FISH CREEK SOCKEYE SALMON - TECHNICAL REVIEW

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Virginia P. Litchfield
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REGIONAL INFORMATION REPORT No. 2A01-30

Alaska Department of Fish and Game
Commercial Fisheries Division
333 Raspberry Road
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ABSTRACT

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INTRODUCTION

We examined available limnological, juvenile, smolt, and adult salmon data to evaluate possible causes of a recent decline of sockeye salmon escapements into Fish Creek. A technical review meeting involving numerous staff of the Alaska Department of Fish and Game (ADF&G) as well as the Cook Inlet Aquaculture Association (CIAA) was held in the spring of 2001. The information in this report was compiled from this meeting as well as from previous studies of Fish Creek sockeye salmon and their habitat.

Fish Creek sockeye salmon rear in Big Lake, which is located in the Matanuska-Susitna Borough, about 25 km west of Wasilla (Figure 1). It is one of the larger lakes in the area with a surface area of 12.1×10^6 m^2 and a maximum depth of 27 m (Figure 2). The drainage basin area encompasses over 27.6×10^7 m^2 with Meadow Creek being the major inlet. The outlet, Fish Creek, flows about 25 km to Knik Arm in Cook Inlet.

Due to its close proximity to a large population center (Anchorage, Wasilla), Big Lake has become a popular recreational area. Summer activities include swimming, jet skis, water-skiing, fishing, boating, camping, and wildlife viewing. Many residents use the thick ice that forms in the winter for transportation to their homes or camps. Snow machine and motorcycle races occur during the winter months. Lakeshore development has increased from 100 cabins in 1953 to 565 structures today (McKibben, Mat-Su Borough, personal communication). There are no public water or wastewater facilities servicing the Big Lake area. Water is obtained by on-sight wells and wastewater is disposed through septic systems, holding tanks, cribs, pit privies or similar structures (Dames and Moore, 1998).

All five species of Pacific salmon (*Oncorhynchus* spp.) are found in the Big Lake watershed, although only sockeye (*O. nerka*) and coho (*O. kisutch*) salmon have been documented in the lake. Historically, Big Lake was a major sockeye salmon producer with escapement counts ranging from 2 to 306 thousand fish (1938-2001, Table 1). Sockeye salmon escapements averaged 56 thousand from 1940-1959, 20 thousand from 1960-1979, and 58 from 1980-2001 (Fox and Shields, 2001). Returns during the later period were supplemented by production from the Big Lake Hatchery (Figure 1).

ADF&G does not estimate population sizes of resident fish species but has made observations based on the ADF&G Sport Fish State Wide Harvest Survey (Howe et al., 1999). Resident fish species include rainbow trout (*O. mykiss*), Arctic char (*Salvelinus alpinus*), burbot (*Lota lota*), round whitefish (*Prosopium cylindraceum*), longnose sucker (*Catostomus catostomus*), threespine stickleback (*Gasterosteus aculeatus*), prickly sculpin (*Cottus asper*) and Arctic lamprey (*Lampetra japonica*). Sweet and Rutz (2001) recently documented northern pike (*Esox lucius*) in the Big Lake watershed.

DISTRIBUTION OF SPAWNERS

The distribution of sockeye salmon spawners in the Big Lake watershed was examined in the 1970's, 1991-1993, and 1999, but no comprehensive investigations have evaluated the quality and productivity of spawning habitat. This makes it difficult to determine if the system either has been or is now spawning limited.

Three subpopulations of sockeye salmon likely occur in the Big Lake watershed. Fry from Meadow Creek migrate downstream to rear in the lake, while fry from lakeshore spawners do not migrate and fry from outlet spawners migrate upstream (ADF&G, 2001). Meadow Creek spawners migrate into the system earlier than lakeshore or outlet spawners.

An important spawning site is located on Meadow Creek, downstream from the Big Lake Hatchery. It is a relatively shallow area that can freeze solid during harsh winters. During its operation, the hatchery discharged well water that kept this site from freezing, but this is no longer done.

In 1969, a cofferdam was constructed at the outlet of Big Lake to raise lake water levels. Prior to construction of this dam, a large fraction of the Fish Creek sockeye salmon population spawned near the lake outlet. The design of this structure prevents fry emerging from redds below the dam from migrating back up into Big Lake to rear. There is some concern that development of shoreline habitat has had a detrimental effect on spawning and rearing habitat. A large percentage of the shoreline area has been altered from its natural vegetative state, eliminating overhanging trees and introducing sediments or contaminates that may impact rearing fry.

LIMNOLOGY AND SOCKEYE SALMON CARRYING CAPACITY

Big Lake's potential for anthropogenic eutrophication due to growing urbanization was documented years ago. During 1983-1984, the first comprehensive investigation to determine the trophic state of Big Lake was conducted by the United States Geological Survey (Woods, 1985, 1986, 1992). Woods (1992) classified Big Lake as oligotrophic based on seasonal levels of total phosphorus, total nitrogen, chlorophyll *a*, and secchi disk transparency (Appendix A). However, a plot of chlorophyll *a* as a function of total phosphorus for 23 lakes in the Matanuska-Susitna Borough (Figure 3) showed that Big Lake was near the upper end of the oligotrophic range (Edmundson et al., 2000). Woods (1992) further identified a hypolimnetic layer of oxygen-depleted water uncharacteristic of oligotrophic systems. Dissolved oxygen levels sufficient to affect fish survival (<5 mg L^{-1}) occurred at depths below 10-15 m, encompassing slightly less than one-half of the total lake volume during its peak development. Woods (1992) postulated that this layer developed during winter as organic matter decomposed on the bottom. Unexpectedly, the layer continued through summer, because the water column rapidly stratified in spring preventing sufficient mixing of the water column. The fall turnover reaerated the hypolimnion. Woods (1992) concluded that the biological oxygen demand in Big Lake was large relative to the supply rate of oxygen to the hypolimnion. If so, any increase in oxygen demand via primary production could increase the hypolimnetic oxygen deficit possibly shifting the lakes trophic state toward mesotrophic or eutrophic conditions. However, data collected by ADF&G in 2001 (May, June, July, September, October) indicated that this layer of low dissolved oxygen occurred at depths below 10-15 m at only the eastern station during late summer. Dissolved oxygen concentrations remained relatively high throughout the water column during the entire 2001 season at the western station.

Surveys conducted by ADF&G in the fall of 1999 (August, October) indicated that the limnology of Big Lake had not changed substantially since 1983-1985 (Table 2 and Appendix A). Nitrogen to phosphorus ratios (>15:1, Smith, 1982) indicated that phosphorus rather than nitrogen limited primary production in Big Lake (Table 2). Net samples collected in 1985 (July, August, September, October) indicated that the seasonal mean total biomass (1,021 mg dry weight m^{-2}) of zooplankton in Big Lake was above the average for 18 other sockeye salmon rearing lakes in Alaska and elsewhere (Koenings and Kyle, 1997). Furthermore, large-bodied cladocerans, an important food for rearing sockeye salmon, comprised about 20% of the total zooplankton biomass. Other sockeye salmon rearing lakes that produce relatively large smolts, such as Hidden Lake, exhibit similar plankton community structures. We will continue to monitor water chemistry, nutrients, and chlorophyll *a* levels in Big Lake as part of a cooperative project with the Alaska Department of Environmental Conservation to determine regional nutrient criteria. Results from future surveys will give us a clearer picture of present nutrient levels and the trophic state of Big Lake.

We used three limnological models, euphotic volume, euphotic zone depth, and zooplankton biomass to estimate the number of spawners required to seed Big Lake at carrying capacity (Koenings and Burkett, 1987; Koenings and Kyle, 1997). All three models used limnological inputs to estimate the biomass of smolt at carrying capacity. The biomass of smolt was then converted to numbers of adults required to produce that biomass using an average smolt weight of 20 g (Barton and Barrett, 1973; Chlupach and Kyle, 1990), an egg-to-smolt survival of 2% (Barton and Barrett, 1973), an assumed fecundity of 2,887 eggs/female (Chlupach and Kyle, 1990), and an assumed equal sex ratio. The models produced estimates of 21,000, 17,000, and 43,000 spawners to seed Big Lake at carrying capacity for the euphotic volume, euphotic zone depth, and zooplankton biomass models, respectively (Table 3).

In contrast to these results, Chlupach and Kyle (1990) used an euphotic volume model to estimate that Big Lake could produce about 1.2 million optimum-size smolts (4-5 g), which would be produced by approximately 42,000 spawners if the rest of the assumptions were used. Our estimate using a similar euphotic volume model differs from Chlupach and Kyle's (1990) estimate, because we used the mean weight of smolt observed at Big Lake (20 g) rather than the weight of an optimum-size smolt. The assumed egg-to-smolt survival we used was based on observations at Big Lake prior to enhancement, because survivals of wild sockeye salmon in Big Lake declined after enhancement (Chlupach and Kyle, 1990). Thus, our estimates should be viewed as the number of spawners at carrying capacity assuming a healthy habitat and wild salmon stock.

Using estimates of the lakes phytoplankton primary production ($3.6x10^8$ g C yr^{-1}, Woods, 1992) and standard ecological transfer efficiencies (15%, Parsons et al., 1977), we further estimated that Big Lake could produce $1.35x10^8$ g $yr^{-1}$of fish biomass (wet wt). Chlupach and Kyle (1990) observed maximum smolt populations of about $1x10^6$ mostly age 1 smolts (avg. wet wt. 20 g). Since all of the biomass of these age-1 smolts was accrued during a single year, these data indicate juvenile sockeye salmon may comprise about 15% of the annual fish production in Big Lake. But, this estimate should be considered conservative, because we did not account for predation losses of salmon.

HATCHERY STOCKING

In 1973, ADF&G identified Big Lake as a system that could benefit from restoration efforts (Barton and Barrett, 1973). The Big Lake Hatchery was constructed on Meadow Creek in 1975, and from 1977-1993 sockeye and coho salmon fingerlings reared at the hatchery were released into the Big Lake watershed (Tables 4 & 5). During this period chinook salmon (*O. tshawytscha*) and rainbow trout reared at other hatcheries were also stocked into the watershed (Table 6).

During hatchery operations a weir was operated on Meadow Creek that prevented sockeye salmon from utilizing spawning habitat upstream of the hatchery. From about 1986-1989, hatchery operators actively stopped sockeye salmon from migrating up Meadow Creek to prevent introduction of infectious hematopoietic necrosis virus (IHNV) into the hatchery water source. Prior to those years most of the return was used for hatchery broodstock, but some were passed voluntarily and others escaped past the weir. In most years the weir was opened after the sockeye salmon eggtake and then closed again several weeks later to collect coho salmon broodstock. After 1989, a portion of the run was allowed past the weir on a daily basis, and then after the sockeye salmon eggtake the weir was opened (Dan Moore, ADF&G, personal communication).

In 1993, Big Lake Hatchery was closed, but sockeye salmon fingerlings reared at the Eklutna and Trail Lakes hatcheries continued to be stocked into the watershed by CIAA. Coho and chinook salmon, and rainbow trout were not stocked into the watershed after 1993. CIAA has annually taken about 5,000 Fish Creek sockeye salmon (ADF&G, 2001) for broodstock (1993: 7,200; 1994: 5,348; 1995: 6,400; 1996: 6,400; 1997: 6,400; 1998: 3,922; 1999: 1,115; 2000: 2,808; 2001: 4,532). Broodstock has been taken from either Meadow Creek, the lake shoreline, or lake outlet. About 3,000,000 of the fry from these fish have been stocked into Meadow Creek and 2,000,000 into Blodgett Lake (Fig. 1, Table 4). Stocking into Blodgett Lake was intended to re-establish a spawning population in Meadow Creek, but no evaluation has been done.

SALMON SURVIVAL AND ADULT RETURNS

There is evidence to suggest that Big Lake was producing fish at approximately the same rates as Tustemena and Hidden Lakes prior to the construction of the Big Lake Hatchery. Barton and Barrett (1973) estimated that 1,006,054 smolts emigrated from Big Lake in 1973, 2 years prior to construction of the hatchery. Ninety-nine percent of these smolts were age-1 fish, produced by the 1971 brood year escapement of 31,900. The egg-to-smolt survival from this brood year escapement was estimated to be 2.2% assuming a mean fecundity of 2,887 eggs/female (Chlupach and Kyle, 1990). These data are consistent with a typical egg-to-fry survival of 10% (Chlupach and Kyle, 1990) and a fry-to-smolt survival of about 20%. Fry-to-smolt survivals in Tustemena and Hidden Lakes averaged 15 and 21%, respectively (Kyle et al. 1990, Kyle 1992).

Efforts to determine fry-to-smolt and smolt-to-adult survival of wild and hatchery stocks have been hindered by a lack of continuous smolt enumerations and poor tagging procedures (Tarbox, 1992). Sockeye salmon smolts emigrating from Big Lake were enumerated from 1978 through 1991 (Chlupach and Kyle, 1990). However, prior to 1986 a subsampling method was used that enumerated smolts only about 10% of the available time, and it appears that smolt numbers had been underestimated (Tarbox, 1992). From 1986-1991, a more valid subsampling procedure was used and the smolt estimates appeared to be more realistic (Tarbox, 1992). Fry released from the Big Lake hatchery were fin clipped in 1977-1978 and coded-wire-tagged (CWT) from 1985-1991 (Table 4). However in 1985-1987 and in 1991, tagged and untagged fry were released in separate groups to minimize the possible spread of IHNV (Dan Moore, ADF&G, personal communication). Tarbox (1992) concluded that this practice likely violated the assumption that the tagged fish were representative of untagged fish causing biased population estimates. Thus, wild and hatchery smolt populations estimated by Chlupach and Kyle (1990) may only be valid for smolt years 1988-1990. During these years, fry-to-smolt survivals were much higher for hatchery (5.7-7.0%) than wild (0-0.1 %) salmon (Chlupach and Kyle, 1990).

