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CHIGNIK SALMON STUDIES

WINTER ECOLOGY OF SOCKEYE SALMON IN THE CHIGNIK LAKES, ALASKA

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for

CHIGNIK REGIONAL AQUACULTURE ASSOCIATION

Approved

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Director

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KEY WORDS

Alec River, Black Lake, Chignik Lake, coho salmon, dissolved oxygen, food habits, population fluctuations, overwintering, sockeye salmon, winter ecology, winterkill

INTRODUCTION

Annual adult sockeye (*Oncorhynchus nerka*) production in Black Lake, Alaska, fluctuates more than that of nearby Chignik Lake or other major sockeye systems in western and central Alaska for which data are available (Ruggerone et al. 1992). The winter period is a potential critical period for juvenile sockeye salmon in Black Lake (Ruggerone et al. 1991). Low dissolved oxygen levels were hypothesized by Ruggerone and Rogers (1989) to occur under the ice because large amounts of detritus and oxidation of inorganic compounds consume oxygen in the shallow, productive lake (<13 ft), and few processes replenish the consumed oxygen. During late February 1990, Ruggerone et al. (1991) observed exceptionally low dissolved oxygen near the bottom of the lake during a 2-week sampling period. The lower 40% of the lake did not contain sufficient oxygen to maintain sockeye salmon (i.e., <57% oxygen), although oxygen in the surface waters was adequate. Total habitat available to sockeye in Black Lake was reduced by ~60% relative to the previous spring because oxygen and water level were low.

The objective of this study was to reexamine the quality of sockeye habitat in Black Lake during 13-26 February 1992 and compare this habitat with that during February 1990. Physical characteristics of Black Lake, including dissolved oxygen, water temperature, ice thickness, depth and water volume, were measured. The distribution of juvenile sockeye salmon and other fishes relative to dissolved oxygen and temperature was examined by placing baited minnow traps under the ice. Catches of sockeye were compared with those in Chignik Lake. If significant numbers of sockeye overwintered in Black Lake, then considerably more age-0 sockeye should be captured in Black Lake relative to Chignik Lake because the number of spawners per m^3 of lake volume was 28 times greater in Black Lake during 1990.

METHODS

Physical Characteristics

Sampling of water beneath the ice of Black Lake was accomplished by drilling 10-inch-diameter holes with a power ice auger. Measurements of dissolved oxygen, temperature, depth, and ice thickness were recorded at 52 stations, including Alec Bay, Alec River, and Black River (Fig. 1). Vertical profiles of dissolved oxygen and temperature were recorded when depth exceeded 0.5 m. Dissolved oxygen and temperature were measured using an Orion Model 840 dissolved oxygen meter. A Hydrolab DataSonde 3 was deployed under the ice near the north shore of Black Lake in order to examine diel and daily changes in dissolved oxygen, temperature and lake level. Dissolved oxygen, temperature and ice thickness were also recorded at three stations in Chignik Lake (Clark Bay offshore, Clark Bay nearshore, and the lake outlet) for comparison with values in Black Lake.

The volume of water in Black Lake during winter was estimated from the winter lake level estimate (outlet benchmark) and lake depth data collected during June 1992. Lake volume was adjusted for changes in lake area, ice cover, and the oxygen content (57%) at which salmonids reportedly become stressed (Davis 1975).

The volume of water flowing from Alec River to Alec Bay and Black Lake outlet was estimated by drilling holes in the ice at 2 m intervals and measuring water depth, ice thickness, and velocity. Water velocity was estimated by a Gurely No. 622 current meter.

FISH ABUNDANCE

The relative abundance of fishes in Black Lake was estimated with baited commercial fry traps (6.4 mm^2 mesh, 46 cm long x 23 cm diameter) placed beneath the ice. The traps were baited with salmon eggs placed in a perforated plastic container. Ten traps were set along the oxygen profile transect extending from near Sand Pt. to the point near the old Fisheries Research Institute shelter (i.e., stations 3, 4, 5, 6, 7, and 10; Fig. 1). Traps were set immediately below the ice and on the bottom at each station except for exceptionally shallow areas (stations 3 and 10). Three traps were also placed near the right bank of Black River approximately 100 m below the confluence with Chiaktuak Creek. Traps were sampled every day when possible. Bait was changed after 2–3 days or when it began to loose color.

Baited traps were set in Chignik Lake for comparison with fish catch rates in Black Lake. Traps were set in the lake outlet and the nearshore and offshore area of Clark Bay. Three traps were set immediately below the surface and on the bottom at both the outlet and nearshore Clark Bay stations. Three trap lines were set at the offshore Clark Bay station. Traps on each line were set immediately below the ice and at depths of 10 m and 20 m. Distance between trap lines was at least 10 m in order to minimize competition between traps (Rickard 1980). Three traps were also place in Chignik River and the outlet of Village Creek.

OXYGEN TOLERANCE OF SOCKEYE AND COHO SALMON

The oxygen tolerance of sockeye and coho (*O. kisutch*) salmon was tested by placing 10 or more fish in a sealed fry trap and exposing the fish to several oxygen levels available in Black Lake for one or more days. Care was given to fish during capture and redeployment. Oxygen tolerance of fishes was also examined by comparing fish catches in bottom traps of Black Lake with ambient oxygen levels.

FISH FOOD HABITS AND ZOOPLANKTON ABUNDANCE

Stomachs of fishes captured in Black and Chignik lakes were examined for prey, which were identified to the lowest taxonomic group possible. At least 50 fish of each species were examined when possible.

Zooplankton species and abundance were sampled just below the ice and near the bottom of Black Lake at station 6. A plankton pump (38 L min^{-1} @ 5 min) and a 223-μ mesh net were used to collect the zooplankton. In Chignik Lake, zooplankton were sampled by hauling a 0.5-m-diameter net (223-μ) from 40 m to the surface.

RESULTS

PHYSICAL CHARACTERISTICS

The surface of Black Lake froze in mid-November, and by late February ice covered over 99% of the lake surface area. Open water occurred between Sand Pt. and the sandspit extending from the Alec River delta, and at the outlet of the lake where water began to flow downriver. During the 2-week sampling period, continuous wind blew cold Arctic air through the area and caused these areas to become covered by ice. Black River was nearly covered by ice by late February except for a 5-m-wide opening where current was relatively great. The surface of Alec River, Fan Creek, and Chiaktuak Creek was frozen. Ice thickness on Black Lake averaged 0.53 m (range: 0.30-0.60 m, Table 1). Ice covered more area of Black Lake during 1992 than February 1990 and was approximately 11 cm thicker.

The water height of Black Lake was about 0.78 m less during February (lake level = -1.38 m) than mid-June 1992 (-0.60 m). Average depth of water below the ice was estimated from the detailed depth survey conducted during June 1992, ice thickness and density, and changes in lake level and wetted perimeter. Average depth under the ice during February was 1.1 m (or 1.54 m including ice) compared to 1.94 m during June 1992 (Table 2). Maximum depth under the ice was 2.91 m.[1] Average depth during winter declined only 0.84 m because much of the shallow area during spring was frozen to the bottom during winter (e.g., portions of Alec Bay and the western end of the lake). Surface area and water volume of the lake during winter was 67% and 36% of that during spring, respectively. Water volume was estimated to be 29 million m^3 during winter compared with 80 million m^3 during spring. During winter, approximately 61% and 56% of the decline in area and volume, respectively, was related lower lake level. The remainder was due to ice cover. These estimates of decline are greater than those during February 1990 (73% of area and 45% of volume of spring 1992 level) because in 1990 the lake level was 0.18 m higher and ice was thinner.

Water temperature in Black Lake ranged from 0.1 to 3.7 °C and significantly increased with depth ($n = 160$, $p<0.001$, $r^2 = 0.80$, Fig. 2). Dissolved oxygen ranged from 0.1 to 15.9 mg L^{-1} or 1–112% saturation depending on location and water depth (Table 1). Dissolved oxygen significantly declined from an average 10.75 mg L^{-1} just below the ice to 8.0 mg L^{-1} at 0.6 m and 3.3 mg L^{-1} at 1.7 m below the ice ($n = 159$, $p <0.001$, $r^2 = 0.63$, Fig. 3). Dissolved oxygen relative to

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[1] The maximum depth during winter (2.91 m) compares favorably with the maximum depth during spring (4.2 m) when lake level was -0.60 m. For example, winter water depth (2.91 m) plus ice thickness (0.44 m after subtracting ice above water) plus lake level change (0.78 m) produces an adjusted maximum depth of 4.13 m, which is nearly identical to that measured during spring.

saturation at a given temperature also declined from approximately 74% just below the ice to 57% at 0.55 m and to 24% at 1.65 m below the ice (n = 159, $p < 0.001$, $r^2 = 0.62$, Fig. 3). Diel changes in oxygen content of the water were not measured because the Hydrolab DataSonde instrument failed under the ice. The instrument was replaced at no cost.

