September 1999

LAKE PEND OREILLE FISHERY RECOVERY PROJECT

Period Covered October 1, 1996 to September 30, 1997

Annual Progress Report 1997

DOE/BP-98065-2

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LAKE PEND OREILLE FISHERY RECOVERY PROJECT

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ABSTRACT

During the winter of 1996-97, the elevation of Lake Pend Oreille was kept 1.2 m higher in an attempt to recover the impacted kokanee fishery. This was the first winter of the scheduled three-year test. We found that kokanee spawned on the newly inundated gravels provided by the higher water levels. Many of the redds were at depths of 0.5 to 2 m with the highest density of redds at the 1.2 m depth. We also found the numbers of kokanee spawning in tributary streams declined sharply with the higher lake levels. Presumably, these fish spawned on the lakeshore because of the abundance of shoreline gravel rather than migrate up tributary streams.

Kokanee spawning sites were mapped around the entire perimeter of the lake. Most spawning occurred at the southern end of the lake; however, kokanee utilized the newly available spawning gravels throughout much of lake's shorelines.

Unusually high spring run-off in 1997 produced an inflow to the lake of 4,360 m^3/s and raised the lake 1 m above full pool. We found that all age-classes of kokanee declined sharply between 1996 and 1997. Survival rates of all age-classes were at or near the lowest point on record. The cause of these declines is unknown; possible causes include kokanee emigrating from the lake and mortality of kokanee due to dissolved gasses in the northern third of the lake reaching 120% to 130% of saturation. High dissolved gasses were caused by the Cabinet Gorge and Noxon dams on the Clark Fork River. Kokanee population declines caused by flooding would have masked any benefits to the population resulting from a higher winter lake level.

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INTRODUCTION

The decline of the kokanee *Oncorhynchus nerka kennerlyi* population in Lake Pend Oreille has been largely attributed to the current operation of Albeni Falls Dam (Maiolie and Elam 1993; Paragamian and Ellis 1994). Historical population trends and harvest data indicated winter pool elevation affected kokanee abundance and harvest. Drawdowns of the lake below the elevation needed for flood control exposed most of the shoreline gravel, which limited kokanee spawning. In an attempt to recover the kokanee population, the Idaho Department of Fish and Game proposed raising the minimum winter lake level to 626.7 m (2056 feet) above mean sea level, approximately 1.5 m above the minimum level used from 1966 to 1995. Gravel surveys conducted in 1994 determined this would increase the amount of suitable kokanee spawning gravel by 560 percent (Fredericks et al., 1995).

The Northwest Power Planning Council directed the U.S. Army Corps of Engineers to change the winter elevation of Lake Pend Oreille beginning in 1996. The lake was to be kept above an elevation of 626.4 m (2055 feet, 1.2 m higher) for three winters. They also directed the Bonneville Power Administration fund the Idaho Department of Fish and Game to investigate the effect of lake level changes on kokanee production, possible movements of shoreline gravel and sediment, a lake energy budget including zooplankton, predation levels, predator abundance, *Mysis* shrimp and food availability for fry and adult kokanee, changes in the abundance of warm-water fish species, concerns about Eurasian water milfoil, and effects on wildlife and waterfowl. These studies were to be conducted between 1996 and 2001. After this time, fishery managers were to meet and discuss options for managing the lake levels on a long-term basis. This report covers our first year of findings on this study.

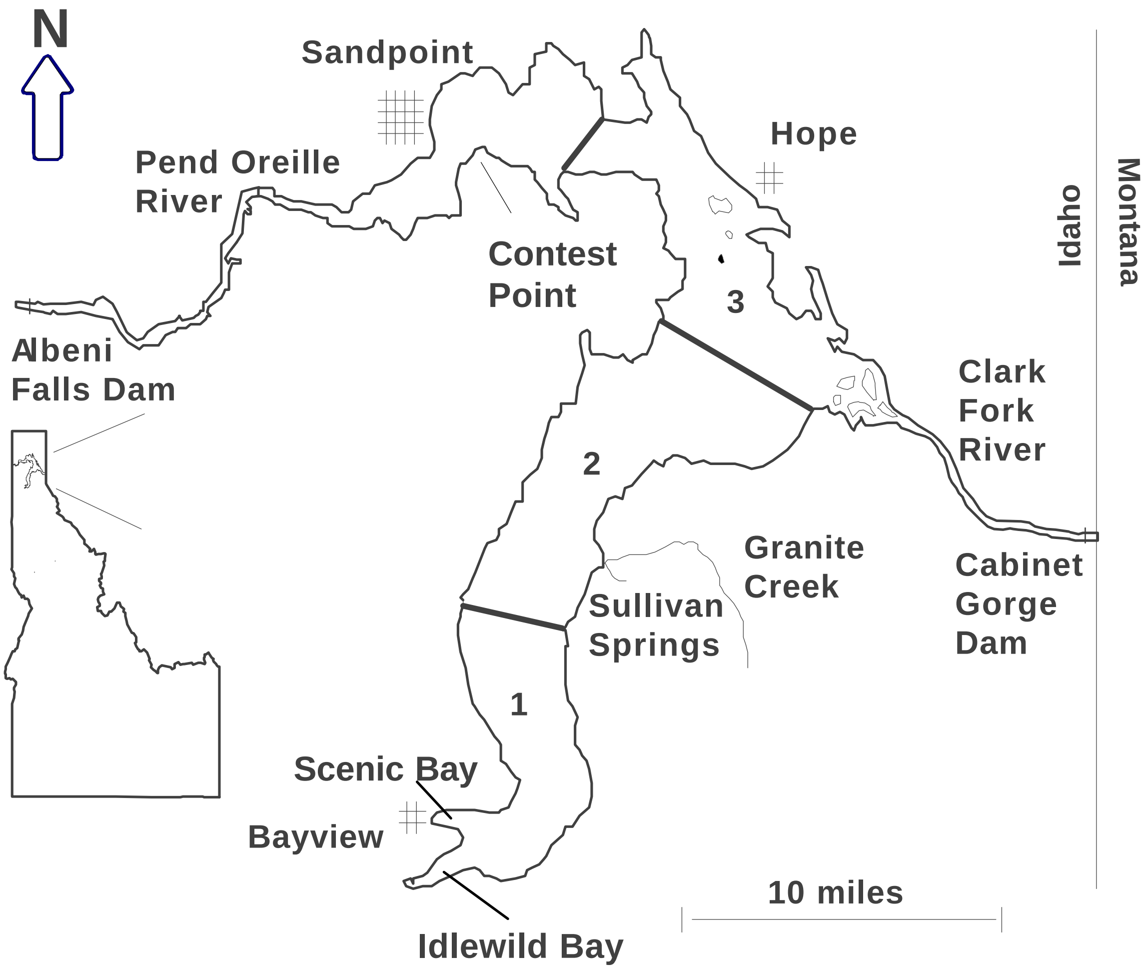
OBJECTIVE

To return kokanee harvest to 750,000 fish annually with a mean length of 250 mm. This will be possible once the adult kokanee population reaches 3.75 million fish.

STUDY AREA

Lake Pend Oreille is located in the northern panhandle of Idaho (Figure 1). It is the state's largest lake and has a surface area of 38,300 ha, a mean depth of 164 m and a maximum depth of 351 m. Summer pool elevation of Lake Pend Oreille is 628.7 m. Pelagic habitat used by kokanee (area inside the 91.5 m contour in sections 1 and 2, and the area inside the 36.6 m contour in section 3) is considered to be 22,546 ha (Figure 1)(Bowler 1978). The Clark Fork River is the largest tributary to the lake. Outflow from the lake forms the Pend Oreille River.

