IDAHO
DEPARTMENT OF FISH & GAME

Joseph C. Greenley, Director

FEDERAL AID TO FISH & WILDLIFE RESTORATION

Job Performance Report

Project F-73-R-1

SUBPROJECT III: LAKE & RESERVOIR INVESTIGATIONS

Study II: Pend Oreille Lake Fisheries Investigations

Period Covered: 1 March 1978 - 28 February 1979

by

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Principal Fishery Research Biologist

Bruce E. Rieman Fishery Research Biologist

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August, 1979

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SUBPROJECT III: LAKE & RESERVOIR INVESTIGATIONS Study II:
Pend Oreille Lake Fisheries Investigations

Job I. Pend Oreille Lake Creel Census by

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Job II. Kokanee Spawning Trends in Pend Oreille Lake by

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Job III. Limnological Studies in Pend Oreille Lake by

Bruce E. Rieman Fishery Research Biologist

Job IV. Kokanee Life History Studies in Pend Oreille Lake

by

Bert Bowler
Principal Fishery Research Biologist
Period Covered: 1 March 1978 to 28 February 1979 August, 1979

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INTRODUCTION

The primary objective of the Pend Oreille Lake studies is assessment of the kokanee population in the lake. Parameters influencing population abundance or stock density of kokanee include basic productivity of the water, fish growth, production, mortality (natural and fishing), spawning escapement, survival, and recruitment of new fish to the population (Fig. 1). Through a program of limnological studies, echosounding, midwater trawling, spawning escapement evaluation, age and growth analysis and angler harvest and opinions, we hope to gain more knowledge about kokanee population dynamics in Pend Oreille for development of alternatives to managing the kokanee fishery in the lake.

Description of the Area and its Fishery

Pend Oreille Lake is a large oligotrophic lake located in the mountains of Northern Idaho (Fig. 2). In 1952 the lake was impounded by Albeni Falls Dam on the Pend Oreille River from which the lake level can fluctuate from an elevation of 625 m (2,049 ft) to 629 m (2,062 ft) or a maximum drawdown of about 4 m (13 ft). After impoundment the lake surface area expanded to 38,348 ha (94,720 acres). Pend Oreille Lake is one of the deepest lakes in the United States with a maximum depth of 351 m (1,152 ft) and a mean depth of approximately 164 m (538 ft). The long axis of the lake lies north-south along the direction of the prevailing winds. The Clark Fork River is the major tributary entering the lake (Fig. 2).

The kokanee salmon (*Onchorhynchus nerka*) is the predominant fish species in Pend Oreille Lake. Its population has been supported by natural reproduction since entering the lake in the early 1930s. They are primarily of the late-spawning variety (spawning 1 November to 1 January) although the lake does support a small population of early-spawners (spawning 1 September to 15 October) in Trestle Creek. Kokanee are the major prey species for the Gerrard rainbow (Kamloops) trout (*Salmo gairdneri*) which has gained national recognition. Kamloops ranging to 16.8 kg (37.0 lb) have been caught in the lake. Other game fish species in the lake include Dolly Varden (*Salvelinus malma*), rainbow trout (*Salmo gairdneri*), cutthroat trout (*Salmo clarki*), mountain whitefish (*Prosopium williamsoni*) lake whitefish (*Coregonus clupeaformis*) and a few spiny-rayed species.

Until the early 1970s Pend Oreille Lake was the most popular kokanee fishing lake in Idaho. It supported a commercial fishery with an average annual sport and commercial yield of 1,000,000 kokanee from 1951 (when catch statistics were first recorded) to 1965 with an annual average of 225, 000 hours of angling effort. Since 1965 the kokanee catch has steadily declined to present levels of less than 200,000. In 1973 the commercial fishery was terminated and a reduced sport limit was imposed. Overall, catch statistics indicate that present levels of kokanee abundance in the lake are not what they were in the mid 1960s when anglers enjoyed catch rates of 2.5 to 3.0 fish per hour. Prompted by these trends, the Idaho Department of Fish and Game initiated a comprehensive study of the kokanee population and the Pend Oreille system in 1974.

Several perturbations have occurred in Pend Oreille Lake since the early 1950s when kokanee populations were well established. The construction of Cabinet Gorge Dam on the Clark Fork River in 1952 eliminated a spawning run of kokanee. Also in the same year completion of Albeni Falls Dam on the Pend Oreille River changed the

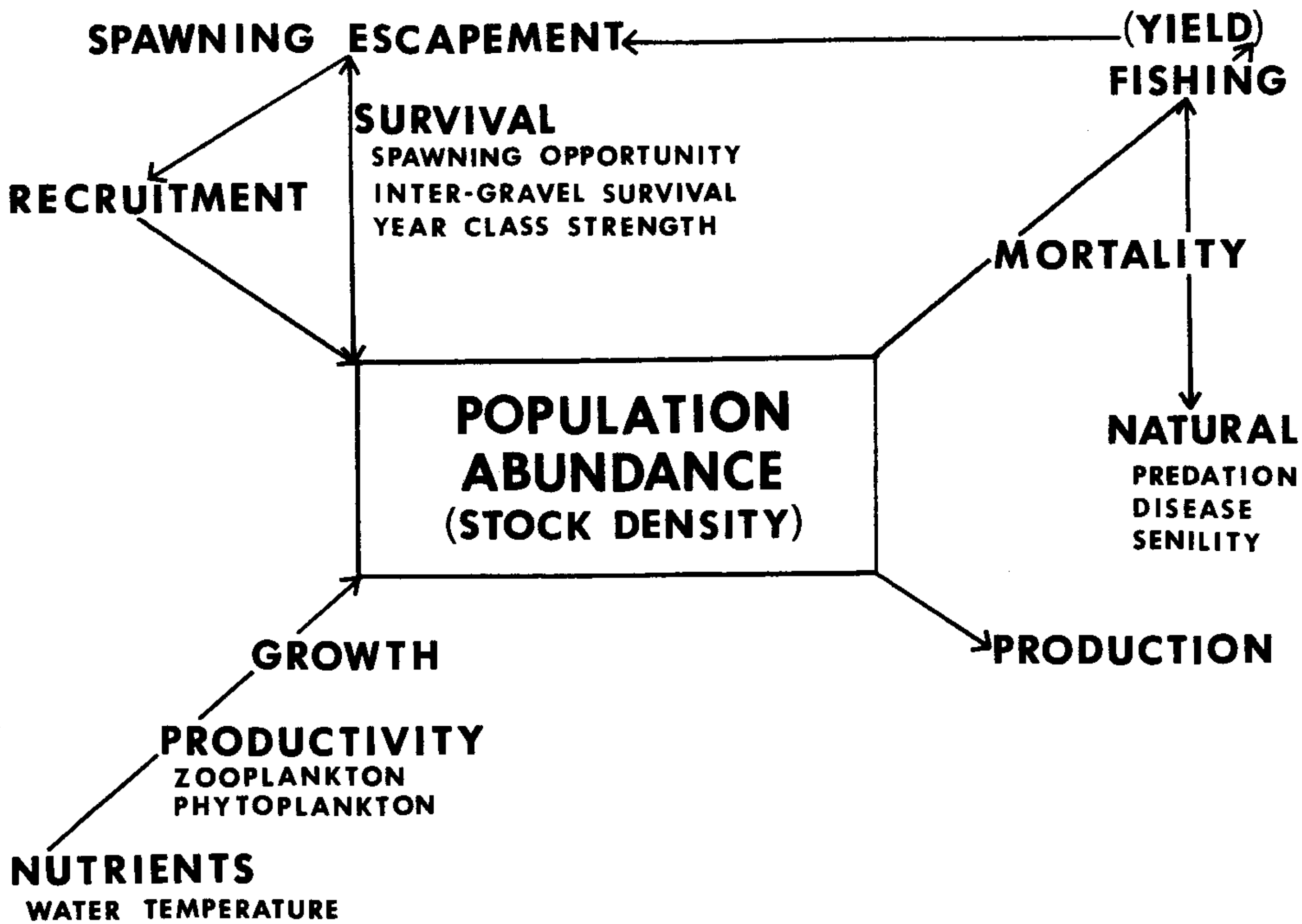

Figure 1. Diagram of parameters influencing the population abundance (stock density) of kokanee in Pend Oreille Lake.

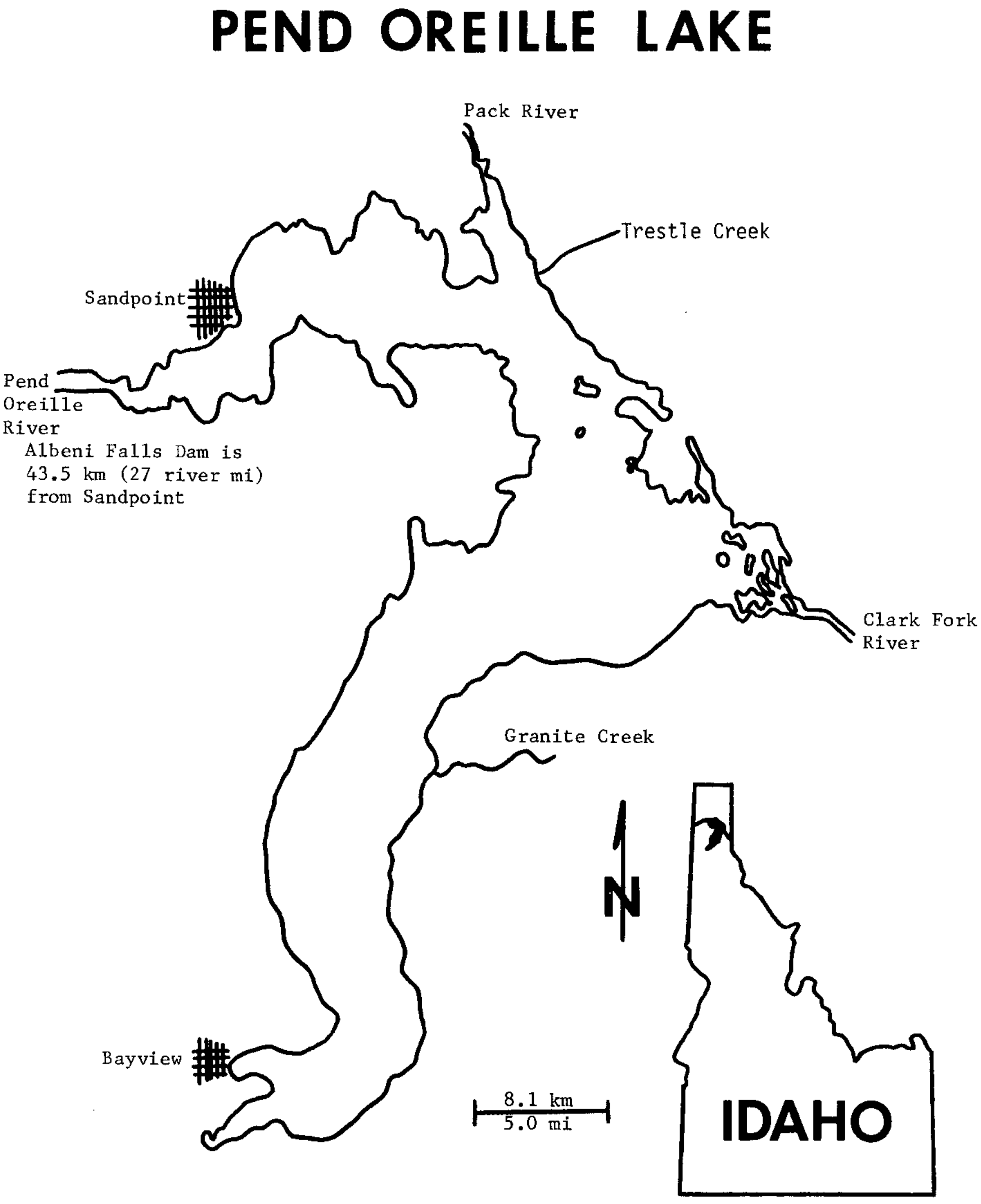

Figure 2. Pend Oreille Lake, Idaho.

water level regime of the lake. Shoreline gravels that were not previously avail-able to kokanee spawners were watered by reservoir levels held in November and December during spawning. It was suggested that newly watered gravels attracted kokanee spawners.

The kokanee population, although somewhat cyclical, continued to increase during the late 1950s and early 1960s (based on catch statistics) after the construction of both dams. One might speculate that kokanee production lost from the Clark Fork River may have been replaced by increased kokanee spawning success in new shoreline gravels created by higher reservoir water levels.

Between 1951 and 1968 the lake water level was drawn down an average of 1.3 m (4.2 ft) per year after 15 November when kokanee embryos were deposited in shoreline gravels and resulted in mortalities. Since 1968 the lake has been held at a minimum pool level before much kokanee spawning commenced. Quantifying mortality related to operations of Albeni Falls Dam is difficult because data was not collected during the 1960s. Cummulative effects of repeated dewatered shoreline gravels on consecutive kokanee year-classes may have influenced the downward trend in population beginning in the mid 1960s.

Another lake perturbation occurred after Mysis relicta (opposum shrimp) were released into the lake to provide additional kokanee forage. They were first introduced in 1968 and by 1974 had become well established, severely altering macro zooplankton composition. Preferred kokanee food items were reduced in abundance and shifted temporarily to a later occurrence.

There is little indication that predator populations of Kamloops trout and Dolly Varden have changed appreciably in Pend Oreille Lake in the past 20 years. Catch statistics indicate that Dolly Varden may have declined since the early 1950s but have stabilized since the 1960s to present levels with slight variations from year to year. Kamloops catch has remained relatively constant with average fluctuations. in catch. Hatchery released Kamloops during the late 1950s and 1960s appeared to contribute little to angler creels, suggesting poor survival. As of 1978, less than 0.10% of 500,000 marked hatchery Kamloops returned to angler creels. Poor survival has been attributed to a hatchery broodstock that had been removed from the wild many generations.

As the kokanee population declines, predation likely becomes a more significant form of natural mortality. The hatchery broodstock of Kamloops used to stock Pend Oreille Lake has been replaced by a feral population which should enhance survival of future releases. Future plans include very limited Kamloops releases until the prey population can support additional predators. The present feral broodstock program was initiated to provide a hatchery return of wild fish.

Kokanee populations in Pend Oreille Lake continue to decline. Mortalities associated with reservoir water levels have been minimized since the early 1970s. Little is known about changes in gravel quality in the shoreline areas in the past 30 years but tributary gravels have deteriorated significantly. Kokanee food supply has been dramatically altered with the introduction of Mysis relicta. Predation up-on kokanee will likely become more significant as numbers decline. This report evaluates in detail possible causes of the decline and alternatives to restoring the kokanee population in the lake.

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Peter Hassemer - fishery and limnological data collection and analysis. Jim

Lukens - kokanee age and growth analysis.

Virgil Moore - kokanee age and growth analysis.

Anthony Bubb - creel census clerk.

Carolyn Cox - creel census clerk.

Charles Parker - creel census clerk.

Clark Fork Hatchery personnel - kokanee embryo collection, incubation, rearing and release.

Washington Water Power Company - providing temporary help.

U.S. Army Corps of Engineers - assistance in kokanee spawning evaluation and contract for limnological data collected on the lake.

JOB PERFORMANCE REPORT

State of Idaho

Name: LAKE AND RESERVOIR INVESTIGATIONS

Project No. F-73-R-1

Title: Pend Oreille Lake Creel Census

Study No. II

Job No. I

Period Covered: 1 March 1978 to 28 February 1979

ABSTRACT

In 1978 Pend Oreille Lake sport anglers fished an estimated 226,453 hours during 48,470 man-days to catch 178,135 fish between 13 January and 30 November. Sixty-one percent of the anglers fished for kokanee which comprised 94% of the estimated catch while 39% fished for trout, including Dolly Varden, which comprised 5% of the estimated catch. A small percentage of the anglers (negligible) fished for whitefish and spiny-rayed species which made up 1% of the total catch.

