cumulative percent of sculpin emigration from Summer Bay Lake, 1999 (A); Cumulative percent of sculpin emigration from Summer Bay Lake, 1998-1999 (B).

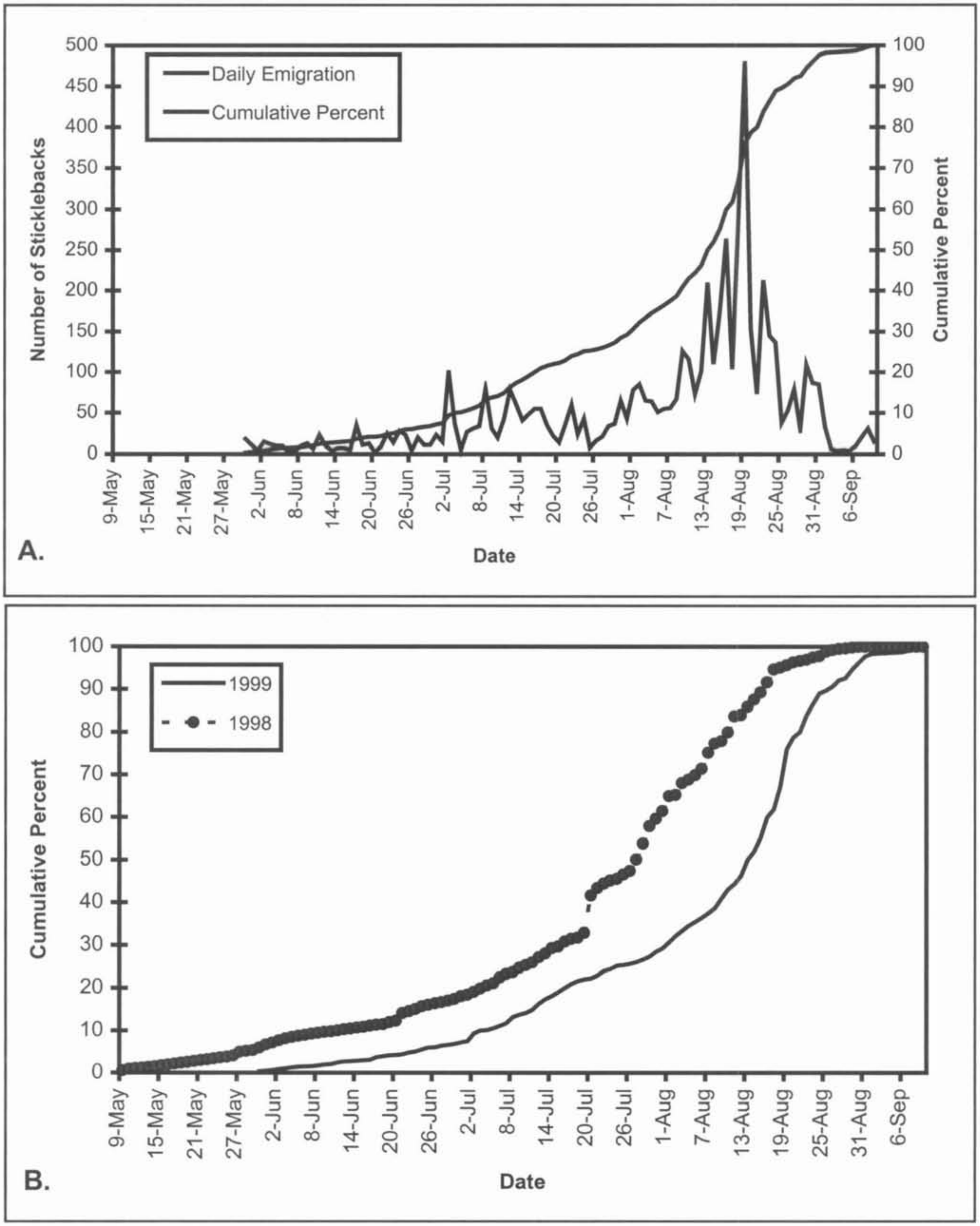


Figure 11. Daily and cumulative percent of stickleback emigration from Summer Bay Lake, 1999 (A); Cumulative percent of stickleback emigration from Summer Bay Lake, 1998-1999 (B).

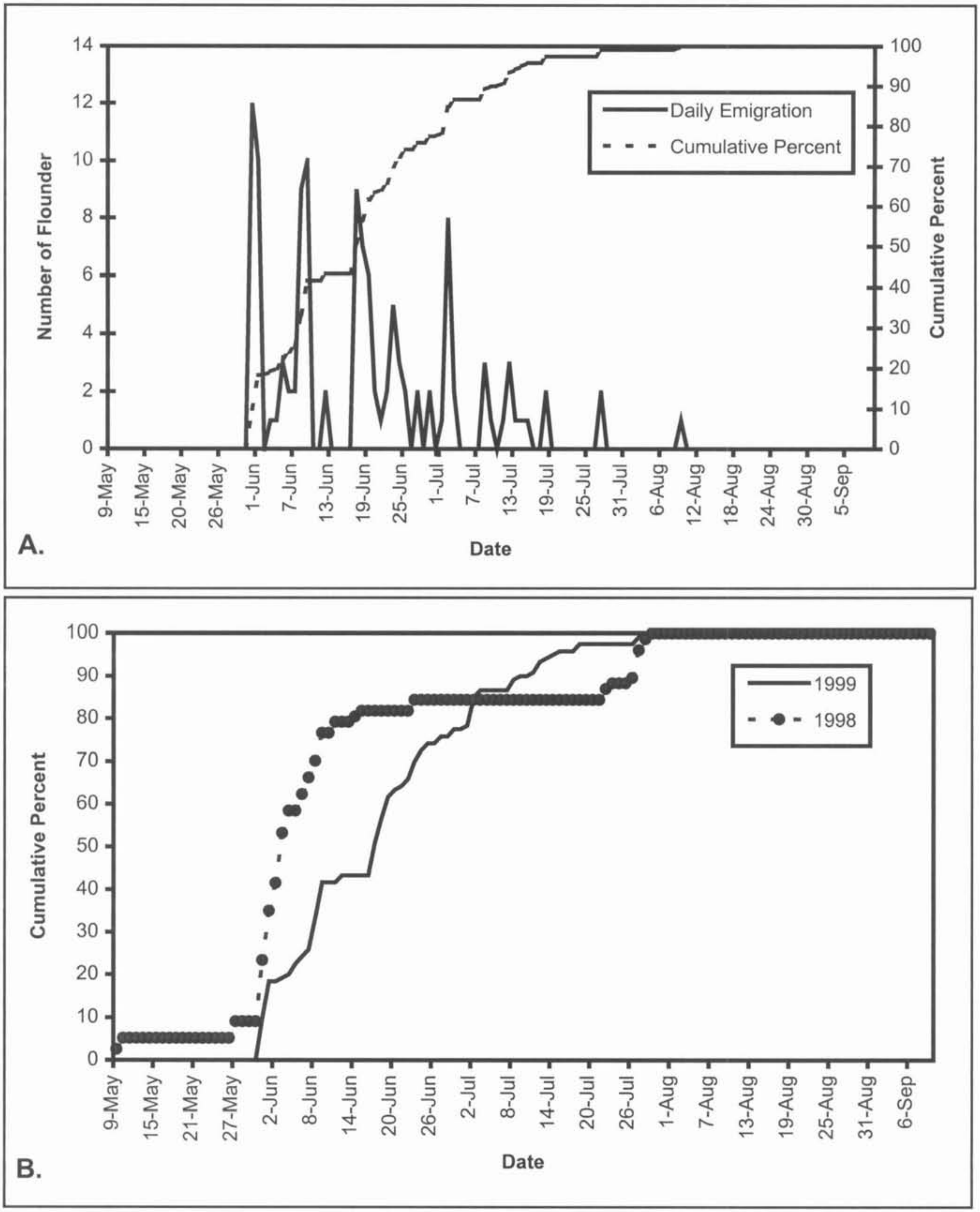


Figure 12. Daily and cumulative percent of flounder emigration from Summer Bay Lake, 1999 (A); Cumulative percent of flounder emigration from Summer Bay Lake, 1998-1999 (B).