Lake Pend Oreille is a temperate, oligotrophic lake. Summer temperatures (May to October) average approximately 9^{o}C in the upper 45 m (Rieman 1977; Bowles et al., 1987, 1988, 1989). Thermal stratification typically occurs from late June to September. Operation of Albeni Falls Dam on the Pend Oreille River keeps the lake level high and stable at 628.7 m during summer (July-September) followed by reduced lake levels of 625.1 m during fall and winter (typical dam operation between 1966 and 1996). During the first three winters of this study, the winter lake level will be held above 626.4 m.



Section	Area (hectares)
1	6386
2	7775
3	8384

Figure 1. Map of Lake Pend Oreille, Idaho, showing three sections used in estimating kokanee abundance by widwinter trawling. Insert depicts the area of kokanee habitat in each section.

A wide diversity of fish species is present in Lake Pend Oreille. Kokanee entered the lake in the early 1930s from Flathead Lake, and were well established by the 1940s. Other game fish include: Gerrard rainbow trout *Oncorhynchus mykiss,* bull trout *Salvelinus confluentus*, lake trout *Salvelinus namaycush,* westslope cutthroat trout *Oncorhynchus clarki lewisi*, lake whitefish *Coregonus clupeaformis*, and mountain whitefish *Prosopium williamsoni*, in addition to several other cool and warm-water species.

METHODS

Midwater Trawling

We conducted standardized midwater trawling in Lake Pend Oreille from September 29 to October 4, 1997. These dates were during the dark phase of the moon, which optimized the trawl's capture efficiency (Bowler et al., 1979).

The lake was divided into three sections (Figure 1), and a stratified random sampling scheme was used to estimate kokanee abundance and density. Twelve transects were randomly selected within each section and one haul was made along each transect.

The midwater trawl and sampling procedures were described in detail by Rieman (1992). The net was 13.7 m long with a 3 m x 3 m mouth. Mesh sizes (stretch measure) graduated from 32 mm, 25 mm, 19 mm and 13 mm in the body of the net to 6 mm in the cod end. The trawl net was towed at a speed of 1.5 m/s by a 8.5 m boat. We determined the vertical distribution of kokanee by using a Raytheon Model V850 depth sounder with a 20^{o} hull mounted transducer. A step-wise oblique tow was conducted along each transect, which sampled the entire vertical distribution of kokanee.

Fish from each trawl sample were counted and placed on ice until morning. Then, each kokanee was measured and weighed individually. All fish over 150 mm were checked for maturity. Scales were taken from 10 fish in each 10 mm size interval for aging.

Fish numbers/transect (haul) were divided by transect volume and the age-specific and total number of kokanee for each stratum and lake total were calculated using standard expansion formulas for stratified sampling designs (Scheaffer et al., 1979). The area of each section was calculated for the 91.5 m contour; however, Section 3 (the northern end) was calculated from the 36.6 m contour because of shallower water. The 91.5 m contour was used because it represents the pelagic area of the lake where kokanee are found during late summer (Bowler 1978). For consistency, these same areas have been used each year since 1978. Ninety-percent confidence intervals were calculated on the kokanee abundance estimates (Scheaffer et al., 1979).

To estimate the wild egg-to-fry survival, the estimated number of wild fry in the lake was divided by the potential number of eggs deposited naturally in the lake the previous year (wild PED). Wild PED was calculated by estimating the number of mature female kokanee of ages 3, 4, and 5 in the lake during trawl sampling and multiplying it by the mean fecundity of females seen at the Granite Creek spawning station. We then subtracted the number of eggs collected by hatchery personnel at the Cabinet Gorge Hatchery and Granite Creek egg-take stations to determine the number of eggs spawned by wild fish.

Spawner Counts and Surveys

We walked standard shoreline areas and tributaries (Appendix A) and counted spawning kokanee to continue this data set. All areas surveyed have been documented as historical spawning sites (Jeppson 1960). Nine shoreline areas were surveyed once a week for three straight weeks starting with the third week in November 1997. All kokanee, either alive or dead, were counted. The highest count at each site was reported.

Seven tributary streams were surveyed on November 24 and December 1, 1997 by walking upstream from the mouth to the highest point utilized by kokanee. Trestle Creek, which supports a run of early spawning kokanee, was also surveyed on September 19, 1997 for spawners.

We also surveyed the entire shoreline of Lake Pend Oreille to determine locations used for shoreline spawning. The shoreline of the lake was divided into 14 sections, beginning and ending at prominent landmarks. The perimeter of the lake was surveyed as far downstream as Contest Point (Appendix C, Figure 2). Surveys were conducted from December 10 to December 29, 1997. The depth and area of each redd were estimated using a PVC (polyvinyl chloride) pipe that was marked for depth and contained a 1 m long arm to help estimate redd area. Water clarity was sufficient for us to clearly see redds at 5 m water depths, however, redds became difficult to identify below 8 m depths. We tabulated the depth and area of redds within each section separately so that future changes could be identified.

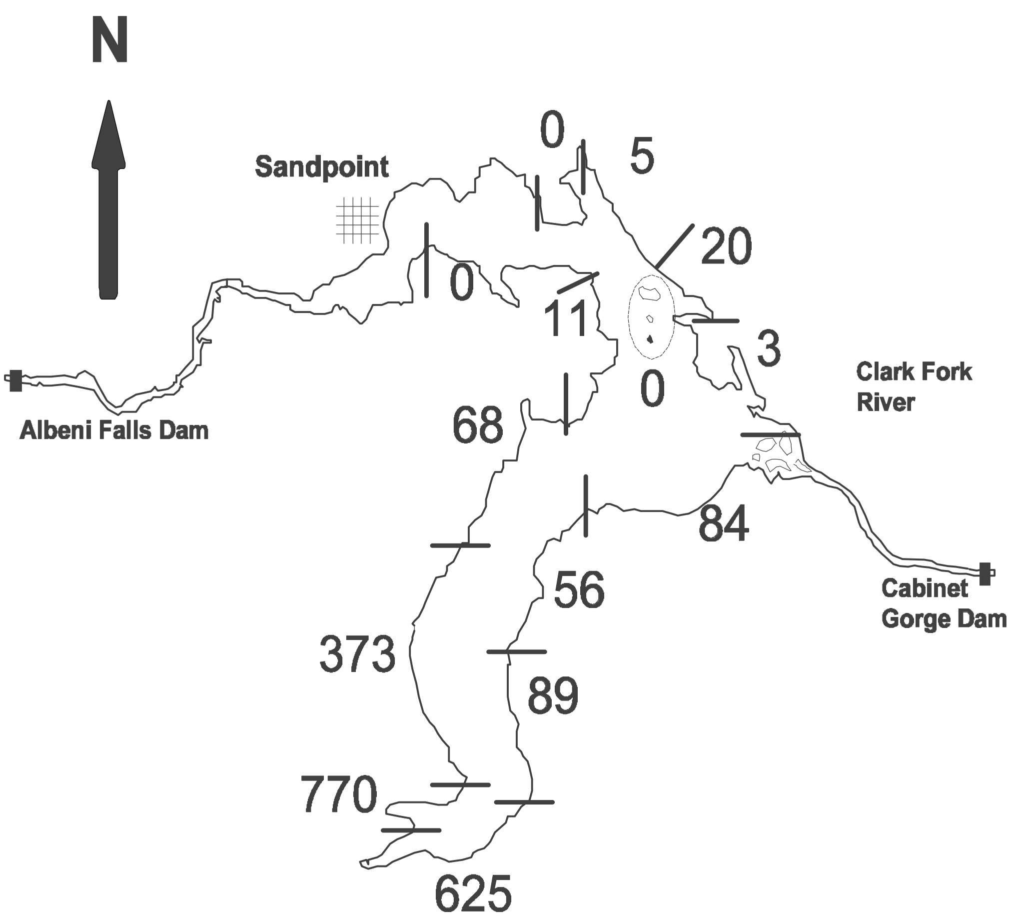


Figure. 2 Location of kokane redds on the shorelines of Lake Pend Oreille, Idaho. The total area (m^2) of redds in each section is shown.