Davis (1975) suggested that oxygen saturation levels below 57% at <5°C were not suitable for maintaining healthy salmon populations. During February, water below 0.55 m averaged ≤57%. Assuming that the top 0.6 m of the water column was suitable for sockeye salmon (Table 2), approximately 14.2 million m^3 of water was ≥57% oxygen. This volume represents 18% of the spring water volume. Of the 82% reduction in habitat during winter, 23% was attributed to low oxygen, 33% to ice cover, and 44% to low lake level. For comparison, in February 1990 sockeye habitat was reduced by 67% based on the same methods used in 1992. Less habitat was lost in 1990 because water level was higher, ice was thinner, and oxygen content of the water was greater. The estimate of habitat reduction in February 1992 might be somewhat high if sockeye can tolerate lower oxygen levels than reported by Davis (1975). Additional research is needed to refine the oxygen threshold level for salmon.

The oxygen content of the old and new channel of Alec River was 13.2 mg L^{-1} or 89% of saturation (Table 1). Temperature was near the freeze point (0.0°C). Discharge of Alec River was 5.55 $m^3 s^{-1}$ (196 $ft^3 s^{-1}$). Approximately 74% of the water or 4.1 $m^3 s^{-1}$ (145 $ft^3 s^{-1}$) entered the new channel leading to the outlet of Black Lake. Ice thickness of the new channel (19 cm) was less than that of the old channel (23 cm), reflecting the greater average velocity of the new channel (0.29 m s^{-1} or 0.96 ft s^{-1}) relative to the old channel (0.24 m s^{-1} or 0.80 ft s^{-1}). Total discharge during 1992 was somewhat greater than that during February 1990 (4.9 $m^3 s^{-1}$ or 174 $ft^3 s^{-1}$), although the measurement technique during 1992 was much more precise. In 1990, the percentage of water flowing to the outlet was slightly less (64%). In contrast to Alec River, water near the bank of Black River was warmer (0.2°C) and contained less oxygen (10.4 mg L^{-1} or 72%) after passing through Black Lake.

Chignik Lake froze about 1 month earlier than Black Lake (16 December), and travel by snow machine was safe a few days prior to 30 December (J. Lind, Chignik Lake Village, pers. comm.). Ice thickness on Chignik Lake was approximately 0.64 m (Table 3), which was 14 cm greater than that in 1990. Temperature increased from 0.4°C just below the ice to 0.6°C at 1 m and 1.3°C at 40 m. The lake was saturated with dissolved oxygen from the surface to 40 m (>12.8 mg L^{-1} or 90%).

FISH ABUNDANCE

Fishes in Black Lake were sampled during 97 trap nights. No juvenile sockeye salmon were captured by baited minnow traps placed just below the ice or on the bottom of the lake. In contrast, 0.7 coho per 24 hours were captured near the surface and 3.6 coho per 24 hours were captured near the bottom (Table 4). In areas where both surface and bottom traps were fished, bottom traps (2.8±0.6 SE) captured significantly more coho than surface traps (0.7±0.3 SE; ANOVA df = 1, 39; F = 9.122; $p < 0.005$). Oxygen content in the bottom traps (24±2%) was significantly lower than the surface traps (Fig. 4; 58±4%; df = 1, 39; F = 64; p <0.001), whereas temperature in the bottom traps was significantly greater (2.0 vs. 0.6 °C; df = 1, 39; F = 110; p <0.001). Thus, coho salmon appear to prefer the warm, low-oxygen water more than the cold, high-oxygen water.

Significantly more sockeye salmon were captured per trap per 24 h in Chignik Lake (7.4±1.0) than Black Lake (0.0; Fig. 5; df = 1, 192; F = 11.3; p <0.001), indicating that few sockeye remained in Black Lake. Within Chignik Lake, sockeye were most abundant in the lake outlet (15.2±3.0), followed by the offshore (6.2±0.9) and nearshore area (0.6±0.2) of Clark Bay. Traps set near the surface (9.3±1.3) caught significantly more sockeye than bottom traps (2.0 ± 0.7; df = 1, 136; F = 24.2; p <0.001). Sockeye in the offshore area of Clark Bay were significantly more abundant at 20 m (12.6±1.6) than 10 m (1.8±0.6) and the surface (4.1±0.9; df = 2, 68; F = 25; p <0.001).

Length at age frequency distribution of sockeye captured in Chignik Lake indicates that numerous young-of-the-year sockeye from Black Lake migrated to Chignik Lake. Sockeye typically grow faster in Black Lake relative to Chignik Lake (Narver 1966, Parr 1972); thus, age-0 sockeye from Black Lake can be distinguished from their Chignik Lake counterparts. The slower growth of Chignik Lake sockeye is related to late emergence from gravel, colder water, and high density of planktivorous fishes to which the emigration of sockeye fry from Black Lake contributes. Two modes are identifiable in the frequency distribution of age-0 sockeye: one at 45 mm and the other at 64 mm (Fig. 6). The smaller mode at 45 mm probably represents Chignik Lake sockeye whereas the larger mode probably represents Black Lake sockeye. Mean live length of these two modes is 47 mm and 67 mm. Age-1 sockeye averaged 72.0±0.2 mm (live length). Most of the age-1 fish probably belong to the Chignik Lake stock because these fish will migrate at age-2 in spring, and Chignik Lake receives the great majority of the adults having spent two winters in fresh water.

Relative abundance of the two length-frequency modes for the age-0 sockeye in Chignik Lake suggests that the Chignik Lake stock (29%) was considerably less abundant than the Black Lake stock (71%, Fig. 6). Age-1 sockeye should generally be less abundant than age-0 sockeye because age-1 fish experienced an additional year of mortality. However, age-1 sockeye represented 88% of the total Chignik Lake stock, assuming all age-1 fish belonged to Chignik Lake. The relatively small catch of age-0 sockeye from Chignik Lake may be an artifact of sampling, which was limited to Clark Bay and the lake outlet, rather than the result of a relatively weak year class. The adult return in 1995 should help resolve this inconsistency.

Numbers of all fish species caught per trap per 24 h was significantly less in Black Lake (3.2±0.6) relative to Chignik Lake (17.5±1.8; df = 1, 192; F = 34.7; p <0.001; Table 4). No difference in capture rates for coho salmon in the two lakes was detected (2.0±0.34; df = 1, 192; F = 0.183; p = 0.67), although coho were captured more frequently on the bottom (3.2±0.4) than near the surface of the two lakes (0.9±0.2; df = 1, 192; F = 25.4; p<0.001).

No sockeye were captured in either Chignik River, Village Creek, or Black River during 43 trap nights (Table 4). Catches of all fish species were exceptionally low in the two rivers and creek. Significantly fewer fishes were captured in the river and creek traps (0.4±0.7) than traps placed on the bottom of Black and Chignik lakes (16.2±2.8; df = 1, 101; F = 14.4; p <0.001).

OXYGEN TOLERANCE OF SOCKEYE AND COHO SALMON

No sockeye salmon were captured in Black Lake; therefore, we transported sockeye from Chignik Lake to Black Lake in order to conduct tests by placing fish in cages at known oxygen concentrations. All transported sockeye were in good condition at the start of the tests and stress was probably minimal (Dr. Lynnwood Smith, fish physiologist, Univ. Washington, pers. comm.). No sockeye were released into Black Lake.

Eighty-nine of 90 sockeye survived the 21–24 hour exposure to 32–72% oxygen (4.2–10.2 mg L^{-1}, Fig. 7, Table 5). Forty percent of sockeye survived the 21 hour exposure to 24% oxygen (3.3 mg L^{-1}). All sockeye died when oxygen levels reached 6-17% oxygen (0.9–2.3 mg L^{-1}).

Coho salmon tolerated low oxygen better than sockeye salmon. All juvenile coho survived 24-hour exposure to 21–47% oxygen (3.0–6.6 mg L^{-1}, Fig. 7, Table 5). All coho survived 4–5 day exposure to 23–24% oxygen (3.2-3.3 mg L^{-1}). Baited fry traps captured 8 coho in water containing 13–20% oxygen (1.6-3.2 mg L^{-1}) and 14 coho in water containing 21-27% oxygen (2.8–3.6 mg L^{-1}, Fig. 7). All captured coho were alive after exposure to low oxygen for up to 24 hours.

FISH FOOD HABITS AND ZOOPLANKTON ABUNDANCE

Few fishes consumed significant quantities of food during February. Only 1.5% of sockeye collected in Chignik Lake consumed food (avg. = 0.1 mg $fish^{-1}$; Table 6). All prey were unidentifiable. Approximately 9% of the coho consumed food (3.3 mg $fish^{-1}$), of which 52% was fish by weight. Chinook (*O. tshawytscha*) did not consume food. Fishes that tend to forage on benthic prey tended to contain more food. Approximately 23% of Dolly Varden char (*Salvelinus malma*) contained food (13.1 mg $fish^{-1}$), of which nearly all prey were caddis fly larvae. Thirty-three percent of threespine stickleback (*Gasterosteus aculeatus*) consumed prey (9.8 mg $fish^{-1}$), but none of the prey were identifiable. The coastrange sculpin (*Cottus aleuticus*) consumed prey more frequently than other fishes (37%) and contained the greatest weight of prey (17.8 mg $fish^{-1}$). In Black Lake, 18.9% of coho consume prey (6.7 mg $fish^{-1}$), of which 58% consisted of amphipods (Table 7).