We estimated survival to the smolt stage for wild and hatchery salmon combined using estimates of number of spawners from 1984-1988, number of hatchery fry released from 1985-1989, and number and age composition of smolts emigrating from Big Lake, 1986-1991. Numbers of wild fry entering Big Lake were estimated assuming an average fecundity of 2,887 eggs/female and an egg-to-fry survival of 10% (Chlupach and Kyle, 1990). Survival to the smolt stage averaged 3.7 % (Table 7); substantially lower than fry-to-smolt survivals in Tustemena or Hidden lakes (Kyle et al. 1990, Kyle 1992). Chlupach and Kyle (1990) concluded that fry-to-smolt survival of sockeye salmon in Big Lake was lower than expected and that survivals of wild salmon declined while survivals of hatchery salmon increased from 1976-1987. Their conclusion regarding temporal changes in survival of wild and hatchery salmon may not be valid, because they used CWT data that likely produced biased stock contribution estimates in some years. However, our results, which do not rely on CWT data, support their conclusion that fry-to-smolt survival of sockeye salmon in Big Lake was lower than expected during the late 1980's.

Our ability to evaluate the success of the Big Lake sockeye salmon stocking program has also been hindered by lack of continuous smolt enumerations and problems estimating total adult returns. The weighted age-composition method of catch allocation (Tobias and Tarbox, 1999) used to estimate stock contributions to Upper Cook Inlet (UCI) commercial harvests cannot be applied to Fish Creek sockeye salmon, because the average sockeye salmon escapement into Fish Creek is only about 3% of the average total escapement into all sockeye salmon-producing systems in UCI. The age-composition method assumes that sockeye salmon escapements into unsurveyed streams account for 15% of enumerated escapements, so the uncertainty associated with contribution estimates for smaller systems is considerable. We further cannot assume that all sockeye salmon commercially harvested in Knik Arm originated from Fish Creek, because sockeye salmon escapements into Cottonwood Creek (1997-2000) were approximately equal to those into Fish Creek (Sweet and Rutz, 2001).

Lacking a sufficient time series of accurate smolt population or total adult return estimates, we used Fish Creek sockeye salmon escapements and personal use harvests to estimate inriver returns of wild and hatchery sockeye salmon to this system. Age composition data collected at the Fish Creek weir were used to construct brood tables (Appendix B). We estimated the aggregate survival to adult of wild and hatchery stocks for brood years 1975-1996 using inriver adult returns (Appendix B). Numbers of wild fry entering the system were estimated as previously described (Chlupach and Kyle 1990). We first tested for a difference between mean Fish Creek sockeye inriver adult returns prior to stocking (1938-1978) and during stocking (1979-2001). Inriver returns were significantly higher (p=0.012) during stocking (mean=64,457) than before stocking (mean=34,398). Our results supported Chlupach and Kyle's (1990) conclusion that hatchery stocking significantly increased escapements into Fish Creek.

Although, the sockeye salmon-stocking program at Big Lake increased inriver returns, survivals from fry to adult also decreased during the period of hatchery stocking. Fry-to-adult survival over this 22-year period was lower than expected (mean=0.6%). Fry-to-adult survival based on inriver adult returns should be about 2% assuming 20% fry-to-smolt survival (Kyle et al. 1990a, Kyle 1992), 20% smolt-to-adult survival (Koenings et al., 1993), and a 50% commercial exploitation rate (Tobias and Tarbox, 1999). Further, a times-series plot of the data indicated an apparent inverse relationship between the estimated number of fry rearing in the system and survival (Figure 4). A plot of the natural logarithm transformed survivals against number of fry indicated a significant (p=0.007) negative relationship (Figure 5), and a time series plot of the residuals from the regression model indicated a significant (p=0.031) negative temporal trend (Figure 6).

The low aggregate survival to adult of wild and hatchery stocks was likely due to poor survival during freshwater lifestages, because fry-to-smolt survivals in Big Lake were about ¼ of survivals in other sockeye salmon systems during the late 1980's (Table 7). The much lower fry-to-smolt survivals of wild than hatchery sockeye salmon documented in the late 1980's (Chlupach and Kyle, 1990) supports the conclusion that the low aggregate survival of these stocks was due to poor survival of the wild stock. The declining temporal trend in aggregate survivals to adult (Figure 6) was consistent with the declining fry-to-smolt survival of wild stocks observed by Chlupach and Kyle (1990). Low survivals of sockeye salmon during freshwater lifestages were likely due to one or a combination of the following: (1) low egg-to-fry survival of wild sockeye salmon, (2) high predation on sockeye salmon fry in Big Lake, or (3) low dissolved oxygen in Big Lake. The practice of preventing sockeye salmon from utilizing spawning habitat in Meadow Creek above Big Lake Hatchery likely caused poor egg-to-fry survival of wild salmon if spawners were crowded into the shallow area below the weir. Further, installation of a cofferdam at the lake outlet has prevented sockeye salmon fry emerging from gravels below the dam from migrating into Big Lake to rear. A reduction in the productivity of these two subpopulations could have produced the declining trend in aggregate survivals observed since the mid 1970's (Figure 6). High predation on wild and hatchery sockeye salmon may have also contributed to the observed low survivals in Big Lake. During the mid 1980's, an average of 1.2 million coho salmon fry were stocked into Big Lake. This level of stocking probably increased the coho salmon population in the lake by a factor of 2.7 (assuming mean natural coho salmon escapements of 2,200). Juvenile coho salmon are significant predators on juvenile sockeye salmon in rearing lakes (Ruggerone, 1989). Resident northern pike, rainbow trout, and Arctic char probably also prey on juvenile sockeye salmon in Big Lake. Although, ADF&G does not estimate population sizes of resident fish, ADF&G Sport Fish State Wide Harvest Surveys indicate that rainbow populations appear to be slightly on the decline while char and burbot populations remain stable (Howe et al., 1999). The presence of northern pike has only recently been documented in the watershed (Sweet and Rutz, 2001). Finally, it seems unlikely that low dissolved oxygen caused direct mortality of juvenile sockeye salmon. Dissolved oxygen levels within a few meters of the bottom were low enough to cause mortality, but juveniles could easily avoid these areas. Nevertheless, low dissolved oxygen levels (<5mg L^{-1}) below 10-15 m depths probably limited the habitats available to foraging juvenile sockeye salmon, but the large size of smolts produced in Big Lake indicate that juveniles achieved high feeding rates in available habitats.

The observed inverse relationship between number of fry and their subsequent survival (Figure 5) indicates compensatory mortality. Compensation has been attributed to cannibalism of juveniles by adults, disease transmission, redd superimposition, or density-dependent juvenile growth coupled with size-dependent predation (Hilborn and Walters, 1992). Available data indicate that disease transmission, redd superimposition, or density-dependent growth may have contributed to the compensation observed among sockeye salmon rearing in the Big Lake watershed. IHNV mortality of sockeye salmon fry was observed at Big Lake Hatchery in 1978, 1979, 1986, and 1987 (Table 4). Our estimates of fry-to-adult survival were relatively high for brood years 1978 and 1979 when hatchery-reared fry comprised less than 7% of the total estimated fry population, but survival was low for brood years 1986 and 1987 when hatchery fry comprised about 60% of the total fry population (Appendix B). Redd superimposition may have also contributed to poor egg-to-fry survival of wild salmon during the late 1980's when adult returns and hatchery egg takes were relatively high (Appendix B). During this period, wild spawners were crowded into the shallow area below the eggtake weir at Big Lake hatchery. It seems unlikely that density-dependent growth caused compensation, because the system has historically produced large smolts averaging 130 mm (age 1) and 163 mm (age 2), and smolt sizes were only weakly related to number of smolts (Chlupach and Kyle, 1990). However, smolts are individuals that have survived lake residence. Size-dependent juvenile growth coupled with size-dependent predation could result in large smolts depending on the size composition of the predator field (Rice et al., 1997).

Low sockeye salmon escapements into Fish Creek since 1998 were due to poor survival of the 1993-1995 year classes (Appendix B). The cause of this decline is unclear, but it was associated with (1) closure of the Big Lake Hatchery during which the flow of well water from the hatchery into lower Meadow Creek was shut off, and (2) an increase in the numbers of hatchery-reared fry stocked into Blodgett Lake. The spawning habitat below the hatchery in Meadow Creek is relatively shallow, so shutting off the water supply from the hatchery may have caused the area to freeze during harsh winters. Stocking fry into Blodgett Lake was intended to re-colonize spawning habitats in Meadow Creek above the hatchery, but we do not know if this strategy has been successful or if fry stocked into Blodgett Lake survive at a lower rate. Survival of the 1996 year class has increased, but substantial declines in the numbers of fry stocked into the system from subsequent year classes suggests that returns may decline further.

CONCLUSIONS

1. Low dissolved oxygen levels sufficient to affect fish survival (<5mg L^{-1}) occurred at depths below 10-15 m during the early 1980's, but in 2001 this layer was much less extensive. Dissolved oxygen levels within a few meters of the bottom were low enough to cause mortality during the early 1980's, but juveniles could easily avoid these areas.

2. Total nitrogen and phosphorus concentrations in Big Lake today are similar to those in the early 1980's.
3. Estimates based on limnological models indicated that the number of spawners required to produce a smolt population at carrying capacity ranged from 17,000 to 43,000.
4. The aggregate survival of sockeye salmon (wild & hatchery combined) to the smolt stage was about ¼ of survivals in other sockeye salmon systems during the late 1980's.
5. During this same period, survival of wild salmon to the smolt stage was an order of magnitude lower than hatchery salmon stocked into the Big Lake watershed.
6. Inriver returns of adult sockeye salmon were significantly higher (p=0.012) during stocking (mean=64,457) than before stocking (mean=34,398).
7. The aggregate survival of sockeye salmon (wild & hatchery combined) to the adult stage was inversely related to the estimated number of fry rearing in Big Lake and survivals have declined since the mid 1970's.
8. The causes of the decline in survival of Fish Creek sockeye salmon over the past 25 years are unclear but a decline in production of the wild stock seems most likely. A decline in wild stock production may have resulted from installation of a cofferdam at the lake outlet reducing the productivity of the subpopulation spawning below the dam, and the practice of preventing adult salmon from utilizing spawning habitats in Meadow Creek above the Big Lake Hatchery.
9. A decline in sockeye salmon escapements into Fish Creek since 1998 was associated with closure of the Big Lake Hatchery during which wells supplying water to lower Meadow Creek were shut off, and the number of hatchery-reared fry stocked into Blodgett Lake was increased.

RESEARCH RECOMMENDATIONS

A five-year investigation of sockeye salmon production in the Big Lake watershed is recommended. The studies would determine spawner habitat utilization, embryo survival, egg-to-fall fry survival, fall fry-to-smolt survival, and smolt-to-adult survival of both wild and hatchery salmon (Table 8). Study results will be used to identify the causes of poor returns of Fish Creek sockeye salmon and develop stock rehabilitation strategies.

Spawner habitat utilization will be examined by operating weirs on Fish Creek and Meadow Creek. The first otolith thermally marked salmon will return in 2002 and the entire hatchery return will be marked in 2003. Otolith samples will be collected at both the Fish Creek and Meadow Creek weirs to estimate numbers of wild and enhanced sockeye salmon in the escapement. The difference between salmon counts at these two sites will be used to estimate stock-specific numbers of stream and lakeshore spawners. Ground surveys will later be conducted to determine spawner distribution in both stream and lake habitats. Information from these surveys will be used to stratify stream habitats by spawner density, substrate type and stream gradient. Egg digs will then be conducted in late September within each stratum to estimate embryo survival among stream habitats.

Limnological investigations will be conducted to characterize the rearing habitat available for juvenile salmon in Big Lake (presently funded for 1 year). Nutrient levels are currently being monitored in the two major basins of Big Lake as part of a cooperative project with Alaska Department of Environmental Conservation and ADF&G to establish regional nutrient criteria for water quality. General water quality and zooplankton samples as well as physical data are being collected monthly May – September.

Samples of juvenile sockeye salmon will be collected periodically from May-September to determine diet composition. A sample of these fish will also be analyzed for mixed-function oxidases (Stegeman and Lech, 1991) to examine their exposure to toxins in Big Lake.

Hydroacoustic and tow-net surveys will be conducted in early October to estimate fry population size and determine age and size composition. The following spring, a smolt trap will be operated to estimate smolt population size. Historically, smolt emigrate in large groups during a very narrow time period making smolt enumeration difficult. A systematic sampling design will be employed to subsample the migrant smolt population. Otolith samples will be collected from both fry and smolt to estimate stock composition. Fry-to-smolt and smolt-to-adult survivals will be estimated for both wild and enhanced stocks.

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Table 1. Summary of sockeye salmon escapements into the Big Lake watershed, 1938-2001. Escapements are weir counts unless otherwise noted. Counting occurred downstream of Knik Road prior to 1983, at South Big Lake Road from 1983-1991, and at Lewis Road from 1992-present.