Anglers seeking kokanee fished an estimated 120,363 hours to catch 164,508 kokanee for an average catch rate of 1.4 fish per hour. The 1978 kokanee catch and effort was the lowest recorded since 1951 when the census commenced.

The estimated kokanee yield in 1978 weighed 18,914 kg (41,705 lb) which is equivalent to 0. 84 kg/ha (.75 lb/acre). Large kokanee ranging to 53 cm (21 in) in length and weighing 1.6 kg (3.5 lb) appeared in the 1978 catch.

Early-spawning kokanee contributed very little to angler success on the north end of the lake during 1978 (1.2%). In 1974 and 1975, 3.5 million early-spawning kokanee fry were released into the north end tributaries of the lake.

The net economic value of the total fishery in 1978 was estimated at 2.3 million dollars.

The estimated rainbow trout catch in Pend Oreille Lake during 1978 was 6,878. Of that total, 1, 754 were trophy Kamloops (over 43.2 cm, 17 in long). Anglers expended 65.6 hours for each trophy Kamloops caught.

Annual mortality of Kamloops fully recruited to the catch was estimated at 0.56. Kamloops become fully recruited to the catch at age 6. Trophy Kamloops may consume from 600,000 to 1, 000,000 kokanee annually.

To date an estimated 0.09% of hatchery released Kamloops have returned to the creel, suggesting the program utilizing domestic broodstock as an egg source for release was marginal.

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RECOMMENDATIONS

1. Maintain the daily bag limit of 25 kokanee in Pend Oreille Lake until there are indications that the stock size is increasing.

2. Develop a kokanee enhancement program on the lake to provide additional recruitment for increasing angler success and providing more forage fish for Kamloops trout and Dolly Varden. The enhancement program should utilize only late-spawning kokanee, preferably Pend Oreille stock.

3. Carefully consider future releases of Kamloops from the Clark Fork Fish Hatchery so as not to increase predation pressure on kokanee. Releases should be kept at a minimum and used only to provide a feral return to the hatchery.

4. Continue to monitor the contribution of larger kokanee (longer than 30 cm, 11.8 in) to the catch to assess the impact of Mysis relicta on kokanee growth.

5. Continue to monitor the lengths and weights of trophy Kamloops trout and Dolly Varden to assess any significant changes in condition factor.

OBJECTIVES

1. To provide minimum estimates of angling effort and harvest of important sport fisheries in Pend Oreille Lake.

2. To assess the size and age composition of the important fish species taken in the catch.

3. To assess the contribution of hatchery-reared fish to the fishery.

4. To evaluate annual trends in the catch of the important sport fish taken from Pend Oreille Lake and make management recommendations.

TECHNIQUES USED

During 1978, we conducted a creel census on Pend Oreille Lake similar to that of the previous 7 years in order to provide minimum estimates of angling pressure and harvest of the important sport fishes. Because of budgetary problems we reduced our sampling effort in six of the twelve census areas.

Project personnel collected creel data from 12 major access areas on the lake from 13 January to 30 November 1978. We stratified the total time period into 21 two-week intervals to reduce error due to time and provide seasonal catch comparisons. One Saturday, one Sunday and one weekday were selected at random during each 2-week interval. Dates of the 2-week intervals were established in such a way that they could be added to compare with the 46-day intervals used in previous census years.

We censused six of the high-use areas (north end--Garfield Bay, Trestle Creek, Johnson Creek; south end--Farragut, MacDonalds, Boileaus) 6 weekend days and 3 week-days during the 46-day interval. The remaining low-use access areas (north end--Sandpoint, Kamloops Resort, Ellisport Bay; south end--JD's, Vista Bay, Bubb's) were sampled 2 weekend days and 1 weekday during the same interval.

Estimates of catch and effort were made by expanding the census data by class-day (either weekend days or weekdays) by 2-week intervals for the entire year. For example, we defined an angler man-day as one angler fishing one day regardless of actual fishing time. Multiplying the number of anglers interviewed on a given day by the number of similar class-days within a 2-week interval resulted in the estimated minimum number of angler man-days. Likewise, we made similar expansions-for estimated catch and effort. Catch rates were measured from actual interview data. We classified expanded data as "estimated minimum" because a varying percentage of the lake anglers exit through uncensused landings.

Census personnel, in addition to recording catch data, measured kokanee seasonally and measured all creeled trout and Dolly Varden. Since 1968, census personnel have inspected Kamloops trout entering the creel for fin clips to assess the contribution of hatchery-reared fish to the fishery.

Also this year, we estimated, by percentage, the contribution of early-spawning kokanee to the catch by examining flesh color. During 1974 and 1975, 3.5 million early-spawning kokanee fry were introduced into Pend Oreille Lake. Fish were examined one day per week from 7 July to 4 August at the Trestle Creek resorts. We noted a definite distinction in flesh coloration between the two strains in the lake with the early strain having a darker red coloration than the late variety.

FINDINGS

Total Catch and Effort

In 1978, Pend Oreille Lake sport anglers fished an estimated 226,453 hours during 48,470 man-days to catch 178,135 fish between 13 January and 30 November (Tables 1, 2, 3). Sixty-one percent of the anglers fished for kokanee which made up 94% of the estimated catch while 39% fished for trout including Dolly Varden which comprised 5% of the estimated catch. A small percentage of the anglers (negligible) fished for whitefish and spiny-rayed species which made up 1% of the total catch.

Comparative catch and effort data for the years 1951 through 1978 are summarized in the Appendix (Tables A-U).

Kokanee Catch (Yield)

During 1978 anglers harvested an estimated 167,640 kokanee from Pend Oreille Lake (Table 1). For those anglers seeking kokanee only, the estimated catch was 164,508 fish caught in 120,363 hours of effort for a catch rate of 1.4 kokanee per hour (Figs. 1 & 2; Table 4; Appendix Tables A & H). The kokanee catch, catch rate and effort declined in 1978 compared to 1977 (Fig. 2).

We estimated the kokanee yield in weight for the lake during 1978 at 18,914 kg (41,705 lb) which is equivalent to .84 kg/ha (.75 lb/acre).

Table 1. Estimated minimum fishing pressure, effort and harvest, Pend Oreille Lake, Idaho, 1978.

Period	Angler man-days	Hours fished	Kokanee	Cut-throat	Dolly Varden	Rain-bow	White-fish	Spiny-*rays*	Other trout	Non-game
13-Jan-27-Feb	449	1,973	3,038	-		-				
28 Feb-14 Apr	473	1,801	110			-	-		-	
15 Apr-30 May	9,958	55,475	3,810	193	1,076	1,913	42	32	36	--
31 May-15 July	11,669	52,426	31,103	290	200	2,192	79	383	21	26
16 July-30 Aug	13,231	58,062	65,411	212	37	1,271	26	178	--	85
31 Aug-15 Oct	8,714	40,293	61,981	92	61	1,068	87	295	13	--
16 Oct-30 Nov	3,976	16,423	2,187	26	95	434	--	26	6	--
Total	48,470	226,453	167,640	813	1,469	6,878	234	914	76	111

Table 2. Resident sport fishing pressure, effort and harvest, Pend Oreille Lake, Idaho, 1978.

Period	Angler man-days	Hours fished	Kokanee	Cut-throat	Dolly Varden	Rain-bow	White-fish	Spiny-rays	Other trout	Non-game
13 Jan-27 Feb	410	1,795	2,776	--						
28 Feb-14 Apr	187	700	27	--		--			--	
15 Apr-30 May	6,772	38,136	1,556	121	953	1,289	32	32	27	--
31 May-15 July	5,223	23,939	14,812	146	77	887	54	135	15	10
16 July-30 Aug	3,550	16,281	13,949	126	32	494	6	95	--	79
31 Aug-15 Oct	4,084	19,224	28,333	62	35	601	64	128	13	--
16 Oct-30 Nov	1,937	8,092	647	26	70	200	--	26	2	--
Total	22,163	108,167	62,100	481	1,167	3,471	156	416	57	89

Table 3. Nonresident sport fishing pressure, effort and harvest, Pend Oreille Lake, Idaho, 1978.

Period	Angler man-days	Hours fished	Kokanee	Cut-throat	Dolly Varden	Rain-bow	White-fish	Spiny-*rays*	Other trout	Non-game
13 Jan-27-Feb	39	178	262	-						-
28 Feb-14 Apr	286	1,101	83	--		-				
15 Apr-30 May	3,186	17,339	2,254	72	123	624	10	--	9	--
31 May-15 July	6,446	28,487	16,291	144	123	1,305	25	248	6	16
16 July-30 Aug	9,681	41,781	51,462	86	5	777	20	83	--	6
31 Aug-15 Oct	4,630	21,069	33,648	30	26	467	23	167	--	--
16 Oct-30 Nov	2,039	8,331	1,540	--	25	234	--	--	4	--
Total	26,307	118,286	105,540	332	302	3,407	78	498	19	22

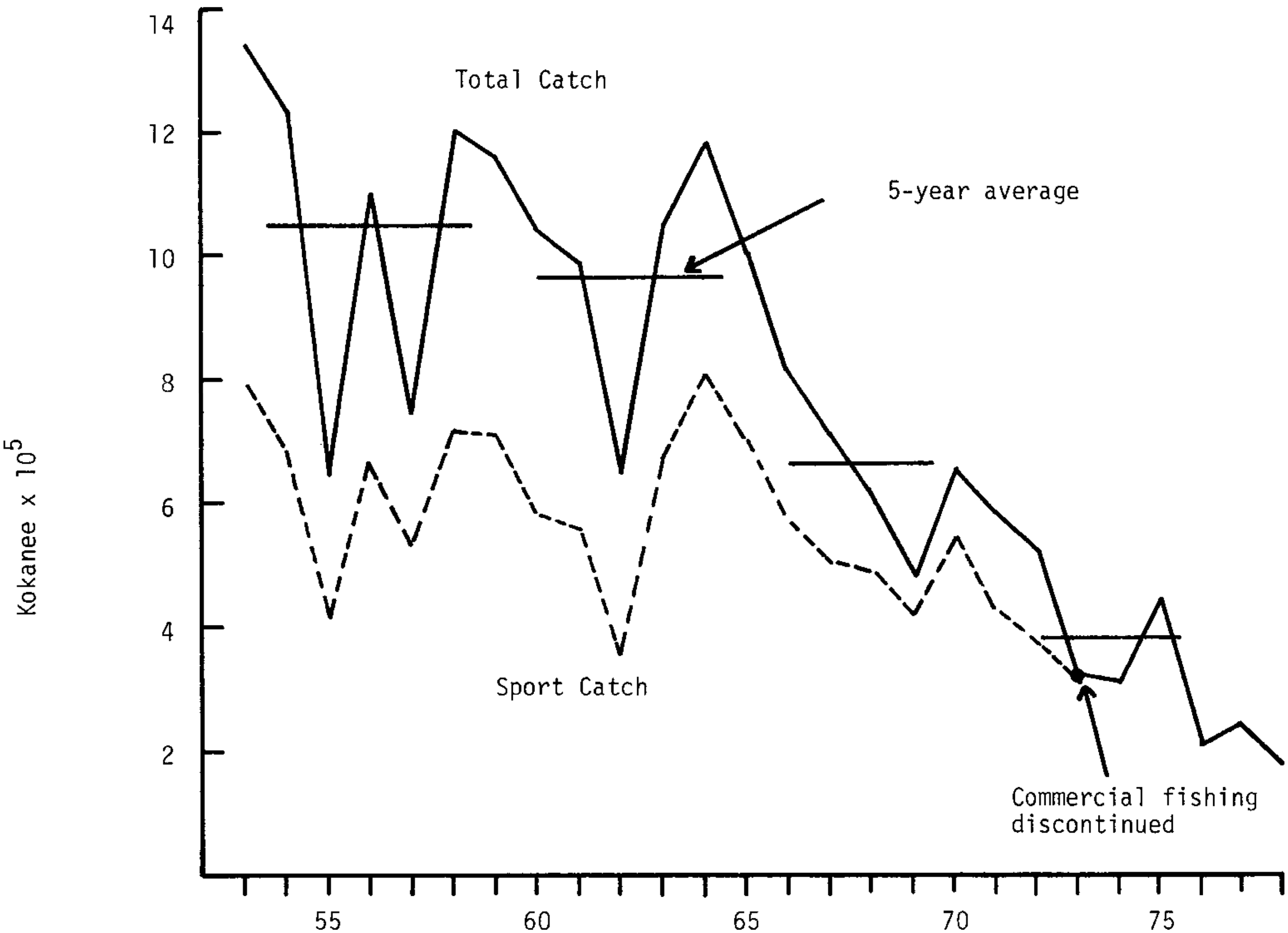


Figure 1. Estimated total kokanee catch and kokanee sport catch for Pend Oreille Lake from 1953-78.

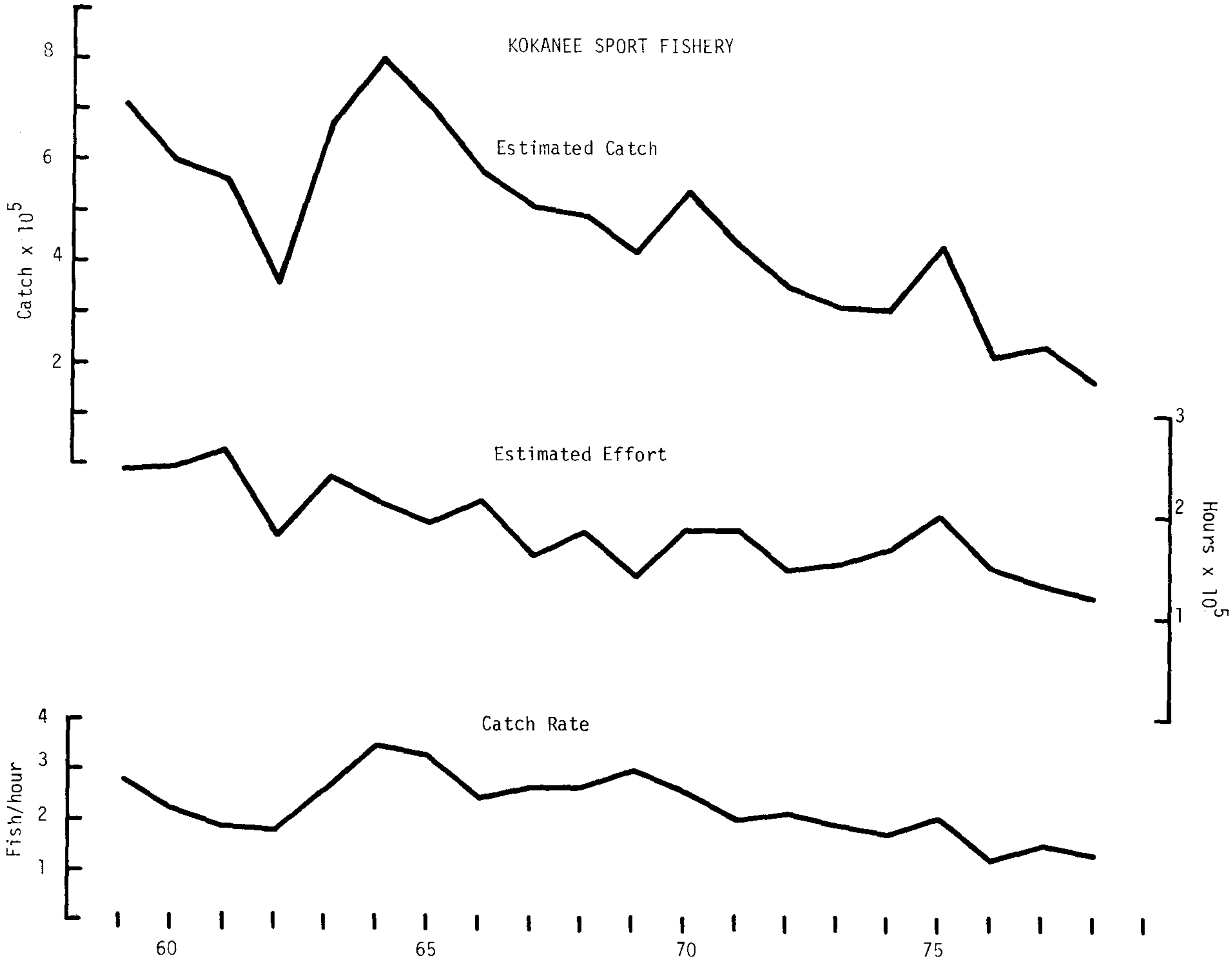


Figure 2. Estimated catch, effort and catch rate for the kokanee sport fishery in Pend Oreille Lake from 1959 to 197

Table 4. Catch data for interviewed anglers seeking kokanee, Pend Oreille Lake, Idaho, 1978.