Sampling of zooplankton in Chignik Lake and Black Lake indicated that few prey were available for planktivorous fishes such as sockeye salmon. In Chignik Lake, only *Daphnia* (57 m^{-3} or 2,300 m^{-2}) and *Bosmina* sp. (6 m^{-3} or 255 m^{-2}) were captured in the single vertical haul from 40 m. *Daphnia* and *Bosmina* were unexpected during February because adults generally die during winter, leaving eggs to hatch during spring. In Black Lake, only *Daphnia* (132 m^{-3}) and spiders (25 m^{-3}) were captured during two samples collected by a plankton pump.

DISCUSSION

PHYSICAL CHARACTERISTICS, FISH ABUNDANCE AND OXYGEN TOLERANCE

During February 1992, low water level, thick ice cover, and low oxygen concentration caused potential sockeye habitat in Black Lake to be reduced by 82% relative to that during moderate spring water level (-0.60 m). Habitat reduction was considerably greater in 1992 relative to February 1990 because in 1990 water level was higher, ice was thinner, and oxygen concentration was higher. In February 1990, potential habitat was nearly twice that of 1992. Thus, habitat quality and quantity during winter is marginal; it can vary from year to year and might influence the large fluctuations in adult returns to Black Lake.

Although 434,500 sockeye spawned in the Black Lake drainage during 1990 (Thompson and Owen 1992) and probably produced approximately 70-130 million fry, no juvenile sockeye were captured in Black Lake during 97 trap-nights of sampling. The low catch rate indicated that few sockeye were present in Black Lake during winter. Subsequent sampling of sockeye smolts in Black River during May through July supports the conclusion that few sockeye were in Black Lake. During spring, the total smolt catch was only 266 fish, and the total outmigration was approximately 150,000 to 375,000 smolts (preliminary estimate based on 2-5x the mark/recapture rate for emigrating sockeye fry).

Age-length analysis of sockeye captured in Chignik Lake indicated that many Black Lake sockeye emigrated to Chignik Lake before the February sampling period. Factors causing these sockeye to leave Black Lake early are not known, but likely factors include shallow water, discharge of sockeye fry into the lake outlet through Alec River's left channel (previously called the "new" channel), the sandspit extending across the lake and isolating the outlet area, and poor habitat during winter. I cannot accurately predict the adult return from the Black Lake sockeye that overwintered in Chignik Lake, but intuition suggests that the run in 1995 will not be above average.

Oxygen tolerance tests and the relatively great abundance of coho in Black Lake indicate that sockeye tolerate low oxygen less than coho salmon. Short-term oxygen tolerance tests demonstrated that sockeye begin to die at higher oxygen levels than coho salmon. Few adult coho spawn in tributaries to Black Lake relative to sockeye, yet juvenile coho were much more abundant than sockeye in the lake. Coho preferred the relatively warm bottom areas of Black Lake even though these areas had exceptionally low oxygen. Thus, the relatively large abundance of coho in Black Lake may be related to their ability to tolerate low oxygen levels.

Although many sockeye fry leave Black Lake during spring and summer, exceptionally high densities of sockeye salmon in Black Lake during early September 1961–70 and in 1992 (380±81 [SE] age-0 sockeye per 10 min tow; Narver 1966, Parr 1972, and unpublished data) demonstrate that many sockeye salmon inhabit Black Lake prior to winter. If many sockeye inhabited Black Lake during fall prior to the winter 1992 sampling period, then what caused the exceptionally low numbers that were first detected in late February? Either sockeye salmon died during the winter or they emigrated to Chignik Lake or both. Interestingly, spring growth was exceptional among the few sockeye that overwintered in Black Lake and migrated as smolts to Chignik Lake during early June (unpublished data). Great spring growth of smolts leaving Black Lake, as indicated by scale measurements, occurred during an exceptionally cold spring and late ice-breakup. Thus, sockeye that survive the winter period in Black Lake encounter excellent feeding conditions in early spring that should enhance their survival to the adult stage.

Available data suggest that improvement of habitat in Black Lake might increase sockeye survival and reduce the number of years having exceptionally low adult returns. This hypothesis assumes that the discharge of numerous sockeye fry into the lake outlet and shallowness of the lake stimulates the large emigration to Chignik Lake, and that poor habitat quality during winter causes either mortality or premature emigration, or both. In other words, the hypothesis of increased sockeye survival through habitat modification assumes that premature emigration of sockeye fry is a behavioral response rather than a genetic response to unfavorable conditions in Black Lake. If habitat of Black Lake could be improved, then fewer Black Lake sockeye fry might migrate to Chignik lake (and compete with Chignik sockeye for food), growth would be greater, and mortality might be less than it is currently. The ultimate test of whether adult returns to Black Lake can be stabilized and enhanced would be to divert Alec River away from the outlet and back into Alec Bay and stabilize water level of Black Lake near high water. The latter action would nearly double habitat in Black Lake during winter. An additional test that should be considered is aeration, which would replenish oxygen consumed by the sediments. Aeration might work best in a few localized areas of this relatively large lake after lake level was stabilized.

FISH FOOD HABITS AND ZOOPLANKTON ABUNDANCE

Few fishes, especially planktivorous sockeye, consumed food during winter. The lack of food consumption reflected the lack of food. Although greatly reduced relative to summer, sockeye salmon still require energy in winter (0.32% to 0.43% body weight of food per day, Brett et al. 1969). A 2-g sockeye would require 6-9 mg food per day at <3°C. Without feeding, sockeye would lose approximately 0.1% to 0.14% body weight per day at 0° to 1°C, or an average of 3.6, 7.2, and 10.8% body weight after 30, 60, and 90 days, respectively. A slight loss of body weight during winter would probably not adversely affect most sockeye populations, but the Chignik Lake stock is unique. Chignik sockeye experience a relatively high density of fish and grow slowly. If the condition factor of Chignik sockeye is low at the beginning of winter, then the lack of food, even at these cold temperatures, might affect sockeye survival.

REFERENCES

Brett, J.R., J.E. Shelbourn and C.T. Shoop. 1969. Growth rate and body composition of fingerling sockeye salmon, *Oncorhynchus nerka*, in relation to temperature and ration size. J. Fish. Res. Board Can. 26:2363-2394.

Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. J. Fish. Res. Board Can. 32:2295-2332.

Narver, D.W. 1966. Pelagial ecology and carrying capacity of sockeye in the Chignik Lakes, Alaska. Ph.D. Thesis. University of Washington, Seattle, WA. 348 pp.

Parr, W.H. 1972. Interactions between sockeye salmon and lake resident fish in the Chignik Lakes, Alaska. M.S. Thesis. University of Washington, Seattle, WA. 103 pp.

Rickard, N.A. 1980. Life history and population characteristics of the prickly sculpin (*Cottus asper*) in Lake Washington. Master's thesis. University of Washington, Seattle.

Ruggerone, G.T., C. Harvey, J. Bumgarner. and D.E. Rogers. 1992. Investigations of salmon populations, hydrology, and limnology of the Chignik Lakes, Alaska. FRI-UW-9211. University of Washington, Seattle. 30 p.

Ruggerone, G.T., D. Helton and D.E. Rogers. 1991. Potential factors influencing the large annual fluctuations of adult sockeye salmon returning to Black Lake, Alaska. FRI-UW-9117. University of Washington, Seattle. 15 p.

Ruggerone, G.T. and D.E. Rogers. 1989. Proposal to evaluate factors influencing the large fluctuations of adult sockeye salmon returning to Black Lake, Alaska. Fish. Res. Instit. Univ. Washington, Seattle.

Thompson, F.M. and D.L. Owen. 1992. Annual finfish management report 1990. Chignik Management Area. Alaska Dept. Fish and Game. Kodiak, AK.