Hatchery Fry Marking

All kokanee fry released from the Cabinet Gorge Fish Hatchery in 1997 were marked by "cold branding" their otoliths (Volk et al., 1990). This was the first year that all fry released into Lake Pend Oreille were cold branded. The intent of this marking was to be able to separate hatchery and wild kokanee throughout their life cycle by comparing growth patterns on saggita otoliths.

Cabinet Gorge Fish Hatchery personnel reared and marked all of the kokanee fry stocked into the lake in 1997. Fry within an individual raceway were from eggs collected within seven days of each other. Thermal treatments were initiated five to ten days after fry entered their respective raceways. In order to create recognizable otolith marks, a series of five 24 h cool water events were scheduled. Each of the 24 h cool water (approximately 5^{o}C) events was followed by a return to normal rearing temperatures (approximately 10^{o}C) for 24 h. Total treatment was completed in nine days. Twenty fry from each raceway were sacrificed to verify the thermal marking. These fry were sent to the Washington Department of Fish and Wildlife, Otolith Laboratory, in Olympia Washington. Recognizable otolith marks were verified on all thermally treated individuals.

Fry were stocked in Lake Pend Oreille at Sullivan Springs on June 25 and 26, and stocked into the Clark Fork River on July 2, 1997. We sent 100% (n=318) of the kokanee fry collected during the September trawling to the Washington Department of Fish and Wildlife for analysis. They catalogued each fish, recorded total length, and removed, cleaned and catalogued the saggita otoliths. Under a fume hood, otoliths were positioned on a glass plate and surrounded with a preformed rubber mold. Rubber molds were then filled with clear fiberglass resin and warmed in an oven for approximately 1 h for curing. The resulting blocks of resin containing the otoliths were cut into groups of four otoliths per block for sectioning and polishing. Blocks of four otoliths were lapped on a rotating disc of 500-grit carborundum paper until the nucleus of each otolith was clearly visible. The otoliths were then polished using a rotating polishing cloth saturated with a one micron deagglomerated alpha alumina and water slurry. After lapping and polishing, the otoliths were examined with a compound microscope at 200-power and/or 400-power magnification. Patterns within the otolith were compared to those on reference samples taken from the hatchery during fry rearing. Each otolith was examined by two independent readers for accuracy.

Shrimp Abundance

Opossum shrimp, or *Mysis* shrimp, *Mysis relicta* were sampled on June 4 to 6, 1997 to estimate their abundance and determine whether changes in shrimp abundance could influence the outcome of the lake level experiment. All sampling occurred at night during the dark phase of the moon. Eight sampling sites were randomly located in each of three sections of the lake (Figure 3). Student's t-tests were used to determine if densities were significantly different between lake sections (Scheaffer et al., 1979). We used GPS (global positioning system) coordinates to locate each sampling site.

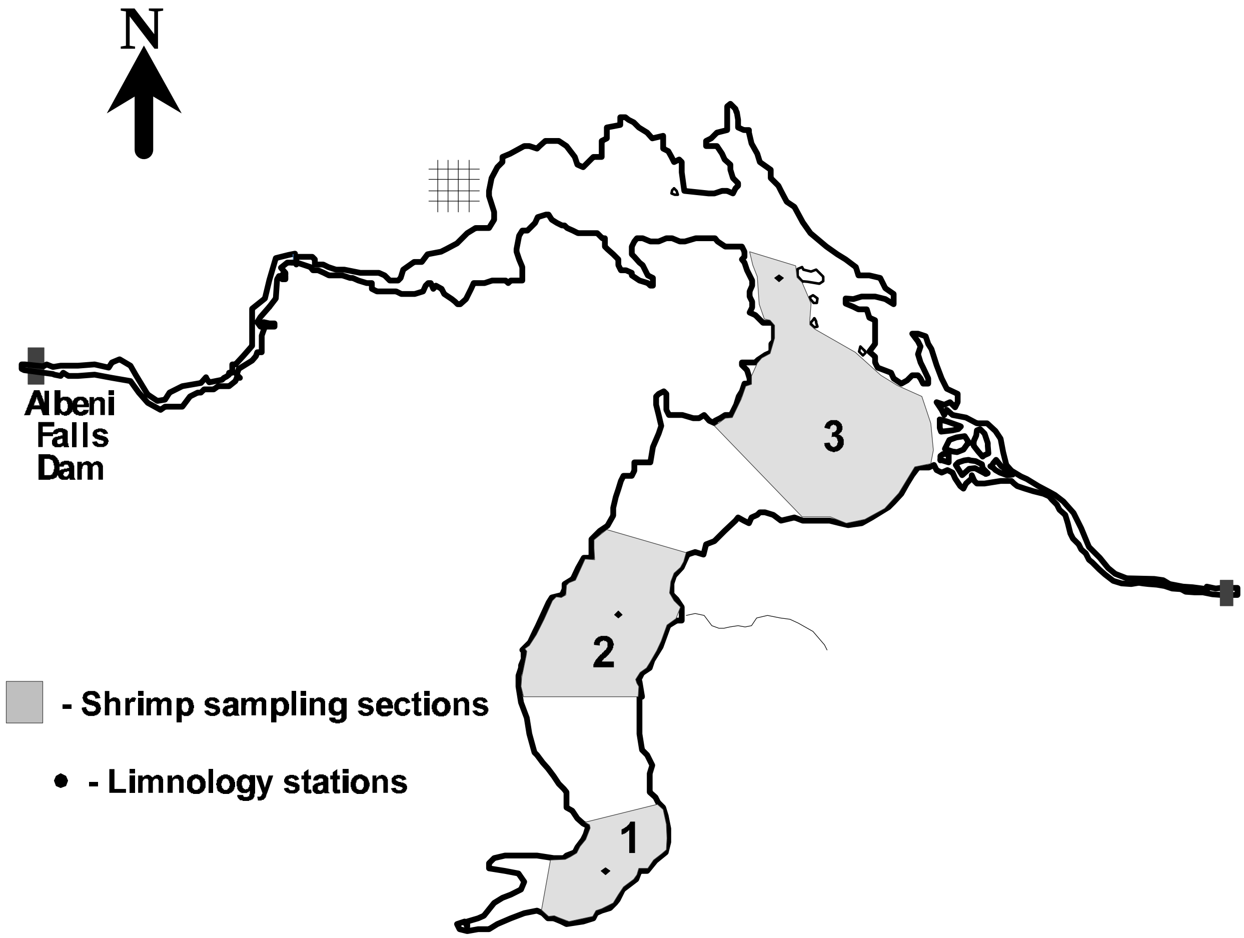


Figure 3. Three sections of Lake Pend Oreille used for estimating Mysis Shrimp abundance and the location of three limnological stations.

We collected shrimp using a hoop net that was 1 m in diameter and equipped with a flowmeter. Net mesh and cod-end bucket mesh measured 1,000 µm and 500 µm, respectively. We lowered the net to a depth of 45.7 m (150 ft) and raised it to the surface at a rate of 0.5 m/s (meters per second) using an electric winch. Shrimp were immediately placed in denatured ethanol for preservation.