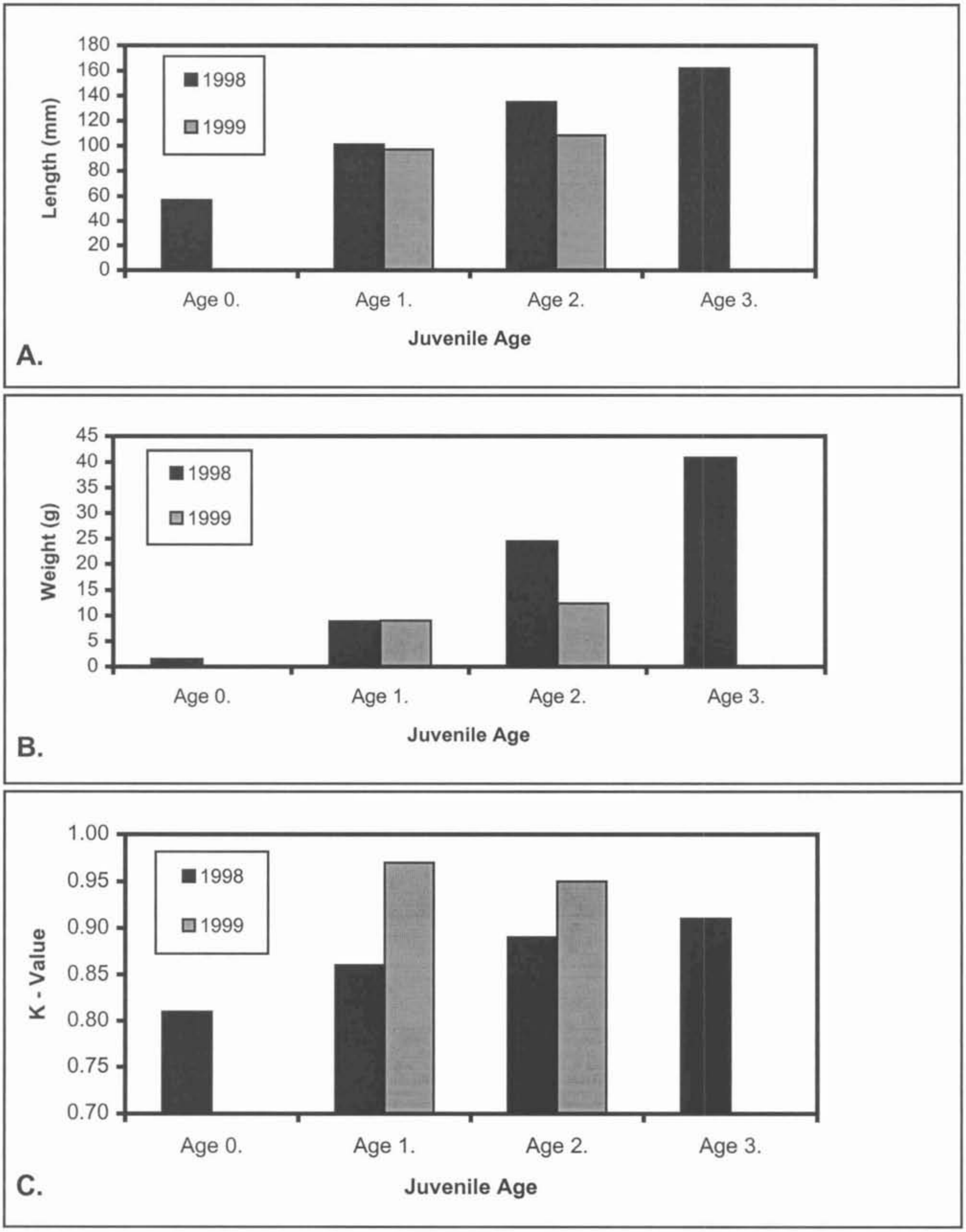


Figure 13. Length (A); Weight (B); Condition (C) of sockeye salmon smolt sampled from Summer Bay Lake, 1998-1999.

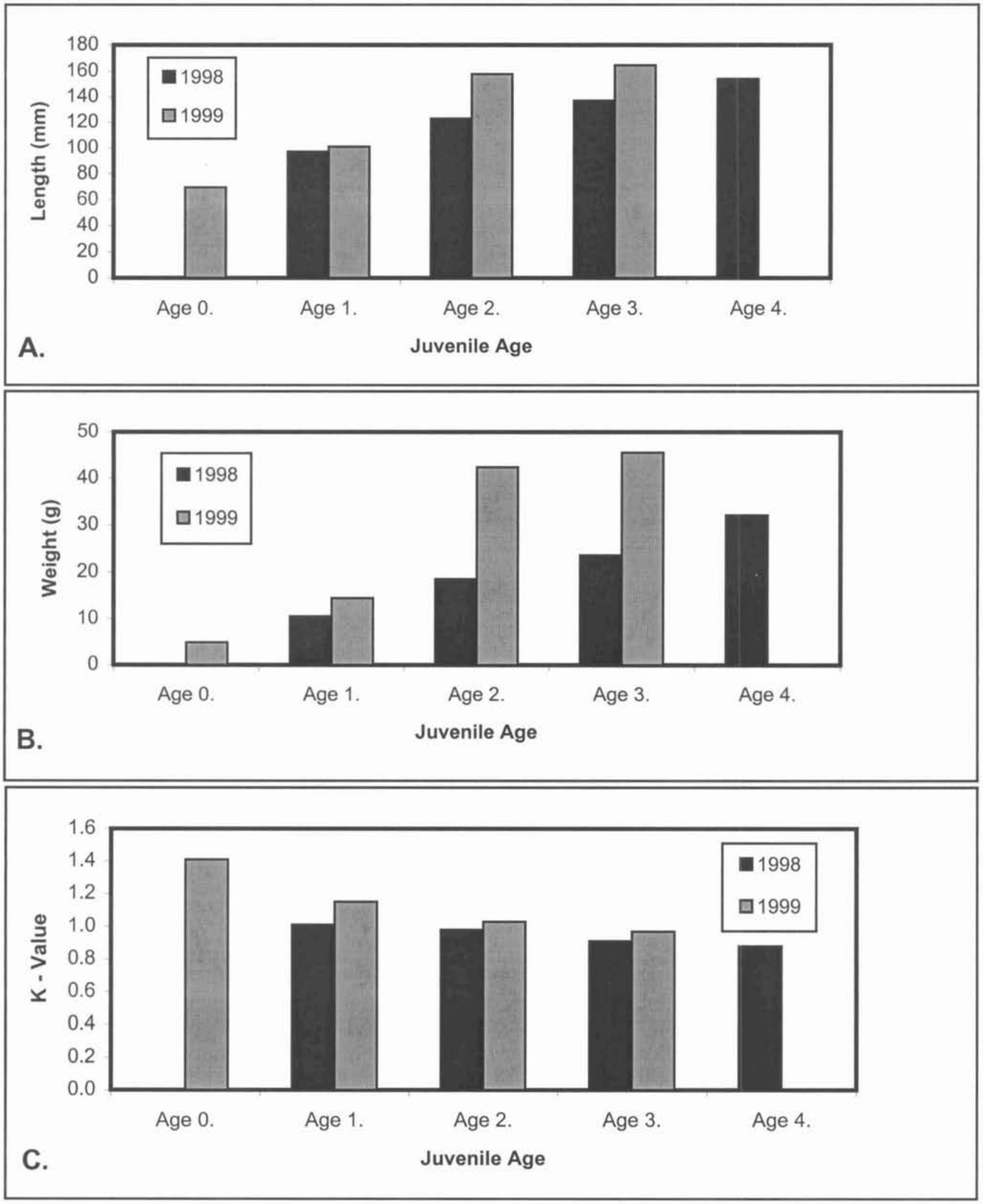


Figure 14. Length (A); Weight (B); Condition (C) of coho salmon smolt sampled from Summer Bay Lake, 1998-1999.