FIGURES

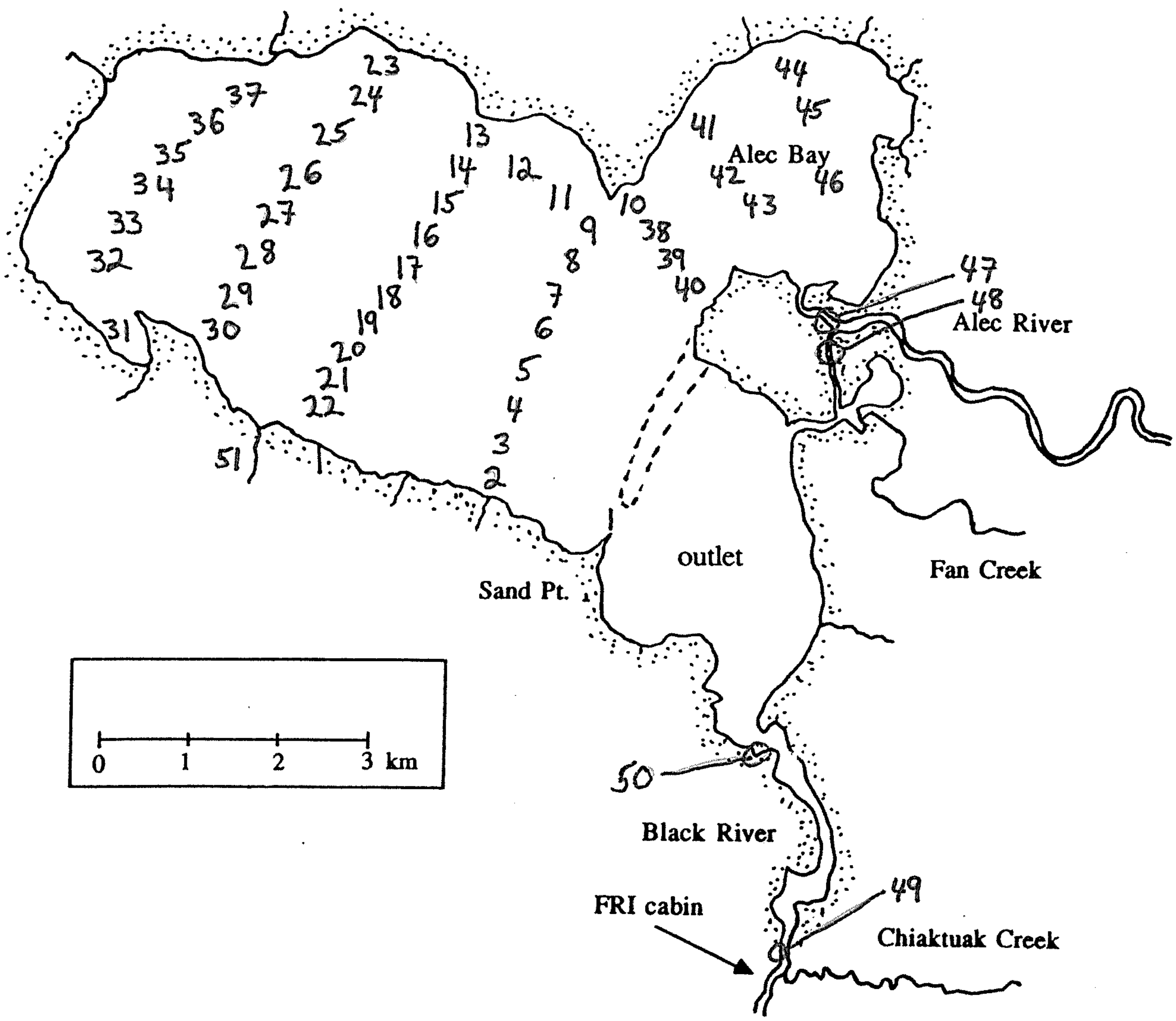

Figure 1. Black Lake in the Chignik Lake system, Alaska. Numbers refer to sampling stations for dissolved oxygen, temperature, ice thickness and depth measurements. Note the channel connecting Alec River with the outlet area and the sandspit that separates the main lake from the outlet during low water.

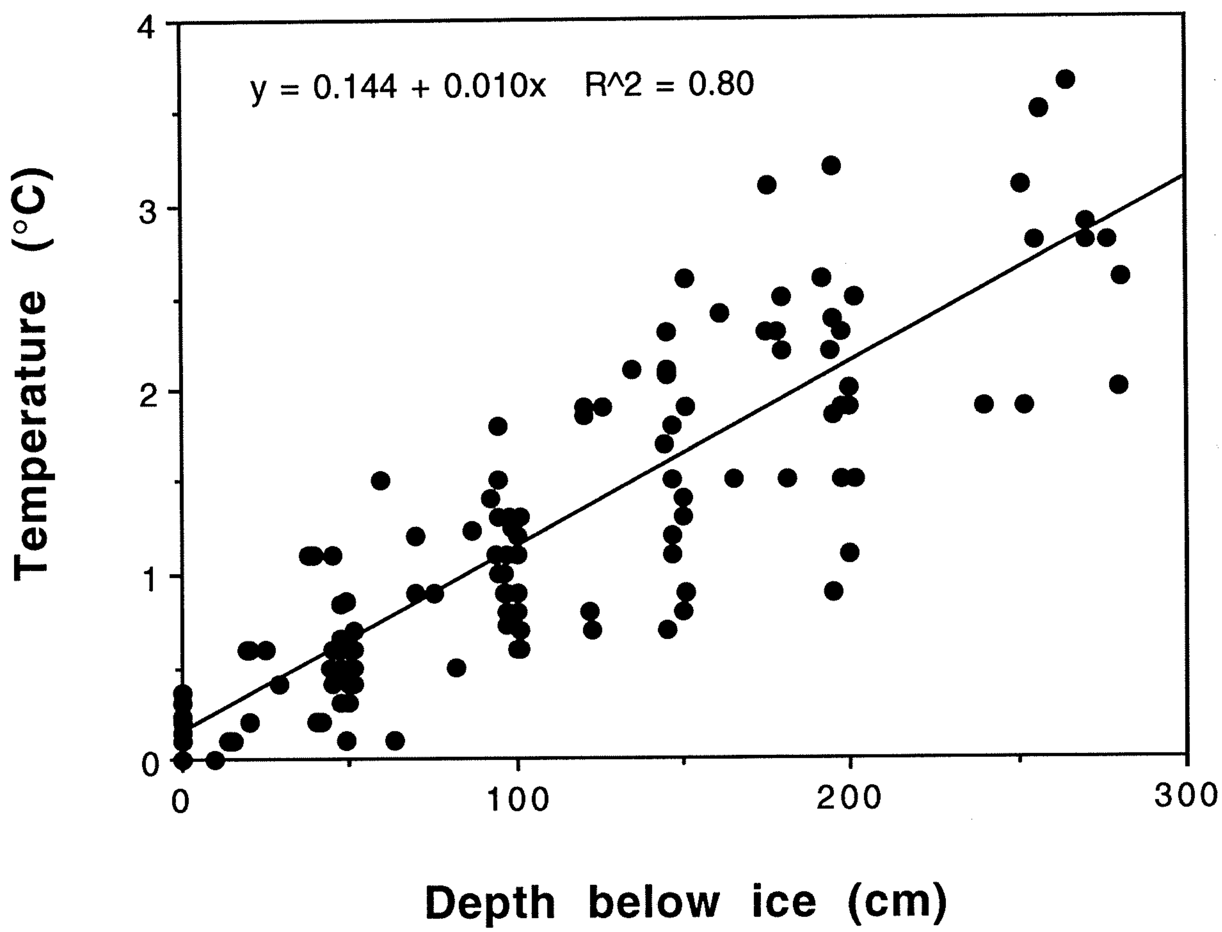

Figure 2. Relationship between temperature and distance below ice in Black Lake.

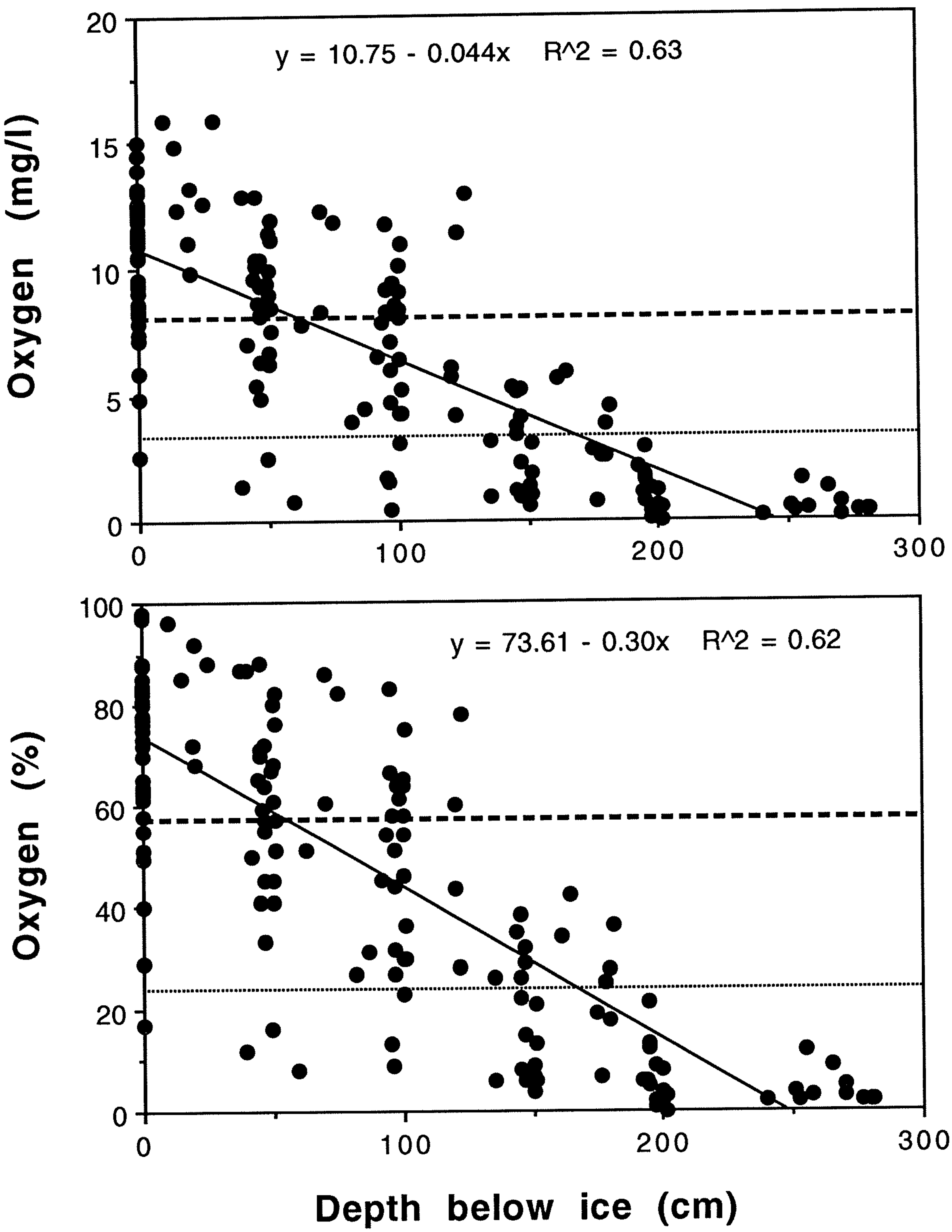

Figure 3. Relationship between oxygen content of water (mg L^{-1} or % of saturation) and distance below ice in Black Lake.