Month	Anglers	Hours fished	Kokanee	Other game fish	Kokanee per hour	All game fish per hour	Kokanee per angler
January	26	114	150	--	1.3	1.3	5.8
February	76	313	472	--	1.5	1.5	6.2
March	83	317	23	--	0.1	0.1	0.3
April	102	350	11	1	0.03	0.03	0.1
May	326	1,282	1,084	65	0.8	0.9	3.3
June	1,109	4,363	5,566	256	1.3	1.3	5.0
July	1,184	4,945	5,636	128	1.1	1.2	4.8
August	812	3,400	4,868	69	1.4	1.5	6.0
September	1,160	5,208	10,061	116	1.9	2.0	8.7
October	404	1,801	2,149	27	1.2	1.2	5.3
November	1	2	--	--	0.0	0.0	0.0
Total	5,283	22,095	30,020	662			
Average (weighted)					1.4	1.4	5.7

Age Composition of the Catch

The kokanee catch in Pend Oreille Lake Primarily consists of age 4 (3+) and 5 (4+) fish with varying percentages of age 3 (2+) taken annually (Irizarry and Ellis 1977). The percentage of age 3 fish taken in the catch appears dependent on the strength of their year-class and how that compares with the strength of the age 4 and 5 year-classes. Generally the catch has averaged about 10% age 3 kokanee from 1951 to 1975 but in 1976 and 1977 it doubled to over 20% suggesting the ratio of age 4 and 5 kokanee to age 3 kokanee increased during the 1976 and 1977 fishing years (Bowler and Ellis 1978). The percentage of all age 3 kokanee in the catch decreased to 6% in 1978 indicating a reduction in the ratio between the 1974 (age 4) and 1975 (age 3) year classes. Trawl data substantiates a wider margin between the 1973 and 1974 year-classes than between the 1974 and 1975 year-classes.

Much of the aging for differentiating among age classes has been done by separating length frequency distributions. Segregating age 3 kokanee from age 4 and 5 fish by modal distribution has been quite easy but separating age 4 and 5 kokanee was virtually impossible because of the overlap (Bowler and Ellis 1978). An example of a typical length frequency that has been verified by actual aging is expressed in Figure 3. The age 4 immature kokanee were skewed to the left of the age 4 distribution suggesting they may be slightly retarded in growth resulting in an age 5 spawner for the following year.

Kokanee Size

Larger kokanee began appearing in the catch in 1977. For both 1977 and 1978 kokanee ranged to 53 cm (21 in) in length and weighed 1.6 kg (3.5 lb). Kokanee larger than 30.0 cm (11.8 in) made up 1.9% of the catch in 1977 and 0.5% in 1978 (Table 5). Kokanee larger than 30.0 cm rarely appeared in the catch in previous years.

Contribution of Early-Spawning Kokanee to the Catch

All of the early-spawning kokanee introduced into Pend Oreille Lake in 1974 and 1975 were released in the north end tributaries (Bowler 1976). Trestle Creek, the only known stream that supports a sustaining run of early kokanee is also on the north end of the lake.

To estimate the contribution of early-run fish to the catch we divided the north end of the lake into two areas. Area A was from Sandpoint to and including Pearl Island and Area B was from Picard Point to Granite Point. We estimated that early-run fish made up 3.6% of the kokanee catch on the north end of the lake in 1977 and 1.2% in 1978 during July and August. The percentages were consistently higher in Area A than B during both years suggesting the kokanee were congregating near natal tributaries especially in August (Table 6).

Economic Value of the Fishery

Even though the Pend Oreille kokanee catch has declined from an estimated 1,000,000 annually to less than 200,000, the economic worth of the fishery remains intrinsically high. Jeppson in 1955 defended the importance of the commercial fishery by assessing its net worth at $43,981. Capitalizing this value at 4% he

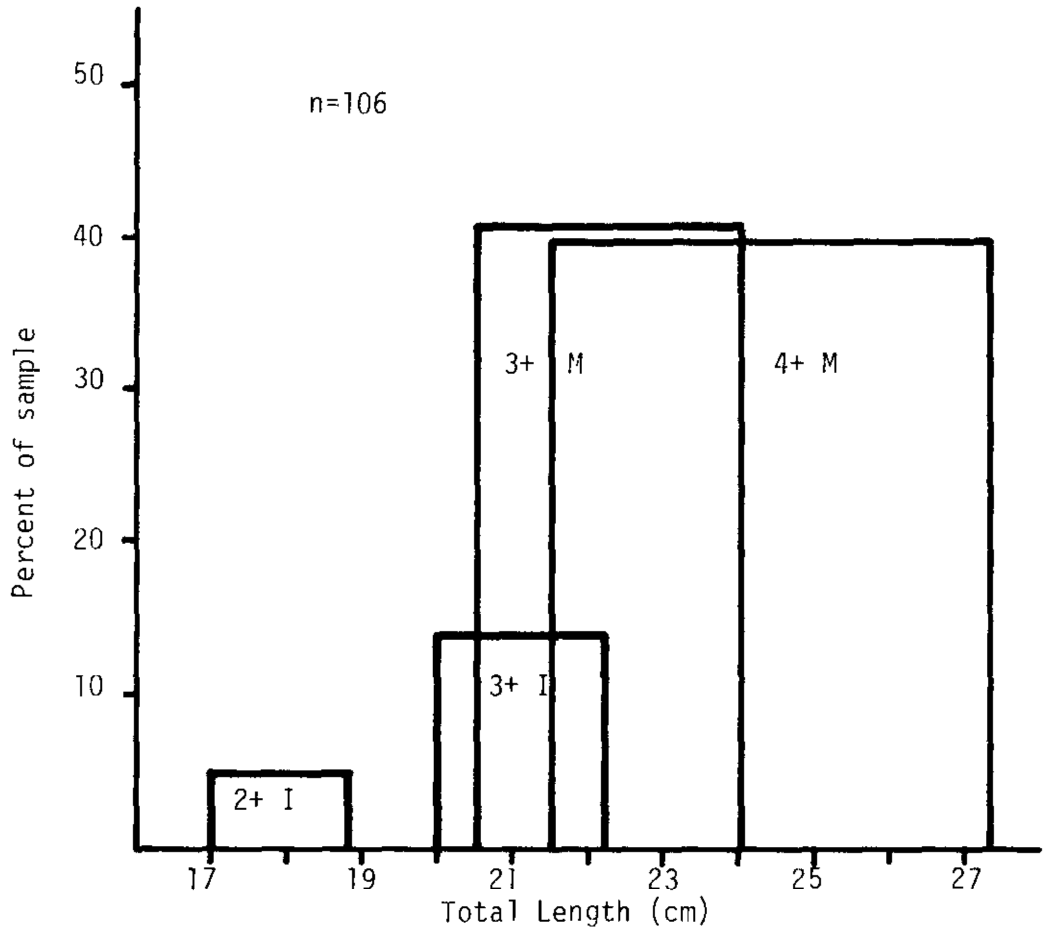


Figure 3. Length frequency of 106 aged kokanee taken from the Pend Oreille Lake catch in July, 1978. Width of the histograms indicates the size range for the particular age (M denotes mature, I denotes immature).

Table 5. Length frequency distribution of 2,255 kokanee from the catch and 385 kokanee from the late-spawning populations, Pend Oreille Lake, Idaho, 1978.

Length group (mm)	1978 Creel Census						1978 Spawners		
	13 Jan-27 Feb	28 Feb-14 Apr	15 Apr-30 May	31 May-15 July	16 July-30 Aug	31 Aug-15 Oct	Males	Females	Total
150-4			1						
155-9									
160-4									
165-9									
170-4				1					
175-9				1					
180-4				2					
185-9				2	2	2			
190-4	8		11	3	2	2			
195-9	29	1	11	11	4	4			
200-4	52		8	12	2	12			
205-9	71		19	32	3	5			
210-4	61	3	54	43	20	11			
215-9	41	3	50	67	16	15			
220-4	18	5	57	97	22	20		1	1
225-9	7	3	63	85	35	12			
230-4	7	1	55	71	56	18		4	4
235-9	1	1	37	67	78	42	1	4	5
240-4	1	1	26	44	62	68	5	17	22
245-9	1		12	23	56	65	6	28	34
250-4	1		7	16	33	46	25	38	63
255-9			7	7	23	38	25	34	59
260-4	1	1	11	5	17	33	28	27	55
265-9			3	5	12	14	28	11	39
270-4	1		7	3	5	6	17	6	23
275-9			3	2	3	5	15	7	22
280-4			1	1	4	1	8		8
285-9							5	1	6
290-4			1		1	1	4	3	7
295-9			2		2		1	1	2
300-4			1				2		2
305-9									
310-4			1				4		4
315-9							1		1

Table 5. Continued.

Length group (mm)	1978 Creel Census 13 Jan-27 Feb	28 Feb-14 Apr	15 Apr-30 May	31 May-15 July	16 July-30 Aug	31 Aug-15 Oct	1978 Spawners Males	Females	Total
320-4			1				2	2	4
325-9							1		1
330-4			2				2		2
335-9							1		1
340-4			1				2		2
345-9									
350-4							1		1
355-9									
360-4									
365-9							1		1
370-4							1		1
375-9									
380-4			1						
385-9							2		2
390-4			1						
395-9								1	1
400-4									
405-9									
410-4							1		1
415-9									
420-4								1	1
425-9									
430-4								1	1
435-9									
440-4			1						
445-9									
450-4									
455-9			1		1		2		2
460-4									
465-9									
470-4					1				
475-9									
480-4									
485-9									
490-4									

Table 5. Continued.

Length group (mm)	1978 Creel Census						1978 Spawners		
	13 Jan-27 Feb	28 Feb-14 Apr	15 Apr-30 May	31 May-15 July	16 July-30 Aug	31 Aug-15 Oct	Males	Females	Total
495-9									
500-4							1		1
505-9									
510-4							1		1
515-9							1		1
520-4							1		1
525-9							1		1
530-4									
535-9									
540-4							2		2
Total	300	19	456	600	460	420	198	187	385

Table 6. Contribution of early-spawning kokanee to the 1978 kokanee harvest in Pend Oreille Lake.

Date	*Section	Kokanee checked	Early spawners	Percentage
7/7/78	A	2	--	0.0
	B	175	1	0.6
7/14/78	A	23	--	0.0
	B	108	--	0.0
7/21/78	A	40	2	5.0
	B	315	--	0.0
7/26/78	A	29	1	3.4
	B	24	--	0.0
8/4/78	A	63	10	15.9
	B	400	--	0.0
Total		1,179	14	1.2

*Section A - from Sandpoint to and including Pearl Island B - from Picard Point to Granite Point valued the commercial fishery at $1,099,500.

Using Gordon's 1967 value per angler day of $24 for lake fishing for salmonids in Region 1 (Gorden et al. 1973), 29,602 angler man-days expended for kokanee fishing in 1978 and a 1978 consumer price index of 2.009, the net economic value of the kokanee fishery was $1,427,290 in 1978. Using the same method and 48,470 angler man-days for the total fishery in Pend Oreille Lake in 1978 we calculated the net economic value for the entire fishery at $2,337,030. The capitalized value at 5% equals $46,740,600.

Trout and Dolly Varden

Trout fishing in Pend Oreille Lake during 1978 was better than in 1977 (Appendix Table D). We interviewed 4,153 sport anglers seeking trout (including Dolly Varden) that fished 22,351 hours to catch 1,203 trout for a catch rate of 18.6 hours per fish (Table 7).

Dolly Varden

Sport anglers seeking Dolly Varden fished an estimated 6,426 hours to catch 786 Dolly Varden (Table Q). An additional 683 Dolly Varden were caught by anglers seeking other salmonids for a total estimated catch of 1,469. The total included 887 (67.2%) trophy Dolly Varden (over 43.2 cm, 17 in) (Appendix Table D). We measured 244 Dolly Varden that ranged from 25.4 to 91.4 cm (10-36 in) with an average length of 48.5 cm (19.1 in). The trophy Dolly Varden (164) averaged 53.8 cm (21.2 in) in length and 2.0 kg (4.3 lb) in weight (Appendix Table T). Interviewed anglers that were seeking Dolly Varden caught this species at a rate of 8.1 hours per fish (Table 8).

Cutthroat

Anglers seeking cutthroat trout fished an estimated 10,495 hours in 1978 to catch 524 cutthroat for a catch rate of 0.05 fish per hour (Table 9 & Appendix Table P). An additional 289 cutthroat were caught by anglers seeking other salmonids. Cutthroat entering the creel measured between 20.3 and 45.7 cm (8.0-18.0 in) with an average length of 32.0 cm (12.6 in).

Rainbow Trout Including Trophy Kamloops

The estimated rainbow trout catch in Pend Oreille Lake during 1978 was 6,878 of which 1,754 were trophy Kamloops (over 43.2 cm, 17 in) (Appendix Table D). Sport anglers seeking trophy Kamloops expended an estimated 88,969 hours to catch 1,334 fish for a catch rate of 65.6 hours per fish (Table 10 & Appendix Table R). An additional 420 trophy Kamloops were caught by anglers seeking other salmonid species.

We measured 1,359 rainbow in the creel during 1978 that ranged between 14.6 and 88.9 cm (5. 8-35.0 in) with an average length of 40.6 cm (16.0 in). We also measured 347 trophy Kamloops that averaged 62.5 cm (24.6 in) in length and 3.5 kg (7.8 lb) in weight (Appendix Table T).

Of the 347 Kamloops weighed, 295 (85%) were under 6.8 kg (15 lb); 38 (11%) were between 6. 8 and 9 kg (15-19.8 lb); 13 (3.7%) were between 9.1 kg and 11.2 kg (20-24.8 lb); and 1 (0.3%) was over 11.3 kg (25 lb).

Table 7. Catch data for interviewed anglers seeking trout (all species combined), Pend Oreille Lake, Idaho, 1978.

Month	Anglers	Hours fished	Trout	Other game fish	Trout per hour	All game fish per hour
April	603	3,961	160	18	0.04	0.04
May	1,194	6,456	337	29	0.05	0.06
June	674	3,562	303	127	0.08	0.12
July	561	2,815	115	9	0.04	0.04
August	203	1,151	61	14	0.05	0.06
September	174	831	64	14	0.08	0.09
October	474	2,308	129	3	0.06	0.06
November	270	1,267	34	--	0.03	0.03
Total	4,153	22,351	1,203	214		
Average (weighted)					0.05	0.06

Table 8. Catch data for interviewed anglers seeking Dolly Varden, Pend Oreille Lake, Idaho, 1978.

Month	Anglers	Hours fished	Dolly Varden	Other trout	Other game fish	Dolly Varden per hour	All trout per hour	All game fish per hour
April	30	178	25	6	--	0.14	0.17	0.17
May	102	519	61	17	7	0.12	0.15	0.16
June	9	44	6	7	7	0.14	0.29	0.45
July						--	--	--
August	2	8	1	--	--	0.12	0.12	0.12
September	-	--	-			-	-	--
October	2	14	1	--	--	0.07	0.07	0.07
November			-			-		--
Total	145	763	94	30	14			
Average (weighted)						0.12	0.16	0.18

Table 9. Catch data for interviewed anglers seeking cutthroat, Pend Oreille Lake, Idaho, 1978.