Brood Year	Escapement	Brood Year	Escapement
1938	182,463	1970	25,000 [3/]
1939	116,588	1971	31,900 [4/]
1940	306,982	1972	6,981
1941	55,077	1973	2,705
1942	.	1974	16,225
1943	.	1975	29,882
1944	.	1976	14,032
1945	.	1977	5,183
1946	57,000 [1/]	1978	3,555
1947	150,000 [1/]	1979	68,739
1948	150,000 [1/]	1980	62,828
1949	68,240	1981	50,479
1950	29,659	1982	28,164
1951	34,704	1983	118,797
1952	92,724	1984	192,352
1953	54,343	1985	68,577
1954	20,904	1986	29,800
1955	32,724	1987	91,215
1956	32,663 [5/]	1988	71,603
1957	15,630	1989	67,224
1958	17,573	1990	50,000
1959	77,416 [2/ 5/]	1991	50,500
1960	80,000 [2/ 5/]	1992	71,385
1961	40,000 [2/ 5/]	1993	117,619
1962	60,000 [2/ 5/]	1994	95,107
1963	119,024 [2/ 5/]	1995	115,000
1964	65,000 [2/ 5/]	1996	63,160
1965	16,544 [2/]	1997	54,656
1966	41,312 [2/ 5/]	1998	22,853
1967	22,624 [2/ 5/]	1999	26,746
1968	19,616 [2/ 5/]	2000	19,533
1969	12,456	2001	43,486

[1/] Escapement enumerated by ground surveys.

[2/] Escapement enumerated using a counting screen.

[3/] Includes 3,500 sockeye salmon behind weir when it washed out on 8/8/70.

[4/] Includes 500 sockeye salmon behind weir when it was removed on 8/7/71.

[5/] Partial counts due to termination of counting before the end of the run.

Table 2. Summary of total phosphorus and total nitrogen values and nitrogen to phosphorus ratios (by atoms) for Big Lake in 1983-1985 and 1999.

Date	Station	Number of Observations	Depth (m)	Total Phosphorus (g L^{-1} P)	Total Nitrogen (g L^{-1} N)	N:P Ratio
1983	W	15	1-2	8.5	206	55
1983	W	45	5-24	13.5	235	41
1983	E	15	1-2	9.4	224	56
1983	E	42	5-15	17.3	258	42
Mean				12.2	231	49
1984	W	13	2	10.4	213	51
1984	W	39	8-23	15.3	250	42
1984	E	13	2	8.8	234	63
1984	E	39	5-15	21.2	311	48
Mean				13.9	252	51
1985	W	4	1	6.5	199	69
1985	W	4	13-18	9.9	233	54
1985	E	4	1	8.7	220	58
1985	E	4	9-12	17.8	280	43
Mean				10.7	233	56
1999	W	2	1	6.4	203	71
1999	W	2	19-22	23.6	358	35
1999	E	2	1	7.6	231	71
1999	E	2	12-13	12.7	251	46
Mean				12.6	261	56

Table 3. Carrying capacity of Big Lake for juvenile sockeye salmon using 3 limnological models: EV - euphotic volume model, EZD - euphotic zone depth model, and ZB - zooplankton biomass model.

Model	Value of Indep. Variable	Predicted Smolt Biomass (kg)	Predicted No. Smolt	Predicted No. Eggs (1000's)	Predicted No. Spawners
EV (m^3 x 10^6)	111.9	12,139	606,965	30,348	21,024
EZD (m)	13.1	9,776	488,810	24,440	16,931
ZB (mg dw/m^2)	1021	24,739	1,236,965	61,848	42,846

Table 4. Numbers of sockeye salmon stocked into the Big Lake watershed, 1977-2001.

Brood Year	Release Year	Return Years	Stock	Egg Take	Fish Released and Site: Hatchery	Blodgett Lake or Upstream	Big Lake Shore Areas	Transferred to Eklutna Hatchery	Total	Marks	Hatchery	Comments
1975	1976	1979, 1980	Meadow Cr	180,000	71,000				71,000	No	Big Lake	
1976	1977	1980, 1981	Meadow Cr, Fish Cr	10,000,000	2,200,000		4,400,000		6,600,000	Fin [2/]	Big Lake	
1977	1978	1981, 1982	Tustumena L, Fish Cr	8,700,000	3,600,000		2,100,000		5,700,000	Fin [3/]	Big Lake	
1978	1979	1982, 1983	Meadow Cr, Fish Cr	9,800,000					0	No	Big Lake	IHN Loss [1/]
1979	1980	1983, 1984	Meadow Cr	5,000,000	747,000				747,000	No	Big Lake	IHN Loss
1980	1981	1984, 1985	Meadow Cr, Fish Cr	4,700,000	400,000		3,600,000		4,000,000	No	Big Lake	
1981	1982	1985, 1986	Meadow Cr, Fish Cr	5,700,000	3,100,000	1,200,000			4,300,000	No	Big Lake	
1982	1983	1986, 1987	Meadow Cr, Fish Cr	8,600,000	4,200,000	2,400,000			6,600,000	No	Big Lake	
1983	1984	1987, 1988	Meadow Cr	9,300,000	7,400,000				7,400,000	No	Big Lake	
1984	1985	1988, 1989	Meadow Cr, Fish Cr	16,200,000	8,900,000	3,500,000			12,400,000	CWT [4/]	Big Lake	
1985	1986	1989, 1990	Meadow Cr, Fish Cr	21,600,000	14,100,000	922,000			15,022,000	CWT [5/]	Big Lake	
1986	1987	1990, 1991	Meadow Cr	17,500,000	11,700,000				11,700,000	CWT [6/]	Big Lake	IHN Loss
1987	1988	1991, 1992	Meadow Cr, Fish Cr	20,300,000	14,000,000		281,000		14,281,000	CWT [7/]	Big Lake	IHN Loss
1988	1989	1992, 1993	Meadow Cr	19,700,000	13,200,000		1,200,000		14,400,000	CWT [8/]	Big Lake	
1989	1990	1993, 1994	Meadow Cr	14,800,000	10,800,000		531,000		11,331,000	CWT [9/]	Big Lake	
1990	1991	1994, 1995	Meadow Cr	14,700,000	8,400,000		1,600,000		10,000,000	CWT [10/]	Big Lake	
1991	1992	1995, 1996	Meadow Cr	7,400,000	1,400,000	1,200,000	535,000	1,000,000	4,135,000	No	Big Lake	
1992	1993	1996, 1997	Meadow Cr	9,000,000	3,000,000	1,600,000		1,500,000	6,100,000	No	Big Lake	
1993	1994	1997, 1998	Meadow Cr	9,000,000	3,000,000	2,000,000			5,000,000	No	Eklutna	
1994	1995	1998, 1999	Meadow Cr	7,700,000	3,000,000	2,000,000			5,000,000	No	Eklutna	
1995	1996	1999, 2000	Meadow Cr	8,000,000	3,000,000	2,000,000			5,000,000	No	Eklutna	
1996	1997	2000, 2001	Meadow Cr	8,000,000	2,900,000	1,100,000			4,000,000	No	Eklutna	
1997	1998	2001, 2002	Meadow Cr	8,000,000	3,000,000	2,000,000			5,000,000	No	Eklutna	
1998	1999	2002, 2003	Meadow Cr	5,100,000	197,000				197,000	Otolith	Trail Lake	IHN Loss
1999	2000	2003, 2004	Meadow Cr	1,500,000	846,000				846,000	Otolith	Trail Lake	
2000	2001	2004, 2005	Meadow Cr	3,600,000					0	Otolith	Trail Lake	IHN Loss

[1/] infectious hematopoietic necrosis.

[2/] No data available.

[3/] Tagged fish released with untagged fish.

[4/] Tagged fish released one day before untagged fish.

[5/] Tagged fish released with 2 million untagged fish. 13 million fish released with no tagged fish.

[6/] Tagged fish released with 6.0 million untagged fish. 5.7 million fish released with no tagged fish.

[7/] Tagged fish released with untagged fish. No specific data available.

[8/] Tagged fish released with untagged fish. No specific data available.

[9/] Tagged fish released with untagged fish. No specific data available.

[10/] Tagged fish released with 6.336 million untagged fish. 3.679 million fish released with no tagged fish.

Table 5. Numbers of coho salmon produced at Big Lake Hatchery and stocked into the Big Lake watershed, 1977-1993.

Brood Year	Release Year	Stock	Lifestage	Fish Released and Site: Hatchery	Blodgett Lake or Upstream	Big Lake Shore Areas	Fish Creek	Total	Marks
1976	1977	Fish Cr	Fingerling			41,000		41,000	No
1977	1978	Meadow Cr, Fish Cr	Fingerling		51,000	26,000	24,000	101,000	Fin
1978	1979	Meadow Cr, Fish Cr	Fingerling	47,000			336,000	383,000	Fin
1979	1980	Fish Cr	Fingerling			451,000		451,000	Fin
1980	1981	Fish Cr	Fingerling	14,000		104,000		118,000	Fin
1981	1982	Fish Cr	Fingerling	468,000	129,000			597,000	Fin
1982	1983	Meadow Cr, Fish Cr	Fingerling	1,132,000	247,000			1,379,000	CWT
1983	1984	Meadow Cr, Fish Cr	Fingerling	624,000	362,000			986,000	CWT
1984	1985	Meadow Cr, Fish Cr	Fingerling	1,492,000	150,000			1,642,000	CWT
1985	1986	Big Lake [1/]	Fingerling	2,189,000	166,000			2,355,000	CWT
1986	1987	Big Lake	Fingerling	1,746,000	505,000		207,000	2,458,000	CWT
	1988	Big Lake	Smolt	20,000				20,000	CWT
1987	1988	Big Lake	Fingerling	1,419,000	213,000		198,000	1,830,000	CWT
	1989	Big Lake	Smolt			15,000		15,000	CWT
1988	1990	Big Lake	Smolt			22,000		22,000	CWT
1989	1990	Big Lake	Fingerling	364,000	71,000		69,000	504,000	CWT
	1991	Big Lake	Smolt	400			81,000	81,400	CWT
1990	1992	Big Lake	Smolt				75,000	75,000	CWT
1991	1993	Big Lake	Smolt				68,000	68,000	CWT
1992	1993	Big Lake	Fingerling		105,000	162,000		267,000	No

[1/] Big Lake stock is a mixture of Fish Cr and Meadow Cr

Table 6. Numbers of chinook salmon and rainbow trout stocked into the Big Lake watershed, 1977-1993. Chinook salmon were reared at the Crooked Creek Hatchery and rainbow trout were reared at the Fort Richardson Hatchery.

Brood Year	Release Year	Species	Stock	Lifestage	Fish Released and Site: Hatchery	Blodgett Lake or Upstream	Big Lake Shore Areas	Fish Creek	Total	Marks
1976	1977	Chinook	Crooked Cr	Fingerling	56,000				56,000	No
1987	1987	Rainbow	Big Lake	Fingerling		6,300			6,300	No
-	1988	Rainbow	Big Lake	Catchables			24,000		24,000	Fin
1988	1988	Rainbow	Big Lake	Fingerling		12,000			12,000	No
1989	1989	Rainbow	Big Lake	Fingerling		5,800	216,000		221,800	No
1990	1990	Rainbow	Big Lake	Fingerling			450,000		450,000	No
1991	1991	Rainbow	Big Lake	Fingerling		5,800	462,000		467,800	No
1992	1992	Rainbow	Big Lake	Fingerling		12,000	299,000		311,000	No
1993	1993	Rainbow	Big Lake	Fingerling		6,100			6,100	No

Table 7. Estimated survival to smolt for sockeye salmon (wild and hatchery combined) emigrating from Big Lake, brood years 1984-1988. Average age composition was used to estimate numbers of age 1 & 2 smolts emigrating from Big Lake in 1990-1991.

Brood	Number	Release	Number of fry		Age 1 Smolt			Age 2 Smolt				Fry to Smolt
Year	Spawners	Year	Wild	Hatchery	Year	Number	Percent	Year	Number	Percent	Total	Survival
1984	192,352	1985	27,862,187	12,400,000	1986	477,742	71.2%	1987	193,079	28.8%	670,821	1.7%
1985	68,577	1986	9,933,378	15,022,000	1987	1,258,728	97.4%	1988	33,779	2.6%	1,292,507	5.2%
1986	29,800	1987	4,316,530	11,700,000	1988	580,411	82.6%	1989	122,534	17.4%	702,945	4.4%
1987	91,215	1988	13,212,493	14,281,000	1989	1,061,928	-	1990	206,437	-	1,268,365	4.6%
1988	71,603	1989	10,371,695	14,400,000	1990	448,181	-	1991	204,377	-	652,558	2.6%
Mean	90,709		13,139,257	13,560,600		765,398	83.7%		152,041	16.3%	917,439	3.7%

Table 8. Annual budget, in thousands of dollars, for proposed Fish Creek sockeye salmon rehabilitation studies.