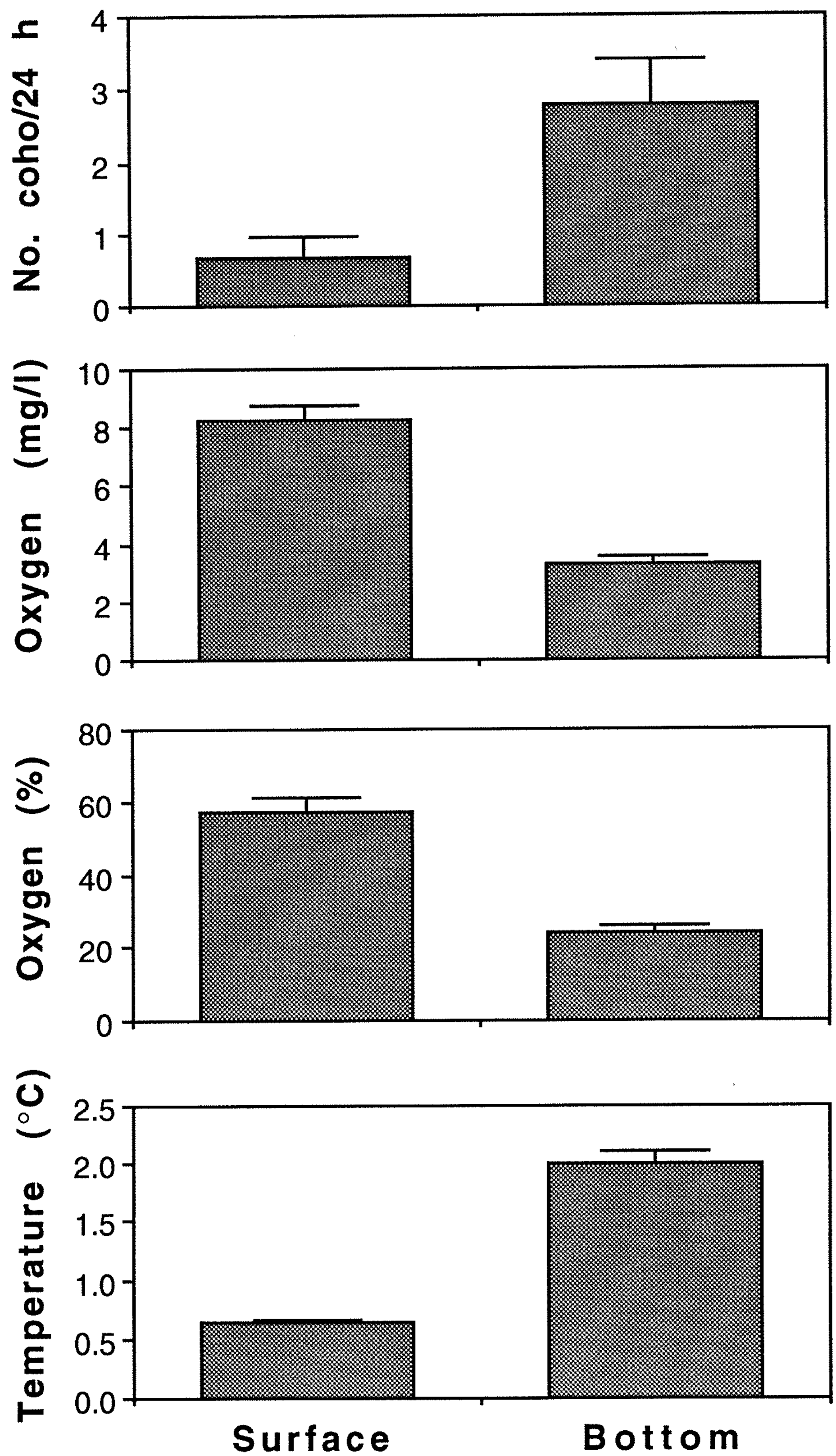

Figure 4. Comparison of catch rates of coho salmon with oxygen content and temperature of water near the ice/water interface and the bottom of Black Lake.

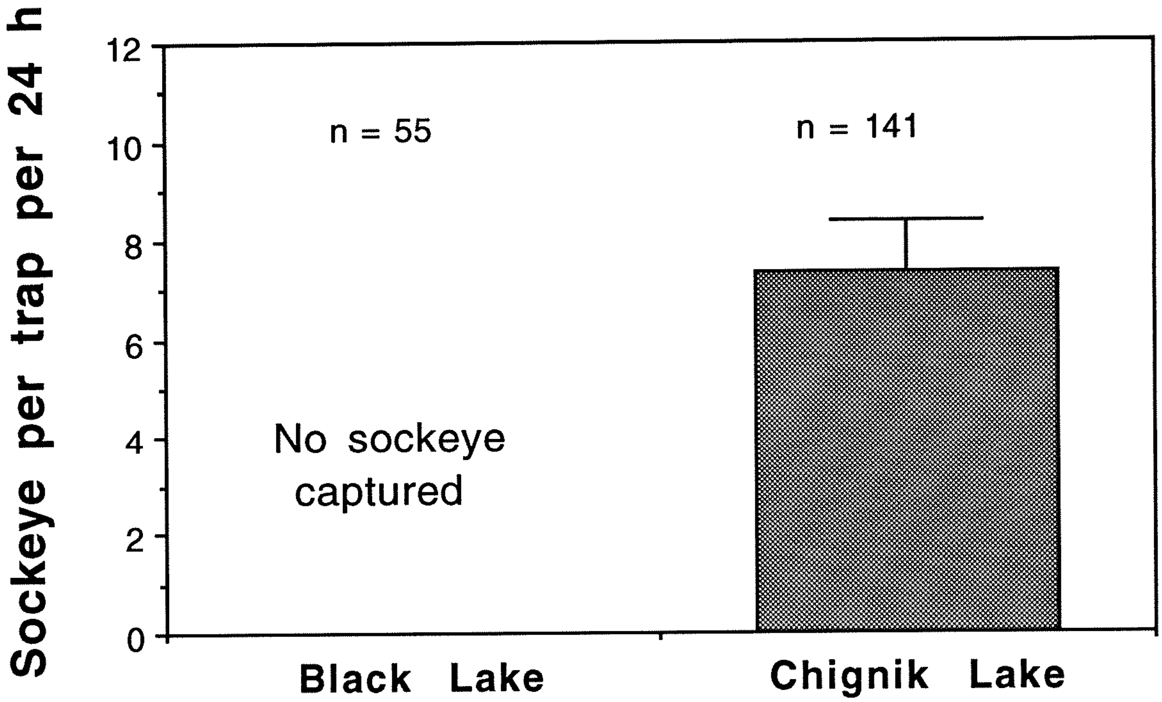

Figure 5. Comparison of sockeye catch rates in Black Lake and Chignik Lake.