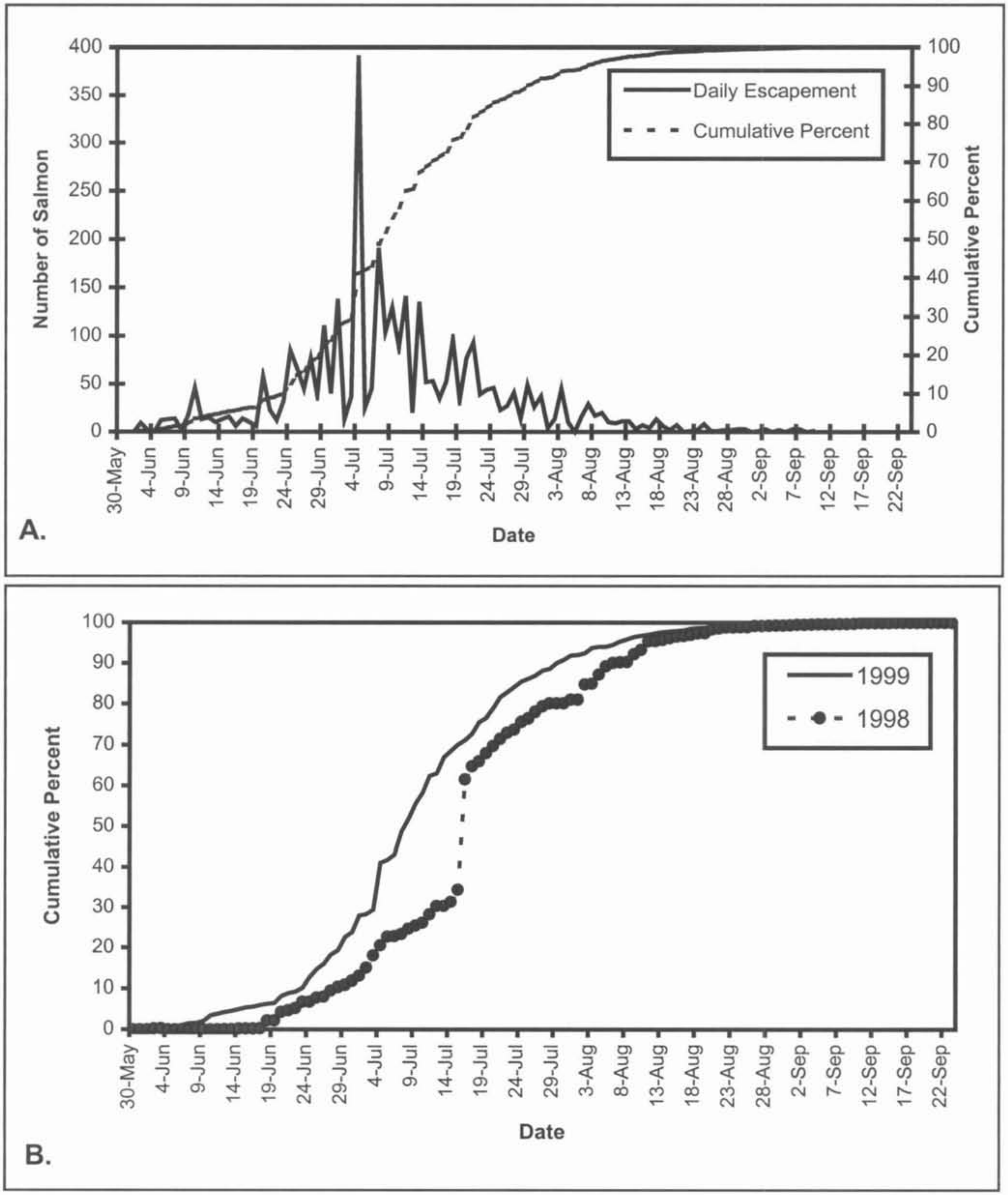


Figure 15. Daily and cumulative percent of adult sockeye salmon escapement into Summer Bay Lake, 1999 (A); Cumulative percent of adult sockeye salmon escapement into Summer Bay Lake, 1998-1999 (B).

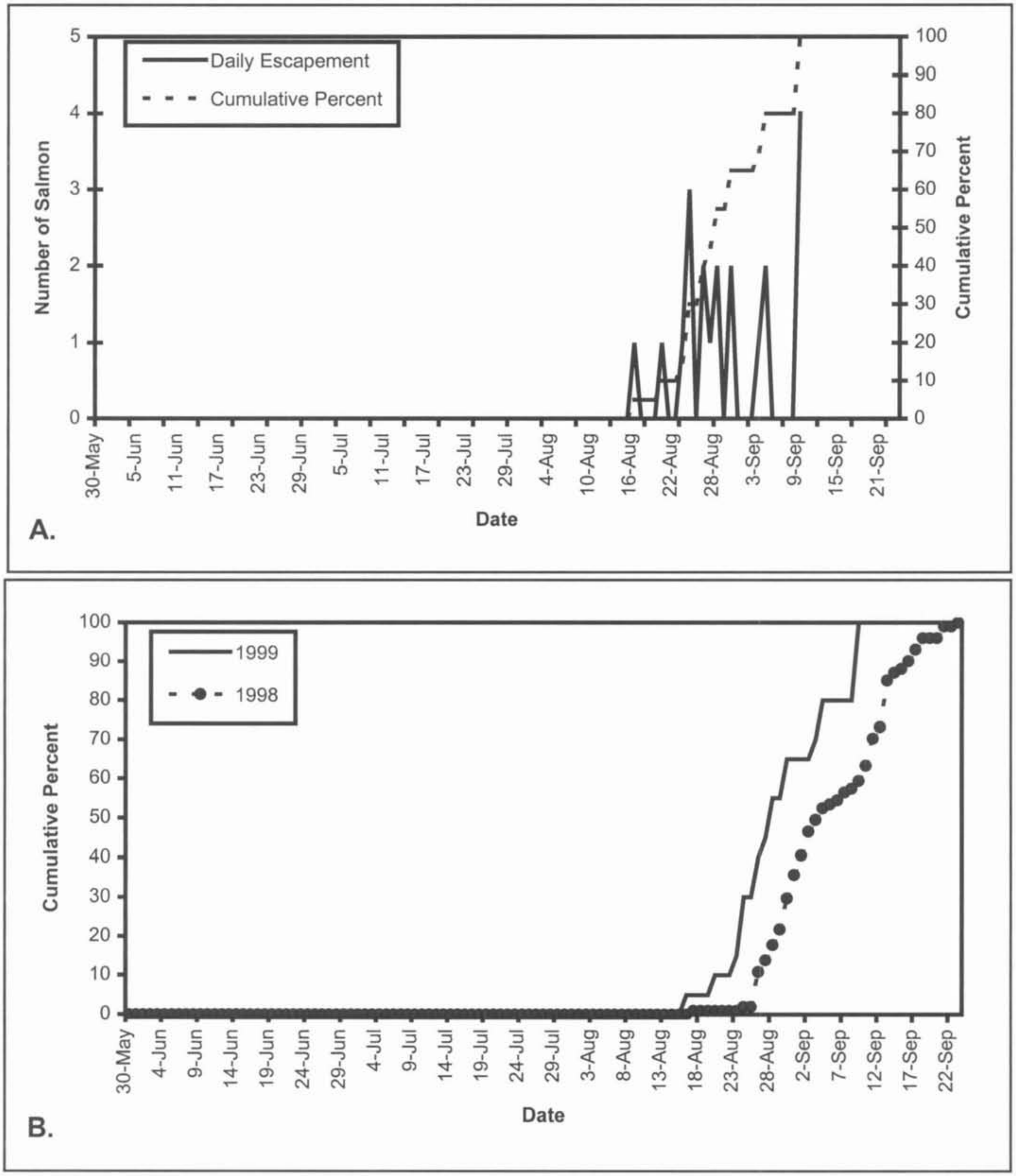
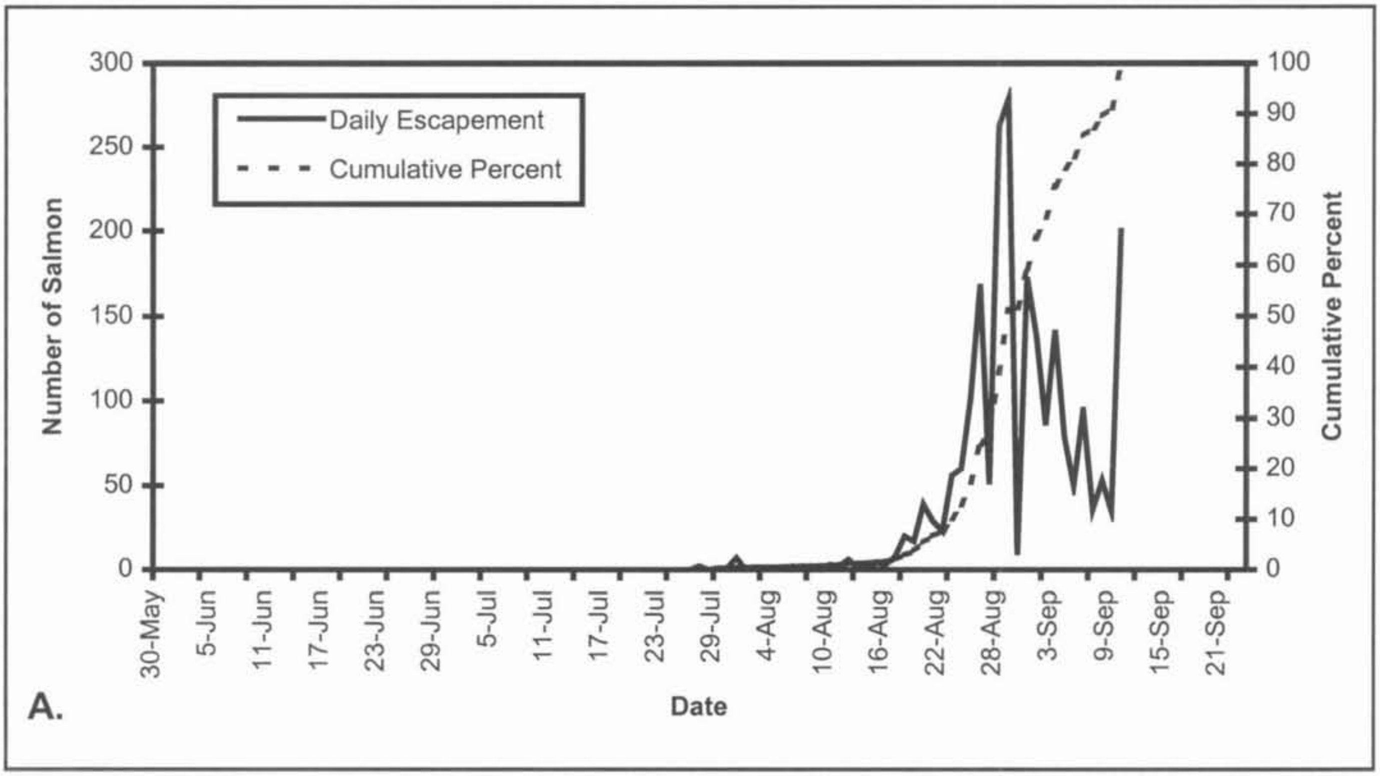


Figure 16. Daily and cumulative percent of adult coho salmon escapement into Summer Bay Lake, 1999 (A); Cumulative percent of adult coho salmon escapement into Summer Bay Lake, 1998-1999 (B).