Mysids were measured from the tip of the rostrum to the end of the telson, excluding setae, and classified into five categories according to sex characteristics; young-of-the-year (yoy), immature males and females, and mature males and females (Gregg 1976, Pennak 1978).

Limnology

We measured water temperature, dissolved oxygen, and water clarity (Secchi transparency) monthly from March through December 1997. Data were collected at three standardized stations, which represented the southern, middle, and northern sections of the lake (Figure 3). Sample dates were approximately the middle of each month. We used a Yellow Springs Instrument Company model 57 meter to measure temperature and dissolved oxygen from the surface to a depth of 59 m. The meter was calibrated before each survey using the "water saturated air" method suggested by the manufacturer. Water clarity was monitored at each station using a 20 cm Secchi disc during each survey.

RESULTS

Midwater Trawling

In 1997, we estimated kokanee abundance at 4.57 million fish (Table 1). Kokanee fry were the most numerous age-class: 2.23 million (+/- 15%). Hatchery fry (determined by the temperature mark on the otoliths) made up 37% of the total fry number in the southern end of the lake, 68% of the fry in the middle section of the lake, and 59% of the fry in the northern end of the lake. Based on these percentages we estimated the lake contained 1.02 million wild fry and 1.21 million fry of hatchery origin. We estimated the lake also contained 1.15 million age-1 kokanee (+/- 31%), 770,000 age-2 kokanee (+/- 25%), 380,000 age-3 kokanee (+/- 25%), and 41,000 age-4 kokanee (+/- 74%). No age-5 fish were sampled.

All of the age-4 kokanee and 7% of the age-3 kokanee in the trawl samples were found to be mature. Therefore, we estimated the lake contained 67,000 mature fish, of which 50% were estimated to be female. Fecundity averaged 335 eggs per female kokanee as determined at the Sullivan Springs egg station in 1997. Therefore, potential egg deposition was estimated at 11.19 million eggs. Hatchery crews collected 532,000 eggs at Sullivan Springs and 10,500 eggs at the Cabinet Gorge Fish Hatchery Ladder. This left 10.65 million eggs to be naturally spawned on the lakeshore and in tributary streams.

During 1996, we estimated 134.7 million eggs were laid on the lakeshore and tributaries. These eggs produced 1.02 million wild fry in 1997, for a wild egg-to-fry survival rate of 0.73%. Total PED to fry survival rate (including hatchery fry) was 1.5%. Survival rates of other age-classes of kokanee ranged from 22% for age-1 to age-2 fish, to a low of 7% for age-3 to age-4 fish (Table 2).

Spawner Counts and Surveys

Counts of kokanee spawning along the shoreline in 1997 were similar to past years; 2,518 fish. Nearly all of these fish, however, were seen at one location in Scenic Bay (Table 3).

Table 1. Kokanee population statics based on trawling lake Pend Oreille, Idaho, September 1997.

	Age					
	0	**1**	**2**	**3**	**4 and 5**	**Total**
Population estimate (millions)	2.23	1.15	0.77	0.38	0.04	4.57
+/- 90% CI	15%	31%	25%	25%	74%	
Density (fish/ha)	99	51	34	17	2	203
Mean weight (g)	1.9	26.5	41.7	59.1	103.8	
Standing stock (kg/ha)	0.2	1.4	1.4	1	0.2	4.2
Mean length (mm)	59	149	175	196	230	
Length range (mm)	20-90	80-180	150-200	170-230	200-250	

Table 2. Survival rates (%) for kokanee year classes (by age), in Lake Pend Oreille, Idaho, 1977-1996. Year class is the year eggs were laid.

Year			**Age Class**			
Class	**Eggs to 0**[a]	**0 to 1**	**1 to 2**	**2 to 3**	**3 to 4**	**Eggs to 3**
1996	1.5					
1995	7.3	21				
1994	1.9	78	22			
1993	3.1	42	110	12		0.17
1992	1.8	12	400	44	7	0.40
1991	4.9	32	47	106	59	0.80
1990	3.1	67	98	76	15	1.55
1989	2.8	25	94	256	38	1.70
1988	3.8	35	111	63	92	0.94
1987	6.3	16	124	53	83	0.66
1986	5.2	47	72	27	82	0.48
1985	1.4	47	65	88	44	0.37
1984	2.0	64	73	45	97	0.43
1983	7.3	39	66	63	81	1.26
1982	--	70	70	43	77	2.49
1981	2.4	59	53	[b]		
1980	1.3	119	18	[b]		
1979	1.4	80	47	[b]		
1978	1.0	50	79	[b]		
1977	1.6	72	73	[b]		

[a] Survival rate includes both wild and hatchery fry.

[b] Unable to calculate survival rate since age 3 and 4 kokanee were not separated prior to 1986.

Table 3. Counts of kokanee spawning along the shorelines of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly count.

Year	Bayview	Farragut Ramp	Idlewild Bay	Lakeview	Hope	Trestle Cr. Area	Sunnyside	Garfield Bay	Camp Bay	Anderson Point	Total
1997	2509	0	0	0	0	7	2	0	0	-	2,518
1996	42	0	0	4	0	0	0	3	0	-	49
1995	51	0	0	0	0	10	0	13	0	-	74
1994	911	2	0	1	0	114	0	0	0	-	1,028
1992	1,825	0	0	0	0	0	0	34	0	-	1,859
1991	1,530	0	-	0	100	90	0	12	0	-	1,732
1990	2,036	0	-	75	0	80	0	0	0	-	2,191
1989	875	0	-	0	0	0	0	0	0	-	875
1988	2,100	4	-	0	0	2	0	35	0	-	2,141
1987	1,377	0	-	59	0	2	0	0	0	-	1,438
1986	1,720	10	-	127	0	350	0	6	0	-	2,213
1985	2,915	0	-	4	0	2	0	0	0	-	2,921
1978	798	0	0	0	0	138	0	0	0	0	936
1977	3,390	0	0	25	0	75	0	0	0	0	3,490
1976	1,525	0	0	0	0	115	0	0	0	0	1,640
1975	9,231	0	0	0	0	0	0	0	0	0	9,231
1974	3,588	0	25	18	975	2,250	0	20	0	50	6,926
1973	17,156	0	0	200	436	1,000	25	400	617	0	19,834
1972	2,626	25	13	4	1	0	0	0	0	0	2,669

Counts of kokanee spawning in tributary streams dropped to their lowest number ever recorded (Table 4). Only 644 kokanee were seen which was well below the average of 8,150 seen during counts between 1972 and 1996. Nearly all of these fish (615) were early spawning kokanee that were counted in Trestle Creek during September 1997. During the November to December spawning season most tributaries had few, if any, fish. For example, Spring Creek contained only three fish instead of its typical 2,000 to 4,000 spawners.

We surveyed 2,100 m^2 of redds along the shoreline of the lake (Figure 2). The most heavily used areas were in the south end of the lake. Scenic Bay had the most redds (770 m^2), followed by the shoreline section from Idlewild Bay to Gold Creek (627 m^2). The north end of the lake had notably fewer redds, although considerable areas of spawning habitat were present.

The depths of the redds ranged from 0.3 to 6.1 m (Figure 4, Appendix B). The modal depth of spawning was 1.22 m.

Shrimp Abundance

The estimated mean density of shrimp during June, 1997 was 520 shrimp/m^2 (Table 5). This included 270 young-of-the-year shrimp/m^2 (<7 mm) and 250 juvenile and adult shrimp/m^2. Mean density of juvenile and adult shrimp dropped for the third year in a row (Figure 5).