Month	Anglers	Hours fished	Cutthroat	Other trout	Other game fish	Cutthroat per hour	All trout per hour	All game fish per hour
April	19	92	7	8	1	0.08	0.16	0.17
May	123	619	19	105	22	0.03	0.20	0.24
June	139	657	22	161	119	0.03	0.28	0.46
July	85	348	19	41	9	0.05	0.17	0.20
August	34	183	16	33	14	0.09	0.27	0.34
September	21	80	8	37	14	0.10	0.56	0.74
October	43	194	10	26	2	0.05	0.19	0.20
November		--				-		
Total	464	2,173	101	411	181			
Average (weighted)						0.05	0.24	0.32

Table 10. Catch data for interviewed anglers seeking trophy Kamloops rainbow over 432 mm (17 in), Pend Oreille Lake, Idaho, 1978.

Month	Anglers	Hours fished	Kamloops (over 432 mm)	Kamloops (under 432 mm)	Other trout	Other game fish	Kamloops per hour	All trout per hour	All game fish per hour	Hours per trophy Kamloops
April	554	3,691	52	35	27	17	0.02	0.03	0.03	71.0
May	969	5,318	61	53	21	11	0.02	0.02	0.03	87.2
June	526	2,861	65	28	14	1	0.03	0.04	0.04	44.0
July	476	2,467	36	9	10	--	0.02	0.02	0.02	68.5
August	167	960	6	2	3	--	0.01	0.01	0.01	160.0
September	153	751	16	1	2	--	0.02	0.02	0.02	46.9
October	429	2,100	33	30	29	1	0.03	0.04	0.04	63.6
November	270	1,267	27	2	5	--	0.02	0.03	0.03	46.9
Total	3,544	19,415	296	160	111	30				
Average (weighted)							0.02	0.03	0.03	65.6

Age Composition of Kamloops Catch

Anderson (1978) analyzed 421 Kamloops scales taken from the catch in Pend Oreille Lake and the Clark Fork River from 1972 through 1976. Their frequency of occurrence is described in Figure 4. By plotting a catch curve (Fig. 4) we estimated the instantaneous rate of total mortality (Z) of those Kamloops fully recruited to the fishery to equal 0.81. Annual mortality (a) of the recruits to the fishery equalled 0.56 with an annual survival rate (s) of 0.44. It appears the Kamloops in Pend Oreille Lake are not fully recruited to the fishery until age 6.

A length weight relationship for Kamloops is described in Figure 5. Hatchery

Releases

Since 1968 hatchery personnel have released 3,720,395 Kamloops fry into Pend Oreille Lake. Also between 1968 and 1974 they released 658,204 sub-adult Kamloops (76-127 mm, 3-5 in) into the lake of which 502,835 (76%) were fin clipped (Table 11). To date 446 fin clipped Kamloops have been checked in the creel for a return of 0.09%.

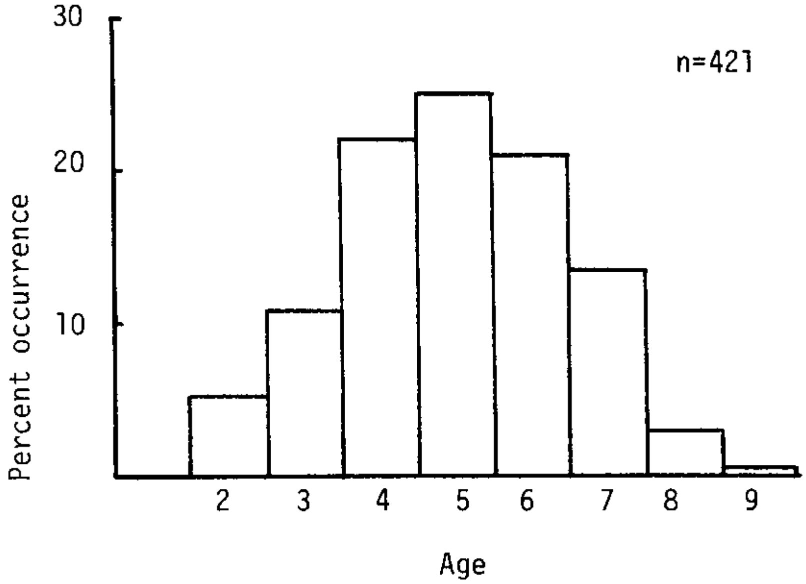
DISCUSSIO

N Kokanee Yield

The kokanee catch in Pend Oreille Lake has declined steadily since 1964 with the exception of a few years when surges in catch occurred. Changes in the sport catch correlated well with changes in the commercial catch through the termination of the commercial fishery in 1973 (Fig. 1). This suggests that although the commercial fishery was more efficient than the sport fishery, changes in the sport catch likely reflected changes in fish abundance, especially after 1973 (Fig. 1). Sport fishing effort has remained relatively constant since 1964 with the exception of a steady decline from 1976 to 1978. The loss of effort in the last 3 years was likely the result of anglers moving to Coeur d'Alene Lake where kokanee fishing has been much better. Kokanee catch rates have also shown a downward trend in Pend Oreille Lake since 1964. Overall, the catch statistics indicate that present stock abundance is not equivalent to the stock sizes enjoyed during the mid-1960s.

The estimated kokanee yield in weight for Pend Oreille in 1978 was 18,914 kg (41,705 lb) (.84 kg/ha; .75 lb/acre). The morphoedaphic index (TDS/mean depth) for the lake indicates that it could produce yields of 1 to 2 kg/ha (0.9 to 1.8 lb/acre).

Attempts were made in 1974 and 1975 to bolster the kokanee yield in 1977 and 1978 by introducing 3.5 million kokanee fry of the early-spawning variety into the lake. Returns to the creel in 1977 from the 1974 year-class (3.6%) and in 1978 from the 1974 year-class (1.2%) were very low suggesting marginal survival of those year-classes. Returns to the creel of early-spawning kokanee introduced into Coeur d'Alene Lake have also been low in past years. Spawning age fish have failed to return to streams where they were released into Coeur d'Alene Lake (Bowler 1975) No early-spawning kokanee were observed in the Pack River streams in Pend Oreille Lake in the fall of 1978. There is little evidence from both lakes to indicate that early-spawning kokanee have contributed significantly to angler creels. Releases of late-spawning fish have been more successful in Coeur d'Alene Lake.



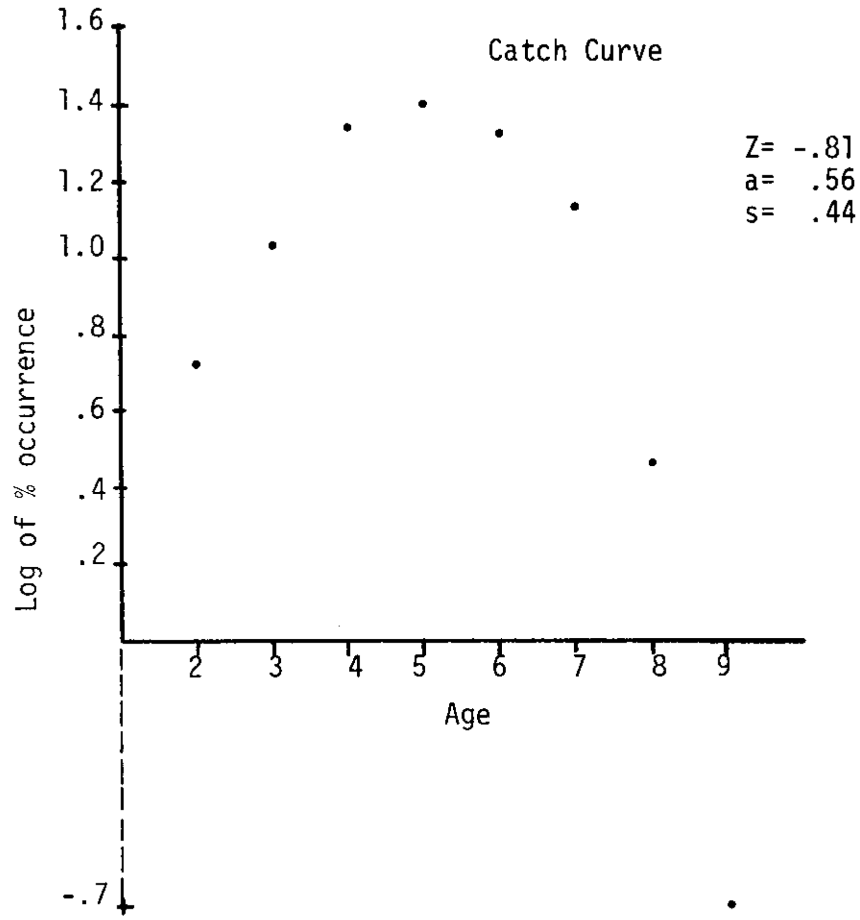


Figure 4. Percent occurrence by age of 421 Kamloops trout collected in the Pend Oreille Lake catch from 1972 through 1976. Also the respective catch curve including (Z) instantaneous rate of total mortality, (a) annual mortality rate and (s) annual survival rate.

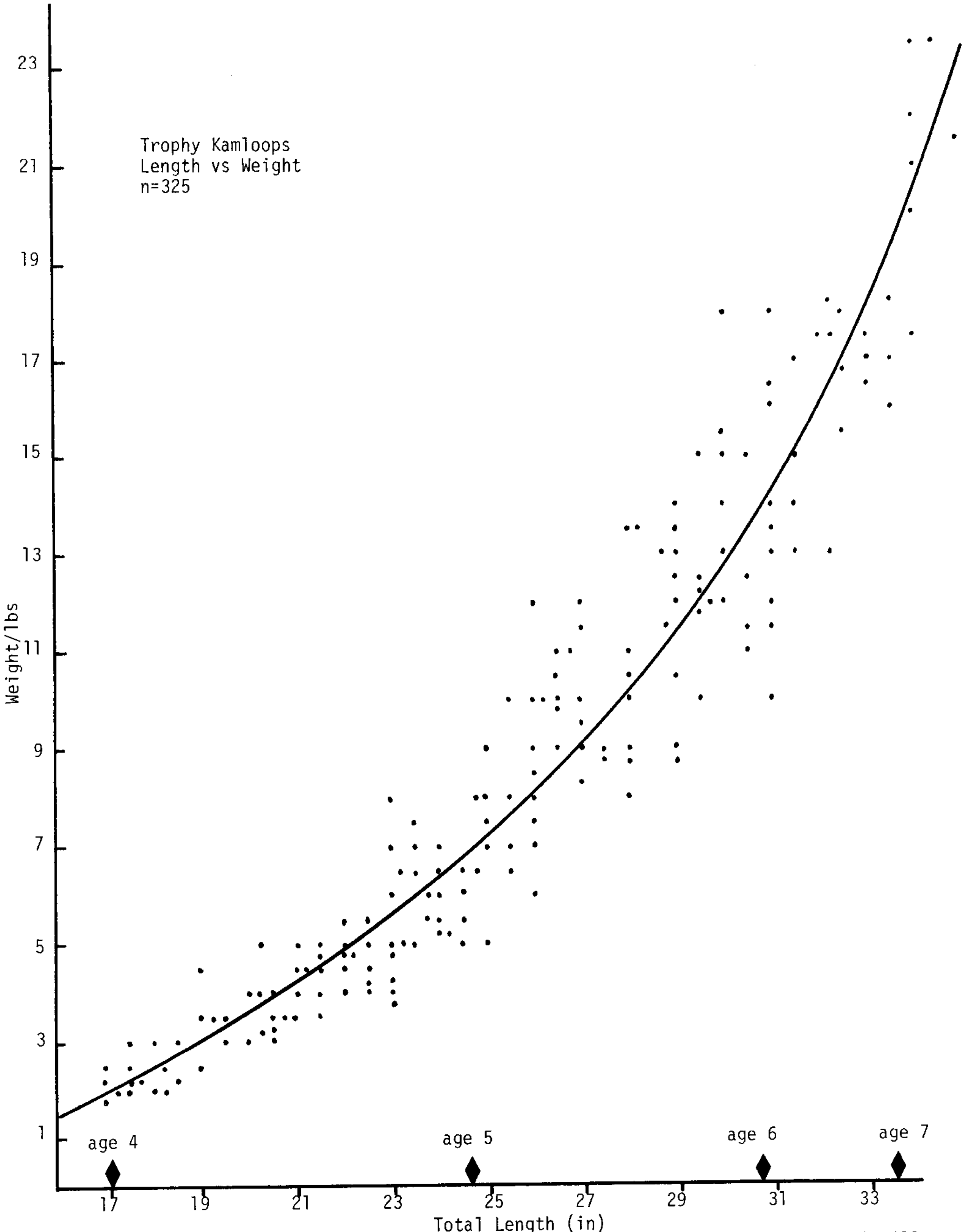


Figure 5. Length-weight relationship for 325 Kamloops trout taken in the Pend Oreille Lake catch in 1976.

Table 11. Total marked Kamloops trout releases and returns of marked Kamloops trout to the creel, Pend Oreille Lake, Idaho, 1968-1977.

						Estimated number returned		
Year	Adipose clip only	Adipose combination clip*	Total clipped	Total released	Percent clipped	Adipose clip only	Adipose combination clip	Total returned
1968	141,752	--	141,752	144,002	98	--	--	--
1969	100,530	--	100,530	119,676	84	51	--	51
1970	13,390	71,23n	84,620	89,180	95	14	--	14
1971	510	32,315	32,825	66,652	49	128	2	130
1972	--	56,237	56,237	56,237	100	23	--	23
1973	--	69,474	69,474	69,474	100	8	85	93
1974	--	17,397	17,397	72,918	24	13	84	97
1975	--	--	--	40,065	0	3	22	25
1976	--	--	--	--	--	0	13	13
1977	--	--	--	--	--	0	0	0
Totals	256,182	246,653	502,835	658,204	76	240	206	446

*An adipose combination clip is either an adipose-right vertral or adipose-left ventral fin clip.

Age Composition of the Kokanee Catch

The age of kokanee creeled in Pend Oreille Lake ranges from age 3 (2+) to 6 (5+) with the predominant ages being age 4 (3+) and 5 (4+) which corresponds to age at maturity. A higher percentage of age 3 kokanee were taken in the 1976 and 1977 catch than were recorded in 1978 and previous years. The percentage of age 3 kokanee creeled appears dependent on the strength of that year-class and how that compares to the strength of the age 4 and 5 year-classes. The larger the ratio of the age 3 to age 4 and 5 year-classes of kokanee in the lake (assuming the age 3 kokanee are more abundant) the larger the harvest of age 3 kokanee.

Also harvest of age 3 kokanee appears to be influenced by growth. Most of the harvest of age 3 fish occurs after mid-July when they reach a critical size of 17.0 cm (6.7 in) in length. If growth is good such as occurred in the summer of 1977 the kokanee reach 17.0 cm earlier and are exposed to the fishery longer.

Kokanee Size

Modal size of kokanee taken in the catch in 1977 and 1978 was similar (24.5 cm, 9.7 in) to those measured in previous years but in 1977 and 1978 kokanee larger than 30.0 cm (11.8 in) appeared in the catch. Of those kokanee measured, 1.9% were larger than 30.0 cm in 1977 and 0.5% were larger in 1978. We attribute the larger individual kokanee, which did not appear in the catch previously, to the consumption of *Mysis relicta.* Nineteen percent of the kokanee stomachs analyzed in 1977 and 23% in 1978 contained *Mysis* but the shrimp made up only 4 to 12% of the total diet of all ages for both years, suggesting a small percentage of the kokanee elaborated tissue from *Mysis.*

Net Economic Value of the Fishery

The net economic value of the kokanee fishery in Pend Oreille Lake in 1978 was measured at 1.4 million dollars with the total fishery valued at 2.3 million dollars, suggesting the net value is quite high for a resident sport fishery and has significant economic value to the residents of the state. Although net value reflects total net benefit that could be realized if a perfectly discriminating monopolistic owner charged each user of the resource the maximum price he was willing to pay (consumer surplus), the gross expenditures by anglers utilizing Pend Oreille Lake are also considered quite high (Bill Goodnight, personal communication). Gross expenditures include durable goods (tackle and gear, boating equipment, etc.) and transfer costs (transportation, lodging, food and liquor, etc.). Gross expenditures can be a measure of net inflow of dollars to the local economy of which the Pend Oreille Lake fishery would be very important to nearby communities as well as resort owners along the lake.