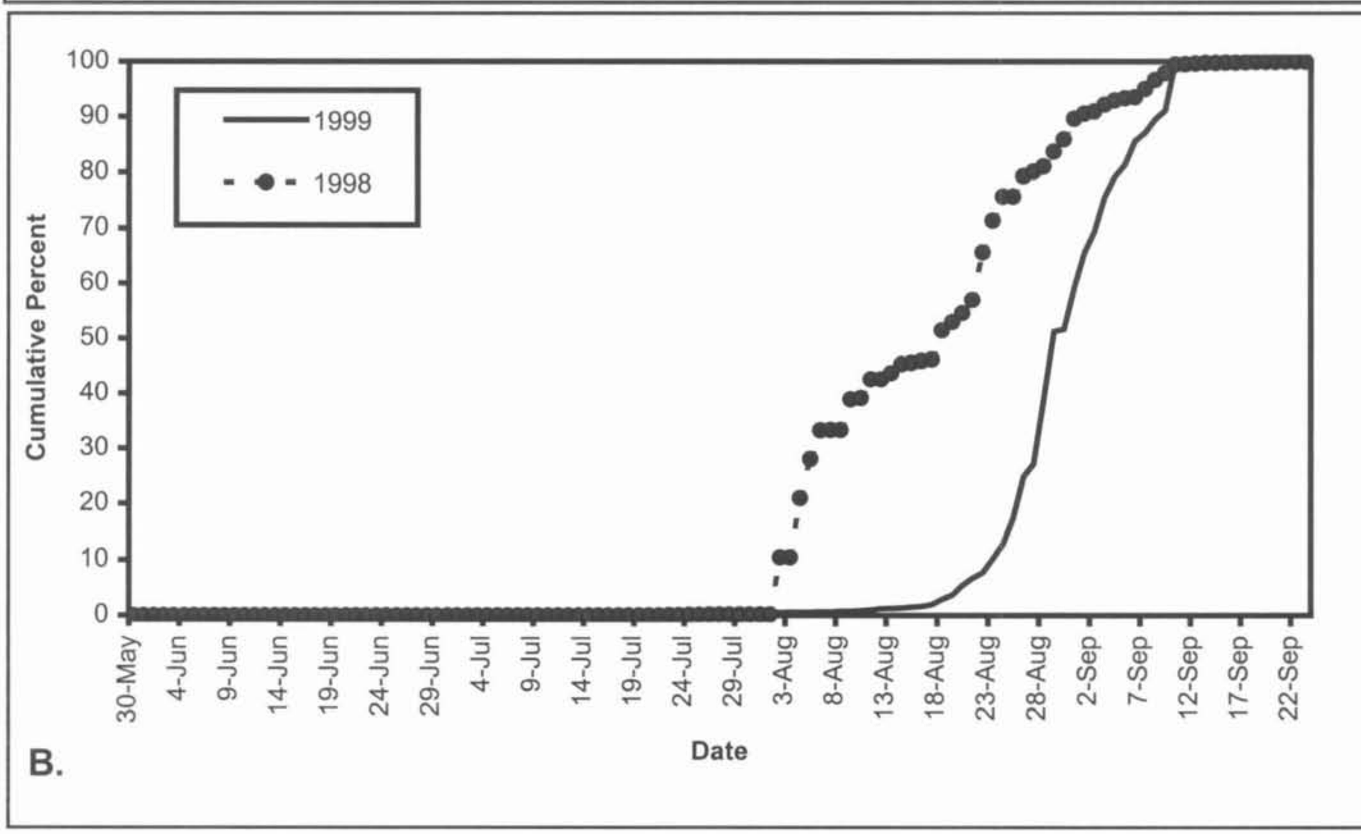


Figure 17. Daily and cumulative percent of pink salmon escapement into Summer Bay Lake, 1999 (A); Cumulative percent of adult pink salmon escapement into Summer Bay Lake, 1998-1999 (B).

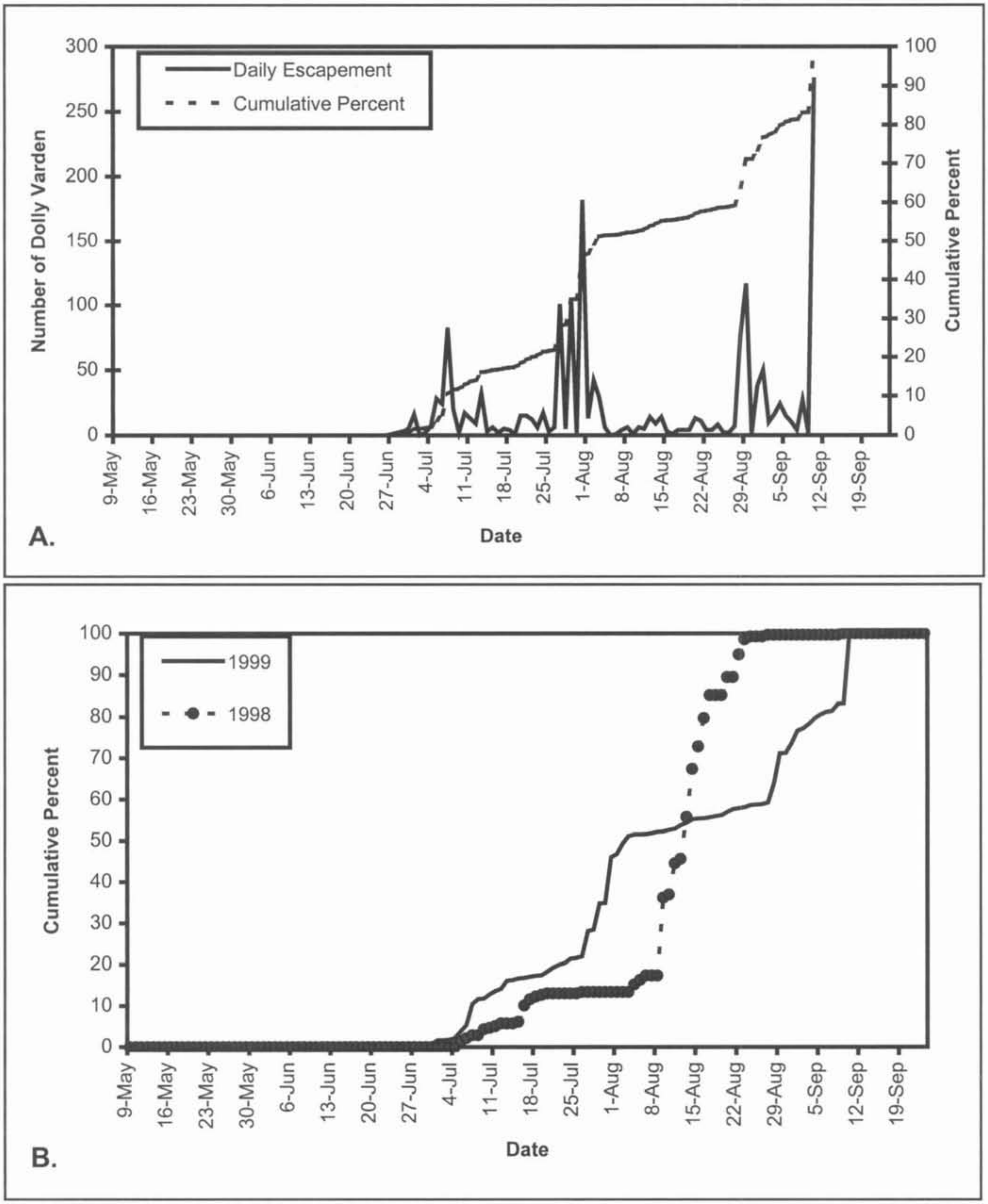


Figure 18. Upstream Dolly Varden migrants into Summer Bay Lake, 1999 (A); Cumulative percent of upstream Dolly Varden migrants into Summer Bay Lake, 1998-1999 (B).