Project	Line Item 100	200	300	400	500	Total
Fish Creek Weir	9.6			0.5		10.1
Meadow Creek Weir	9.6			2.5		12.1
Ground Surveys	1.9			0.5		2.4
Egg Digs	2.7			1.0		3.7
MFO analysis			2.0			2.0
Fall Hydroacoustic Surveys	1.0			0.5		1.5
Smolt Trap	9.6			0.5		10.1
Otolith sample processing	4.2			0.5		4.7
Line Item Total	38.5	0.0	2.0	6.0	0.0	46.5

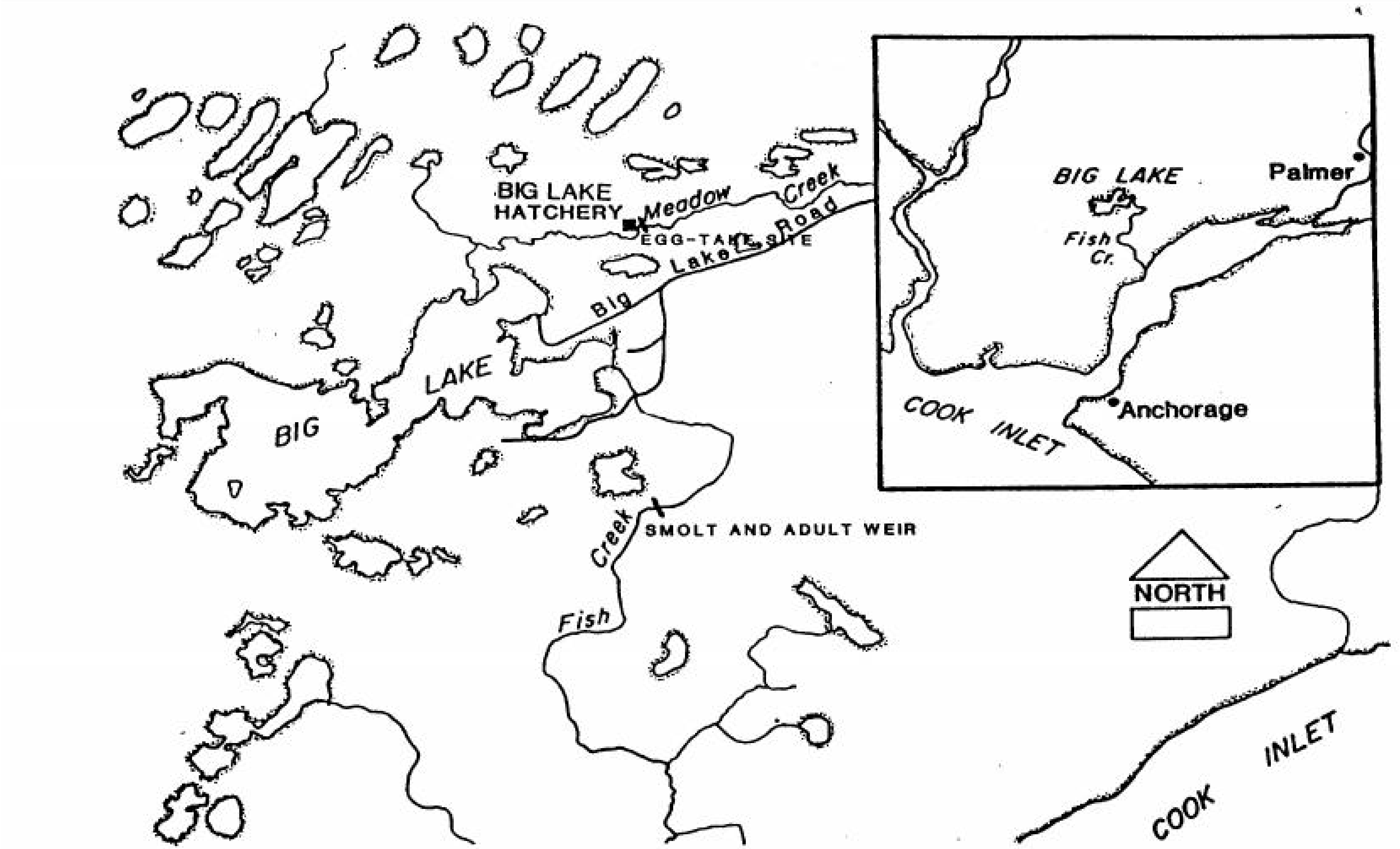

Figure 1. Location of Big Lake at the head of Knik Arm showing location of Big Lake Hatchery, smolt and adult weirs, and egg-take site.

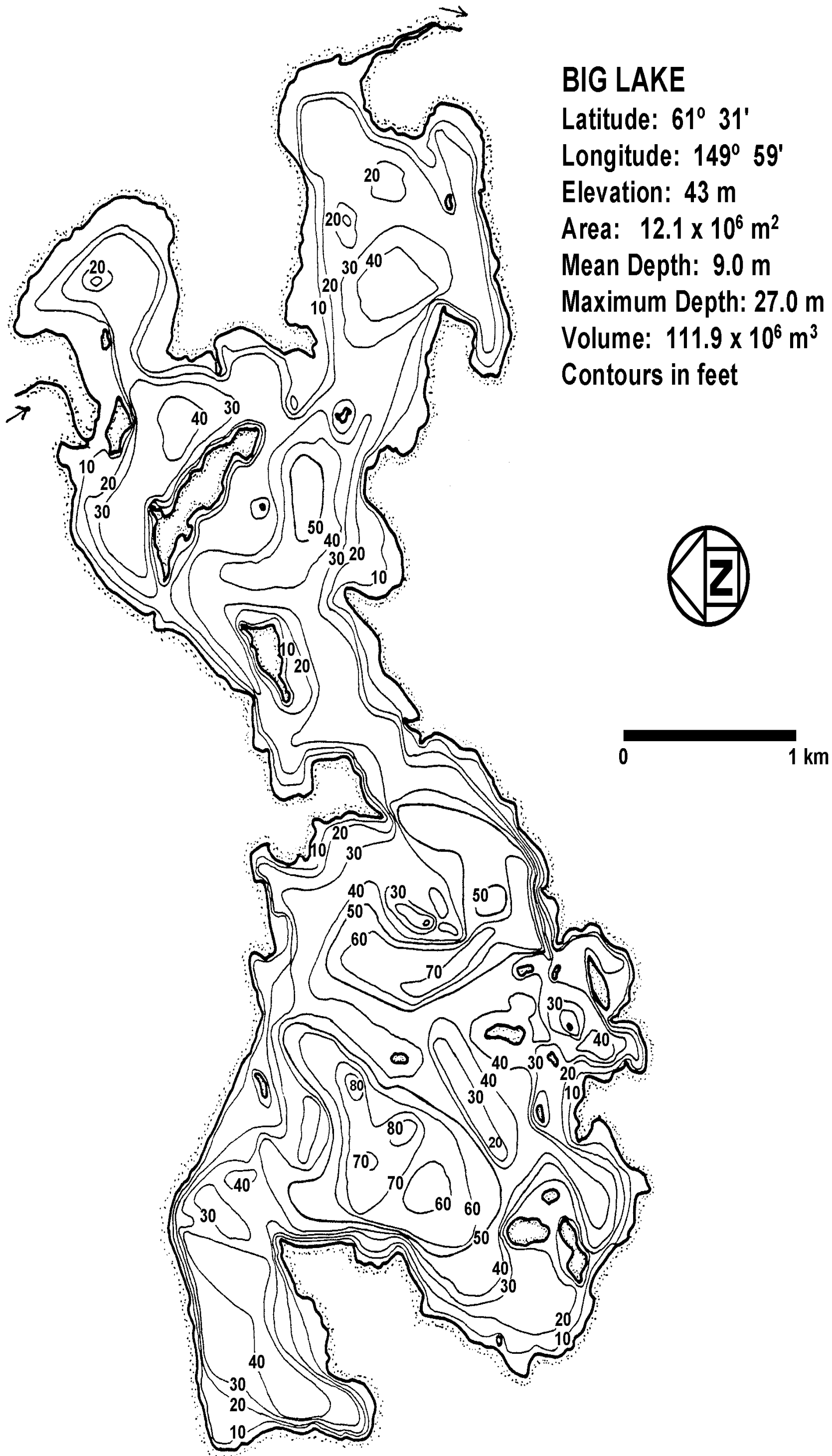

Figure 2. Morphometric map of Big Lake.

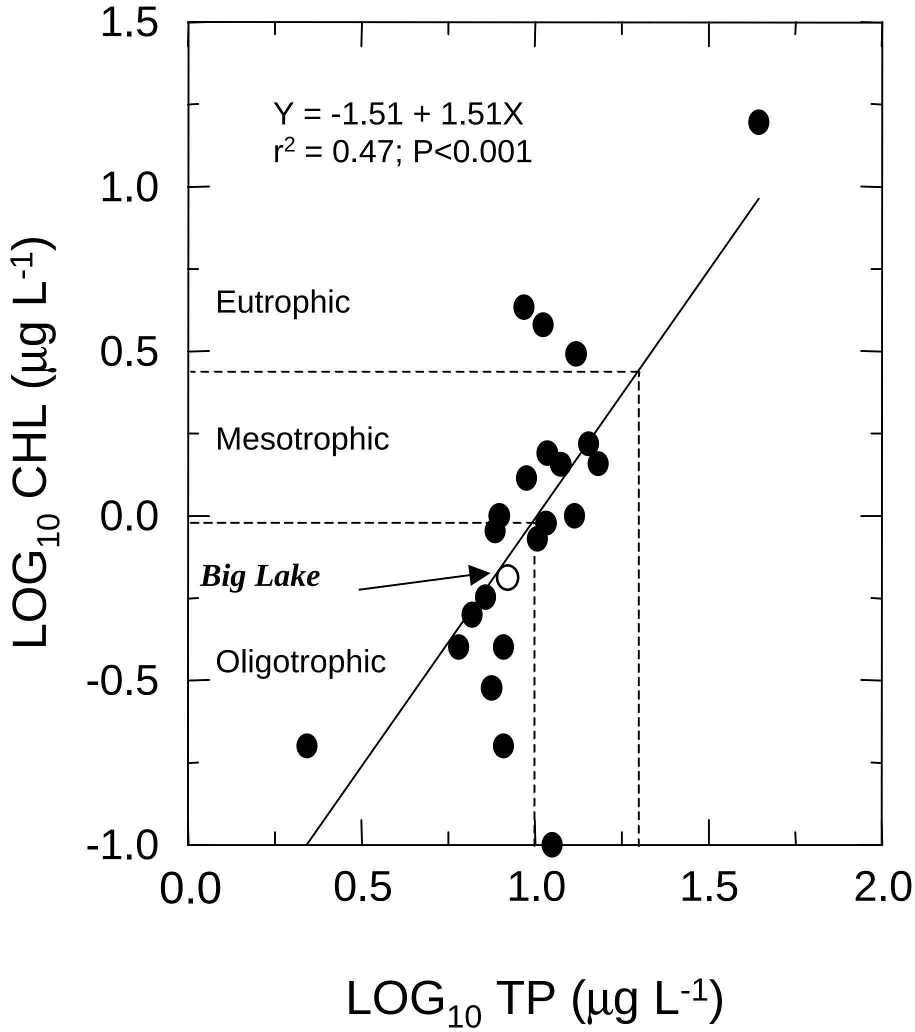

Figure 3. Phosphorus-chlorophyll *a* relationship derived for 25 lakes in the Matanuska-Suisitna Borough in relation to trophic state. Data from Big Lake (open circle) are annual means for 1983 and 1984.

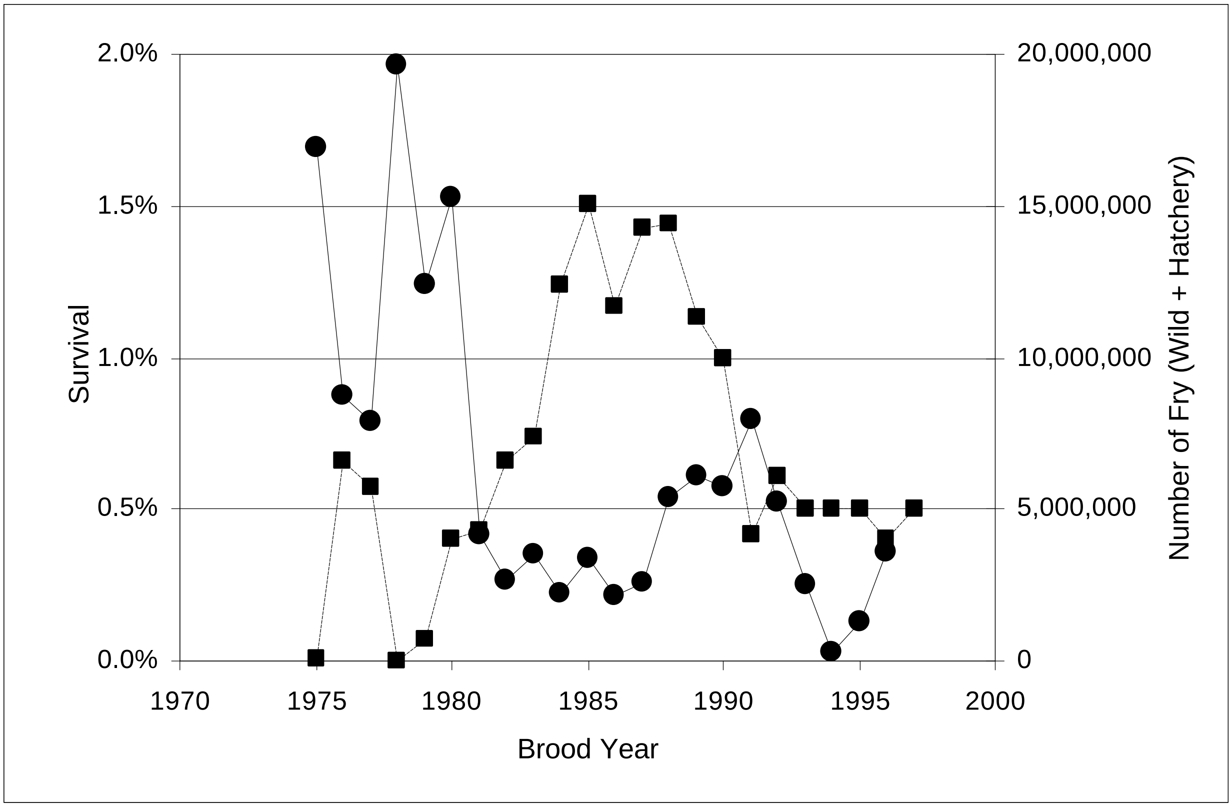

Figure 4. Time series of the number of sockeye salmon fry stocked into the Big Lake watershed (solid squares) and survival (solid circles) from fry to adult inriver return (escapement + personal use harvest).