Shrimp densities were significantly ($P<0.05$) lower in the northern section of Lake Pend Oreille. This difference was apparent in both the young-of-the-year shrimp as well as the juvenile and adult shrimp (Table 5).

Limnology

The northern section of the lake had considerably lower water transparencies than the middle and southern sections (Table 6). Transparencies averaged only 4.4 m at the northern end versus 7.3 m and 7.0 m at the middle and southern sections, respectively. During spring run-off in May, transparency dropped to its lowest point of 0.7 m at the northern station. The maximum Secchi depth of 16.5 m was recorded at the mid-lake station during April.

Water temperatures in the lake ranged from a low of 2.9°C at the surface during March to a high of 21.9°C at the surface during August 1997 (Figure 6). Stratification began in mid-June with water temperatures exceeding 14°C at this time. Stratification broke down between mid-September and mid-October. Water over 14°C reached a depth of 21 m in the northern section, 16 m in the middle section, and 19 m in the southern section during the September 17 survey.

Dissolved oxygen concentrations were similar among all three stations in 1997. Concentrations ranged from 13.5 mg/l in May to 8.2 mg/l in September on the south end of the lake; from 14.0 mg/l in May to 8.3 in September at the mid-lake station; and from 13.6 mg/l in May to 8.2 in September at the northern station. As expected, dissolved oxygen declined as temperature increased.

Table 4. Counts of kokanee spawning in tributaries of Lake Pend Oreille, Idaho. The numbers shown indicate the highest weekly counts at each site.

Year	S. Gold	N. Gold	Cedar	Johnson	Twin	Mosquito	Lightning	Spring	Cascade	Trestle[a]	Trestle	Total
1997	0	20	6	0	0	--	--	3	--	615	0	644
1996	0	42	7	0	0	--	--	17	--	753	0	819
1995	166	154	350	66	61	--	0	4,720	108	615	21	6,261
1994	569	471	12	2	0	--	0	4,124	72	170	0	5,420
1992	479	559	--	0	20	--	200	4,343	600	660	17	6,878
1991	120	550	--	0	0	--	0	2,710	0	995	62	4,437
1990	834	458	--	0	0	--	0	4,400	45	525	0	6,262
1989	830	448	--	0	0	--	0	2,400	48	466	0	4,192
1988	2,390	880	--	0	0	--	6	9,000	119	422	0	12,817
1987	2,761	2,750	--	0	0	--	75	1,500	0	410	0	7,496
1986	1,550	1,200	--	182	0	--	165	14,000	0	1,034	0	18,131
1985	235	696	--	0	5	--	127	5,284	0	208	0	6,555
1978	0	0	0	0	0	0	44	4,020	0	1,589	0	5,653
1977	30	426	0	0	0	0	1,300	3,390	0	865	40	6,051
1976	0	130	11	0	0	0	2,240	910	0	1,486	0	4,777
1975	440	668	16	0	1	0	995	3,055	0	14,555	15	19,740
1974	1,050	1,068	44	1	135	0	2,350	9,450	0	217	1,210	15,525
1973	1,875	1,383	267	0	0	503	500	4,025	0	1,100	18	9,671
1972	1,030	744	0	0	0	0	350	2,610	0	0	1,293	6,027

([a]) September count of early spawning kokanee.

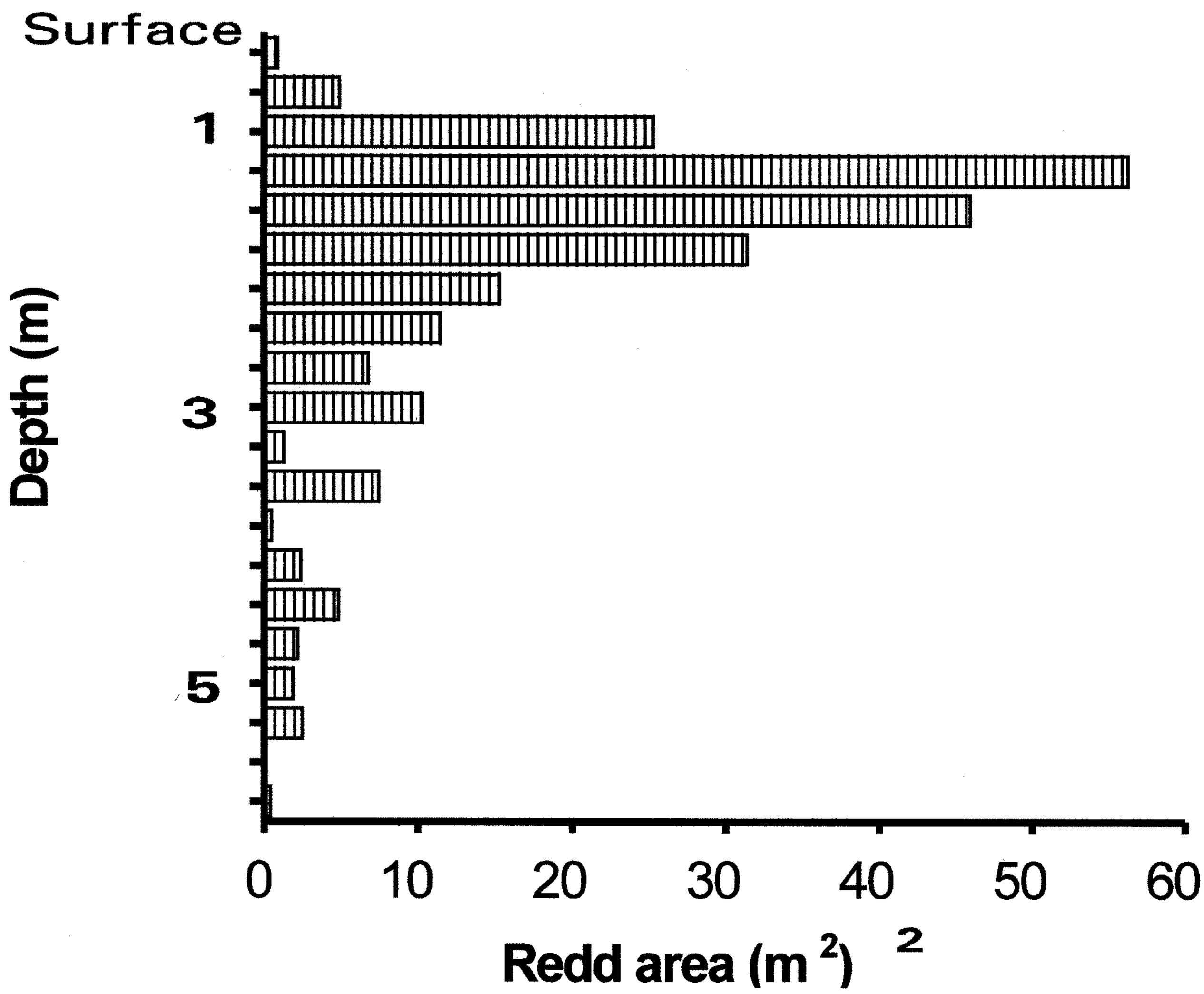


Figure 4. Depth distribution of kokanee redds in Lake Pend Oreille, Idaho. Area of redds is the sum of all redds surveyed around the perimeter of the lake.

Table 5. Densities (per m^2) of *Mysis* shrimp in Lake Pend Oreille, Idaho, June 4-6, 1997. Sections are shown in Figure 3.