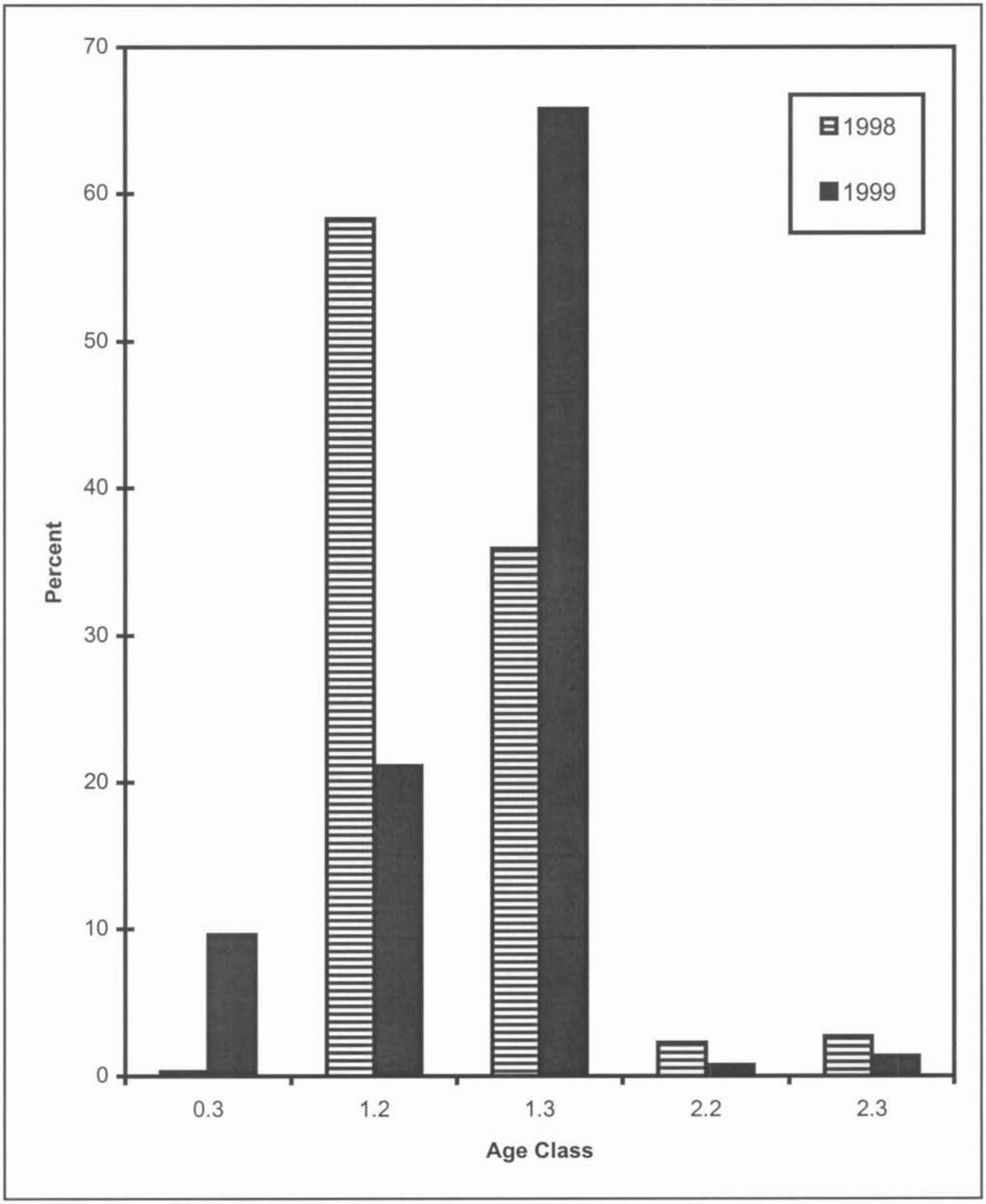


Figure 19. Age composition of major age classes of Summer Bay Lake sockeye salmon escapement, 1998-1999.

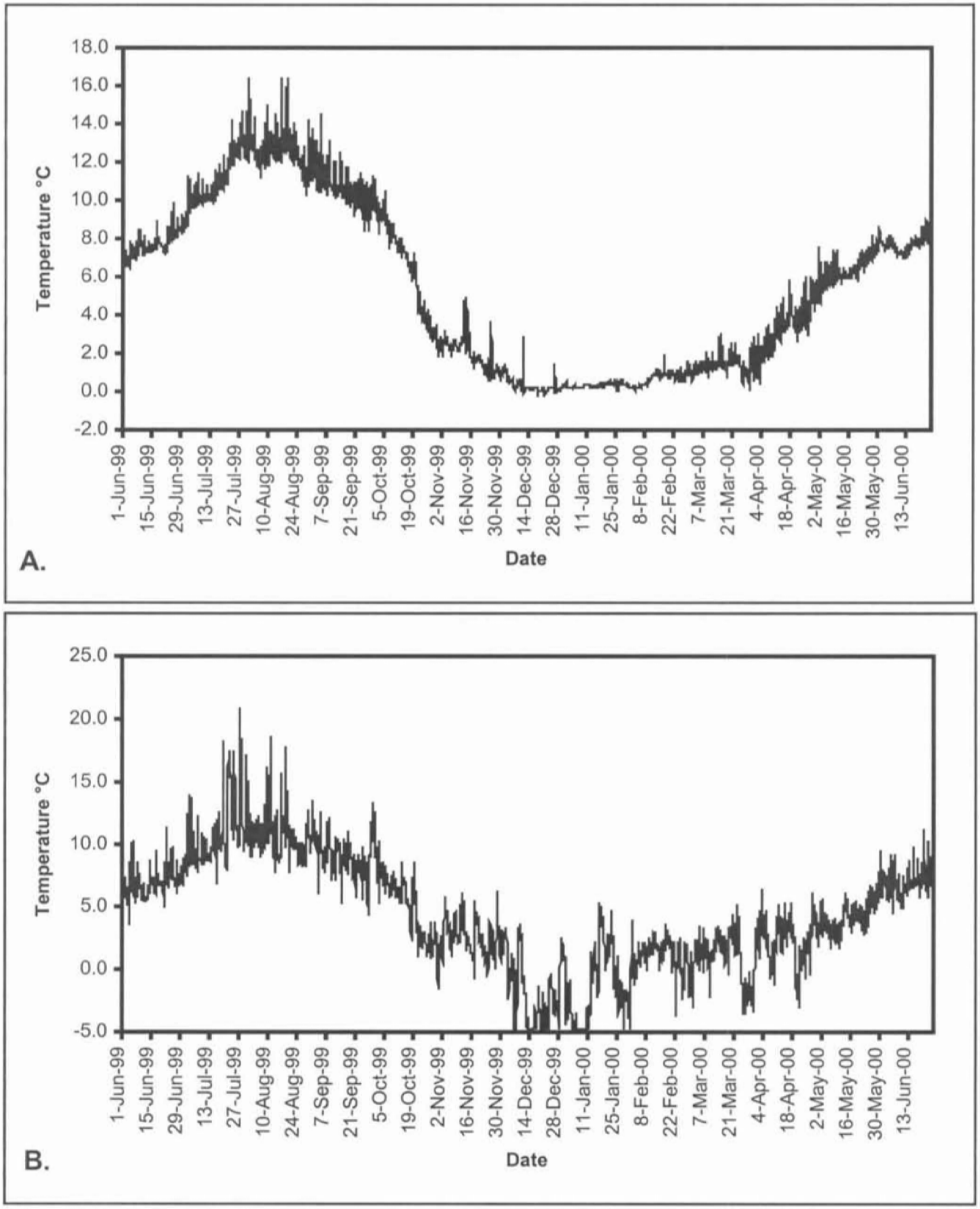


Figure 20. Summer Bay Lake Creek water temperature (A); Air temperature (B) from 1 June 1999 through 24 June 2000.

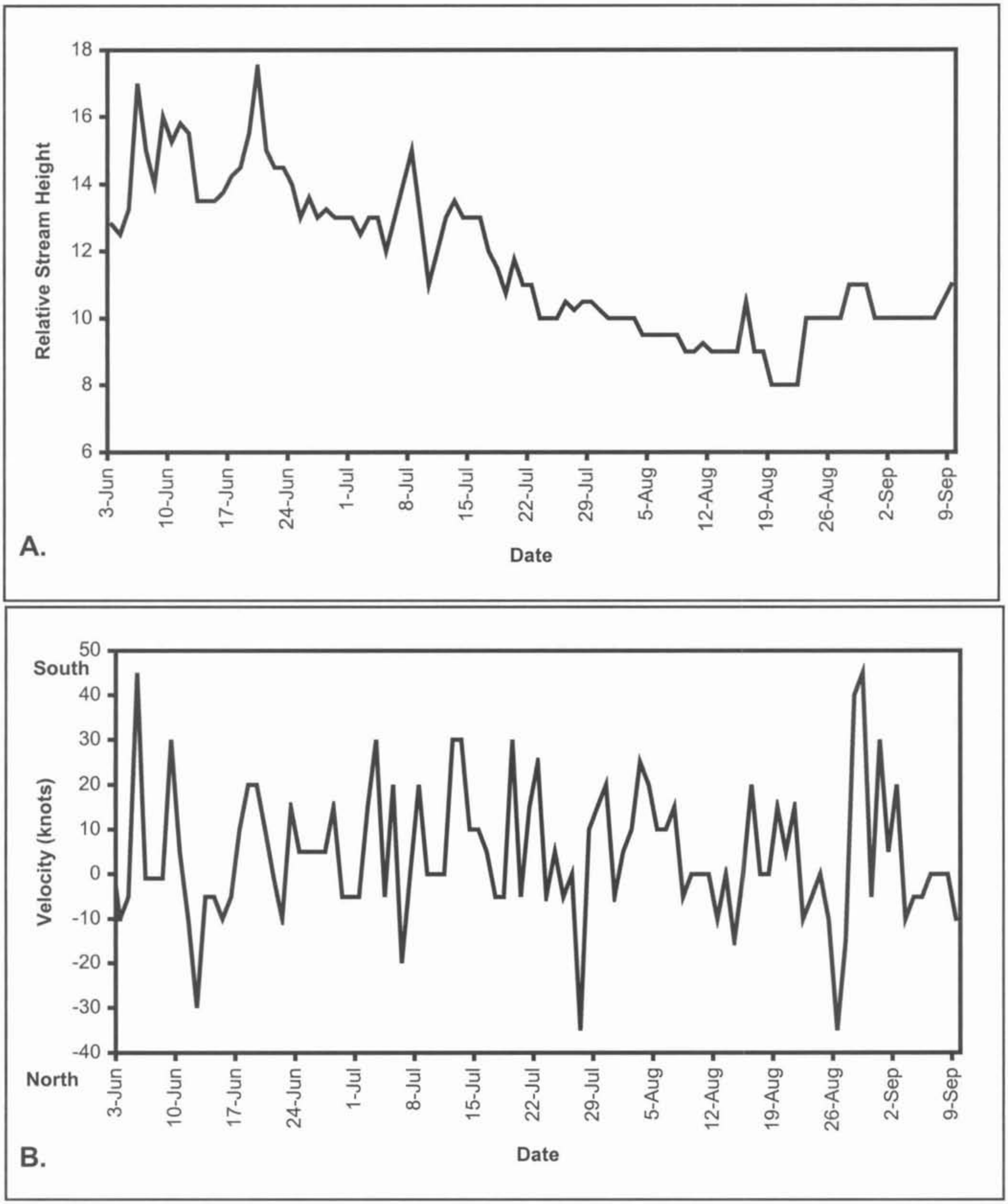


Figure 21. Summer Bay Lake Creek relative stream height (cm; A); Wind velocity (kn; B), from 3 June through 9 September 1999.