Trophy Species

The catch of trophy Kamloops trout and Dolly Varden has remained relatively constant in the lake since the mid-1960s with the exception of an increase in Kamloops catch in the last 3 years. We have observed a slight decrease in mean weight of both species since the early 1970s although the condition factors have not changed significantly with the possible exception of Kamloops in 1977 (Anderson 1978). Recent declines in mean weight of Kamloops may be attributed to younger age fish recruiting to the fishery as well as the subsequent reduction in kokanee abundance. Younger age Kamloops entering the creel in the lake fishery have steadily increased since 1974, perhaps partially in response to angling restrictions in the Clark Fork River fishery in the early 1970s. The Clark Fork Kamloops catch was predominately mature fish. Kamloops

Predation

Trophy Kamloops (over 43.2 cm, 17 in) primarily forage on age 2 and 3 kokanee (Bowler 1977). Using catch statistics we have estimated the lake may support from 3,000 to 5,000 trophy size Kamloops. Also by plotting the mean weight gain of each age-class of Kamloops and using a 20% conversion efficiency of kokanee flesh to Kamloops flesh we estimated Kamloops could be consuming from 600,000 to 1,000,000 kokanee annually. Although Pend Oreille Dolly Varden are smaller than Kamloops they would also be contributing to predation mortality on kokanee. As prey (kokanee) abundances decline with a stable predator population, mortality due to predation becomes more significant to prey population stability.

Hatchery Program for Kamloops

The hatchery program for enhancing the Kamloops stock in Pend Oreille Lake has contributed very little to angler success. The program presently underway to replace the domestic brood fish with wild stock should improve survival and return! to the creel. Accompanying the program of improving Kamloops broodstock should be a program of kokanee enhancement to ensure an adequate food base for the trophy species.

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APPENDIX

Table A. Estimated minimum number of angler man-days by license class, Pend Oreille Lake, Idaho, 1951-1978.

Year	Total	Resident	Nonresident	Commercial
1951	60,172	--	--	--
1952	57,814	26,836	30,051	927
1953	99,855	47,786	44,877	7,192
1954	90,566	40,956	41,619	7,991
1955	67,645	31,386	32,257	4,002
1956	87,813	45,432	38,006	4,375
1957	72,355	35,207	34,229	2,919
1958	88,453	45,532	36,862	6,059
1959	75,057	36,671	34,914	3,472
1960	77,162	35,564	36,385	5,213
1961	81,387	33,648	42,453	5,286
1962	59,379	23,656	31,348	4,375
1963	72,221	31,788	35,805	4,628
1964	66,225	26,703	35,295	4,227
1965	58,263	27,440	26,256	4,567
1966	65,340	24,710	37,976	2,654
1967	54,699	20,564	31,559	2,576
1968	55,414	18,379	35,492	1,543
1969	45,025	17,549	26,606	870
1970	61,815	21,944	37,715	2,156
1971	60,137	23,751	33,790	2,596
1972	50,506	21,214	26,971	2,321
1972	46,582	19,929	25,873	780
1974	49,206	22,124	27,082	--
1975	58,323	26,291	32,032	--
1976	53,705	20,179	33,526	--
1977	50,554	20,740	29,814	--
1978	48,470	22,163	26,307	--

Table B. Estimated minimum number of hours fished by license class, Pend Oreille Lake, Idaho, 1951-1978.

Year	Total	Resident	Nonresident	Commercial
1951	330,923	--	--	--
1952	308,850	133,539	169,372	5,939
1953	522,692	234,173	242,764	45,755
1954	459,271	189,920	221,512	47,839
1955	327,551	139,639	163,819	24,093
1956	406,538	196,226	181,397	28,915
1957	331,476	148,236	165,556	17,684
1958	400,683	192,199	171,033	37,451
1959	345,406	162,296	162,830	20,280
1960	372,266	162,531	176,806	32,929
1961	384,702	156,142	192,610	35,950
1962	274,554	108,380	138,339	27,835
1963	350,128	154,371	165,126	30,631
1964	314,220	125,842	164,446	23,932
1965	281,230	128,817	126,334	26,079
1966	295,781	113,085	166,206	16,490
1967	245,837	95,147	133,442	17,248
1968	242,859	83,200	150,157	9,502
1969	197,202	83,349	109,106	4,747
1970	261,785	91,878	157,446	12,461
1971	265,514	107,753	141,844	15,917
1972	222,908	96,097	113,475	13,336
1973	211,034	92,099	115,292	3,643
1974	226,973	104,936	122,037	--
1975	262,605	121,425	141,180	--
1976	241,736	92,724	149,012	--
1977	228,512	98,812	129,700	--
1978	226,453	108,167	118,286	--

Table C. Estimated minimum catch of kokanee by license class, Pend Oreille Lake, Idaho, 1951-1978.

Year	Total	Resident	Nonresident	Commercial
1951	820,486	--	--	170,500
1952	514,913	183,657	268,116	63,140
1953	1,335,881	412,288	382,593	541,000
1954	1,232,916	326,568	362,844	543,504
1955	650,375	181,492	228,610	240,273
1956	1,092,651	423,092	240,294	429,265
1957	751,113	256,280	277,699	217,134
1958	1,197,426	365,082	359,132	473,212
1959	1,161,913	377,065	332,001	452,847
1960	1,039,200	320,041	278,571	440,588
1961	991,955	257,362	305,361	429,232
1962	650,960	168,847	190,039	292,074
1963	1,049,339	359,677	314,291	375,371
1964	1,162,625	357,152	452,962	352,511
1965	1,007,292	385,007	319,034	303,251
1966	808,744	220,317	351,403	237,024
1967	710,312	218,629	290,081	201,602
1968	618,405	207,058	288,454	122,893
1969	483,292	180,294	242,109	60,889
1970	654,848	173,672	367,981	113,195
1971	590,058	189,377	242,383	158,298
1972	521,048	172,952	186,499	161,597
1973	328,739	127,291	195,767	5,681
1974	319,286	132,981	186,305	--
1975	438,382	208,347	230,035	--
1976	218,639	67,932	150,707	--
1977	238,548	72,616	165,932	--
1978	167,640	62,100	105,540	--

Table D. Estimated minimum catch of kokanee, Kamloops, Dolly Varden and cutthroat trout, Pend Oreille Lake, Idaho, 1951-1978.

Year	Kokanee	Kamloops	Trophy Kamloops	Dolly Varden	Trophy Dolly Varden	Cutthroat
1951	820,486	678		1,775		5,271
1952	514,913	535		2,393		5,850
1953	1,335,881	3,158		5,035		8,201
1954	1,232,916	2,533		3,660		5,322
1955	650,375	2,954		3,811		4,982
1956	1,092,651	3,251		3,288		5,343
1957	751,113	2,938		2,117		5,138
1958	1,197,426	5,286		1,348		5,881
1959	1,161,913	4,906		1,677		3,659
1960	1,039,200	9,626	1,380	2,616	1,491	3,730
1961	991,955	5,355	873	966	568	2,641
1962	650,960	6,556	1,136	1,434	817	2,615
1963	1,049,339	10,323	1,442	1,049	671	3,069
1964	1,162,625	4,942	870	929	502	1,757
1965	1,007,292	4,763	1,141	1,460	672	1,744
1966	808,744	4,978	1,040	1,199	740	2,040
1967	710,312	3,349	767	657	512	788
1968	618,405	4,169	832	624	387	782
1969	483,292	3,297	889	862	588	954
1970	654,848	4,419	1,105	640	493	1,256
1971	590,058	4,462	892	967	532	965
1972	521,048	3,384	880	928	504	1,114
1973	328,739	4,422	663	751	503	973
1974	319,286	4,337	737	847	466	500
1975	438,382	3,671	1,101	838	469	1,250
1976	218,639	5,868	1,643	1,253	789	814
1977	238,548	5,861	1,524	1,251	713	896
1978	167,540	6,878	1,754	1,469	987	813

Table E. Estimated minimum fishing pressure, effort and harvest for commercial anglers seeking kokanee, Pend Oreille Lake, Idaho, 13 January - 31 May 1959-1973.

Year	Estimated angler man-days	Estimated hours fished	Estimated kokanee catch	Kokane per angler*	Kokanee per hour*
1959	3,472	20,280	452,847	113.8	18.4
1960	5,213	32,929	440,588	96.1	14.9
1961	5,286	35,950	429,232	73.7	10.9
1962	4,375	27,835	292,074	60.7	10.0
1963	4,628	30,631	375,371	72.6	10.8
1964	4,227	23,932	352,511	92.6	16.0
1965	4,567	26,079	303,251	73.3	12.6
1966	2,654	16,490	237,024	77.8	12.8
1967	2,576	17,248	201,602	77.8	12.7
1968	1,543	9,502	122,893	66.9	10.9
1969	870	4,747	60,889	101.9	17.2
1970	2,156	12,461	113,195	64.1	10.3
1971	2,596	15,917	158,298	60.7	10.2
1972	2,321	13,336	161,597	62.6	11.0
1973**	780	3,643	5,681	6.0	1.3
Total (1959-1972)	46,484	287,337	3,701,372	--	--
Average (weighted)	3,320	20,524	264,384	75.6	12.4

*Based on interview (actual) data.

**Commercial fishing terminated on 1 April 1973.

Table F. Estimated minimum fishing pressure, effort and harvest for sport anglers seeking kokanee, Pend Oreille Lake, Idaho, 13 January - 31 May 1959-1978.

Year	Estimated angler man-days	Estimated hours fished	Estimated kokanee catch	Kokanee per angler*	Kokanee per hour*
1959	11,441	51,359	174,028	14.9	3.3
1960	11,327	53,307	167,930	13.9	3.0
1961	12,768	63,250	152,016	11.1	2.2
1962	8,063	40,670	85,057	10.7	2.1
1963	13,696	66,470	221,454	15.1	3.0
1964	10,203	43,336	201,516	21.2	4.5
1965	12,391	61,468	255,610	19.2	4.0
1966	10,804	52,241	151,465	13.4	2.8
1967	10,145	31,197	158,372	13.9	2.9
1968	7,776	32,918	122,712	14.9	3.5
1969	5,325	25,172	85,775	18.3	4.0
1970	7,582	30,469	62,253	8.3	2.0
1971	12,457	51,338	133,880	8.9	2.1
1972	8,959	35,793	118,383	12.1	2.9
1973	3,973	16,201	13,045	2.4	0.6
1974	3,146	13,703	18,810	5.0	1.2
1975	6,375	26,564	59,766	9.6	2.2
1976	4,278	16,278	21,106	4.1	1.0
1977	2,316	8,620	2,550	1.1	0.3
1978	2,354	9,234	6,611	2.8	0.7
Total	165,379	729,588	2,212,339	--	--
Average (weighted)	8,269	36,479	110,617	11.2	2.5

*Based on interview (actual) data.

Table G. Estimated minimum fishing pressure, effort and harvest for sport anglers seeking kokanee, Pend Oreille Lake, Idaho, 1 June - 30 November 1959-1978.

Year	Estimated angler man-days	Estimated hours fished	Estimated kokanee catch	Kokanee per angler*	Kokanee per hour*
1959	40,561	193,841	535,038	12.6	2.7
1960	39,985	195,509	430,682	9.7	2.0
1961	36,811	202,020	410,707	8.6	1.8
1962	33,806	139,248	273,829	7.6	1.7
1963	36,567	174,149	452,514	11.6	2.5
1964	38,622	172,337	608,598	15.4	3.2
1965	28,940	134,895	448,431	14.2	3.1
1966	39,572	162,641	420,255	9.8	2.3
1967	32,776	130,461	350,338	11.1	2.7
1968	36,925	150,965	372,800	10.6	2.5
1969	28,767	116,875	336,628	10.7	2.6
1970	38,935	155,788	479,400	11.0	2.7
1971	32,968	136,529	297,880	8.3	2.0
1972	28,010	112,975	241,068	7.9	1.9
1973	32,799	137,937	310,013	9.1	2.1
1974	35,761	154,556	300,476	8.5	1.9
1975	40,629	174,317	378,616	8.9	2.0
1976	33,578	134,633	196,808	5.6	1.4
1977	31,618	127,221	232,757	7.4	1.7
1978	27,248	111,129	157,897	6.1	1.4
Total	694,878	3,018,026	7,234,735	--	--
Average (weighted)	34,7[4]4	150,901	361,737	9.1	2.1

*Based on interview (actual) data.

Table H. Estimated minimum fishing pressure, effort and harvest for sport anglers seeking kokanee, Pend Oreille Lake, Idaho, 13 January - 30 November 1959-1978.

Year	Estimated angler man-days	Estimated hours fished	Estimated kokanee catch	Kokanee per angler*	Kokanee per hour*
1959	52,002	245,200	709,066	13.1	2.8
1960	51,312	248,816	598,612	10.7	2.2
1961	49,579	265,270	562,723	9.2	1.9
1962	41,869	179,918	358,886	8.3	1.8
1963	50,263	240,619	673,968	12.5	2.6
1964	48,825	215,673	810,114	16.8	3.5
1965	41,331	196,363	704,041	15.6	3.3
1966	50,376	214,882	571,720	10.7	2.5
1967	42,921	161,658	508,710	11.9	2.7
1968	44,701	183,883	495,512	11.4	2.7
1969	34,092	142,047	422,403	12.4	3.0
1970	46,517	186,257	541,653	10.4	2.6
1971	45,425	187,867	431,760	8.5	2.1
1972	36,969	148,768	359,451	9.0	2.2
1973	36,772	154,138	323,058	8.3	2.0
1974	38,907	168,259	319,286	8.1	1.8
1975	47,004	200,881	438,382	9.0	2.1
1976	37,856	150,911	217,914	5.4	1.3
1977	33,934	135,841	235,307	6.9	1.6
1978	29,602	120,363	164,508	5.7	1.4
Total	860,257	3,747,614	9,447,074	--	--
Average (weighted)	43,013	187,381	472,354	9.5	2.2

*Based on interview (actual) data.

Table I. (Part 1). Pend Oreille Lake kokanee catch by month, 1951-1958.

Year	Kokanee catch by month											Total catch
	January	February	March	April	May	June	July	August	September	October	November	
1951			315,852	27,781	50,508	183,882	88,248	43,706	84,234	26,275		820,486
1952				14,379	126,979	107,521	79,405	39,056	66,172	81,401		514,913
1953		50,466	255,549	203,791	190,203	234,300	140,141	56,206	95,779	107,144	2,302	1,335,881
1954		8,963	96,637	180,081	358,689	203,896	192,094	50,018	93,946	46,806	1,786	1,232,916
1955		24	23,762	61,515	200,674	99,188	23,388	67,792	136,641	37,383	8	650,375
1956	433	3,359	212,597	299,637	226,911	64,036	66,619	55,985	142,753	20,289	32	1,092,651
1957		39,885	85,926	129,715	102,188	38,454	42,147	88,447	196,838	27,499	14	751,113
1958	26,400	105,974	81,481	200,611	227,203	42,356	101,736	117,508	223,693	70,459	5	1,197,426

Table I. (Part 2). Pend Oreille Lake kokanee catch by period, 1959-1978.