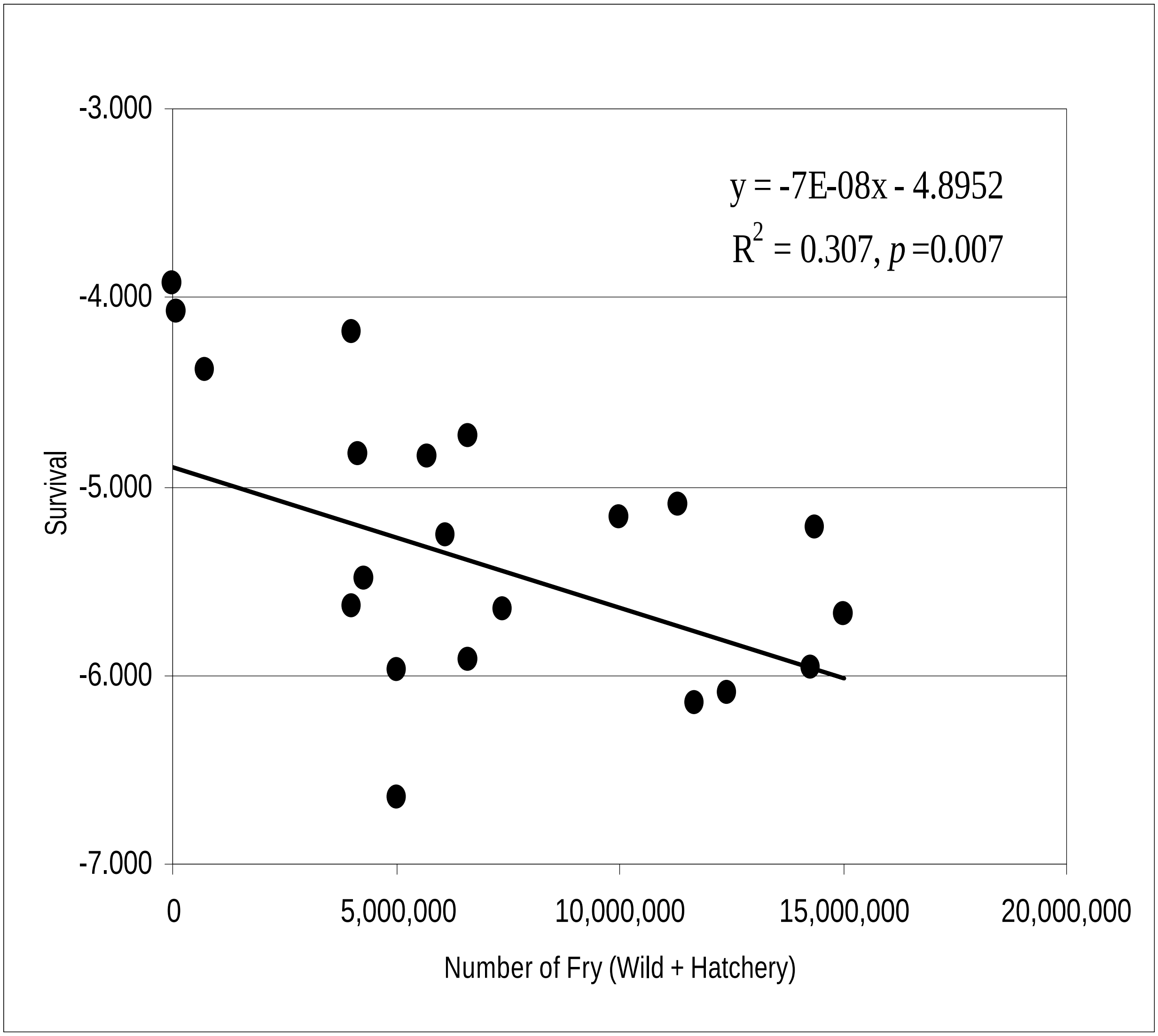

Figure 5. Relationship between the estimated number of sockeye salmon fry rearing in Big Lake and survival (natural-logarithm transformed) from fry to adult inriver return (escapement + personal use harvest).

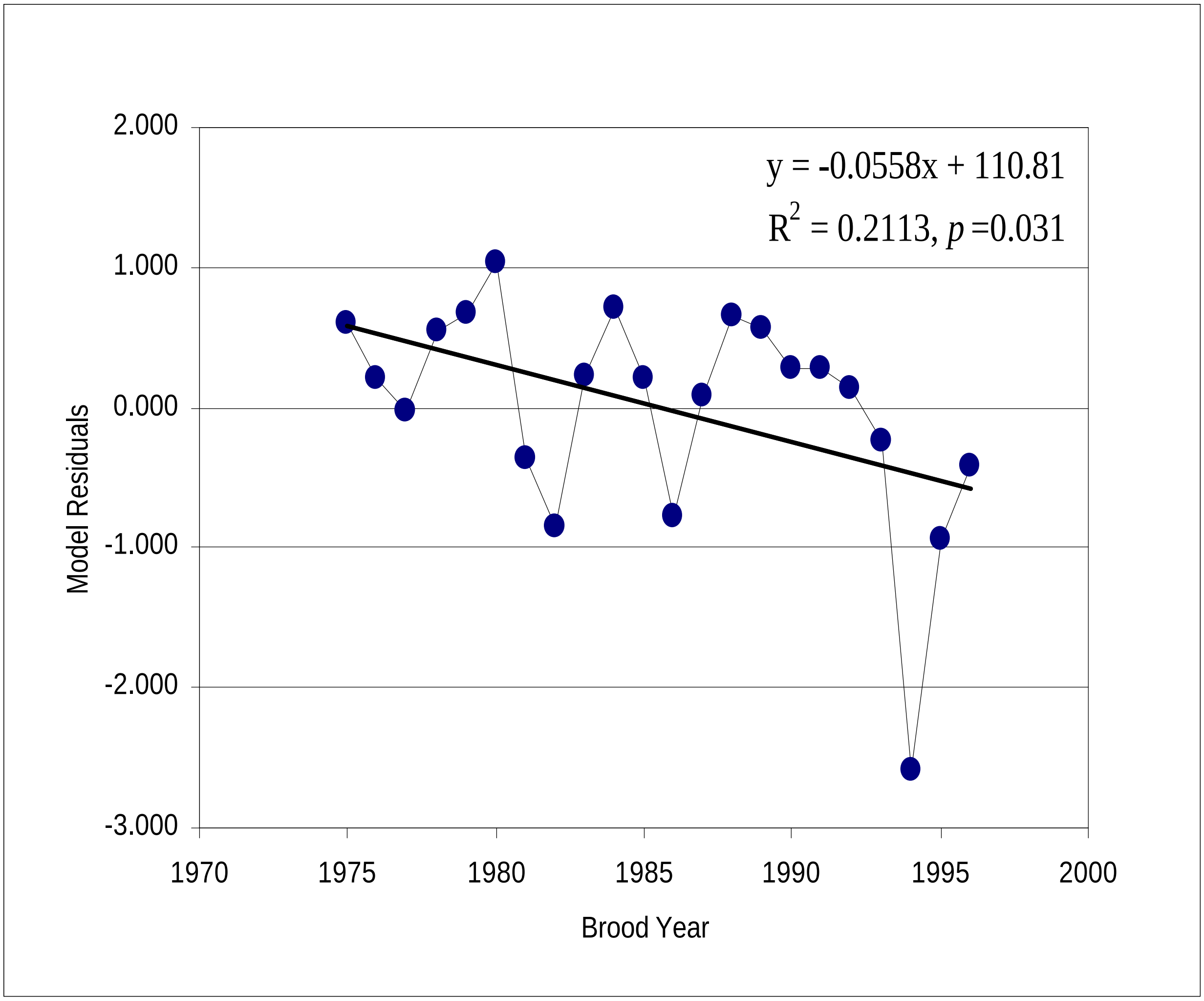

Figure 6. Times series of residuals from a regression model relating number of sockeye salmon fry rearing in Big Lake and survival (natural-logarithm transformed) from fry to adult inriver return (escapement + personal use harvest).

Appendix A. General water chemistry, nutrient and algal pigment concentrations for Big Lake, 1983 - 1985, 1999. Mean values (bold) and ranges (*italics*) are given for each year.

Date	Sta	Depth (m)	Specific conductance (mhos cm $^{-1}$)	pH (Units)	Alkalinity (mg L^{-1})	Turbidity (NTU)	Color (Pt units)	Calcium (mg L^{-1})	Magnesium (mg L^{-1})	Iron (g L $^{-1}$)	Total-P (g L $^{-1}$ P)	Total filter-able-P (g L $^{-1}$ P)	Filterable reactive-P (g L $^{-1}$ P)	Total Kjel-dahl nitrogen (g L $^{-1}$ N)	Ammonia (g L $^{-1}$ N)	Nitrate+ nitrite (g L $^{-1}$ N)	Reactive silicon (g L $^{-1}$ Si)	Particulate Organic carbon (g L $^{-1}$)
01/26/1983	E	1	128	7.6	65	na	na	18.9	4.0	9	16.5	6.1	4.4	184	6.8	57	3345	132
01/26/1983	E	5	120	7.3	60	na	na	18.4	3.4	51	17.8	5.0	3.6	137	3.5	78	3610	98
01/26/1983	E	10	119	7.3	60	na	na	19.4	3.0	88	10.1	5.8	5.0	135	4.1	125	3898	115
01/26/1983	E	14	124	7.2	62	na	na	19.9	3.0	424	21.5	9.7	8.5	211	85.2	154	4517	149
01/26/1983	W	1	119	7.5	61	na	na	19.4	3	7	11.6	8.1	5.4	194	8.0	45	3062	75
01/26/1983	W	8	111	7.5	57	na	na	18.9	2.4	5	9.2	6.4	4.8	140	4.8	46	2893	132
01/26/1983	W	15	111	7.4	56	na	na	17.4	3	9	12.4	9.5	8.6	119	3.6	73	3158	319
01/26/1983	W	21	113	7.2	57	na	na	17.9	3.7	12	24.7	16.5	13.7	401	8.9	118	3731	18
02/23/1983	E	1	128	7.5	62	na	na	18.6	3.0	21	10.8	8.5	3.8	219	8.6	50	3386	167
02/23/1983	E	5	119	7.5	59	na	na	17.2	2.4	37	7.7	5.8	3.5	149	3.4	74	3428	na
02/23/1983	E	10	124	7.3	62	na	na	19.1	2.7	132	9.5	7.1	5.2	147	2.8	122	4232	na
02/23/1983	E	14	133	7.3	66	na	na	20.0	3.0	472	21.5	13.3	8.0	234	99.5	117	4563	na
02/23/1983	W	1	119	7.5	59	na	na	18.1	2.7	11	10.9	7.2	4.1	215	6.2	40	3066	107
02/23/1983	W	5	114	7.4	56	na	na	17.7	2.4	11	9.5	9.5	5.4	189	5.4	44	2930	na
02/23/1983	W	12	112	7.4	56	na	na	16.7	2.4	11	10.5	10.3	7.1	158	2.9	77	3253	na
02/23/1983	W	18	113	7.2	56	na	na	16.7	2.7	18	16.3	17.6	14.0	157	3.2	114	3729	na
03/23/1983	E	1	116	7.4	61	na	na	na	na	12	10.3	3.5	2.0	184	4.7	26	3046	140
03/23/1983	E	5	112	7.3	56	na	na	na	na	44	8.4	4.0	2.5	170	3.2	94	3351	na
03/23/1983	E	10	115	7.2	63	na	na	na	na	148	9.7	6.2	5.5	134	2.3	152	4294	na
03/23/1983	E	14	121	7.2	64	na	na	na	na	583	22.3	9.7	8.4	217	76.6	135	4915	na
03/23/1983	W	1	109	7.6	60	na	na	16.9	3.1	27	8.2	4.2	1.9	174	3.6	19	3269	58
03/23/1983	W	5	102	7.5	57	na	na	15.6	2.2	26	9.0	5.5	4.1	159	3.5	46	3179	na
03/23/1983	W	12	112	7.3	63	na	na	17.8	1.7	32	12.0	9.5	7.9	151	1.8	86	3739	na
03/23/1983	W	22	118	7.4	60	na	na	17.8	2.8	39	18.7	15.4	13.9	144	2.0	192	4387	na
04/20/1983	E	1	113	7.1	57	na	na	20.0	2.8	51	8.2	3.8	1.9	182	7.4	8	3371	118
04/20/1983	E	5	125	7.1	62	na	na	25.0	2.8	7	10.4	2.9	1.8	228	4.8	26	3698	na
04/20/1983	E	9	140	7.2	77	na	na	22.0	4.0	121	8.8	4.3	3.2	171	6.5	127	4830	na
04/20/1983	E	13	138	7.1	.	na	na	22.0	4.0	406	18.0	7.2	6.3	206	28.4	163	5241	na
04/21/1983	W	1	111	7.7	56	na	na	20	1.6	10	8.7	4.7	2.2	179	5.1	4	181	254
04/21/1983	W	5	116	7.6	57	na	na	18	4	10	9.6	4.0	4.5	184	2.8	4	184	na
04/21/1983	W	13	119	7.4	63	na	na	20	2.8	26	7.6	3.7	3.3	151	4.1	61	151	na
04/21/1983	W	22	125	7.4	65	na	na	20	2.8	101	18.7	14.2	11.6	118	5.2	149	118	na
05/25/1983	W	2	105	7.4	60	na	na	na	na	na	10.4	4.1	1.4	207	3.5	1	207	360
05/25/1983	W	10	104	7.5	58	na	na	na	na	na	9.5	4.2	1.8	218	6.0	17	218	na
05/25/1983	W	18	117	7.5	65	na	na	na	na	na	8.3	3.7	1.6	172	8.3	33	172	na
05/25/1983	W	23	108	7.6	66	na	na	na	na	na	17.4	4.3	2.1	199	12.7	39	199	na
05/26/1983	E	2	98	7.6	58	na	na	na	na	na	11.7	5.3	1.9	217	5.4	4	2774	313
05/26/1983	E	10	124	7.4	66	na	na	na	na	na	12.4	4.6	2.5	235	18.9	30	4160	na
05/26/1983	E	15	131	7.6	71	na	na	na	na	293	13.7	5.0	2.9	225	44.7	37	4627	na
06/06/1983	W	2	105	7.8	57	na	na	na	na	na	8.5	4.5	1.2	175	2.2	4	2786	722
06/06/1983	W	10	110	7.6	60	na	na	na	na	na	17.7	4.0	1.6	238	3.0	4	3268	na
06/06/1983	W	15	113	7.3	62	na	na	na	na	23	11.2	4.1	1.9	194	8.2	10	3429	na
06/06/1983	W	19	114	7.5	63	na	na	na	na	na	14.4	4.4	2.1	187	8.5	15	3494	na
06/07/1983	E	2	101	7.8	61	na	na	na	na	na	8.5	5.3	1.4	182	2.6	4	2688	na
06/07/1983	E	10	120	7.2	63	na	na	na	na	na	13.0	6.1	2.8	205	4.8	6	3876	na
06/07/1983	E	15	130	7.2	70	na	na	na	na	374	20.5	6.1	2.9	288	88.0	28	4841	na
06/20/1983	E	2	102	7.8	47	na	na	na	na	na	9.1	4.0	1.5	236	4.4	4	2605	278
06/20/1983	E	5	107	7.7	60	na	na	na	na	na	9.8	4.6	1.2	238	4.0	4	2766	na
06/20/1983	E	10	117	7.4	59	na	na	na	na	na	21.2	6.8	2.5	293	5.2	3	3659	na
06/20/1983	E	15	123	7.2	61	na	na	na	na	123	13.9	5.7	2.2	166	2.8	9	4250	291