APPENDIX

Appendix A. Photographs of the *M/V Kuroshima* and the oil spill in Unalaska Bay, Alaska.

Plate A. *M/V Kuroshima* with the outlet of Summer Bay Lake in the foreground.

Plate B. *M/V Kuroshima* hard aground with Emperor geese in the foreground.

Plate C. Oil from the *M/V Kuroshima* on Summer Bay Lake shore.

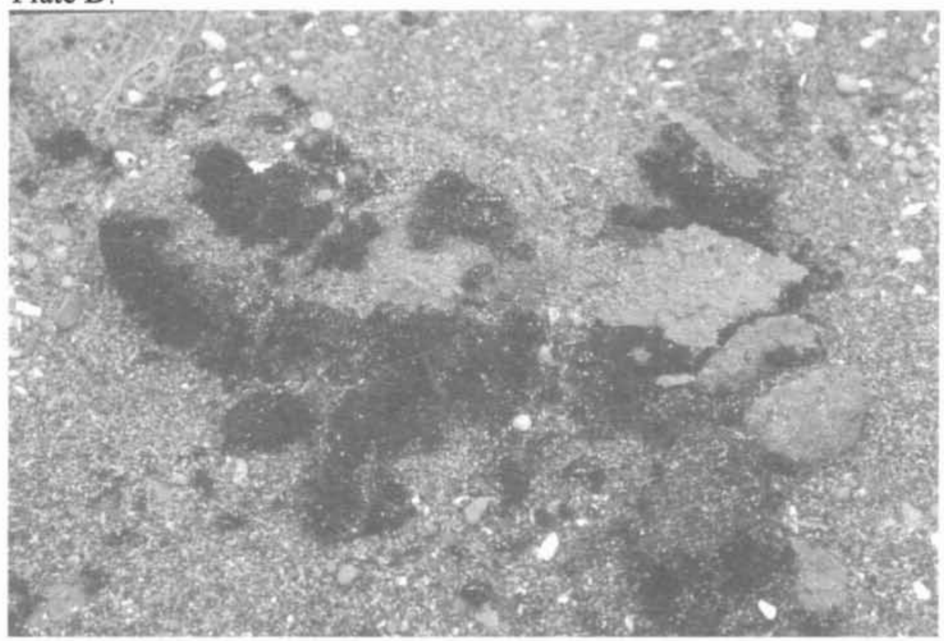
Plate D. Oil mixed with sand and organic matter from the *M/V Kuroshima* one year after the spill event on Summer Bay beach.

Plate A.

Plate B.

Plate C.

Plate D.



Appendix B. Photographs of Summer Bay Lake fishery monitoring project.

Plate 1. Fisheye view of the weir at Summer Bay Creek below the bridge and Summer Bay.

Plate 2. Public on bridge viewing weir operation.

Plate 3. View of Summer Bay Lake from the bridge.

Plate 4. View of smolt trap, live box, and Summer Bay Creek below the bridge.

Plate 5. Summer Bay Lake bridge, weir, adult trap, smolt trap, live box, and connex living quarters in the background.

Plate 6. Smolt weir showing rack master supports, smolt trap, and live box.

Plate 7. Smolt trap and live box.

Plate 8. Smolt trap.

Plate 1

Plate 2

Plate 3

Plate 4

Plate 5

Plate 6

Plate 7

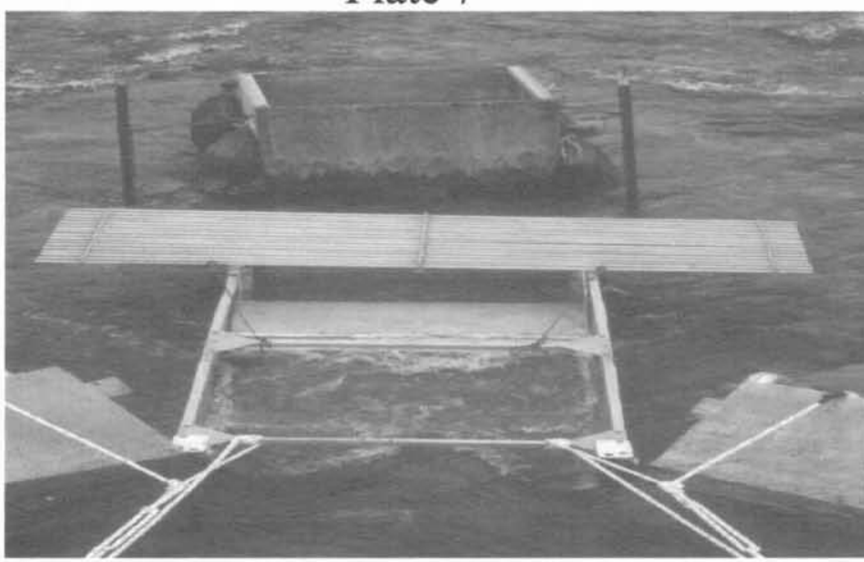


Plate 8

Appendix C. Climatological observations at Summer Bay Lake weir, 1999.

	Military	Temperature °C		Cloud Cover		Visibility	Wind		Stream	
Date	Time	Air	Water	%	Ceiling	(miles)	Direction	Velocity (k)	Height (cm)	Comments
31-May	1200			100	1500	20	S	25		Scattered light rain
1-Jun	1200			90	2000	20	SSW	20-45		Gusty, scattered light rain
2-Jun	1200			60	2500	10	S	5		Fog bank to North
3-Jun	1300	8.3	7.2	100	800	5	N	5-10	12.80	Heavy rain in am
4-Jun	1200	12.2	7.8	60	2500	20	NW	5	12.50	Very nice day
5-Jun	1200	8.5	7.4	100	1000	5	SSE	45+	13.25	Very bad day, occasional light rain
6-Jun	1200	11.5	7.0	100	400	<2	Variable	1+	17.00	Rain and fog
7-Jun	1200	9.0	8.0	<10	unlimited	unlimited	NE	1+	15.00	Very nice day
8-Jun	1200	10.0	8.0	<1	unlimited	unlimited	NNW	1+	14.00	Very nice day
9-Jun	1200	8.5	7.5	100	1600	8	S	30+	16.00	Showers
10-Jun	1200	8.0	8.0	100	1000	10	ESE	5	15.25	
11-Jun	1200	7.5	7.0	95	2000	15	NE	5-10	15.80	
12-Jun	1200	6.0	7.0	100	1000	10	N	25-30	15.50	
13-Jun	1200	7.0	7.0	100	<100	1/2	NE	5	13.50	Fog and drizzle
14-Jun	1200	11.0	7.5	100	1500	10	NW	<5	13.50	Patches of fog
15-Jun	1200	8.0	7.0	100	500	5	NW	10	13.50	Rain
16-Jun										
17-Jun										
18-Jun	1200	7.0	8.0	100	100	1	SE	20	14.50	Rain
19-Jun	1300	8.0		100	200	2	E	20	15.50	Rain
20-Jun	1500	8.5	7.0	100	1800	5-10	ESE	10	17.50	Scattered rain, gust east 60 in am
21-Jun	1200	12.0	8.0	95		20	Variable	1+	15.00	Nice day, calm, 15-20 knot winds by pm
22-Jun	1200	18.0	9.0	<10	unlimited	20	NNW	<10	14.50	Nicest day yet!
23-Jun	1200	11.0	9.0	100	1500	10	SE	15	14.50	Back to normal
24-Jun	1300	14.0	9.0	98	2500	20	SE	5	14.00	Pleasant
25-Jun	1200	12.2	9.0	60	2000	20	SSW	<5	13.00	Even nicer
26-Jun	2100		8.0	100	1500	15	Variable	<5	13.60	Rain most of the day
27-Jun	1200	12.2	8.5	100	1500	15	S	<5	13.00	
28-Jun	1200		8.5	100	100	2	E	10-20	13.25	Rain