	Kokanee catch by period							
Year	13 Jan.- 27 Feb.	28 Feb.- 14 Apr.	15 Apr.- 30 May	31 May- 15 July	16 July- 30 Aug.	31 Aug.- 15 Oct.	16 Oct.- 30 Nov.	Total catch
1959	--	233,599	380,173	270,127	113,144	158,622	6,248	1,161,913
1960	19,042	287,126	307,945	131,586	72,112	201,303	20,086	1,039,200
1961	77	239,822	347,946	98,447	41,587	260,326	3,750	991,955
1962	24,005	117,808	240,200	79,608	72,440	103,005	13,894	650,960
1963	212,175	130,142	261,372	55,511	150,634	221,355	18,150	1,049,339
1964	90,162	160,011	293,894	196,037	145,106	273,720	3,695	1,162,625
1965	120,193	287,280	157,907	147,746	36,761	254,740	2,665	1,007,292
1966	72,766	146,076	170,690	95,038	139,628	178,218	6,328	808,744
1967	125,435	62,274	107,762	169,990	73,220	165,761	5,870	710,312
1968	126,179	4,968	99,692	136,559	114,754	136,235	18	618,405
1969	9,266	10,378	124,940	92,529	105,186	135,507	5,486	483,292
1970	50,050	65,378	50,296	190,340	157,069	141,132	583	654,848
1971	24,497	74,938	145,830	167,243	68,129	108,092	1,329	590,058
1972	23,617	129,054	116,514	64,024	88,154	98,955	730	521,048
1973	1,935	8,868	7,607	83,740	113,399	112,676	514	328,739
1974	1,868	9,930	7,259	74,917	122,350	101,269	1,693	319,286
1975	4,640	44,652	7,406	88,718	117,700	173,570	1,696	438,382
1976	9,801	1,103	7,010	31,153	99,096	66,148	4,328	218,639
1977	984	181	1,553	61,839	86,624	86,823	544	238,548
1978	3,038	110	3,810	31,103	65,411	61,981	2,187	167,640

Table J. Catch per hour by month for interviewed anglers (including commercial) seeking kokanee, Pend Oreille Lake, Idaho, 1954-1978.

Year	Monthly catch per hour for kokanee											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Avg.
1954	-	0.8	4.5	5.9	5.2	2.8	2.4	1.4	1.5	2.5	1.3	2.9
1955	-	0.5	3.2	4.3	7.2	2.6	0.7	1.4	1.5	2.4	0.0	2.4
1956	3.5	6.5	7.5	6.2	6.2	1.7	1.1	1.4	2.3	2.7	0.2	3.3
1957	-	5.5	5.1	4.5	4.8	1.3	1.4	2.2	2.8	2.5	-	2.9
1958	7.9	3.4	4.6	8.1	5.2	1.4	1.9	2.6	3.7	3.3	1.0	3.6
1959	-	-	6.6	7.4	6.1	3.0	2.1	1.9	3.1	2.8	-	3.7
1960	0.9	5.3	7.8	4.1	6.4	2.3	1.1	1.6	2.0	2.5	0.3	3.2
1961	0.2	0.7	7.1	2.7	4.4	1.6	1.2	1.1	2.2	2.6	-	2.7
1962	-	5.2	2.5	4.8	4.9	1.4	1.2	1.5	1.7	3.7	0.0	2.6
1963	-	11.4	3.6	2.6	4.3	1.4	2.1	2.5	2.5	4.0	0.2	3.3
1964	3.5	7.3	6.4	4.4	8.6	3.0	1.8	3.1	4.1	3.2	3.7	4.5
1965	6.2	6.7	8.0	2.3	5.4	3.1	1.9	2.2	3.4	3.6	0.0	4.2
1966	11.6	7.1	4.4	0.4	4.8	1.9	1.6	2.6	2.7	2.6	-	3.1
1967	9.5	7.8	3.8	1.3	5.6	2.4	2.0	2.3	3.2	3.8	0.0	3.5
1968	13.3	6.4	0.1	3.7	3.9	2.8	1.7	2.4	2.7	2.4	-	2.9
1969	6.7	2.7	1.7	1.0	6.9	2.0	2.6	2.7	3.3	2.0	0.5	3.5
1970	0.7	3.9	6.2	0.8	3.1	2.4	2.7	3.0	2.9	2.4	0.0	2.9
1971	2.9	1.9	3.6	3.4	4.3	2.3	1.7	1.9	2.1	2.0	0.3	2.6
1972	8.9	6.0	6.1	2.0	4.0	2.1	1.7	2.0	2.3	1.4	1.0	2.8
1973	0.4	0.6	0.8	0.9	0.7	1.7	1.9	2.3	2.4	1.5	0.0	1.9
1974	0.0	1.6	1.5	0.1	1.1	1.8	1.6	1.9	2.4	1.7	0.4	1.8
1975	0.1	2.9	2.9	1.3	1.5	2.0	1.0	2.2	2.4	1.8	0.0	2.1
1976	2.1	1.4	0.4	0.0	0.9	1.0	0.9	2.2	1.5	1.1	0.0	1.3
1977	0.5	0.6	0.1	0.2	0.2	1.0	1.9	1.7	2.2	1.2	0.0	1.6
1978	1.3	1.5	0.1	0.03	0.8	1.3	1.1	1.4	1.9	1.2	0.0	1.4

Table K. Average kokanee size entering angler creels by census period, Pend Oreille Lake, Idaho, 1960-1978.

	Period 1 1/13-2/27			Period 2 2/28-4/14			Period 3 4/15-5/30		
		Average length			Average length			Average length	
Year	No.	mm	(in)	No.	mm	(in)	No.	mm	(in)
1960	49	226	(8.9)	240	226	(8.9)	1,153	234	(9.2)
1961	34	218	(8.6)	258	236	(9.3)	651	249	(9.8)
1962	181	226	(8.9)	364	234	(9.2)	490	246	(9.7)
1963	138	229	(9.0)	100	239	(9.4)	253	241	(9.5)
1964	454	221	(8.7)	403	218	(8.6)	201	234	(9.2)
1965	220	213	(8.4)	358	218	(8.6)	342	224	(8.8)
1966	222	218	(8.6)	193	224	(8.8)	225	234	(9.2)
1967	224	218	(8.6)	84	226	(8.9)	71	224	(8.8)
1968	246	213	(8.4)	100	216	(8.5)	307	226	(8.9)
1969	211	221	(8.7)	119	221	(8.7)	137	226	(8.9)
1970	192	211	(8.3)	210	218	(8.6)	199	226	(8.9)
1971	300	229	(9.0)	300	224	(8.8)	300	231	(9.1)
1972	300	216	(8.5)	300	211	(8.3)	325	229	(9.0)
1973	300	213	(8.4)	300	221	(8.7)	169	229	(9.0)
1974	300	221	(8.7)	300	218	(8.6)	528	229	(9.0)
1975	300	221	(8.7)	300	224	(8.8)	300	234	(9.2)
1976	300	211	(8.3)	--	--	--	270	224	(8.8)
1977	176	208	(8.2)	--	--	--	47	238	(9.4)
1978	300	210	(8.3)	19	224	(8.8)	456	229	(9.0)
Average (weighted) 1960-1978		218	(8.6)	--	224	(8.8)	--	234	(9.2)

Table K. (Cont'd.) Average kokanee size entering angler creels by census period, Pend Oreille Lake, Idaho, 1960-1978.

	Period 4 5/31-7/15			Period 5 7/16-8/30			Period 6 8/31-10/15		
		Average length			Average length			Average length	
Year	No.	mm	(in)	No.	mm	(in)	No.	mm	(in)
1960	234	231	(9.1)	438	236	(9.3)	311	254	(10.0)
1961	21	229	(9.0)	206	249	(9.8)	557	267	(10.5)
1962	192	239	(9.4)	305	239	(9.4)	90	272	(10.7)
1963	253	241	(9.5)	241	244	(9.6)	233	241	(9.5)
1964	201	234	(9.2)	417	239	(9.4)	200	244	(9.6)
1965	305	226	(8.9)	165	231	(9.1)	120	249	(9.8)
1966	250	231	(9.1)	225	241	(9.5)	30	241	(9.5)
1967	240	221	(8.7)	146	236	(9.3)	80	246	(9.7)
1968	187	229	(9.0)	195	241	(9.5)	200	239	(9.4)
1969	119	226	(8.9)	201	234	(9.2)	235	246	(9.7)
1970	204	224	(8.8)	756	231	(9.1)	530	251	(9.9)
1971	600	231	(9.1)	300	231	(9.1)	98	246	(9.7)
1972	600	221	(8.7)	600	231	(9.1)	357	251	(9.9)
1973	600	229	(9.0)	600	231	(9.1)	600	254	(10.0)
1974	600	224	(8.8)	600	226	(8.9)	600	244	(9.6)
1975	600	231	(9.1)	600	229	(9.0)	400	241	(9.5)
1976	460	216	(8.5)	600	213	(8.4)	600	231	(9.1)
1977	600	218	(8.6)	600	224	(8.8)	300	246	(9.7)
1978	600	227	(8.9)	460	240	(9.4)	420	242	(9.5)
Average (weighted) 1960-1978		226	(8.9)	--	231	(9.1)	--	246	(9.7)

Table L. Average kokanee size (early spawners), Pend Oreille Lake, Idaho, 1972-1976.

Year	No. of females	Average length		No. of males	Average length		Total	Average length	
		mm	in		mm	(in)		mm	(in)
1972	150	248	(9.8)	150	250	(9.8)	300	249	(9.8)
1975	39	241	(9.5)	62	243	(9.6)	100	242	(9.5)
1976	32	233	(9.2)	93	244	(9.6)	125	242	(9.5)

Table M. Average size of late-kokanee lakeshore spawners (Bayview) and stream spawners (Granite Creek) by sex, Pend Oreille Lake, Idaho, 1970-1978.

Year	Bayview Average length mm	(in)	Sample size	Granite Creek Average length mm	(in)	Sample size
			Males			
1970				271	(10.7)	160
1971				272	(10.7)	150
1972				259	(10.2)	77
1973	264	(10.4)	43	263	(10.3)	150
1974	266	(10.5)	18	266	(10.5)	195
1975	250	(9.8)	19	257	(10.1)	250
1976	--	--	--	253	(10.0)	137
1977	254	(10.0)	72	266	(10.5)	267
1978	--	--	--	264	(10.4)	167
			Females			
1970				261	(10.3)	163
1971				261	(10.3)	150
1972				253	(10.0)	84
1973	250	(9.8)	15	254	(10.0)	150
1974	249	(9.8)	43	258	(10.2)	213
1975	233	(9.2)	60	250	(9.8)	123
1976	--	--	--	239	(9.4)	141
1977	237	(9.3)	67	253	(10.0)	252
1978	--	--	--	254	(10.0)	183

Table N. Average kokanee size (late-spawners), Pend Oreille Lake, Idaho, 1950-1978. Does not include a small percentage (<1%) of kokanee measured in 1977 and 1978 that exceeded 30.0 cm, 11.8 in.

Year	No. of females	Average length mm	(in)	No. of males	Average length mm	(in)	Total	Average length mm	(in)
1950	--	–		--	–		12	277	(10.9)
1951	29	287	(11.3)	22	302	(11.9)	51	292	(11.5)
1952	158	302	(11.9)	137	310	(12.2)	295	305	(12.0)
1953	949	287	(11.3)	942	302	(11.9)	1,891	295	(11.6)
1954	123	267	(10.5)	102	277	(10.9)	225	272	(10.7)
1955	181	259	(10.2)	193	272	(10.7)	374	264	(10.4)
1956	339	254	(10.0)	322	264	(10.4)	661	259	(10.2)
1957	--	254	(10.0)	--	264	(10.4)	--	259	(10.2)
1958	621	262	(10.3)	832	272	(10.7)	1,453	267	(10.5)
1959	451	267	(10.5)	563	277	(10.9)	1,014	272	(10.7)
1960	239	274	(10.8)	300	290	(11.4)	539	284	(11.2)
1961	341	279	(11.0)	408	290	(11.4)	749	284	(11.2)
1962	229	279	(11.0)	423	290	(11.4)	652	284	(11.2)
1963	160	267	(10.5)	141	279	(11.0)	301	272	(10.7)
1964	48	244	(9.6)	72	256	(10.1)	120	251	(9.9)
1965	88	267	(10.5)	110	259	(10.2)	198	262	(10.3)
1966	104	269	(10.6)	120	262	(10.3)	224	264	(10.4)
1967	80	254	(10.0)	79	267	(10.5)	159	259	(10.2)
1968		–		--	–		--	--	
1969	--	–		--	–		103	259	(10.2)
1970	163	262	(10.3)	160	272	(10.7)	323	267	(10.5)
1971	150	262	(10.3)	150	272	(10.7)	300	267	(10.5)
1972	180	256	(10.1)	202	262	(10.3)	382	259	(10.2)
1973	165	254	(10.0)	193	264	(10.4)	358	259	(10.2)
1974	266	256	(10.1)	264	264	(10.4)	530	262	(10.3)
1975	231	244	(9.6)	363	256	(10.1)	594	252	(9.9)
1976	161	238	(9.4)	155	253	(10.0)	316	245	(9.6)
1977	319	250	(9.8)	339	264	(10.4)	658	257	(10.1)
1978	183	254	(10.0)	167	264	(10.4)	350	259	(10.2)

Table O. Relationship between kokanee catch and drawdown after 15 November, Pend Oreille Lake, Idaho, 1951-1978.

Year	Catch	Drawdown cm	(ft)	Catch (+5 yrs)
1951	820,000	--		1,093,000
1952	515,000	219.5	(7.2)	751,000
1953	1,336,000	42.7	(1.4)	1,197,000
1954	1,240,000	289.6	(9.5)*	1,162,000
1955	650,000	115.8	(3.8)	1,039,000
1956	1,093,000	73.2	(2.4)	992,000
1957	751,000	155.4	(5.1	651,000
1958	1,197,000	88.4	(2.9	1,049,000
1959	1,162,000	76.2	(2.5)	1,163,000
1960	1,039,000	91.4	(3.0)	1,007,000
1961	992,000	170.7	(5.6)	809,000
1962	651,000	103.6	(3.4)	710,000
1963	1,049,000	121.9	4.0	618,000
1964	1,163,000	164.6	5.4	483,000
1965	1,007,000	112.8	3.7	655,000
1966	809,000	170.7	(5.6	590,000
1967	710,000	61.0	(2.0	521,000
1968	618,000	121.9	4.0	329,000
1969	483,000	12.2	(0.4	319,000
1970	655,000	42.7	(1.4)	438,000
1971	590,000	70.1	(2.3)	219,000
1972	521,000	36.6	(1.2)	239,000
1973	329,000	0.0	(0.0)	168,000
1974	319,000	21.3	(0.7)	--
1975	438,000	88.4	(2.9)	--
1976	219,000	51.8	(1.7)	--
1977	239,000	36.6	(1.2)	--
1978	168,000	30.5	(1.0)	--

*Indicated year when no relationship is shown between drawdown and catch.

Table P. Estimated minimum fishing pressure, effort and harvest for sport anglers seeking cutthroat, Pend Oreille Lake, Idaho, 13 January - 30 November, 1960-1978.

Year	Estimated angler man-days	Estimated hours fished	Estimated cutthroat catch	Cutthroat per angler*	Cutthroat per hour*
1960	3,950	13,863	2,365	0.60	0.17
1961	2,178	8,135	1,370	0.63	0.17
1962	2,213	9,983	1,534	0.69	0.15
1963	3,156	13,918	1,645	0.52	0.12
1964	1,716	7,301	1,093	0.64	0.15
1965	1,331	5,871	569	0.43	0.10
1966	1,362	3,933	1,282	0.94	0.33
1967	775	2,960	326	0.42	0.11
1968	702	2,083	469	0.67	0.23
1969	600	1,952	503	0.84	0.26
1970	992	2,823	395	0.40	0.14
1971	873	2,861	544	0.62	0.19
1972	878	3,289	774	0.88	0.24
1973	1,407	5,415	742	0.53	0.14
1974	792	3,478	228	0.29	0.07
1975	992	3,767	781	0.79	0.21
1976	2,146	8,832	596	0.31	0.07
1977	2,206	9,447	616	0.29	0.07
1978	2,127	10,495	524	0.22	0.05
Total	30,396	120,406	16,356	--	--
Average (weighted)	1,600	6,337	861	0.50	0.12

*Based on interview (actual) data.