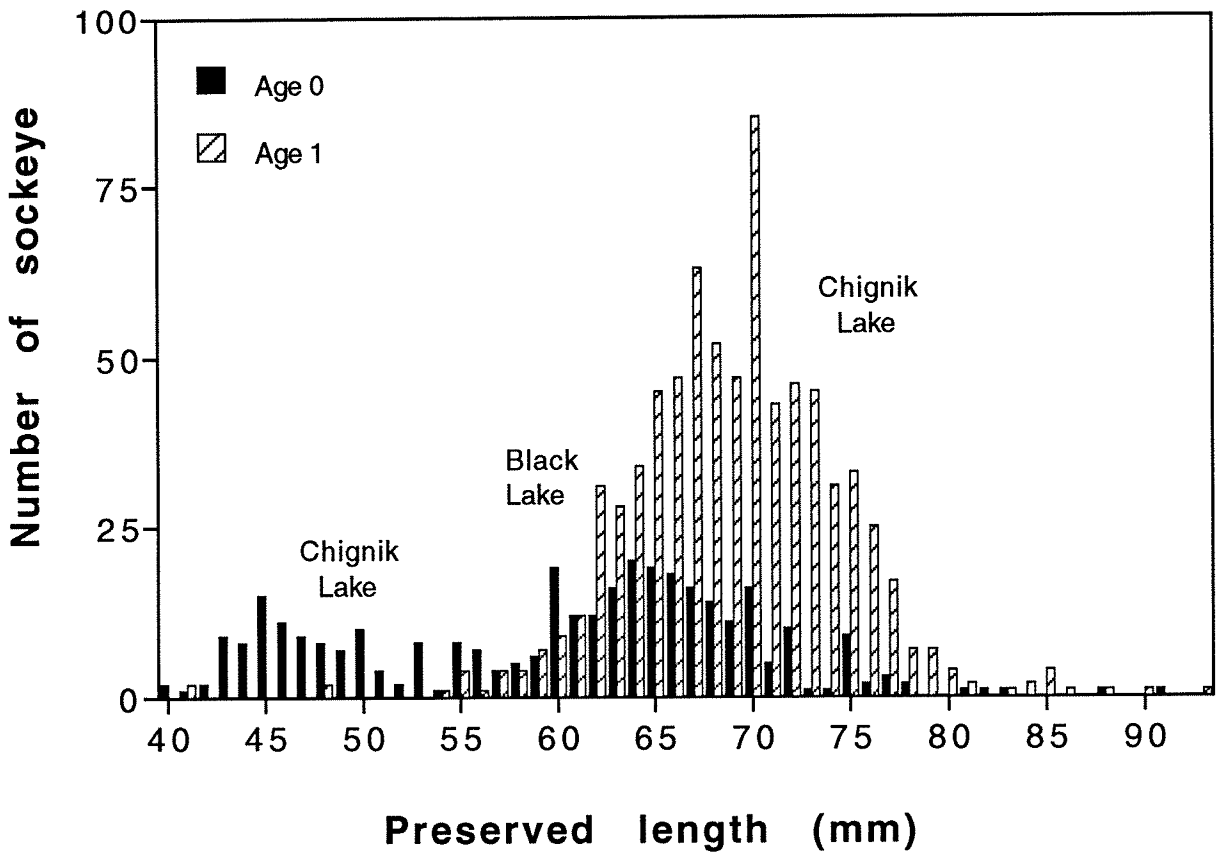

Figure 6. Length at age frequency distribution of sockeye salmon captured in Chignik Lake during February 1992. Among age-0 fish, sockeye in the lower mode originated from Chignik Lake and those in the upper mode originated from Black Lake. Nearly all age-1 sockeye originated from Chignik Lake.

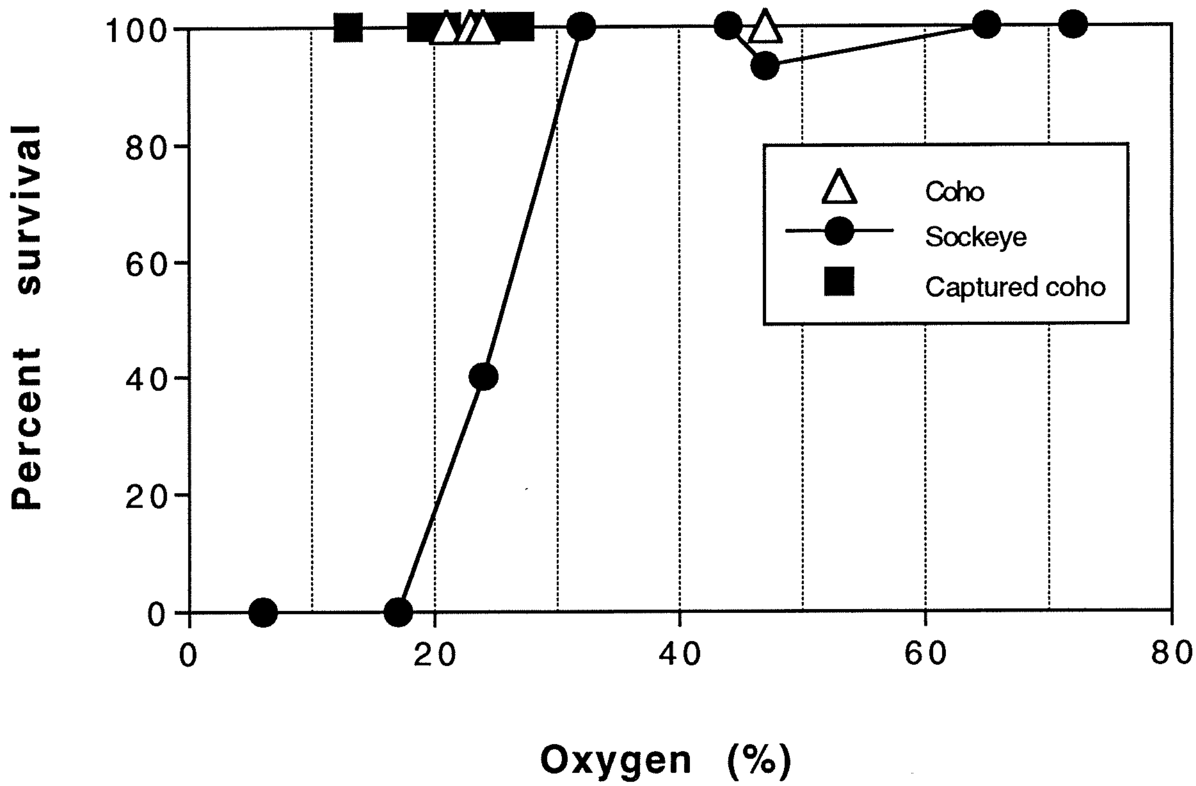

Figure 7. Relationship between survival of juvenile sockeye and coho salmon with percent oxygen saturation. All sockeye tests were ≤24 hours, whereas coho tests were ≤5 days. Values represented by square symbol indicate oxygen content where one or more coho were captured

TABLES

Table 1. Physical characteristics of Black Lake during February 1992.

Station	Date	Time	Ice depth (cm)	Water depth (cm)	Measurement depth (cm)	Temperature (°C)	Oxygen (mg/l)	Oxygen (%)
1	14-Feb	1700	5	92	0	0.3	2.6	17
					82	0.5	3.9	27
2	14-Feb	1730	30	5	0	ND	ND	ND
3	14-Feb	1745	54	57	0	0.6	7.9	54
					47	1.2	1.9	11
3	15-Feb	1030			0	0.1	9.1	60
					47	0.8	6.3	46
3	16-Feb	1130			0	0.1	9.1	62
					47	1.0	4.5	31
3	16-Feb	1130			0	0.0	8.9	60
					47	0.7	5.4	37
3	18-Feb	1130			0	0.2	7.7	53
					47	0.5	6.3	42
3	23-Feb	900			0			
					47	0.3	7.5	52
4	14-Feb	1800	53	97	0	0.2	7.2	50
					87	1.4	2.2	16
4	15-Feb	1100			0	0.1	7.9	54
					87	1.2	3.2	20
4	15-Feb	1100			0	0.1	7.9	54
					87	1.2	6.1	42
4	16-Feb	1200			0	0.1	8.6	59
					87	1.3	5.1	37
4	18-Feb	1140			0	0.2	6.6	45
					87	1.1	6.3	42
4	23-Feb				0	0.3	6.8	47

Table 1—cont.

Station	Date	Time	Ice depth (cm)	Water depth (cm)	Measurement depth (cm)	Temperature (°C)	Oxygen (mg/l)	Oxygen (%)
4	24-Feb				0	0.2	6.5	45
					87	1.2	3.8	29
5	14-Feb	1830	53	205	0	0.2	6.8	47
					97	0.6	4.1	27
					195	1.8	2.1	14
5	15-Feb	1130			0	0.1	7.0	47
					97	0.7	4.5	30
					195	2.0	2.7	20
5	15-Feb	1130			0	0.1	7.6	51
					97	0.7	4.5	29
					195	2.0	2.0	16
5	16-Feb	1220			0	0.0	8.0	54
5	(Oxygen tests with coho)				97	0.6	5.2	34
					195	1.5	2.8	21
5	17-Feb	1730			0			
	(Oxygen tests with coho)				195	1.7	3.1	21
5	18-Feb	1200			0	0.1	7.0	48
	(Oxygen tests with coho)				195	1.9	3.0	22
5	22-Feb	1440			0	0.2	6.7	48
	(Oxygen tests with coho and sockeye)				47	0.6	6.1	43
					97	1.0	5.2	37
					195	2.0	3.4	24
5	23-Feb	1200			0	0.2	7.2	51
	(Oxygen tests with coho and sockeye)				47	0.7	6.6	47
	(2.3 m Secchi depth)							
					147	1.5	4.1	29
					195	1.8	3.6	27
5	24-Feb				0	0.3	7.3	50
					195	2.0	3.6	26
6	15-Feb	1500	51	209	0	0.4	10.6	74
					99	1.3	9.6	67
					199	2.4	1.3	7

Table 1—cont.