-Continued-

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Date	Military Time	Temperature °C Air	Water	Cloud Cover %	Ceiling	Visibility (miles)	Wind Direction	Velocity (k)	Stream Height (cm)	Comments
29-Jun										
30-Jun	1800	9.4	8.5	100	1800	15	ENE	5	13.00	Patches of low clouds and fog
1-Jul	1800	11.7	9.0	100	2500	20	Variable	<5	13.00	
2-Jul	1200	15.0	10.0	30	unlimited	unlimited	Calm	0	12.50	Partly cloudy
3-Jul	1200	14.4	11.0	60	unlimited	unlimited	S	30	13.00	Partly cloudy and windy
4-Jul	2000	11.1	10.0	100	1000	10	NE	5	13.00	Fog in am, Sunny in pm, overcast evening
5-Jul	1800	10.6	10.0	100	2000	20	SW	15-20	12.00	Partly cloudy, windy in am
6-Jul	1830	9.4		80	1000	20	NE	20		
7-Jul										
8-Jul	1230	9.4	10.0	100	1500	5	SW	10-20	15.00	Windy and rainy
9-Jul	1200		11.0	100	1500		N	0	13.00	No wind
10-Jul	1800	9.4	10.5	100	100	5	Calm	0		NE wind in pm and fog in pm
11-Jul									12.00	
12-Jul	1800	9.4	10.5	100	100	1	ESE	30	13.00	Rain, wind, mist, fog
13-Jul	1800	10.6	10.5	100	1000	5	SE	30	13.50	Wind, heavy rain, fog
14-Jul	1800	12.8	11.0	90	200	20	S	10	13.00	Relatively pleasant
15-Jul	1800	12.8	11.0	70	2500	20	S	10	13.00	Partly cloudy
16-Jul	1800	11.7	10.5	100	1000	15	S	<5	12.00	
17-Jul	1800	11.1	12.0	100	1500	20	NW	5	11.50	Overcast, occasional heavy rain
18-Jul	1800		11.0	100	1000	10	NW	<5	10.75	Patchy fog, partly cloudy most of am
19-Jul	1800		11.5	70	2000	20	SE	20-30	11.75	
20-Jul	1800		11.0	100	300	7	NW	5	11.00	
21-Jul	2000		12.0	100	3000	20	SW	10-15	11.00	Am low clouds, pm scattered showers
22-Jul	1900		12.5	100	3000	20	SW	25	11.00	Overcast and windy
23-Jul	1800	13.0	13.0	90	2000	20	ENE	<5	10.00	Sunny, E winds 40-50 in am, showers in pm
24-Jul	1800		13.5	90	2500	20	S	5	10.00	
25-Jul	1800		13.0	100	3000	20	W	<5	10.00	Rain in early am
26-Jul	1800	11.0	12.0	100	500	5	Calm	0	10.50	Rain and fog throughout the day
27-Jul	1800	21.0	14.0	50		unlimited	W	20-35	10.25	Warm balmy Hawaii like weather

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Date	Military Time	Temperature °C		Cloud Cover		Visibility	Wind		Stream	Comments
		Air	Water	%	Ceiling	(miles)	Direction	Velocity (k)	Height (cm)	
28-Jul	1800	15.0	14.0	100	2500	20	SW	5-10	10.50	Mild, scattered showers
29-Jul	1830	10.0	13.0	100	1800	15	SW	10-15	10.50	Overcast and cool
30-Jul	1800	15.0	13.0	30		unlimited	SW	15-20	10.25	SW 40-45 winds in am, mostly sunny
31-Jul	1830		14.0	5		unlimited	NE	<5	10.00	Mostly sunny and warm all day
1-Aug	1800	12.0	11.0	10		unlimited	SW	5	10.00	Mostly sunny but cool
2-Aug	1800	14.0	14.0	100	500	7	E	10	10.00	Stormy in am, E 40 winds, rain all day
3-Aug	1800	11.0	13.5	90	2000	20	SE	25	10.00	scattered showers, windy
4-Aug	1830	11.5	12.5	100	2000	15	SW	20	9.50	
5-Aug	1830	11.5	12.5	100	2000	20	SW	10	9.50	
6-Aug	1800	13.0	13.0	100	2500	20	SW	5-10		Partly cloudy most of the day
7-Aug	1830	14.0	13.0	95	2000	20	SW	10-15	9.50	
8-Aug	1830	10.0	14.0	100	1500	15	NNW	5	9.50	Rainy and windy in am
9-Aug	2000	12.0	13.0	70	2000	20	Calm	0	9.00	Water level estimated due to weir debri loading
10-Aug	1800	16.5	13.0	100	2500	20	Calm	0	9.00	Warm and balmy
11-Aug	1800	11.5	13.0	70	2500	20	Calm	0		Rain throughout day, windy in am
12-Aug	1800	9.5	12.0	100	1500	15	NNE	10	9.00	Bering Sea weather
13-Aug	1800	10.0	13.0	95	500	7	Calm	0	9.00	Thin foggy overcast, blue sky to south
14-Aug	1800	9.0	12.5	100	500	10	NNE	15	9.00	Foggy overcast, cool, Bering Sea weather
15-Aug	2000	7.5	12.5	100	300	10	Calm	0	9.00	Foggy overcast, cool, Bering Sea weather
16-Aug	1800	16.0	12.5	50	3000	20	S	20	10.50	Partly cloudy
17-Aug	1800	12.0	12.0	100	800	10	Calm	0	9.00	
18-Aug	1830	15.0	14.0	85	5000	15	Calm	0		High overcast, cirro stratus
19-Aug	1800	14.0	14.0	5		15	W	15	8.00	Rain early am
20-Aug	1800	10.5	13.0	100	2000	10	SE	5		
21-Aug	1800	10.0	12.8	100	2000	10	SW	15	8.00	Heavy rain in early am
22-Aug	1900	10.5	12.5	50	2000	15	NW	10	8.00	Heavy rain in early am
23-Aug	1800	10.5	12.5	100	3000	10	NW	5	10.00	Heavy intermittent rain throughout the day
24-Aug	1800	10.0	12.5	100	1700	10	Calm	0	10.00	
25-Aug	1900	9.0	11.5	100	500	10	NW	5-10	10.00	Intermittent light rain and low visibility

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Appendix C. (page 4 of 4)

	Military	Temperature °C		Cloud Cover		Visibility	Wind		Stream	
Date	Time	Air	Water	%	Ceiling	(miles)	Direction	Velocity (k)	Height (cm)	Comments
26-Aug	2000	8.0	11.0	100	1800	10	NW	25	10.00	
27-Aug	1800	9.0	11.0	100	1800	10	NE	15	11.00	
28-Aug	1800	11.0	11.5	100	1500	10	SE	35-40		Heavy intermittent rain
29-Aug	1800	12.5	12.5	30	2500	20	SW	20-45		Gusty winds, mostly sunny
30-Aug	1800	10.5	11.5	65	1500	10	NW	5		Heavy rain in am, fog rolling in during pm
31-Aug	1800	13.5	13.0	30		20	SW	30	10.00	Nice but windy
1-Sep	1800	11.5	12.0	85	2500	20	SW	5	10.00	
2-Sep	1900	11.0	11.0	25		20	SW	20	10.00	
3-Sep	1800	10.0	11.5	100	2500	20	NW	10	10.00	Mostly sunny in am, cloudy by pm
4-Sep	1800	10.5	13.5	90	2000	20	NW	5	10.00	
5-Sep	1800	9.5	12.0	100	200	15	NW	5	10.00	
6-Sep	1800	10.0	11.5	100	2500	15	Calm	0	10.00	
7-Sep	1800	9.5	11.0	100	200	15	Calm	0	10.00	Heavy rain
8-Sep	1800	12.0		90	2800	20	Calm	0		Heavy rain in am
9-Sep	1800	7.5	10.0	100	0	1/4	NW	10		Rain and fog

Appendix D. Characteristics of salmonids and previous oil spills that suggest that oil spilled by the *M/V Kuroshima* posed substantial risks to Summer Bay Lake salmonids.

The period of incubation (3.2^0-5^0C) for sockeye salmon eggs ranges from 175-225 days (Burgner 1991). Summer Bay Lake sockeye salmon spawn during August and September on lake shoals and in the primary inlet tributary. Sockeye fry emergence likely occurs in March and April. In most stream situations, fry migrate downstream without delay to nursery areas (Burgner 1991), and in many Alaskan lakes, feed in littoral (nearshore) areas for a month or more before entering pelagic (offshore) zones (Burgner 1991; Coggins 1997). Generally, sockeye salmon shift from a dependence on dipteran insects to pelagic entomostracan zooplankton when making the transition from littoral to pelagic zones in a lake. Variations in feeding strategies have been observed in Alaska Peninsula lakes (Honnold et al. 1996). In non-typical nursery lakes (shallow with little zooplankton), juvenile sockeye salmon feed almost exclusively on insects. Data from stomach content analysis of Summer Bay Lake sockeye salmon suggest a similar feeding strategy. Sockeye salmon spend one or more years in nursery lakes, as indicated by the 1998 and 1999 emigration by age from Summer Bay Lake. Sockeye salmon smolt emigrate in schools and travel in both nearshore and offshore areas before congregating at outlet areas, prior to leaving the lake.

Pink salmon eggs incubate for approximately the same period as sockeye salmon (Burgner 1991), depending on water temperatures. Migrant pink salmon fry can be found from late February to mid-August, throughout the range of the species (Heard 1991). Peak emigrations generally occur from mid April to mid May in Alaska, but have been reported in some areas to occur until late June (K. Brennan, Alaska Department of Fish and Game, Kodiak, personal communication). Emigrations for smaller streams tend to be more compressed over time (shorter emigration curves with steeper slopes); the number of emigration days positively correlated with stream length (Heard 1991). Summer Bay Lake pink salmon fry appeared to have this type of compressed emigration in 1998 and 1999. Pink salmon fry emigrate in schools, tend to orient in areas of increased flow, and commonly move from the spawning grounds to the ocean in one night (Heard 1991). Due to their rapid emigration to the ocean, pink salmon fry feed little in fresh water and exogenous feeding often begins in salt water.