Section - site	Young-of-the-Year/m^2	Juveniles and Adults/m^2	Total shrimp / m2
1-1	1,154	652	1,806
1-2	140	220	360
1-3	828	502	1,330
1-4	321	143	464
1-5	452	109	561
1-6	34	100	134
1-7	218	912	1,130
1-8	305	400	705
Section 1 means	431.5	379.8	811
2-1	169	185	345
2-2	230	252	482
2-3	200	464	664
2-4	318	385	703
2-5	259	244	503
2-6	586	273	859
2-7	302	197	499
2-8	647	187	834
Section 2 means	338.9	273.4	612.3
3-1	60	72	132
3-2	104	156	260
3-3	30	69	99
3-4	62	227	289
3-5	12	67	79
3-6	17	43	60
3-7	53	128	181
3-8	14	57	71
Section 3 means	44	102.4	146.4
Whole lake means	272	251.8	523.3
Standard deviation	286.1	210.4	435.6

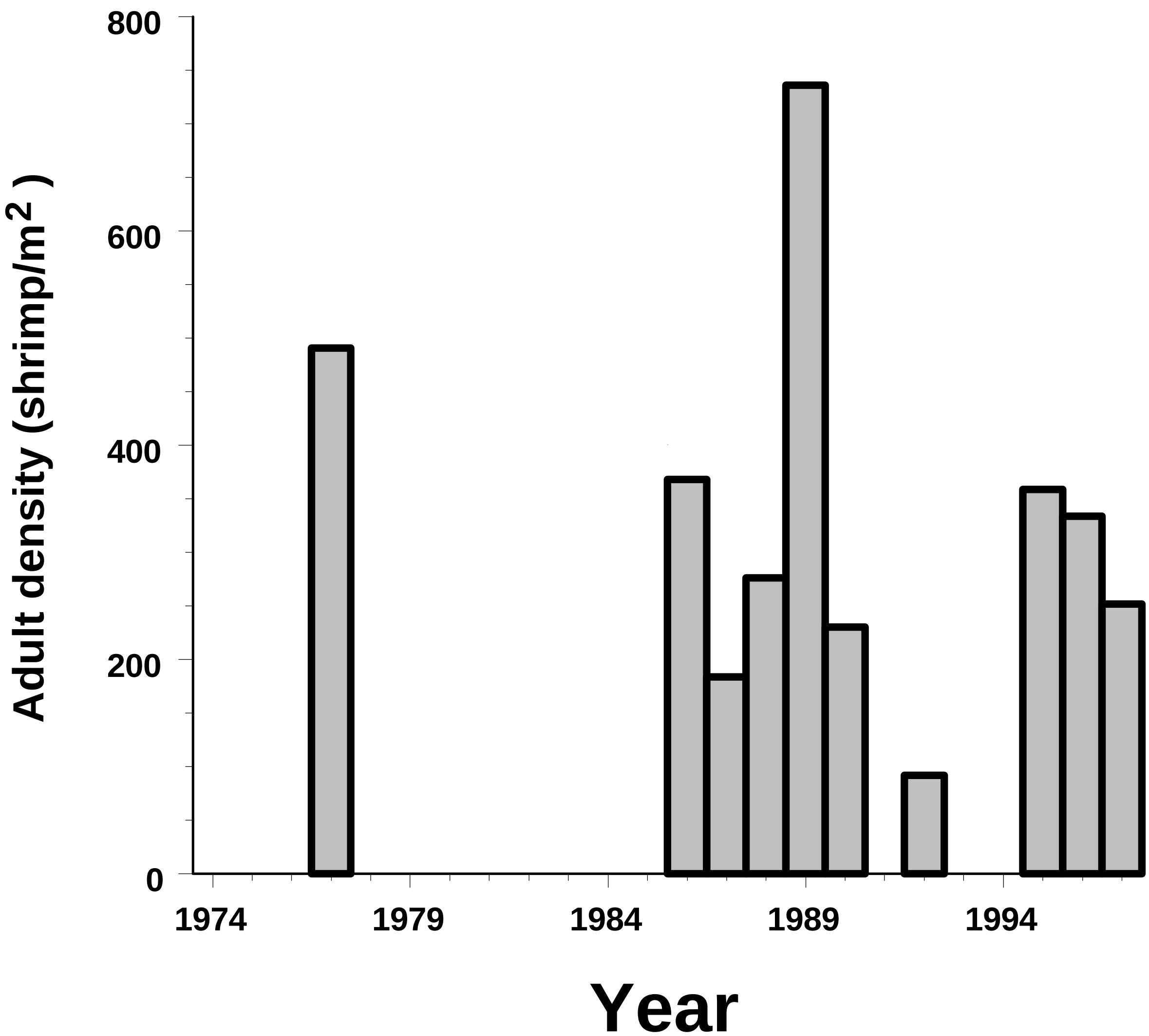


Figure 5. Density of adult and juvenile *Mysis* shrimp in Lake Pend Oreille, Idaho. Gaps in the bar chart indicate no data were collected or that the adult and juvenile fraction could not be determined.

Table 6. Secchi dish transparencies (m) at three locations in Lake Pend Oreille, Idaho, 1953, 1974, and 1997.

	April	May	June	July	Aug.	Sept.	Oct.	Mean
Southern station								
1953	11.9	8.0	3.7	6.1	11.6	8.5	12.8	8.9
1974	8.8	7.6	3.7	3.9	9.2	9.1	9.3	7.4
1997	12.5	4.0	2.7	6.5	8.2	9.0	6.2	7.0
Mid-lake station								
1953	--	--	3.7	6.1	10.7	12.2	12.2	--
1974	--	5.5	2.3	4.7	9.8	9.4	11.6	--
1997	16.5	5.2	2.0	5.0	7.9	6.8	8.0	7.3
Northern station								
1953	3.0	3.7	0.9	6.4	9.4	11.0	10.4	6.4
1974	4.0	0.9	0.4	2.8	9.4	10.2	11.6	5.6
1997	5.3	0.7	1.0	4.0	8.5	5.8	5.5	4.4