Table Q. Estimated minimum fishing pressure, effort and harvest for sport anglers seeking Dolly Varden, Pend Oreille Lake, Idaho, 13 January - 30 November, 1960-1978.

Year	Estimated angler man-days	Estimated hours fished	Estimated Dolly Varden catch	Dolly Varden per angler*	Dolly Varden per hour*
1960	2,455	9,680	1,434	0.58	0.14
1961	1,345	6,445	812	0.56	0.13
1962	1,026	4,887	511	0.44	0.09
1963	933	4,697	554	0.45	0.10
1964	1,800	10,201	428	0.26	0.05
1965	1,037	5,159	797	0.83	0.16
1966	1,017	4,042	490	0.50	0.13
1967	294	1,218	112	0.38	0.09
1968	185	1,117	143	0.90	0.13
1969	377	1,848	298	0.94	0.18
1970	529	2,567	232	0.42	0.08
1971	280	1,237	240	0.60	0.13
1972	538	2,883	191	0.41	0.08
1973	305	1,481	263	0.72	0.15
1974	595	3,215	330	0.70	0.12
1975	315	1,052	166	0.48	0.14
1976	367	1,661	203	0.68	0.14
1977	399	2,277	406	0.57	0.11
1978	1,220	6,426	786	0.65	0.12
Total	15,017	72,093	8,396	--	--
Average (weighted)	790	3,794	442	0.56	0.12

*Based on interview (actual) data.

Table R. Estimated minimum fishing pressure, effort and harvest for sport anglers seeking trophy Kamloops trout over 432 cm (17 in), Pend Oreille Lake, Idaho, 1960-1978.

Year	Estimated angler man-days	Estimated hours fished	Estimated trophy Kamloops catch	Trophy Kamloops per angler*	Trophy Kamloops per hour*
1960	9,009	43,561	767	0.08	0.02
1961	9,224	43,131	493	0.07	0.02
1962	6,744	33,190	929	0.11	0.02
1963	7,855	44,714	678	0.08	0.01
1964	7,968	40,740	527	0.08	0.02
1965	7,682	37,431	865	0.11	0.02
1966	9,650	48,663	884	0.09	0.02
1967	7,950	38,119	700	0.08	0.02
1968	7,805	35,352	600	0.08	0.02
1969	7,777	40,473	582	0.09	0.02
1970	11,157	54,899	811	0.07	0.01
1971	10,614	52,756	847	0.07	0.01
1972	10,123	50,004	748	0.07	0.01
1973	8,449	44,625	479	0.06	0.01
1974	9,757	50,355	687	0.07	0.01
1975	10,993	55,712	759	0.07	0.01
1976	15,195	79,802	1,403	0.08	0.02
1977	14,770	77,327	1,216	0.08	0.01
1978	16,897	88,969	1,334	0.08	0.01
Total	189,619	959,823	15,309	--	--
Average (weighted)	9,980	50,517	806	0.08	0.01

*Based on interview (actual) data.

Table S. Kamloops trout released in Pend Oreille Lake, Idaho, 1941-1978.

Year	Fry (0-3")	Fingerlings (3-6")	Catchables (6+)	Total
1941				2,688
1942				19,813
1943				64,114
1944				--
1945				2,128
1946				14,934
1947				23,909
1948				25,031
1949		7,662	6,875	14,537
1950	106,412	--	6,809	113,221
1951	552,300	12,137	400	564,837
1952	541,676	47,160	806	589,642
1953	320,400	24,000	22,568	366,968
1954	199,000	--	27,850	226,850
1955	84,000	26,400	62,460	172,860
1956	--	--	66,120	66,120
1957	350,500	14,200	71,884	436,584
1958	579,472	70,950	84,871	735,293
1959	574,080	46,325	51,825	672,230
1960	627,968	--	48,000	675,968
1961	113,575	31,035	35,099	179,709
1962	421,090	40,717	51,722	513,529
1963	442,088	253,411	89,999	785,498
1964	308,808	337,910	61,218	707,936
1965	143,735*	28,445	42,629	214,809
1966	402,488	22,020	132,834	557,342
1967	644,584	--	121,169	765,753
1968	563,518	115,105	28,897	707,520
1969	346,685	96,746	22,930	466,361
1970	412,333	71,230	17,950	501,513
1971	176,167	50,525	16,127	242,819
1972	135,928	38,286	17,951	192,165
1973	280,531	50,130	19,344	350,005
1974	494,828	60,393	12,525	567,746
1975	790,703	40,065	--	830,768
1976	519,702	--	--	519,702
1977	4,786	--	--	4,786
1978	--	--	--	_-
Subtotal	10,137,357	1,484,852	1,120,862	
Total				12,895,688

*Includes 112,739 eyed eggs.

Table T. Average lengths and weights of trophy Kamloops trout and Dolly Varden, Pend Oreille Lake, Idaho, 1960-1978.

Year	No. of Kamloops	Average length cm	(in)	Average weight kg	(lb)	No. of Dolly Varden	Average length cm	(in)	Average weight kg	(lb)
1960	89	66.0	(26.0)	--		112	55.1	(21.7)	--	
1961	69	65.8	(25.9)	--		48	54.9	(21.6)	--	
1962	85	64.5	(25.4)	--		59	54.4	(21.4)	--	
1963	124	58.7	(23.1)	--		48	57.9	(22.8)	--	
1964	81	67.3	(26.5)	--		53	59.4	(23.4)	--	
1965	82	66.0	(26.0)	--		63	56.4	(22.2)	--	
1966	87	65.3	(25.7)	--		60	54.9	(21.6)	--	
1967	76	61.0	(24.0)	--		47	51.1	(20.1)	--	
1968	70	65.6	(25.8)	--		43	53.8	(21.1)	--	
1969	78	65.3	(25.7)	--		70	55.6	(21.9)	--	
1970	92	65.0	(25.6)	--		55	56.1	(22.1)	--	
1971	249	67.1	(26.4)	--		136	55.9	(22.0)	--	
1972	237	69.3	(27.3)	4.9	(10.9)	138	51.8	(20.4)	2.7	(5.0)
1973	137	70.4	(27.7)	5.4	(11.8)	131	55.4	(21.8)	2.6	(5.8)
1974	216	67.3	(26.5)	4.7	(10.3)	168	54.1	(21.3)	2.1	(4.6)
1975	235	64.3	(25.3)	3.9	(8.6)	113	55.9	(22.0)	2.3	(5.1)
1976	339	61.2	(24.1)	3.4	(7.4)	190	54.6	(21.5)	2.0	(4.5)
1977	293	60.5	(23.8)	3.1	(6.9)	143	55.9	(22.0)	2.1	(4.7)
1978	347	62.5	(24.6)	3.5	(7.8)	164	53.8	(21.2)	2.0	(4.3)
Average (weighted)		64.5	(25.4)	3.9	(8.5)		54.9	(21.6)	2.2	(4.8)

Table U. Catch data for interviewed anglers seeking trophy Kamloops in Pend Oreille Lake and the Clark Fork River, 1960-1978.*

	Lake Pend Oreille			Clark Fork River		
Year	Hours	Kamloops	Hrs/fish	Hours	Kamloops	Hrs/fish
1960	4,567	76	60.1		No census	
1961	4,066	64	63.5		No census	
1962	3,357	77	43.6		No census	
1963	4,831	65	74.3		No census	
1964	4,459	68	65.6		No census	
1965	3,849	81	47.5		No census	
1966	4,263	88	48.4	867	77	11.3
1967	4,219	66	63.9	2,270	117	19.4
1968	3,533	58	60.9	2,180	61	35.7
1969	4,106	68	60.4	2,100	48	43.8
1970	5,996	83	72.2	1,975	44	44.9
1971**	16,179	236	68.6	1,511	14	107.9
1972	16,566	234	70.8	1,940	37	52.4
1973	13,391	143	93.6	774	23	33.7
1974	16,571	207	80.1	1,590	22	72.3
1975	15,084	209	72.2	960	22	43.6
1976	20,394	317	64.3	--	--	-
1977	18,682	264	70.8	--	--	--
1978	19,415	296	65.6	--	--	--
Total	183,528	2,700	--	16,167	465	--
Average (weighted)	--	--	68.0	--	--	34.8

*Lake vs. river catch rates should not be compared since the lake census extends for 7 months and the river census between 3 weeks and 2½ months. However, the data suggests the trends of each fishery.

**A more intensive census commenced on Pend Oreille Lake in 1971 and would account for the increase catch data for previous years.

JOB PERFORMANCE REPORT

State of Idaho

Name: LAKE AND RESERVOIR INVESTIGATIONS

Project No. F-73-R-1

Title: Kokanee Spawning Trends

Study No. II

Job No. II

Period Covered: 1 March 1978 to 28 February 1979

ABSTRACT

Spawning escapement from both early and late-run kokanee was assessed in Pend Oreille Lake during the 1978-79 spawning season.

Counts from early-run kokanee peaked in Trestle Creek on 8 September 1978 with a count of 1,589. Kokanee run size in Trestle Creek from 1973 to 1978 has varied erratically, ranging in peak counts of nearly 15,000 in 1975 to less than 250 in 1974. Returns to the tributaries in 1977 and 1978 of 3.5 million early kokanee fry released in 1974 and 1975 were very low, suggesting lake survival was marginal.

Fewer late-spawning kokanee were observed in the tributaries and on the shore-lines of Pend Oreille Lake during the 1978 spawning season than were observed in 1977. Granite Creek supported most of the observed tributary spawning while Bayview received most of the shoreline spawners. We passed 16,875 kokanee through the Sullivan Springs Creek weir in 1978. From those trapped kokanee we collected 1.4 million embryos that will be released as fry back into the system in mid-summer of 1979.

Overall, by comparing maximum single counts (trends) of late-run kokanee taken during the spawning years 1972 through 1978, the 1972 and 1976 spawning years were similar, both being from one-third to one-half of the kokanee numbers counted from 1973, 1974, 1975, 1977 and 1978. Escapement trends in the last 3 years indicate the kokanee population is declining in Pend Oreille Lake.

With the addition of midwater trawl data in 1978 we estimated the potential kokanee escapement in the lake by assessing the abundance of mature fish in September. We estimated that the lake supported 988, 000 mature kokanee in early fall which suggests the trend estimates only represent a small percentage of total escapement but do reflect relative year-class strength.

Kokanee ranging to 54 cm (21.3 in) appeared in the spawning populations during 1978. Less than 0.5% of the kokanee in the Granite Creek spawning run during 1977 and 1978 were larger than 30.0 cm (11.8 in). The large kokanee size is a result of Mysis relicta populations in the lake.

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Principal Fishery Research Biologist

RECOMMENDATIONS

1. Because of low returns of early-spawning kokanee to the creel and to the spawning tributaries, discontinue their introduction into the lake.

2. Continue efforts to rehabilitate the kokanee spawning run into Granite Creek by replacing spawning gravels in Sullivan Springs Creek and/or incubating embryos on site or at a hatchery for bolstering the run. Time the releases to favorable food conditions in the lake.

3. Continue operating the weir at the mouth of Sullivan Springs Creek to monitor escapement, collect embryos and evaluate survival of returning adults from known releases.

4. Continue to tetracycline mark kokanee fry released in Granite Creek to monitor survival in the lake.

5. Experiment with scuba and other methods to locate deep spawning along the shorelines of the lake.

6. Continue to collect otolith and length measurements from Granite Creek to correlate age at maturity in the spawning run with year-class strength in the lake.

7. Continue to make estimates of potential escapement from fall trawl and acoustic data.

OBJECTIVES

To develop methodology and arrive at an index of relative abundance of spawning kokanee for year-to-year trend comparisons in Pend Oreille Lake.

To record the location and relative abundance of spawning kokanee in Pend Oreille Lake.

To document the duration and peak time of kokanee spawning.

To evaluate major changes in lake or stream areas used for kokanee spawning in 1978 as compared to those used in the 1950s.

To assess the age structure of the kokanee spawning population in Pend Oreille Lake.

TECHNIQUES USED

We estimated numbers of kokanee utilizing spawning areas of Pend Oreille Lake and its tributaries throughout the 1978-79 spawning season. Counts along the shore-line were made from a boat and by walking. We made tributary counts by walking each stream from its mouth to the upper extent of kokanee spawning. No attempt was made to enumerate kokanee in the Clark Fork River because of the difficulty in making comparable counts from year to year.

For both tributary and shoreline estimates, kokanee were enumerated individually, when possible, but mostly they were counted in numbers of 10s and 100s because of their density. An attempt was made to make each count at a 5-day interval but because of poor observation conditions, we could not maintain the 5-day schedule in all areas of the lake. The U.S. Army Corps of Engineers aided the survey by making kokanee counts from a boat along the shoreline of the north end of the lake.

We made counts of kokanee through the weir at the mouth of Sullivan Springs Creek during the spawning season. We also collected otolith and length measurements of spawning kokanee in various tributaries and along the shoreline in Bayview to assess length and age at maturity.

During the fall of 1978 we collected 1.4 million kokanee embryos from Sullivan Springs Creek. The subsequent fry will be reared at the Clark Fork Fish Hathery and returned to Sullivan Springs Creek in mid-summer of 1979. All fry will be tetracycline marked to evaluate their survival while in the lake and as adults when they return to spawn in 1982 and 1983.

FINDINGS

Early-run Kokanee

Trestle Creek, the only known recipient of a sustained run of early-spawning kokanee in the Pend Oreille Lake drainage, supported more fish in 1978 than in 1977 (Fig. 1). The peak count occurred 8 September 1978 with a count of 1,589. The kokanee run size has been quite erratic from 1973 to 1978 varying from peak counts of nearly 15,000 in 1975 to less than 250 in 1974 (Fig. 1).

During 1974 and 1975, 3.5 million kokanee fry of the early-spawning variety were released into the north end tributaries of the lake (Bowler 1976). Approximately 1,000 kokanee spawners were observed in the fall of 1977 (Bowler 1978) in the tributaries of release but none were found in the fall of 1978.

Late-run Kokanee

Fewer late-spawning kokanee were observed in the tributaries and on the shore-lines of Pend Oreille Lake during the 1978 spawning season than were observed in 1977. Granite Creek supported most of the observed tributary spawning while Bayview received most of the shoreline spawners.

Shoreline spawners were first observed on 6 November 1978 in Bayview. The count peaked in Bayview with 798 counted 13 November (Table 1). The 1978 spawning trend count in Bayview was the lowest observed since 1972 (Fig. 2). Only a few kokanee spawners were seen on the northern shorelines of the lake (Table 1).

Tributary spawners were first observed in Granite Creek on 26 October. We did not regularly count North and South Gold Creeks in 1978 but spot checks indicated only several hundred kokanee in North Gold and less than 100 in South Gold which is comparable to 1977 (Fig. 3). Fewer kokanee were counted in lower Lightning Creek in 1978 than in 1977 but Spring Creek supported runs comparable to 1977 and 1973 (Fig.4) We could not account for any kokanee utilizing Cedar Creek in 1978.

We saw more spawning kokanee in Granite Creek during 1978 than in any other tributary to the lake. Slightly fewer kokanee were counted in 1978 in Granite Creek than in 1977 (Fig. 5). The maximum single count including the accumulated count from the Sullivan Springs Creek weir was 18,226 made 19 December 1978 (Fig. 5).