Station	Date	Time	Ice depth (cm)	Water depth (cm)	Measurement depth (cm)	Temperature (°C)	Oxygen (mg/l)	Oxygen (%)
6	15-Feb	1500			0	0.4	11.2	75
					99	1.3	9.1	64
					199	2.4	1.5	8
6	16-Feb	1250			0	0.1	12.0	82
					99	1.1	10.3	72
					199	2.2	2.9	19
6	18-Feb	1345			0	0.4	10.5	73
					199	2.3	1.6	13
6	22-Feb	1515			0	0.2	11.0	75
	(Oxygen tests with sockeye)				49	0.9	9.6	68
					99	1.2	8.3	59
					149	2.0	6.2	47
					199	2.1	1.9	16
6	23-Feb	1700	55	205	0	0.2	10.1	70
					0.45	0.7	8.7	62
					0.95	1.3	7.5	55
					195	2.3	2.2	15
6	23-Feb	1220			0	0.4	11.6	81
	(Oxygen tests with sockeye)				49	0.9	10.4	74
					99	1.1	8.6	64
					149	2.0	5.9	43
					195	2.4	2.7	19
6	23-Feb	1700	60	200	0	0.3	10.4	73
					40	0.9	9.5	65
					90	1.4	8.0	60
6	24-Feb	1600						
	(Oxygen tests with sockeye)				20	0.6	9.8	68
	20 fish				45	1.0	8.9	66
					70	1.3	8.2	59
					95	1.3	7.8	57
	20 fish				120	1.9	6.0	45
	20 fish				145	2.1	4.5	35
					170	2.5	1.3	9
	20 fish				195	2.7	1.0	7

Table 1—cont.

Station	Date	Time	Ice depth (cm)	Water depth (cm)	Measurement depth (cm)	Temperature (°C)	Oxygen (mg/l)	Oxygen (%)
6	25-Feb	1400			0	0.3	10.2	70
					20	0.6	9.9	68
	20 fish				45	0.8	9.2	64
					70	1.1	8.3	62
					95	1.4	7.1	53
	20 fish				120	1.8	6.1	42
	20 fish				145	2.2	4.0	28
					170	2.5	1.5	12
	20 fish				195	2.6	0.8	6
7	15-Feb		55	190	0	0.4	11.3	79
					95	1.2	10.5	72
					180	2.4	4.5	32
					0	0.5	11.6	79
					95	1.5	8.8	63
					180	2.3	4.0	29
7	16-Feb	1325			0	0.1	12.4	84
					95	1.2	10.2	74
					180	2.6	4.3	31
7	18-Feb	1400			0	0.4	11.5	78
					180	2.6	3.5	26
7	23-Feb				0			
					180			
7	24-Feb				0	0.4	10.6	79
					45	0.6	10.1	71
					95	1.3	7.2	57
					145	2.1	3.8	26
					180	2.6	2.8	21
8	16-Feb	1340	52	188	0	0.1	13.2	88
					98	1.3	9.4	64
					178	2.3	2.6	25
9	16-Feb	1400	50	190	0	0.2	12.5	85
					100	1.2	8.4	58
					180	2.2	2.6	18

Table 1—cont.

Station	Date	Time	Ice depth (cm)	Water depth (cm)	Measurement depth (cm)	Temperature (°C)	Oxygen (mg/l)	Oxygen (%)
10	16-Feb	1415	47	133	0	0.1	11.3	77
	(old FRI cabin, 3 cm snow)				123	0.7	11.4	78
11	16-Feb	1430	50	171	0	0.2	13.1	88
					75	0.9	11.8	82
					161	2.4	5.6	34
12	16-Feb	1500	50	202	0	0.2	12.6	85
					100	1.2	10.1	65
					192	2.6	2.1	6
13	15-Feb	1800	55	275	0	0.3	12.8	87
					95	1.5	11.7	83
					120	1.9	5.7	60
					145	2.3	3.4	22
	(Hydrolab depth)				195	3.2	1.6	13
					265	3.7	1.1	8
13	16-Feb	1500	55	275	0	0.1	13.1	88
	(3 cm snow)				45	0.6	12.8	88
					175	2.3	2.8	19
					265	3.6	1.4	10
14	16-Feb		50	265	0	0.1	10.5	72
	(3 cm snow)				50	0.6	9.0	61
					100	0.8	6.4	46
					150	1.4	0.9	7
					200	2.0	1.2	8
					255	2.8	1.6	12
15	16-Feb		50	280	0	0.1	9.3	63
	(3 cm snow)				50	0.6	6.2	41
					100	0.9	3.1	23
					150	1.3	0.6	4
					200	1.9	0.6	4
					270	2.8	0.7	5
16	16-Feb		53	287	0	0.2	9.1	62
	(3 cm snow)				47	0.5	8.1	57
					97	0.8	0.4	27
					147	1.1	0.9	6
					197	1.9	0.1	1
					277	2.8	0.3	2

Table 1—cont.

Station	Date	Time	Ice depth (cm)	Water depth (cm)	Measurement depth (cm)	Temperature (°C)	Oxygen (mg/l)	Oxygen (%)
17	16-Feb		49	291	0	0.1	9.1	62
	(3 cm snow)				51	0.5	7.5	51
					101	0.7	4.3	30
					151	0.9	1.0	6
					201	1.5	0.0	0
					281	2.6	0.3	2
18	16-Feb		50	290	0	0.1	8.4	58
	(3 cm snow)				50	0.4	6.7	45
					100	0.6	4.3	30
					150	0.8	1.4	9
					200	1.1	0.1	1
					280	2.0	0.3	2
19	16-Feb		53	262	0	0.1	9.6	65
	(3 cm snow)				47	0.5	8.2	55
					97	0.9	6.0	44
					147	1.2	2.3	15
					197	1.5	0.3	2
					252	1.9	0.3	2
20	16-Feb		54	191	0	0.1	8.2	55
	(hard bottom)				46	0.6	8.6	59
	(3 cm snow)				96	1.0	8.2	58
					181	1.5	4.5	36
21	16-Feb		53	132	0	0.1	9.6	64
	(green water)				47	0.3	9.3	64
	(3 cm snow)				122	0.8	4.2	28
22	16-Feb		55	73	0	0.0	9.4	63
	(near Cottonwood Cr, 3 cm snow)				63	0.1	7.8	51
23	18-Feb		49	136	0	0.3	12.3	84
					51	0.6	11.9	82
					126	1.9	12.9	93
24	18-Feb		49	261	0	0.2	12.0	82
					51	0.7	8.5	57
					101	1.3	5.2	36
					151	1.9	3.1	21
					201	2.5	0.5	3
					251	3.1	0.5	4

Table 1—cont.

Station	Date	Time	Ice depth (cm)	Water depth (cm)	Measurement depth (cm)	Temperature (°C)	Oxygen (mg/l)	Oxygen (%)
25	18-Feb		53	267	0	0.1	12.3	84
					47	0.6	10.3	72
					97	1.1	7.1	51
					147	1.8	5.2	32
					197	2.3	1.3	9
					257	3.5	0.4	3
26	18-Feb		50	175	0	0.2	10.9	73
	(hard bottom)				50	0.5	9.9	68
					100	1.1	8.0	54
					165	1.5	5.9	42
27	18-Feb		56	280	0	0.2	10.4	70
	(near Crater Cr)				44	0.5	9.6	65
					94	1.1	7.9	54
					144	1.7	5.3	35
					194	2.2	1.1	6
					270	2.9	0.2	3
28	18-Feb		55	250	0	0.2	11.5	78
					45	0.4	10.3	70
					95	1.0	8.3	58
					145	0.7	1.2	8
					195	0.9	0.8	5
					240	1.9	0.2	2
29	18-Feb		55	80	0	0.2	11.1	75
	(hard bottom)				70	0.9	12.2	86
30	18-Feb		57	48	0	0.2	14.5	98
					38	1.1	12.3	87
31	16-Feb	1730	58	7	0	0.0	5.9	40
	(Crooked Cr bay)							
32	16-Feb		52	102	0	0.1	15.0	88
					92	1.4	6.5	45
33	16-Feb	1800	55	145	0	0.1	12.2	81
					45	1.1	5.4	41
					95	1.8	1.7	13
					135	2.1	0.9	6

Table 1—cont.

Station	Date	Time	Ice depth (cm)	Water depth (cm)	Measurement depth (cm)	Temperature (°C)	Oxygen (mg/l)	Oxygen (%)
34	16-Feb	1815	51	106	0	0.1	4.9	29
					49	0.1	2.5	16
					96	0.9	1.5	9
35	25-Feb	1000	61	69	0	0.1	13.9	97
	(near Crater Cr.)				39	1.1	1.4	12
					59	1.5	0.8	8
36	25-Feb	1030	56	29	0	0.2	11.9	82
					19	0.6	11.0	72
37	25-Feb	1100	58	52	0	0.0	7.9	55
					42	0.2	7.0	50
38	17-Feb		49	186	0	0.1	11.3	76
	(Alec Bay)				51	0.4	11.1	76
					101	0.6	10.9	75
					151	2.6	1.9	13
					176	3.1	0.8	7
39	17-Feb		50	145	0	0.1	12.1	81
	(Alec Bay)				50	0.3	11.4	80
					100	1.2	9.1	64
					135	2.1	3.2	26
40	17-Feb		55	50	0	0.1	12.2	83
	(Alec Bay)				40	0.2	12.8	87
41	23-Feb		45	48	20	0.2	13.2	92
42	23-Feb		53	55	25	0.6	12.6	88
43	23-Feb		56	31	15	0.1	12.3	85
44	23-Feb		53	19	10	0.0	15.9	96
45	23-Feb		56	28	14	0.1	14.9	104
46	23-Feb (Alec Bay)		51	39	29	0.4	15.9	112

Table 1—cont.