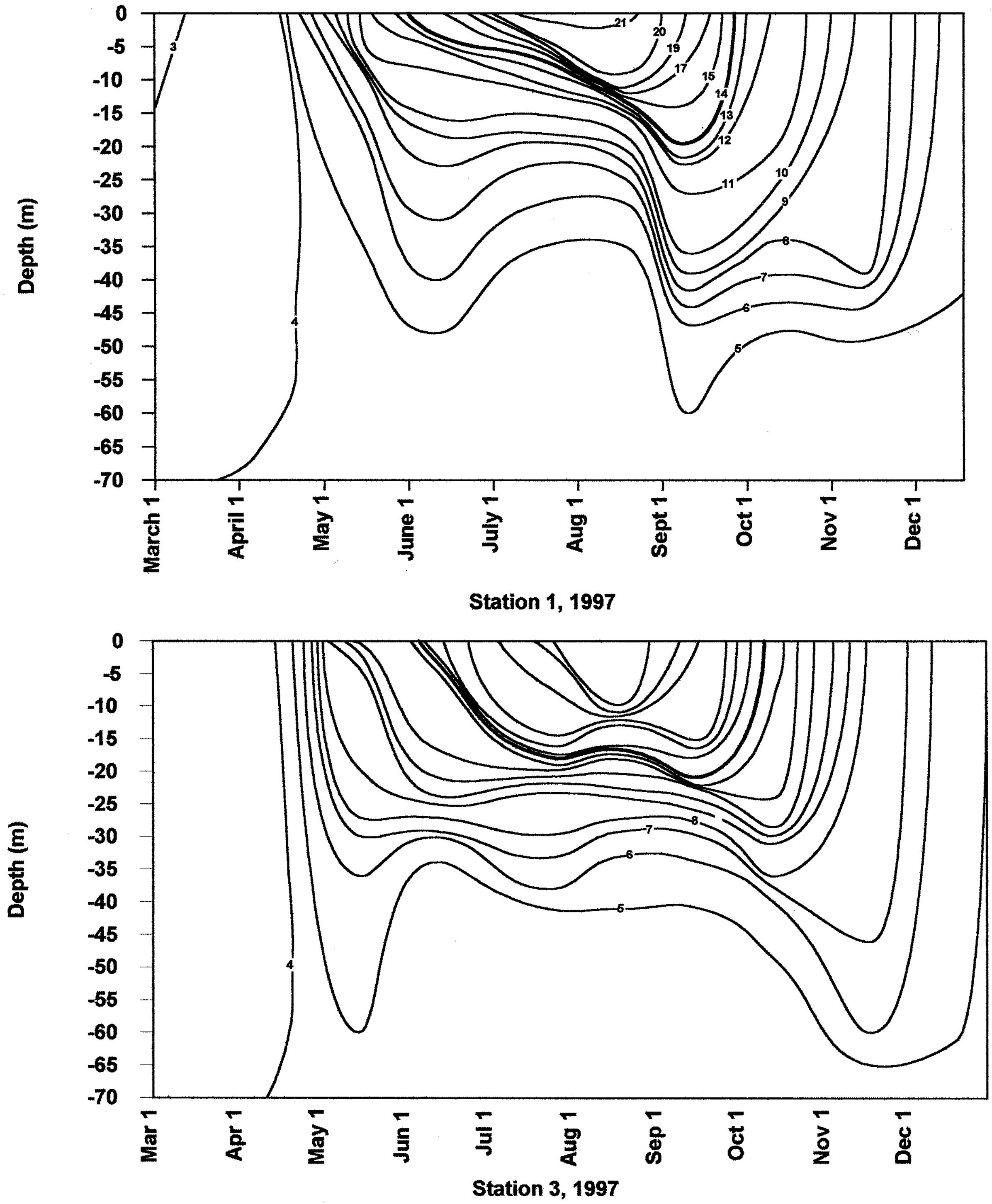


Figure 6. Isopleths of water temperatures (C°) at two sites in Lake Pend Oreille, Idaho. Locations of the sampling stations are illustrated in Figure 3.

DISCUSSION

Kokanee Abundance

During 1997, we made several key findings that suggested higher fall-winter lake levels can improve kokanee abundance. Kokanee readily utilized the new gravel above the 625.1 m (2051 ft) elevation (Figure 4) that was known to contain less silt and sand (Maiolie and Elam 1993). This could have improved the survival of incubating eggs by providing them with more oxygen and allowing waste products to be carried away (Bjornn 1969). Kokanee also appeared to utilize much of the southern half of the lake for spawning. Although not previously mapped, most kokanee were thought to be spawning in the Scenic Bay area as evident in the spawner counts (Table 3). The spreading of spawning activities would have dispersed kokanee redds and minimized their superimposition. A second advantage would be that newly emerged fry would be dispersed throughout the lake, minimizing the potential for intra-specific competition. It also may have reduced the potential for predators to key in on kokanee fry. Lastly, the reduction in the numbers of kokanee spawning in tributary streams may have indicated the kokanee were selecting lakeshore areas for spawning and not migrating up tributaries. Presumably, kokanee would select spawning sites which would maximize the egg's chances for survival, so this could have been a benefit. This possibility, however, goes against the fish's natural instinct to return to natal spawning areas (if, in fact, some adult kokanee had originated from tributary streams).

The experiment, however, suffered a serious setback during 1997. The poor survival rates for all age-classes of kokanee, including fry, nullified any benefits that resulted from higher lake levels. Survival rates of all age-classes were about one half of what would be expected in a normal year. Therefore, no increase in fry numbers could be detected.

Two environmental anomalies were suspected as the primary factors limiting kokanee survival in 1997. The first anomaly was the high flows during spring run-off (Figure 7). Inflow peaked at 4,360 m^3/s and filled the lake to 629.6 m (2065.74 ft); 1.0 m above full pool. High outflows from the lake could have caused kokanee to emigrate in large numbers. In Idaho's Dworshak Reservoir, high flows during winter and spring were found to lead to high entrainment losses of kokanee through the dam (Maiolie and Elam 1997). The second anomaly was very high dissolved gas levels at the north end of the lake. Gas saturation at the 5 m depth was 120-130% as far west as Sandpoint and as far south as Camp Bay (Parametrix 1997). Rainbow and cutthroat trout placed in live cages in the Clark Fork River from June 20 to 24,1997, suffered 100% mortality at a total dissolved gas level of 140% of saturation (Parametrix 1997). The effect of these high dissolved gas levels on kokanee within the lake is unknown. Closer monitoring of dissolved gas is recommended.

Unfortunately, environmental factors also reduced the numbers of adult kokanee in the lake to their lowest point on record. Consequently, potential egg deposition for 1997 was at its lowest point on record. Thus, the second year of the lake level experiment will be strongly affected. We cannot expect to see high numbers of fry in 1998 due to the low potential egg deposition. We will, however, monitor fry abundance and estimate survival of these 13 million eggs.

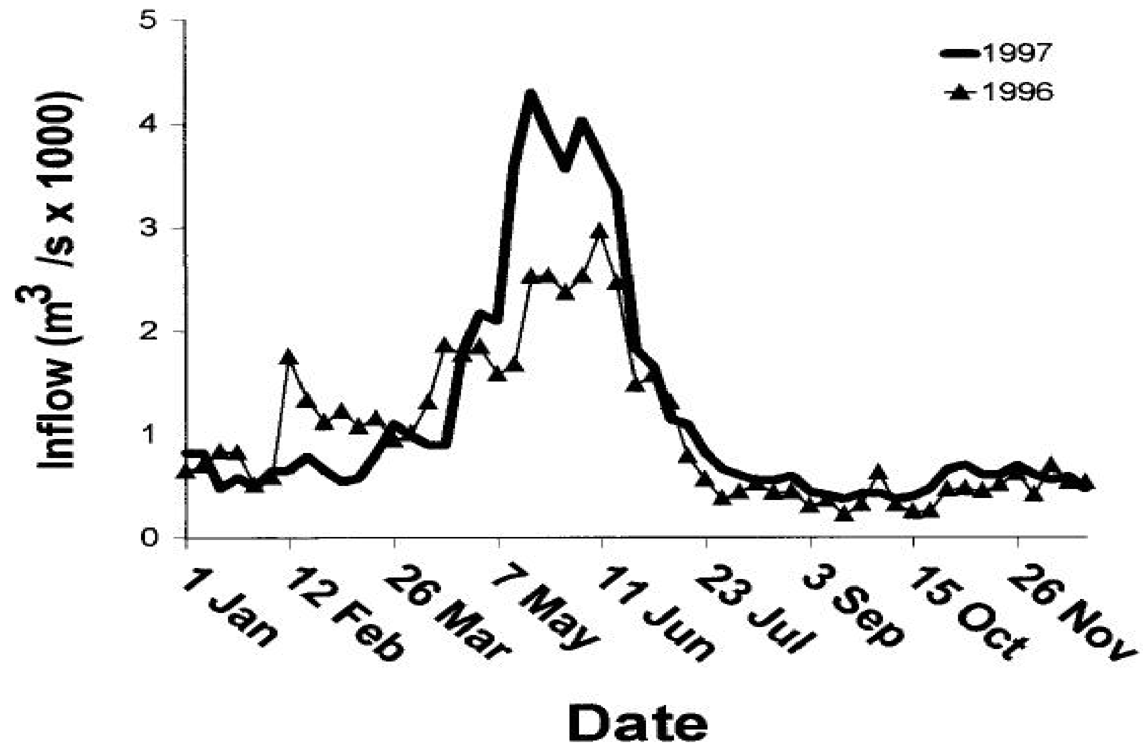


Figure 7. Inflow to Lake Pend Oreille, Idaho, during 1996 and 1997.