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Date	Sta	Depth (m)	Specific conductance (mhos cm $^{-1}$)	pH (Units)	Alkalinity (mg L^{-1})	Turbidity (NTU)	Color (Pt units)	Calcium (mg L^{-1})	Magnesium (mg L^{-1})	Iron (g L $^{-1}$)	Total-P (g L $^{-1}$ P)	Total filter-able-P (g L $^{-1}$ P)	Filterable reactive-P (g L $^{-1}$ P)	Total Kjel-dahl nitrogen (g L $^{-1}$ N)	Ammonia (g L $^{-1}$ N)	Nitrate+ nitrite (g L $^{-1}$ N)	Reactive silicon (g L $^{-1}$ Si)	Particulate Organic carbon (g L $^{-1}$)
06/21/1983	W	2	106	7.9	56	na	na	na	na	na	6.6	4.5	1.3	141	1.6	4	2657	100
06/21/1983	W	10	114	7.5	57	na	na	na	na	na	13.0	5.2	2.1	193	4.7	6	3189	na
06/21/1983	W	16	114	7.3	65	na	na	na	na	na	10.7	5.2	2.1	164	5.3	14	3439	na
06/21/1983	W	23	116	7.3	61	na	na	na	na	75	15.0	7.5	4.2	234	26.0	30	3670	na
07/07/1983	E	2	106	8.0	52	na	na	15.4	3.5	40	8.9	5.6	2.5	371	6.6	3	2560	346
07/07/1983	E	5	107	7.9	54	na	na	16.3	2.7	32	6.8	4.2	1.3	217	3.5	4	2650	na
07/07/1983	E	10	116	7.3	57	na	na	na	na	na	20.4	7.3	2.8	231	7.4	4	3512	na
07/07/1983	E	15	116	7.4	56	na	na	na	na	na	na	5.8	2.5	na	5.1	5	3502	na
07/07/1983	W	2	104	8.0	52	na	na	na	na	na	12.8	8.8	4.3	348	8.8	3	2898	346
07/07/1983	W	10	110	7.5	54	na	na	na	na	na	13.7	5.8	2.0	221	3.7	4	3080	na
07/07/1983	W	16	113	7.4	56	na	na	16.8	3.5	16	10.7	5.0	2.2	164	7.4	3	3637	na
07/07/1983	W	23	114	7.4	56	na	na	na	na	na	15.8	10.3	6.8	198	29.1	34	3926	na
07/20/1983	E	2	106	7.9	54	na	na	16.3	2.7	28	6.7	2.9	1.2	202	3.1	4	2476	232
07/20/1983	E	5	106	8.0	54	na	na	16.3	2.4	24	6.4	2.9	1.5	182	3.6	4	2498	na
07/20/1983	E	10	114	7.5	57	na	na	16.8	2.7	85	17.2	4.8	2.3	248	2.7	4	3704	na
07/20/1983	E	15	126	7.2	64	na	na	18.7	2.7	526	33.4	6.1	6.2	313	67.3	4	5120	na
07/20/1983	W	2	104	7.3	56	na	na	15.4	2.7	12	6.5	3.3	1.5	167	5.4	4	2565	216
07/20/1983	W	10	111	8.0	55	na	na	16.3	2.7	14	12.7	4.5	1.9	204	3.3	4	3213	na
07/20/1983	W	16	106	7.5	56	na	na	12.5	2.0	23	13.6	5.6	4.0	240	13.3	5	3625	na
07/20/1983	W	24	114	7.3	57	na	na	17.3	2.7	59	25.9	14.6	13.6	271	72.6	43	4360	na
08/01/1983	E	2	106	8.0	53	na	na	14.9	1.1	27	6.4	3.9	1.6	182	4.8	4	2383	112
08/01/1983	E	6	110	7.8	55	na	na	16.3	1.1	42	11.3	2.9	1.5	192	3.7	4	2623	na
08/01/1983	E	10	115	7.6	56	na	na	16.3	1.8	80	17.0	5.1	2.9	214	2.9	4	3725	na
08/01/1983	E	15	125	7.2	62	na	na	17.2	2.1	617	26.1	6.9	6.3	198	19.1	4	5121	na
08/02/1983	W	2	105	8.1	54	na	na	14.9	1.8	18	7.2	3.3	2.0	185	4.1	4	2609	194
08/02/1983	W	10	113	7.6	56	na	na	16.3	2.1	14	12.5	4.8	2.4	220	3.5	4	3218	na
08/02/1983	W	17	115	7.4	57	na	na	16.3	2.1	27	10.6	4.2	5.1	171	4.0	31	3982	na
08/02/1983	W	23	116	7.3	56	na	na	16.3	2.1	62	31.9	17.8	17.7	346	79.9	65	4784	na
08/16/1983	W	2	107	8.0	55	na	na	15.4	2.4	na	5.6	3.4	2.2	197	3.3	7	2091	301
08/16/1983	W	10	112	7.5	58	na	na	15.9	3.0	na	13.0	2.3	2.7	220	2.0	1	2565	na
08/16/1983	W	16	112	7.5	58	na	na	15.4	3.0	na	8.0	1.7	2.6	182	2.0	9	2629	na
08/16/1983	W	23	113	7.4	58	na	na	16.2	2.5	50	12.6	4.1	5.2	209	10.1	34	3466	na
08/17/1983	E	2	106	8.0	54	na	na	14.9	3.0	34	6.7	3.2	3.2	189	10.3	2	2462	293
08/17/1983	E	6	112	7.9	58	na	na	14.9	3.0	72	8.5	3.0	2.7	205	5.9	4	2554	na
08/17/1983	E	10	115	7.4	59	na	na	15.9	3.0	77	13.1	4.0	2.8	220	2.9	4	3412	na
08/17/1983	E	14	127	7.2	66	na	na	17.1	2.8	1546	39.7	14.0	13.7	305	81.2	4	4982	na
08/29/1983	W	2	107	8.0	52	na	na	14.7	3.1	11	8.1	3.5	1.9	235	2.6	4	2546	118
08/29/1983	W	10	112	7.5	56	na	na	15.6	3.1	5	12.5	3.5	2.2	242	3.5	4	3166	na
08/29/1983	W	17	113	7.3	57	na	na	17.0	2.4	23	13.5	6.6	6.0	182	3.4	58	3999	na
08/29/1983	W	23	114	7.3	56	na	na	17.0	3.1	38	15.3	9.4	8.8	191	5.2	60	4051	na
08/30/1983	E	2	108	7.8	54	na	na	15.2	3.1	24	8.9	3.6	2.1	238	3.8	4	2492	167
08/30/1983	E	6	109	7.9	53	na	na	15.6	3.1	30	17.7	4.5	2.4	227	6.4	4	2490	na
08/30/1983	E	10	116	7.4	58	na	na	16.5	3.1	115	19.6	4.7	3.0	239	3.4	4	3614	na
08/30/1983	E	14	127	7.2	64	na	na	17.9	3.5	1843	49.2	31.8	31.1	330	104.4	4	5076	na

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Appendix A. Page 3 of 6.

Date	Sta	Depth (m)	Specific conductance (mhos cm $^{-1}$)	pH (Units)	Alkalinity (mg L^{-1})	Turbidity (NTU)	Color (Pt units)	Calcium (mg L^{-1})	Magnesium (mg L^{-1})	Iron (g L $^{-1}$)	Total-P (g L $^{-1}$ P)	Total filter-able-P (g L $^{-1}$ P)	Filterable reactive-P (g L $^{-1}$ P)	Total Kjel-dahl nitrogen (g L $^{-1}$ N)	Ammonia (g L $^{-1}$ N)	Nitrate+ nitrite (g L $^{-1}$ N)	Reactive silicon (g L $^{-1}$ Si)	Particulate Organic carbon (g L $^{-1}$)
09/13/1983	E	2	111	7.7	52	na	na	na	na	na	7.0	3.5	2.3	187	2.2	4	2502	177
09/13/1983	E	6	110	7.7	65	na	na	na	na	na	9.4	2.4	2.3	200	3.5	4	2494	na
09/13/1983	E	10	108	7.8	56	na	na	na	na	na	15.2	2.8	2.8	250	2.4	4	3520	na
09/13/1983	E	14.5	120	7.3	63	na	na	na	na	na	80.5	64.6	57.8	363	76.5	4	5154	na
09/13/1983	W	2	108	7.8	56	na	na	na	na	na	7.0	3.3	2.7	163	1.4	4	2478	270
09/13/1983	W	10	112	7.4	56	na	na	na	na	na	10.2	3.1	2.9	191	1.5	4	3038	na
09/13/1983	W	17	114	7.2	59	na	na	na	na	na	10.6	4.3	4.7	140	0.9	58	3957	na
09/13/1983	W	23	112	7.4	57	na	na	na	na	203	17.9	10.3	11.4	136	2.9	94	4294	na
09/29/1983	E	2	112	7.5	58	na	na	na	na	na	14.5	5.3	3.6	208	19.1	4	2748	156
09/29/1983	E	5	114	7.5	58	na	na	na	na	na	13.5	5.5	3.5	190	16.2	4	2744	na
09/29/1983	E	8	112	7.4	58	na	na	na	na	na	13.8	4.8	3.4	210	16.0	4	2742	na
09/29/1983	E	14.5	113	7.6	56	na	na	na	na	na	12.1	4.9	3.5	192	12.8	4	2760	na
09/29/1983	W	2	110	7.4	57	na	na	na	na	na	9.4	3.2	2.2	166	6.5	6	2788	297
09/30/1983	W	10	110	7.4	55	na	na	na	na	na	9.3	3.1	2.1	165	3.3	6	2831	na
10/01/1983	W	17	112	7.2	58	na	na	na	na	na	12.0	5.5	4.9	201	4.6	43	3485	na
10/02/1983	W	23	114	7.3	57	na	na	na	na	45	18.5	10.9	10.2	153	12.6	69	4118	na
12/19/1983	E	2	104	7.4	63	na	na	17.6	1.8	32	6.6	6.4	4.4	201	19.5	4	3081	na
12/19/1983	E	6	102	7.3	61	na	na	16.3	2.4	na	6.9	4.8	4.3	196	25.3	4	3121	na
12/19/1983	E	10	103	7.2	64	na	na	21.2	2.1	na	8.7	6.4	5.7	174	8.8	64	3468	na
12/19/1983	E	14	106	7.0	65	na	na	22.0	1.8	na	10.9	6.7	6.2	247	49.8	81	3929	na
12/20/1983	W	2	97	7.5	54	na	na	16.7	1.5	na	6.4	6.4	4.1	190	13.6	3	2923	na
12/20/1983	W	8	96	7.4	56	na	na	16.7	1.8	na	8.2	7.0	5.9	185	20.2	7	2951	na
12/20/1983	W	16	97	7.4	57	na	na	18.5	0.5	na	8.9	7.8	6.7	201	28.5	12	3107	na
12/20/1983	W	23	101	7.2	63	na	na	18.0	0.8	45	15.1	12.2	13.5	204	49.0	34	3517	na
1983	Mean		113	7.5	59			17.4	2.6	134	13.7	6.8	5.0	205	14.4	33	3210	211
	Range		96-140	7.0-8.1	47-77			12.5-25.0	0.5-4.0	5-1843	5.6-80.5	1.7-64.6	1.2-57.8	118-401	0.9-104.4	1-192	118-5241	18-722