Coho salmon usually spawn from November to January; however, spawning timing is highly variable (Sandercock 1991). Summer Bay Lake coho salmon have been reported to return as late as mid November to Summer Bay Lake (D. Tracy, Alaska Department of Fish and Game, Kodiak, personal communication), indicating that they may be a late spawning stock. Coho salmon eggs incubate in the gravel for approximately 115-125 days, depending on water temperature, and fry typically emerge from early March to as late as the end of July (Sandercock 1991). Spring freshets may sweep coho fry downstream; however, if emerging late, they may avoid this risk at the expense of higher growth rates. Newly emergent fry often remain in small creeks, sloughs, and other slow moving waters that provide adequate cover and feed. As they increase in size, coho salmon fry will move into larger bodies of water, stream margins, and generally, to areas of greater velocity. In lakes, coho fry will occupy the littoral (nearshore) zones. Typically, the majority of coho salmon fry rear in streams rather than lakes. Minnow trapping in Summer Bay Lake indicated few coho salmon

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fry; however, larger coho salmon juveniles (>70 mm) were common. This suggests that as coho salmon juveniles grow over time, the Summer Bay Lake littoral zone is utilized for rearing. This also suggests that coho fry were not present in typical nearshore rearing areas and may have been displaced or did not survive well, due to oiling. Stream rearing juvenile coho salmon feed primarily on aquatic and terrestrial insects (Sandercock 1991). Lake rearing juvenile coho have been reported to consume zooplankton (Mason 1974; Crone 1981; Kyle 1990; Honnold et al. 1996). Stomach contents of juvenile coho salmon from Summer Bay Lake were comprised exclusively of dipteran insects. Coho salmon spend one or more years in fresh water, as indicated by the 1998 and 1999 Summer Bay Lake smolt age data. Coho salmon smolt emigrate in schools and travel primarily in streams near the surface and in lake nearshore areas (Sandercock 1991).

Dolly Varden usually spawn from September to early November (Scott and Crossman 1979). Anadromous fish enter freshwater after 60 to 160 days of ocean residence. The Summer Bay Lake population enters freshwater from July to September. Lake populations usually move into inlet rivers beginning in August. Eggs hatch in March or April and juveniles emerge in late April to early May. Anadromous stocks often spend three to four years in fresh water prior to going to sea in late May to early July, while non-anadromous stocks may spend from several months to several years in streams and then move into lakes (Scott and Crossman 1979). Stream and lake resident young consume insects, snails, and leeches in the spring and salmon eggs, salmon flesh, and insects in the fall. Larger freshwater resident Dolly Varden consume salmon fry and smolt during their lake emigrations (Coggins and Sagalkin 1999).

Oil spilled in Summer Bay Lake was widely dispersed throughout the lake and nearshore areas from the time of the spill (November 1997) through May 1998 (Honnold et al. 1999). Residual oil was observed in all areas of the lake and outlet stream (on weirs-see Appendix C, Plate 1) throughout the fall of 1999. The spilled oil likely degraded over time; however, the rate of weathering is determined mainly by the ratio of surface area to volume of petroleum in the environment and a variety of environmental conditions (Short and Heintz 1997). The rate of weathering of the *M/V Kuroshima* oil is difficult to predict and high concentrations of oil were observed in nearshore areas six months or more after the spill. Divers also reported substantial amounts of oil on the lake bottom during several surveys in the spring of 1998.

The temporal and spatial distribution of juvenile anadromous and resident fish, their feeding ecology, and other aspects of their early freshwater life history, plus the wide distribution of oil suggest both direct exposure and other indirect impacts as a result of the spilled fuel oil in Summer Bay Lake. Juvenile fish do not necessarily avoid petroleum-contaminated waters (Maynard and Weber 1981). Coho salmon juveniles actually swam in a film of oil in one study (Morrow 1973) and in another study coho salmon smolt only avoided concentrations of oil greater than 2 mg/L, whereas coho salmon presmolt avoided concentrations of 3-4 mg/L (Maynard and Weber 1981). Rice (1973) found that avoidance of the water-soluble fraction of Prudoe Bay crude oil by pink salmon fry varied with stage of fish development, temperature, and salinity.

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Sinking oil can smother and kill fish and their food, though impacts are likely to be localized (Vincente 1994). During a Group V fuel spill in Puerto Rico, diving scientists observed dead fish, living fish with lesions and tumors, and many lethargic territorial fish in nearshore waters adjacent to the point of oil release. Fish and other marine vertebrates can efficiently metabolize aromatic compounds present in oil and the metabolites are excreted (Stein et al. 1998); however, the formation of reactive metabolites can potentially lead to toxic effects (Statham et al. 1976).

Non-floating Group V fuel oils are also likely to readily adhere to aquatic vegetation, affecting the associated animals (NOAA 1994). Submerged aquatic vegetation beds are important primary producers and nursery habitats for juvenile fish (DeMort 1991). In contrast to vertebrates, aromatic compounds can accumulate in invertebrates, because these animals do not efficiently metabolize aromatic compounds (Statham et al. 1976). Thus, partent aromatic compounds can be transferred to higher trophic levels such as fish. In addition, oils that quickly sink or suspend in the water column could have greater impacts to water-column organisms because more of the water-soluble fraction of the oil could actually dissolve rather than be lost by evaporation, which usually is the dominant process for floating slicks (Vincente 1994).

Planktonic larvae are among the most vulnerable organisms after an oil spill because they are sensitive to oil, are affected immediately, and cannot avoid spilled oil (Rice et al. 1984). Planktonic copepods exposed to a high concentration of water soluble fraction of aromatic heating oil showed significant reduction in subsequent length of life, total fecundity, mean brood size, and rate of egg production (Berdugo et al. 1977). Cyclopoid copepods were the only common zooplankters able to survive a pond oil spill in Barrow, while other species died rapidly (O'Brien 1978). This study suggested that zooplankton may be the most susceptible of all arctic freshwater organisms to oil contamination.

Oil toxicity appeared to inhibit algal production and biomass accumulation during the study of contained oil spills in several Alaskan lakes and ponds (Miller et al. 1978). Toxicity by prolonged exposure to weathered oil was not known because the data were ambiguous. Many of the effects observed in the study of ponds appeared to be adequately explained by the elimination of zooplankton at fairly low doses of oil. The dominant zooplankton grazers were eliminated within five days in all of the spills, which predicated an eventual increase in algal biomass, but of a different species composition. It appeared that the algal biomass increase observed when oil was spilled in grazing-dominated systems was more a function of reduced grazing pressure on phytoplankton than upon release of nutrients from oil mineralizaiton. The recovery of the phytoplankton to prespill species composition did not occur after six years and authors concluded that it would probably not happen until the zooplankton were capable of developing to their prespill density. Oil spill effects on the marine benthos have also been recognized, in which species such as amphipods experience a brief period of mortality following oil exposure, followed by a full recovery over time (Spies 1987). Benthos impacts in lakes, however, are largely unknown.

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Damage to the 1988 PWS pink salmon brood, following the EVOS in the spring of 1989, included reduced growth during emigration (Wertheimer and Celewycz 1996; Willette 1996) and reduced survival when adults returned in 1990 (Geiger et al. 1996). The 1989 brood incubated in oiled intertidal environments, which put them at risk of exposure for up to eight months during the sensitive egg and larval stages (Brannon et al. 1995). Pre-emergent pink salmon larvae from oiled streams were exposed to oil for up to two years after the spill (Weidmer et al. 1996). In the first years following the EVOS, oiled streams exhibited an 7% to 21% higher pink salmon embryo mortality than unoiled streams and a continued reduction in survival four to five years after the spill (Bue et al. 1998). The impacts from oil exposure on juvenile pink salmon on subsequent total PWS adult returns were estimated to be a 28% reduction in the first brood year and a 6% reduction in each of the following two brood years (Geiger et al. 1996). The latter level of reduction was projected to occur for at least two more brood years. This analysis was based on the entire productivity of wild stocks in the southwestern portion of PWS, where about 31% of the streams were oiled. The oiled streams were smaller than the unoiled streams in the area, accounting for ~20% of the spawning habitat in the region. The primary pink salmon spawning habitat contaminated was the intertidal and supratidal areas, which represents ~75% of habitat utilized. The remaining 25% of utilized spawning habitat was in upstream sections of PWS streams. Therefore, to have a 6% reduction in adult returns, an 18% to 30% reduction would have to occur in oiled streams. In PWS, tidal leaching of PAH from weathered oil into the incubation substrate at stream deltas could explain persistent elevated embryo mortality observed in pink salmon through 1993, and that spawning habitat at stream deltas had recovered to below lethal thresholds by 1994 (Murphy et al. 1999).

There is a paucity of literature describing oiling effects on sockeye and coho salmon with the exception of several laboratory studies. These studies indicate that both juvenile sockeye and coho salmon experience significantly increased mortality rates at all oil concentrations and at all temperatures (Morrow 1973 and 1974). Coho salmon adults exposed to oil, however, do not appear to lose their homing capabilities (Nakatani et al. 1985), unless concentrations of oil reach 3.2 mg/L (Weber et al. 1981). Actual reductions in sockeye and coho adult returns, as a result of exposure to oil contamination, have not been reported. A simulation model of the effects of a tanker accident (34,000 tons of diesel fuel) in Bristol Bay resulted in predictions of sockeye salmon mortality ranging from 1% to 5% of adult returns and 1% to 2% of the fish being tainted with oil (Bax 1987).