Shimp Abundance

We monitored the shrimp population to determine if changes in shrimp abundance could be affecting kokanee survival. If the shrimp population declines or expands during this experiment, then it could have an effect on the experiment's outcome. At the end of the test, kokanee survival rates will be regressed against shrimp abundance to look for correlations.

Young-of-the-year shrimp in Lake Pend Oreille exert little predation mortality on crustacean zooplankton and do not become potential competitors with kokanee until they reach a length of >8 mm (Chipps 1997). Accordingly, the density of juvenile and adult shrimp provides the best guideline for interpreting potential competition between shrimp and kokanee. Juvenile and adult shrimp in Lake Pend Oreille reached 750/m^2 in 1989 (Figure 5). Over the last three years, their abundance has declined to its current level of 250/m^2. During this first year of our test, we do not anticipate the changes in shrimp abundance will negatively affect the outcome of the experiment.

Limnology

We monitored basic parameters of physical limnology to determine if they influenced the outcome of the lake level experiment. Unusually cold or warm years, for example, could affect survival of fry and bias the test results. Our results will be more meaningful once the five years of this study are completed and individual years can be compared to the survival of kokanee fry.

Survival rates of all age-classes of kokanee were unusually low in 1997 (Table 2). This did not appear to be due to temperature, oxygen, or primary productivity as indicated by Secchi transparency. Temperatures were similar to those recorded between 1985 and 1990 when kokanee survival was higher (Paragamian et al., 1991). Stratification was of a normal duration and provided a good "thermal refuge" of water above 14°C, which would inhibit shrimp and allow zooplankton populations to expand. Oxygen was well above the level needed for fish survival and growth. Piper et al., (1982) stated that 5 ppm is the lowest safe level for trout. Below this level, growth and survival would be reduced. In Lake Pend Oreille during 1997, dissolved oxygen was above 8 mg/L; more than adequate for good fish survival and growth. Secchi transparency indicated primary production was normal (except when the north end of the lake became muddy in the spring). Transparencies were somewhat lower than 1953 and 1974, which could indicate higher primary production, but this would be a benefit to kokanee (Table 6).

RECOMMENDATIONS

1. We recommend continuing the lake level experiment, as planned.
2. Lake inflow, outflow, and dissolved gas saturation should be monitored as habitat variables which could influence test results.

ACKNOWLEDGMENTS

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APPENDICES

Appendix A. Definition of areas surveyed for shoreline spawning kokanee in Lake Pend Oreille, since1972.

Scenic Bay

From Vista Bay Resort to Bitter End Marina (the entire area within the confines of these two marinas).

Farragut State Park

From state park boat ramp go both left and right approximately 1/3 km.
Idlewild Bay, From Buttonhook Bay north to the north end of the swimming area parking lot.

Lakeview

From mouth of North Gold Creek go north 100 meters and south 1/2 km.

Hope/East Hope

Start at the east end of the boat launch overpass and go west 1/3 km.
From Strong Creek go west and stop at Highway 200. Go east to Litehouse Restaurant.
Start at East Hope Marina and go west, stopping at Highway 200.

Trestle Creek Area

From the Army Corps of Engineers recreational area boat ramp go west to mouth of Trestle Creek, including Jeb and Margaret's RV boat launch area.

Sunnyside

From Sunnyside Resort go east approximately 1/2 km.

Garfield Bay

Along docks at Harbour Marina on east side of bay.
From the Idaho Fish and Game managed boat ramp go toward Garfield Creek. Cross Garfield Creek and proceed 1/4 km.
Survey Garfield Creek up to road culvert.

Camp Bay

Entire area within confines of Camp Bay.

Fisherman's Island

Entire Island Shoreline - not surveyed since 1978.

Anderson Point

Not surveyed since 1978.

Appendix B. Area (m^2) of kokanee redds surveyed along each of 14 sections of shoreline of Lake Pend Oreille, Idaho, 1997. See Appendix C for section boundaries.

	Lake Section														
Depth (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Total**
0.30	0.0	0.0	0.0	0.6	7.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.7
0.61	0.0	0.3	1.1	0.3	38.3	4.5	0.0	0.0	0.2	0.0	0.3	0.3	0.0	0.0	45.3
0.91	0.0	2.1	12.5	37.2	100.7	42.0	7.5	2.3	20.9	0.0	3.3	0.2	0.0	0.0	228.7
1.22	0.0	3.9	12.9	136.2	133.7	157.6	22.3	16.4	19.0	0.4	0.7	4.1	0.0	0.0	507.2
1.52	0.0	2.5	18.3	133.0	110.4	90.3	23.2	18.7	14.8	0.5	2.8	0.3	0.0	0.0	414.8
1.83	0.0	1.9	17.3	29.7	94.5	102.3	16.6	7.3	11.9	0.8	1.3	0.3	0.0	0.0	283.9
2.13	0.0	0.0	0.8	13.0	65.1	38.6	11.0	1.8	7.9	0.3	0.0	0.0	0.0	0.0	138.5
2.44	0.0	0.2	2.3	3.8	35.0	53.4	1.3	2.3	4.4	1.2	0.0	0.0	0.0	0.0	103.9
2.74	0.0	0.3	0.6	4.2	51.4	3.8	0.3	0.3	0.2	0.0	0.8	0.0	0.0	0.0	61.9
3.05	0.0	0.0	0.2	9.2	23.3	49.6	1.1	4.5	0.4	0.0	5.0	0.0	0.0	0.0	93.3
3.35	0.0	0.0	0.0	0.3	10.9	0.3	0.2	0.0	0.8	0.0	0.0	0.0	0.0	0.0	12.5
3.66	0.0	0.0	1.6	4.7	11.2	34.5	5.3	1.3	3.5	0.0	5.9	0.0	0.0	0.0	68.0
3.96	0.0	0.0	0.0	0.2	2.9	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3
4.27	0.0	0.0	0.0	0.0	21.6	0.2	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	22.2
4.57	0.0	0.0	0.0	0.0	17.5	26.4	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	44.6
4.88	0.0	0.0	0.0	0.3	16.8	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.7
5.18	0.0	0.0	0.0	0.3	14.9	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.9
5.49	0.0	0.0	0.0	0.0	14.9	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.9
5.79	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
6.10	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6
Total	**0.0**	**11.2**	**67.6**	**373.0**	**770.4**	**625.4**	**89.1**	**55.7**	**84.0**	**3.2**	**20.1**	**5.2**	**0.0**	**0.0**	**2,104.9**

Appendix C. Description of shoreline sections used in mapping kokanee redds during 1997.

Section Number	Location
1	Contest Point to Anderson Point
2	Anderson Point to Long Point
3	Long Point to Maiden Rock
4	Maiden Rock to Cape Horn
5	Cape Horn to Lieberg Point
6	Lieberg Point to Gold Creek
7	Gold Creek to Wiskey Rock
8	Whiskey Rock to Windy Point
9	Windy Point to Clark Fork Delta
10	Clark Fork Delta to Hope Point
11	Hope Point to Boat Basin
12	Boat Basin to Pack River Delta
13	Pack River Delta to Fisherman Island
14	Warren, Cottage, Pearl, and Memaloose Islands

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