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Date	Sta	Depth (m)	Specific conductance (mhos cm $^{-1}$)	pH (Units)	Alkalinity (mg L^{-1})	Turbidity (NTU)	Color (Pt units)	Calcium (mg L^{-1})	Magnesium (mg L^{-1})	Iron (g L $^{-1}$)	Total-P (g L $^{-1}$P)	Total filter-able-P (g L $^{-1}$P)	Filterable reactive-P (g L $^{-1}$P)	Total Kjel-dahl nitrogen (g L $^{-1}$N)	Ammonia (g L $^{-1}$N)	Nitrate+ nitrite (g L $^{-1}$N)	Reactive silicon (g L $^{-1}$Si)	Particulate Organic carbon (g L $^{-1}$)
01/18/1984	W	2	113	7.2	61	na	8	na	na	na	8.5	6.0	5.1	226	6.4	15.0	2792	73
01/18/1984	W	8	110	7.3	61	na	9	na	na	na	6.4	5.5	5.6	211	5.1	26.3	2812	na
01/18/1984	W	16	112	7.1	63	na	8	na	na	6	9.8	8.1	8.6	189	8.5	52.9	3170	na
01/18/1984	W	23	116	6.9	64	na	14	na	na	na	18.5	17.0	16.9	220	7.8	137.8	4027	na
01/19/1984	E	2	120	7.3	58	na	14	na	na	na	7.4	5.7	4.7	198	7.6	17.4	3069	7
01/19/1984	E	6	118	7.1	58	na	15	na	na	na	7.9	5.3	5.2	202	5.2	45.8	3404	na
01/19/1984	E	10	122	6.9	69	na	10	na	na	na	8.8	6.6	6.5	196	6.7	103.5	3815	na
01/19/1984	E	15	133	6.9	71	na	18	na	na	357	30.3	8.6	8.8	556	293.5	95.4	4951	na
02/28/1984	E	2	114	7.5	54	0.2	11	16.6	2.3	8	6.9	7.5	7.1	163	2.5	35.6	3223	73
02/28/1984	E	5	122	7.5	67	0.3	8	18.4	1.9	27	8.1	7.0	7.0	165	2.6	65.4	3451	na
02/28/1984	E	8	126	7.3	70	0.8	10	18.4	2.7	77	8.8	7.6	8.1	150	3.0	123.5	4267	na
02/28/1984	E	11	128	7.3	71	1.4	14	18.4	2.7	143	8.9	8.0	7.9	158	4.2	161.6	4628	na
02/29/1984	W	2	115	7.7	68	0.5	11	16.6	2.7	35	7.2	7.4	6.5	174	1.9	31.9	3016	196
02/29/1984	W	8	111	7.6	65	0.4	5	16.1	2.3	5	5.7	7.7	7.3	143	2.0	48.7	3043	na
02/29/1984	W	16	114	7.5	65	0.5	5	15.7	3.6	17	10.1	11.9	11.9	139	2.8	78.4	3637	na
02/29/1984	W	20	116	7.4	67	1.0	5	17.0	2.7	18	13.6	14.8	14.6	150	4.0	106.1	3956	na
03/27/1984	W	2	114	7.5	68	0.5	6	15.7	2.9	8	9.0	3.4	1.7	156	2.8	1.7	2888	7
03/27/1984	W	8	111	7.3	67	0.3	8	15.3	2.9	6	7.9	4.2	2.9	139	3.4	47.1	2755	na
03/27/1984	W	16	117	7.2	70	0.6	12	16.6	2.9	22	10.1	8.3	7.8	138	5.2	81.0	3470	na
03/27/1984	W	23	124	7.2	74	0.8	10	17.5	3.6	32	17.6	14.2	13.2	128	2.5	177.4	4289	na
03/28/1984	E	2	116	7.3	69	0.5	9	16.6	4.4	14	7.8	3.7	1.6	227	13.6	18.2	3108	7
03/28/1984	E	6	121	7.2	77	0.6	10	18.3	3.6	85	9.1	3.5	3.0	186	5.6	97.3	4012	na
03/28/1984	E	10	130	7.1	77	0.8	10	17.5	2.2	130	9.2	5.0	4.7	203	5.8	149.5	4563	92
03/28/1984	E	14	141	7.0	86	6.6	14	18.8	4.4	1066	21.6	10.5	10.1	309	123.9	120.3	5707	na
05/24/1984	E	2	105	7.7	60	0.8	12	15.6	3.4	75	7.4	3.2	2.0	170	2.3	3.5	2768	257
05/24/1984	E	7	120	7.5	72	1.1	15	17.5	2.7	87	10.7	3.6	2.2	202	2.8	2.0	3484	na
05/24/1984	E	10	132	7.4	77	1.2	22	19.4	3.4	194	10.5	2.2	2.3	192	13.9	23.6	4212	na
05/24/1984	E	15	142	7.8	85	1.4	28	20.4	3.4	556	16.6	3.1	3.2	344	145.5	50.5	4984	na
05/24/1984	W	2	106	7.8	65	1.1	9	15.6	2.7	11	10.1	2.3	2.0	195	2.5	2.5	2853	39
05/24/1984	W	10	117	7.6	69	1.1	11	17.5	2.7	23	10.9	2.8	2.0	192	4.6	13.4	3461	na
05/24/1984	W	16	118	7.6	70	1.1	13	16.6	2.7	24	8.5	1.9	2.0	188	7.9	28.1	3627	na
05/24/1984	W	23	121	7.8	69	1.2	18	17.5	2.7	33	9.6	2.1	2.3	201	20.3	40.5	3914	na
06/06/1984	E	2	107	7.8	53	0.5	13	15.1	1.3	35	9.8	3.8	1.6	188	1.9	2.7	2694	182
06/06/1984	E	7	112	7.6	56	0.6	10	14.2	2.0	40	10.5	2.7	2.1	197	2.3	2.6	2957	na
06/06/1984	E	10	124	7.4	62	1.4	15	16.3	1.6	86	18.1	2.9	2.6	260	5.3	4.7	3952	na
06/06/1984	E	15	132	7.2	66	2.3	18	17.1	2.0	153	13.2	2.8	3.2	225	45.3	22.5	4678	na
06/06/1984	W	2	109	7.8	66	0.5	10	14.7	2.0	20	8.4	2.1	1.3	165	1.8	1.8	2815	114
06/06/1984	W	10	117	7.3	58	0.8	12	16.3	1.3	26	18.0	2.5	2.1	230	3.4	2.6	3364	na
06/06/1984	W	16	118	7.3	60	1.2	12	17.1	1.3	28	13.2	2.7	2.1	182	4.2	8.4	3524	na
06/06/1984	W	22	118	7.5	59	1.2	11	15.5	2.4	37	12.6	2.9	2.3	181	17.4	18.4	3606	na
06/20/1984	E	2	105	7.6	51	0.5	11	15.3	2.5	35	7.1	2.4	2.0	158	2.5	3.4	2524	7
06/20/1984	E	6	113	7.5	53	0.5	10	15.8	2.5	56	11.9	2.7	2.0	199	3.2	3.0	2755	na
06/20/1984	E	10	122	7.0	57	1.0	13	17.2	2.9	72	21.3	3.3	3.3	265	6.8	3.5	3497	na
06/20/1984	E	14.5	125	7.1	59	1.5	13	17.2	2.9	156	23.1	3.4	3.6	241	12.9	6.7	3885	na
06/20/1984	W	2	109	7.8	52	0.4	6	15.8	2.2	24	6.5	2.3	1.8	176	2.8	3.3	2561	41
06/20/1984	W	10	117	7.4	57	0.7	11	16.7	2.5	36	13.0	2.6	2.6	203	3.4	3.1	3071	na
06/20/1984	W	16	119	7.2	57	1.1	11	16.7	3.2	34	12.3	3.5	3.7	201	9.3	17.5	3497	na
06/20/1984	W	23	119	7.1	60	2.7	17	16.7	3.2	76	18.4	6.0	6.3	232	39.5	27.0	3825	na
07/03/1984	E	2	108	7.4	52	1.2	14	15.3	2.3	50	7.5	3.4	2.1	202	1.7	3.1	2518	144
07/03/1984	E	6	113	7.4	56	1.0	13	16.2	2.7	26	9.0	2.9	2.2	174	2.5	3.2	2949	na
07/03/1984	E	10	120	7.1	65	1.0	12	16.7	2.7	53	19.9	3.5	3.2	255	6.8	3.6	3567	na
07/03/1984	E	15	126	7.0	64	4.3	14	18.0	3.1	169	23.0	3.6	3.9	349	64.2	16.4	4438	na

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Date	Sta	Depth (m)	Specific conductance (mhos cm $^{-1}$)	pH (Units)	Alkalinity (mg L^{-1})	Turbidity (NTU)	Color (Pt units)	Calcium (mg L^{-1})	Magnesium (mg L^{-1})	Iron (g L $^{-1}$)	Total-P (g L $^{-1}$ P)	Total filter-able-P (g L $^{-1}$ P)	Filterable reactive-P (g L $^{-1}$ P)	Total Kjel-dahl nitrogen (g L $^{-1}$ N)	Ammonia (g L $^{-1}$ N)	Nitrate+ nitrite (g L $^{-1}$ N)	Reactive silicon (g L $^{-1}$ Si)	Particulate Organic carbon (g L $^{-1}$)
07/03/1984	W	2	109	7.7	55	6.3	8	15.3	1.9	19	7.3	3.6	2.0	172	1.4	3.3	2587	111
07/03/1984	W	10	113	7.8	54	0.8	12	15.8	2.7	15	8.1	3.0	2.1	182	3.1	3.1	3052	na
07/03/1984	W	16	117	7.5	58	0.8	10	16.2	3.1	23	12.0	3.6	2.9	196	7.1	10.4	3567	na
07/03/1984	W	23.5	116	7.5	56	1.3	18	15.8	3.1	37	15.6	5.4	4.6	229	19.7	10.9	3776	na
07/17/1984	E	2	112	7.7	52	.	6	11.7	2.4	24	6.5	2.8	2.1	194	3.9	1.5	2613	137
07/17/1984	E	6	116	7.6	56	1.9	10	11.7	15.2	20	7.5	na	na	189	1.6	1.5	2558	na
07/17/1984	E	10	122	7.0	54	1.5	12	15.3	3.8	30	14.3	2.9	3.0	217	2.0	1.0	3537	na
07/17/1984	E	14.5	124	7.0	62	1.8	15	16.2	8.1	150	19.8	3.6	3.8	253	8.3	2.6	4009	na
07/17/1984	W	2	109	7.2	53	0.5	8	11.1	3.1	3	6.5	2.0	1.6	201	6.3	5.3	2486	933
07/17/1984	W	10	117	7.1	54	0.9	8	14.5	2.4	3	10.8	2.6	2.5	218	4.8	5.3	3175	na
07/17/1984	W	16	119	7.0	54	1.6	6	15.3	1.6	8	11.7	3.3	3.4	221	7.1	14.3	3682	na
07/17/1984	W	23	119	7.1	52	3.2	8	11.1	3.1	35	21.7	13.9	15.4	271	11.5	73.7	4009	na
07/31/1984	E	2	111	7.3	66	0.7	6	16.0	2.0	27	6.6	2.2	2.0	192	1.7	7.2	2595	73
07/31/1984	E	6	114	7.6	56	0.8	6	16.0	2.7	36	6.5	2.8	2.5	187	.	28.1	2631	na
07/31/1984	E	10	121	7.2	57	1.0	15	17.0	3.3	35	11.3	3.1	2.8	241	1.7	6.5	3936	na
07/31/1984	E	15	125	7.2	62	1.4	11	18.0	3.3	176	20.0	4.3	3.6	262	19.3	7.9	4462	na
07/31/1984	W	2	110	7.9	64	1.0	6	15.1	2.7	9	6.8	3.3	2.1	214	1.7	7.4	2522	285
07/31/1984	W	10	117	7.3	60	0.6	11	17.0	2.7	9	9.3	2.8	2.0	195	1.7	7.4	3320	na
07/31/1984	W	16	119	7.2	62	0.9	6	18.0	2.0	21	9.5	3.0	3.2	156	1.7	46.7	4008	na
07/31/1984	W	23	119	6.9	64	2.4	8	16.0	2.7	77	27.7	9.3	10.5	204	25.4	140.1	4679	na
08/14/1984	E	2	112	7.6	57	0.5	10	1.7	1.1	14	6.8	2.6	1.6	204	1.7	5.5	2503	253
08/14/1984	E	6	113	7.4	58	0.7	9	1.8	4.1	19	11.4	2.4	2.2	210	1.7	5.5	2645	na
08/14/1984	E	10	116	7.0	59	0.8	10	0.2	2.7	50	19.4	2.7	2.3	261	1.7	4.3	3774	na
08/14/1984	E	15	116	7.0	64	5.5	21	1.8	0.3	1533	68.9	24.3	30.4	466	171.8	6.0	5380	na
08/14/1984	W	2	108	7.7	54	0.6	5	1.7	3.5	73	13.3	3.3	1.7	221	1.7	5.5	2486	339
08/14/1984	W	10	115	7.0	51	0.8	9	1.7	3.1	214	18.6	3.0	2.5	241	1.7	5.5	3227	na
08/14/1984	W	16	116	7.2	55	0.8	9	1.9	2.6	134	19.2	2.7	2.6	212	1.6	9.4	3509	na
08/14/1984	W	23	120	6.9	57	5.8	9	1.8	12.1	239	72.4	12.1	15.1	361	53.4	73.1	4974	na
08/30/1984	E	2	114	7.4	54	0.7	6	16.9	3.0	27	16.6	2.7	2.0	258	2.1	4.5	2473	99
08/30/1984	E	6	112	7.4	53	0.8	5	2.7	0.3	31	14.6	2.5	1.9	225	1.7	4.5	2473	na
08/30/1984	E	10	113	7.2	57	1.3	8	16.6	3.6	23	20.6	2.6	2.0	242	7.0	5.8	3132	na
08/30/1984	E	15	137	6.8	68	7.6	31	18.7	3.3	4417	172.8	75.6	66.5	936	502.4	6.5	6008	na
08/30/1984	W	2	110	7.1	60	0.7	8	15.1	3.5	21	23.7	4.2	1.6	253	0.8	6.7	2289	188
08/30/1984	W	10	114	7.2	56	0.8	5	16.5	4.2	33	18.3	2.1	1.6	238	3.5	8.4	2692	na
08/30/1984	W	16	116	7.1	59	1.6	8	17.0	3.6	24	12.3	4.1	2.7	272	2.6	43.8	3877	na
08/30/1984	W	21	116	6.8	55	2.6	8	17.5	3.0	79	29.3	10.5	19.9	240	14.0	130.3	4830	na
09/10/1984	W	2	113	7.6	52	0.7	5	15.5	5.4	32	17.8	2.9	1.6	281	1.4	5.3	2784	73
09/10/1984	W	10	113	7.3	54	0.7	8	15.5	5.4	38	11.8	2.9	1.7	290	1.4	6.0	2664	na
09/10/1984	W	16	118	7.1	57	1.2	5	16.5	3.8	41	15.9	3.1	2.6	224	1.7	35.4	4088	na
09/10/1984	W	23	118	7.4	56	1.2	9	16.5	6.3	37	19.4	4.7	4.9	260	2.8	56.4	4232	na
09/11/1984	E	2	113	7.6	55	2.0	5	16.5	4.6	15	16.4	2.3	1.1	303	2.8	6.5	2784	246
09/11/1984	E	6	116	7.5	54	0.7	8	14.6	4.6	60	12.3	2.1	1.6	290	1.6	5.8	2881	na
09/11/1984	E	10	117	7.2	52	1.1	12	16.5	6.3	72	13.4	2.9	1.7	269	4.3	7.4	3629	na
09/11/1984	E	15	113	7.3	54	6.1	22	16.5	7.1	2791	84.8	42.2	30.5	671	2.6	8.4	6163	na
12/11/1984	E	2	114	7.4	52	1.1	21	15.7	1.9	17	8.0	3.8	3.1	236	17.7	235.8	3937	167
12/11/1984	E	6	129	7.6	62	1.1	15	17.6	4.1	36	6.3	3.5	3.4	193	24.3	192.6	4752	na
12/11/1984	E	10	122	7.3	58	2.4	15	17.6	2.8	38	7.8	4.0	2.9	236	24.6	18.6	5120	na
12/11/1984	E	14	125	7.4	66	3.2	15	13.8	2.8	125	12.9	5.7	6.2	307	81.0	39.5	5632	na