Station	Date	Time	Ice depth (cm)	Water depth (cm)	Measurement depth (cm)	Temperature (°C)	Oxygen (mg/l)	Oxygen (%)
47	17-Feb (Alec R. old)	1000	23	25		0.0	13.1	88
48	17-Feb (Alec R. new)	1200	19	43		0.0	13.2	89
49	14-Feb (Black River)	1900		20	10	0.4	11.0	75
49	15-Feb	1230	(Black River)			0.3	11.3	77
49	23-Feb (Black River)	1800		30	15	0.0	9.3	65
50	24-Feb (upper Black R.)	1900		30		0.1	10.2	71
51	16-Feb (Cottonwood Cr. beaver pond)	1700				0.0	7.5	50
52	15-Feb (Crater Cr.)			30		0	0.0	5.5

Table 2. Effects of reduced water level, ice cover, and low oxygen level during winter 1992 on average depth, surface area, and volume of Black Lake. Areas having oxygen saturation values <57% (i.e., ≥0.6 m) were considered to be unsuitable habitat for sockeye salmon (Davis 1975).

Date	Lake level	Avg. depth (m)	Lake area (millions m^3)	% of spring level	Volume (millions m^3)	% of spring level
June 92	-0.60	1.94	41.0	100	79.7	100
Feb. 92 w/ice	-1.38	1.54	32.9	80	50.8	64
Feb. 92 w/o ice	-1.38	1.1	27.5	67	29.0	36
Feb. 92 w/o ice low O_2	-1.38	1.1	27.5	67	14.2	18
Feb. 90 w/o ice low O_2	-1.20	1.2	30.1	73	26.2	33

Table 3. Physical characteristics of Chignik Lake during February 1992.

Station	Date	Time	Ice depth (cm)	Water depth (m)	Measurement depth (m)	Temp (°C)	Oxygen (mg/l)	Oxygen (%)
Clark Bay offshore								
	26-Feb	1500	70	45.0	0.0	0.6	13.7	96
	(Secchi depth =				1.0	0.6	13.3	92
	4.0 m)				5.0	0.6	12.9	90
					10.0	0.6	12.8	91
					20.0	0.9	13.3	94
					40.0	1.3	12.8	92
Clark Bay onshore								
	26-Feb	1700	62	1.1	0.0	0.4	15.2	108
					0.9	0.6	15.8	111
					1.0	0.7	15.6	113
Outlet								
	26-Feb	1730	60	5.0	0.0	0.2	13.8	96
					0.4	0.6	13.4	93
					1.6	0.6	13.2	93
					2.4	0.6	13.0	91

Table 4. Average (± SE) daily catch of juvenile sockeye salmon and other fishes in Chignik Lake and Black Lake fry traps during February 1992.

			Species								
Area	n	Trap nights	Sockeye	Coho	Chinook	Dolly Varden	Sculpin	3-spine stickleback	9-spine stickleback	Whitefish	All fishes
Chignik Lake											
Outlet											
surface	20	30	26.1 ± 4.4	2.5 ± 0.9	0.7 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	1.2 ± 0.4	0.0 ± 0.0	30.6 ± 4.6
bottom	18	30	3.2 ± 1.4	2.5 ± 0.8	0.3 ± 0.2	0.4 ± 0.2	24.5 ± 9.3	0.9 ± 0.3	0.5 ± 0.3	0.4 ± 0.2	32.8 ± 9.2
Clark Bay onshore											
surface	12	21	0.2 ± 0.1	4.3 ± 1.0	0.3 ± 0.3	6.0 ± 1.9	16.9 ± 4.7	4.3 ± 1.7	0.0 ± 0.0	0.0 ± 0.0	31.9 ± 5.5
bottom	20	29	0.9 ± 0.4	3.2 ± 0.7	1.6 ± 0.4	1.9 ± 0.6	6.8 ± 2.1	6.3 ± 1.4	0.5 ± 0.2	0.0 ± 0.0	21.2 ± 3.2
Clark Bay offshore											
surface	23	38	4.1 ± 0.9	0.0 ± 0.0	<.1	<.1	0.0 ± 0.0	0.2± 0.1	0.4± 0.2	0.0 ± 0.0	4.7 ± 0.9
10 m	24	39	1.8 ± 0.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	2.0 ± 0.6
20 m	24	39	12.6 ± 1.6	<.1	<.1	<.1	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	12.8 ± 1.6
Chignik River & Village Cr.											
bottom	23	34	0.0 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	<.1	0.3 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.6 ± 0.2
Black Lake											
Mid-lake											
surface[1]	20	34	0.0 ± 0.0	0.7 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 0.3
bottom[1]	21	43	0.0 ± 0.0	2.8 ± 0.6	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	3.1 ± 0.7
surface	20	34	0.0 ± 0.0	0.7 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 0.3
bottom	35	63	0.0 ± 0.0	3.6 ± 0.6	0.0 ± 0.0	0.1 ± 0.1	0.6 ± 0.3	< 0.1	< 0.1	0.3 ± 0.2	4.7 ± 0.8
Black River	9	9	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

[1] Includes only those areas with traps at both the surface and bottom.

Table 5. Oxygen tolerance of juvenile coho and sockeye salmon in Black Lake during February 1992. Fishes were enclosed within fry traps and held at various levels of dissolved oxygen for 1 to 5 days.

Date	Number of fish	Days held	Depth (cm)	Location	Temp. (°C)	Dissolved oxygen mg/l	Dissolved oxygen %	% survival
				Coho salmon				
2/17	10	1	25	surface	0.4	6.6	47	100
2/17	10	1	195	bottom	1.6	3.0	21	100
2/17	10	1	195	bottom	1.6	3.0	21	100
2/22	10	4	195	bottom	2.0	3.2	23	100
2/22	15	4	195	bottom	2.0	3.2	23	100
2/23	10	5	195	bottom	1.9	3.3	24	100
2/23	15	5	195	bottom	1.9	3.3	24	100
				Sockeye salmon				
2/23	15	1	25	surface	0.4	6.6	47	93
2/23	15	1	195	bottom	1.9	3.3	24	40
2/23	15	1	25	surface	0.6	10.2	72	100
2/23	15	1	195	bottom	2.4	2.3	17	0
2/23	50	1	195	bottom	2.4	2.3	17	0
2/25	20	1	43	surface	0.9	9.0	65	100
2/25	20	1	120	middle	1.9	6.0	44	100
2/25	20	1	150	middle	2.3	4.2	32	100
2/25	20	1	190	bottom	2.7	0.9	6	0

Table 6. Food habits of juvenile sockeye salmon and other fishes in Chignik Lake during February 1992. Total prey weight given as mean ± standard error.

	Sockeye	Coho	Chinook	Dolly Varden	Threespine stickleback	Sculpin
No. sampled	134	109	19	48	58	51
Avg. length (mm)	67.6	90.3	75.3	98.8	62.2	79.5
Range (mm)	55	75	18	107	31	46
Avg. weight (g)	2.8	7.9	4.3	10.4	2.6	8.4
% feeding	1.5	9.0	0.0	22.9	32.8	37.3
Total prey weight (mg)	0.1±0.05	3.1±1.8	0.0	13.1±4.4	9.8±2.8	17.8±5.0
Geom. prey weight (mg)	0.0	0.2	0.0	1.3	1.6	2.4
‰ of body weight	0.0	0.3	0.0	1.6	3.6	2.2
Chironomid larvae (mg)	0.0	0.0	0.0	0.0	0.0	0.0
Caddis fly larvae	0.0	0.5	0.0	12.9	0.0	1.4
Oligochaete	0.0	0.0	0.0	0.0	0.0	0.0
Bivalve	0.0	0.0	0.0	0.0	0.0	0.6
Gastropod	0.0	0.0	0.0	0.0	0.0	7.1
Copepod	0.0	0.0	0.0	0.0	0.0	0.0
Isopod	0.0	0.0	0.0	0.0	0.0	2.0
Fishes	0.0	1.6	0.0	0.0	0.0	0.0
Unidentified Insecta	0.0	0.0	0.0	0.1	0.0	0.0
Unidentified Organic	0.1	1.0	0.0	0.0	9.8	6.7
Inorganic	0.0	0.2	0.4	0.5	0.9	1.9

Table 7. Food habits of juvenile coho salmon in Black Lake during February 1992. Total prey weight given as mean ± standard error.

	Coho
No. sampled	176
Avg. length (mm)	88.0
Range (mm)	80
Avg. weight (g)	8.7
% feeding	18.9
Total prey weight (mg)	6.7±1.7
Geom. prey weight (mg)	0.7
‰ of body weight	0.8
Chironomid larvae (mg)	0.0
Caddis fly larvae	0.1
Oligochaete	0.0
Bivalve	0.0
Gastropod	0.0
Amphipod	3.9
Copepod	0.0
Isopod	0.0
Fishes	0.4
Unidentified Insecta	0.0
Unidentified Organic	2.3
Inorganic	0.0