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Date	Sta	Depth (m)	Specific conductance (mhos cm $^{-1}$)	pH (Units)	Alkalinity (mg L^{-1})	Turbidity (NTU)	Color (Pt units)	Calcium (mg L^{-1})	Magnesium (mg L^{-1})	Iron (g L $^{-1}$)	Total-P (g L $^{-1}$P)	Total filter-able-P (g L $^{-1}$P)	Filterable reactive-P (g L $^{-1}$P)	Total Kjel-dahl nitrogen (g L $^{-1}$N)	Ammonia (g L $^{-1}$N)	Nitrate+ nitrite (g L $^{-1}$N)	Reactive silicon (g L $^{-1}$Si)	Particulate Organic carbon (g L $^{-1}$)	Chloro-phyll a (g L $^{-1}$)	Phaeo-phytin a (g L $^{-1}$)
12/11/1984	W	2	122	7.2	52	1.3	14	17.6	3.5	9	9.5	5.3	4.1	233	7.1	17.1	4923	20	na	na
12/11/1984	W	10	115	7.3	52	1.2	15	16.6	2.8	21	9.1	5.8	5.2	177	5.7	26.9	4962	na	na	na
12/11/1984	W	16	111	6.8	64	1.9	10	16.6	2.8	15	11.4	6.6	6.4	201	9.0	33.1	5159	na	na	na
12/11/1984	W	23	123	7.1	54	1.8	19	17.6	2.8	22	14.9	8.3	7.6	197	20.5	43.2	5501	na	na	na
1984	Mean		117	7.3	61	1.5	11	15.0	3.2	156	16.1	5.9	5.5	232	20.1	34.7	3622	154		
	Range		105-142	6.8-7.9	51-86	0.2-7.6	5-31	0.2-20.4	0.3-15.2	3-4417	5.7-172.8	1.9-75.6	1.1-66.5	128-936	0.8-502	1.0-236	2289-6163	7-933		
07/11/1985	E	1	111	7.2	47	0.78	9	14.8	3.4	69	7.5	4.4	2.0	226	1.7	0.7	2688	130	0.74	0.63
07/11/1985	E	10	106	7.1	54	na	9	16.1	3.8	93	9.6	7.8	4.0	236	1.7	2.8	4035	178	8.49	4.86
07/11/1985	W	1	112	7.3	55	0.8	8	15.2	3.1	32	5.9	4.4	1.7	185	1.7	0.7	2888	104	0.54	0.29
07/11/1985	W	14	124	7.1	55	na	9	16.1	3.4	69	14.0	4.1	2.0	260	5.4	1.3	4017	232	1.68	3.73
08/05/1985	E	1	114	7.3	56	1.0	10	15.2	3.1	83	8.4	6.4	2.4	231	1.7	0.7	2697	322	0.56	0.57
08/05/1985	E	11	111	6.8	58	na	10	16.9	3.8	102	14.1	5.1	2.0	269	1.5	0.7	4071	400	4.19	3.43
08/05/1985	W	1	113	7.4	57	1.0	8	15.2	3.1	47	6.3	4.1	1.5	212	1.5	0.7	2788	219	0.89	0.54
08/05/1985	W	13	122	7.1	57	na	8	16.9	3.4	40	9.0	4.6	1.8	217	4.6	1.3	3622	229	1.82	1.97
09/12/1985	E	1	115	7.4	57	0.9	10	15.2	3.1	74	7.4	4.1	1.6	210	2.5	0.7	2752	300	1.80	2.02
09/12/1985	E	12	137	6.7	65	na	21	18.1	3.4	3302	37.8	18.3	12.2	397	123.2	0.7	5359	956	5.46	9.17
09/12/1985	W	1	102	7.4	60	1.2	8	15.2	3.4	54	5.7	3.9	1.3	190	3.1	0.7	2725	194	0.78	0.57
09/12/1985	W	16	123	7.1	60	na	8	16.5	3.1	68	7.4	4.0	2.2	175	3.1	43.7	4144	158	0.62	0.88
10/08/1985	E	1	na	na	na	na	9	na	na	117	11.5	8.9	2.7	210	1.7	2.4	1617	65	1.53	1.58
10/08/1985	E	9	na	na	na	na	na	na	na	90	9.6	7.9	2.9	215	2.6	0.4	1604	130	1.17	1.45
10/08/1985	W	1	na	na	na	na	6	na	na	48	8.2	6.8	2.0	202	1.7	4.1	1472	158	1.13	0.98
10/08/1985	W	18	na	na	na	na	na	na	na	47	9.3	4.7	2.7	203	1.7	30.4	1687	162	0.75	0.89
1985	Mean		116	7.2	57	0.9	10	16.0	3.3	271	10.7	6.2	2.8	227	10.0	5.8	3010	246	2.01	2.10
	Range		102-137	6.7-7.4	47-65	0.8-1.2	6-21	14.8-18.1	3.1-3.8	32-3302	5.7-37.8	3.9-18.3	1.3-12.2	175-397	1.5-123.2	0.4-43.7	1472-5359	65-956	0.54-8.49	0.29-9.17
08/18/1999	E	1	118	7.8	59	0.6	8	na	na	na	5.7	2.9	1.1	209	15	10	na	na	0.28	0.17
08/18/1999	E	12	140	7.1	63	2.5	10	na	na	na	16.2	6.2	4.4	261	76	14	na	na	0.42	0.41
08/18/1999	W	1	127	7.9	58	0.6	6	na	na	na	5.7	2.8	1.2	203	11	9	na	na	0.25	0.15
08/18/1999	W	22	135	7.0	66	9.1	9	na	na	na	32.1	21.9	20.5	327	115	122	na	na	0.10	0.34
10/12/1999	E	1	130	7.7	60	4.5	13	na	na	na	9.5	na	na	238	7	4	na	na	na	na
10/12/1999	E	13	129	7.7	60	2.6	12	na	na	na	9.1	na	na	223	5	4	na	na	na	na
10/12/1999	W	1	130	7.7	64	5.0	10	na	na	na	7.1	na	na	189	5	4	na	na	na	na
10/12/1999	W	19	136	7.2	63	5.9	10	na	na	na	15.1	na	na	182	4	86	na	na	na	na
1999	Mean		131	7.5	62	3.9	10				12.6	8.5	6.8	229	30	31			0.26	0.27
	Range		118-140	7.0-7.9	58-66	0.6-9.1	6-13				5.7-32.1	2.8-21.9	1.1-20.5	182-327	4-115	4-122			0.10-0.42	0.15-0.41

Appendix B. Time series of the estimated number of sockeye salmon fry rearing in Big Lake and their subsequent survival from fry to adult inriver return (escapement + personal use harvest).

Brood	Number	Release	Number of fry		Total	Return Yr	PU Harvest	Escapement	Escapement Age Comp. (BY+4)			Adult	Adults/
Year	Spawners	Year	Wild	Hatchery	Fry	BY+4	BY+4	BY+4	Age 3	Age 4	Age5	Return	No. Fry
1975	29,000	1976	4,200,650	71000	4,271,650	1979	0	68,739	15.9%	82.7%	1.4%	72,240	1.7%
1976	14,032	1977	2,032,535	6,600,000	8,632,535	1980	0	62,828	5.1%	69.6%	24.5%	75,556	0.9%
1977	5,183	1978	750,758	5,700,000	6,450,758	1981	0	50,479	1.3%	56.9%	41.4%	50,825	0.8%
1978	3,555	1979	514,942	0	514,942	1982	0	28,164	7.0%	23.9%	67.1%	10,120	2.0%
1979	68,739	1980	9,956,844	747,000	10,703,844	1983	0	118,797	9.5%	88.1%	2.3%	132,407	1.2%
1980	62,828	1981	9,100,636	4,000,000	13,100,636	1984	0	192,352	0.7%	84.9%	13.4%	200,103	1.5%
1981	50,479	1982	7,311,883	4,300,000	11,611,883	1985	0	68,577	6.6%	55.4%	37.2%	47,864	0.4%
1982	28,164	1983	4,079,555	6,600,000	10,679,555	1986	0	29,800	12.9%	57.2%	28.6%	28,572	0.3%
1983	118,797	1984	17,207,745	7,400,000	24,607,745	1987	2,200	91,215	6.6%	85.9%	7.5%	86,237	0.4%
1984	192,352	1985	27,862,187	12,400,000	40,262,187	1988	3,000	71,603	13.5%	83.6%	2.9%	90,845	0.2%
1985	68,577	1986	9,933,378	15,022,000	24,955,378	1989	5,000	67,224	3.8%	59.9%	30.9%	84,704	0.3%
1986	29,800	1987	4,316,530	11,700,000	16,016,530	1990	6,500	50,000	0.7%	38.0%	55.5%	34,059	0.2%
1987	91,215	1988	13,212,493	14,281,000	27,493,493	1991	14,369	50,500	6.4%	76.8%	15.1%	70,888	0.3%
1988	71,603	1989	10,371,695	14,400,000	24,771,695	1992	19,002	71,385	0.2%	76.1%	22.9%	132,814	0.5%
1989	67,224	1990	9,737,396	11,331,000	21,068,396	1993	37,224	117,619	0.8%	56.5%	38.7%	128,337	0.6%
1990	50,000	1991	7,242,500	10,000,000	17,242,500	1994	16,012	95,107	5.1%	52.7%	36.6%	98,366	0.6%
1991	50,500	1992	7,314,925	3,135,000	10,449,925	1995	9,102	115,000	6.8%	51.9%	31.1%	90,883	0.9%
1992	71,385	1993	10,340,117	4,600,000	14,940,117	1996	16,682	63,160	0.5%	70.7%	26.1%	85,591	0.6%
1993	117,619	1994	17,037,112	5,000,000	22,037,112	1997	3,277	54,656	0.2%	58.8%	35.7%	55,816	0.3%
1994	95,107	1995	13,776,249	5,000,000	18,776,249	1998	4,036	22,853	1.0%	6.6%	79.5%	5,558	0.0%
1995	115,000	1996	16,657,750	5,000,000	21,657,750	1999	1,083	26,746	13.0%	72.4%	13.2%	27,954	0.1%
1996	63,160	1997	9,148,726	4,000,000	13,148,726	2000	6,925	19,533	0.8%	67.3%	28.6%	46,848	0.4%
1997	54,656	1998	7,916,922	5,000,000	12,916,922	2001	0	43,486	5.3%	30.4%	58.5%	-	-
1998	22,853	1999	3,310,257	197,000	3,507,257	2002	-	-	-	-	-	-	-
1999	26,746	2000	3,874,158	846,000	4,720,158	2003	-	-	-	-	-	-	-
2000	19,533	2001	2,829,355	0	2,829,355	2004	-	-	-	-	-	-	-
2001	43,486	2002	-	-	-	2005	-	-	-	-	-	-	-
Average	61,638		9,033,466	6,390,360	15,423,826		6,564	68,686	4.9%	60.2%	31.7%	75,445	0.6%