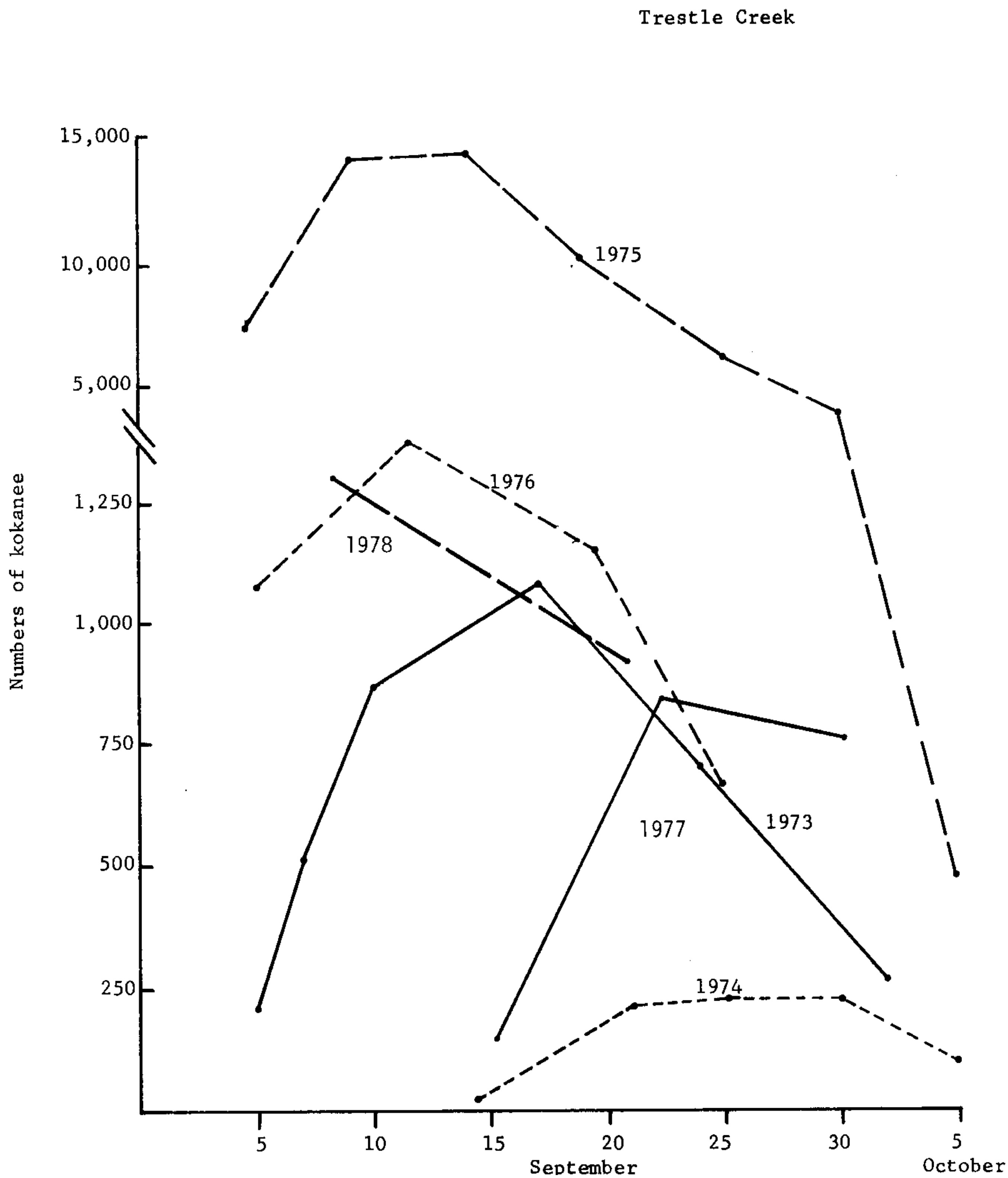

Figure 1. Numbers of early-run kokanee counted in Trestle Creek during the 1973 through 1978 spawning seasons in Pend Oreille Lake.

Table 1. Number of spawning kokanee (late-run) counted along the shoreline areas of Pend Oreille Lake, 1978.

Shoreline	November				December			
	6	13	20	27	5	6	12	18
Bayview Beach (entire)	467	798	425	533	423		110	27
Breakdown:								
Bubb's								
Wheel Inn								
J. D.'s	46	70	55	255	180		22	
Boileaus Bayview Resort	39	128	60	275	243		88	
Navy Yards	147	123	35					
Private Docks	101	12	20					
MacDonald's	134	465	225	3				27
Vista Bay			30					
Jeb's Boat Harbor				100		138		

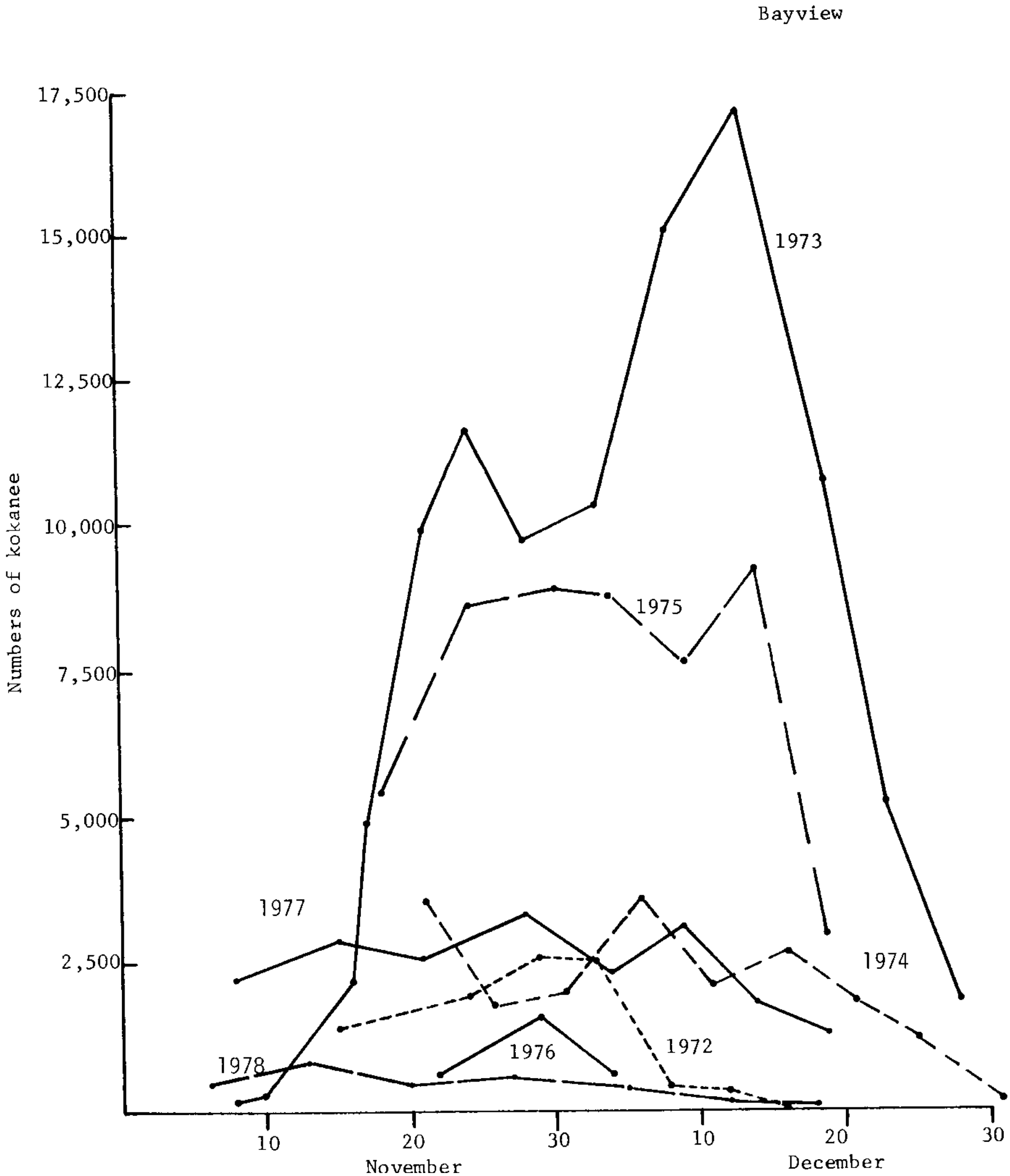

Figure 2. Numbers of lakeshore spawning kokanee counted in the Bayview area during the 1972 through 1973 late-spawning seasons in Pend Oreille Lake.

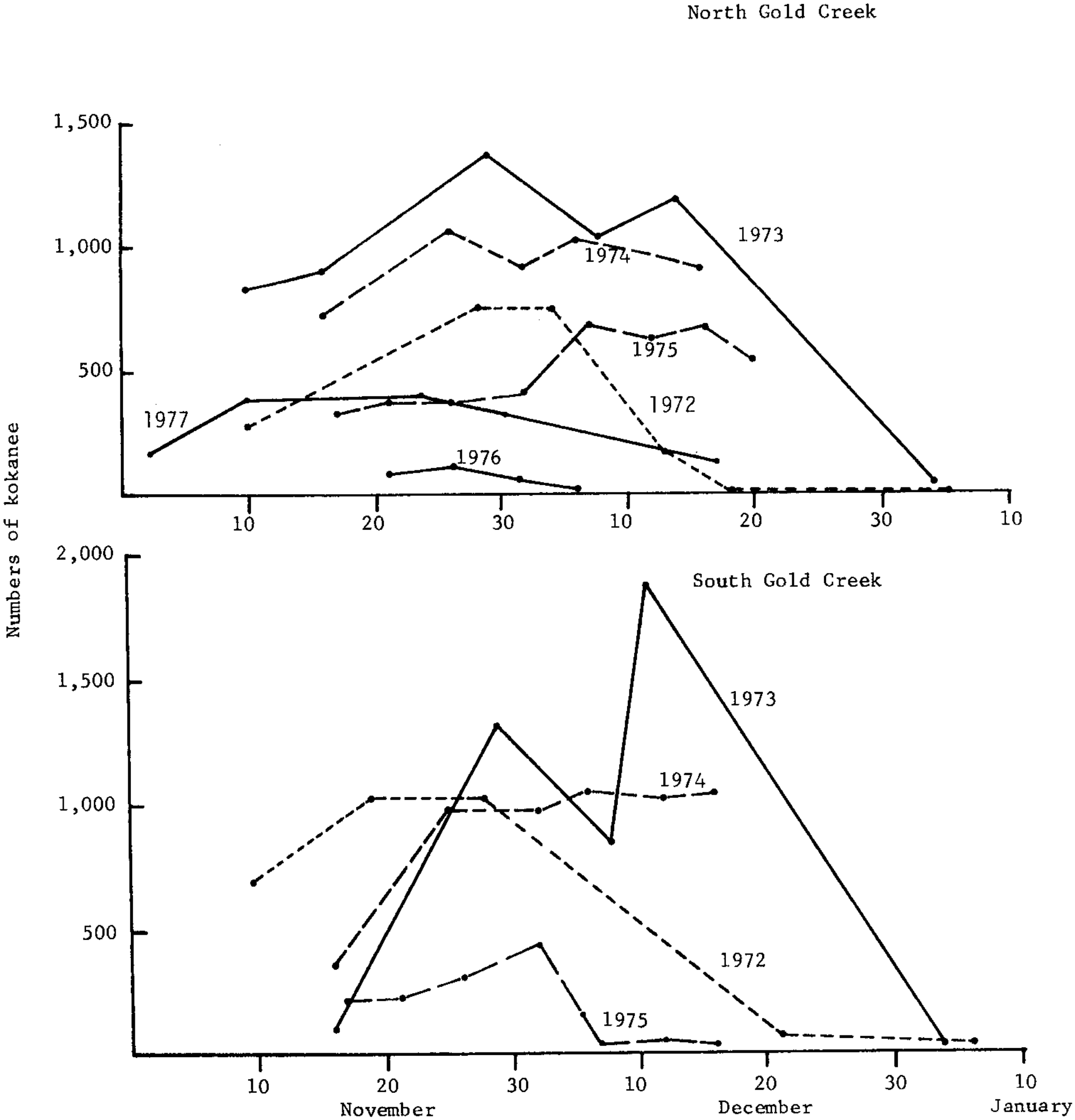

Figure 3. Numbers of spawning kokanee counted in North and South Gold Creeks during the 1972 through 1977 late-spawning seasons in Pend Oreille Lake.

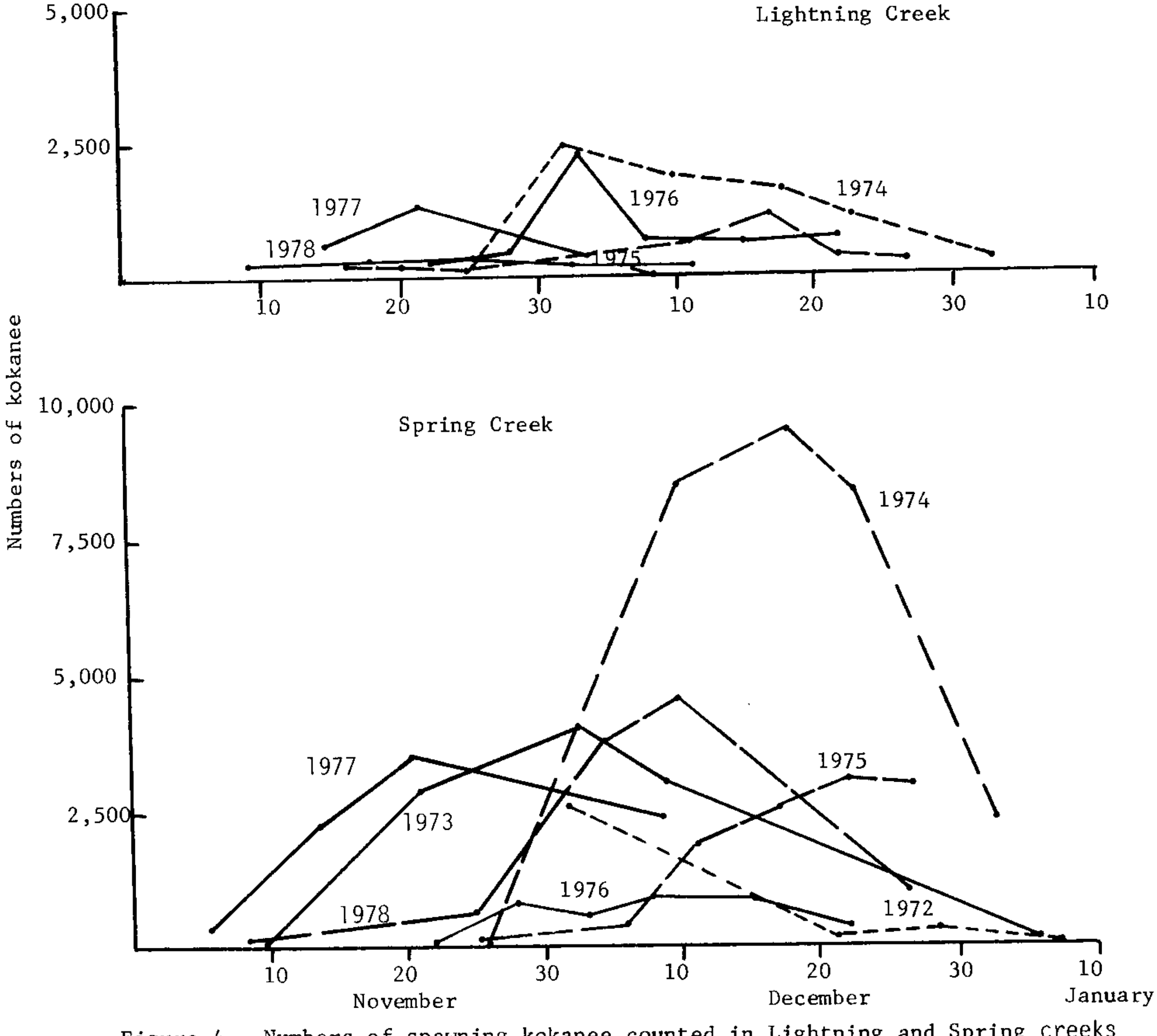

Figure 4. Numbers of spawning kokanee counted in Lightning and Spring creeks during the 1972 through 1978 late-spawning seasons in Pend Oreille Lake.

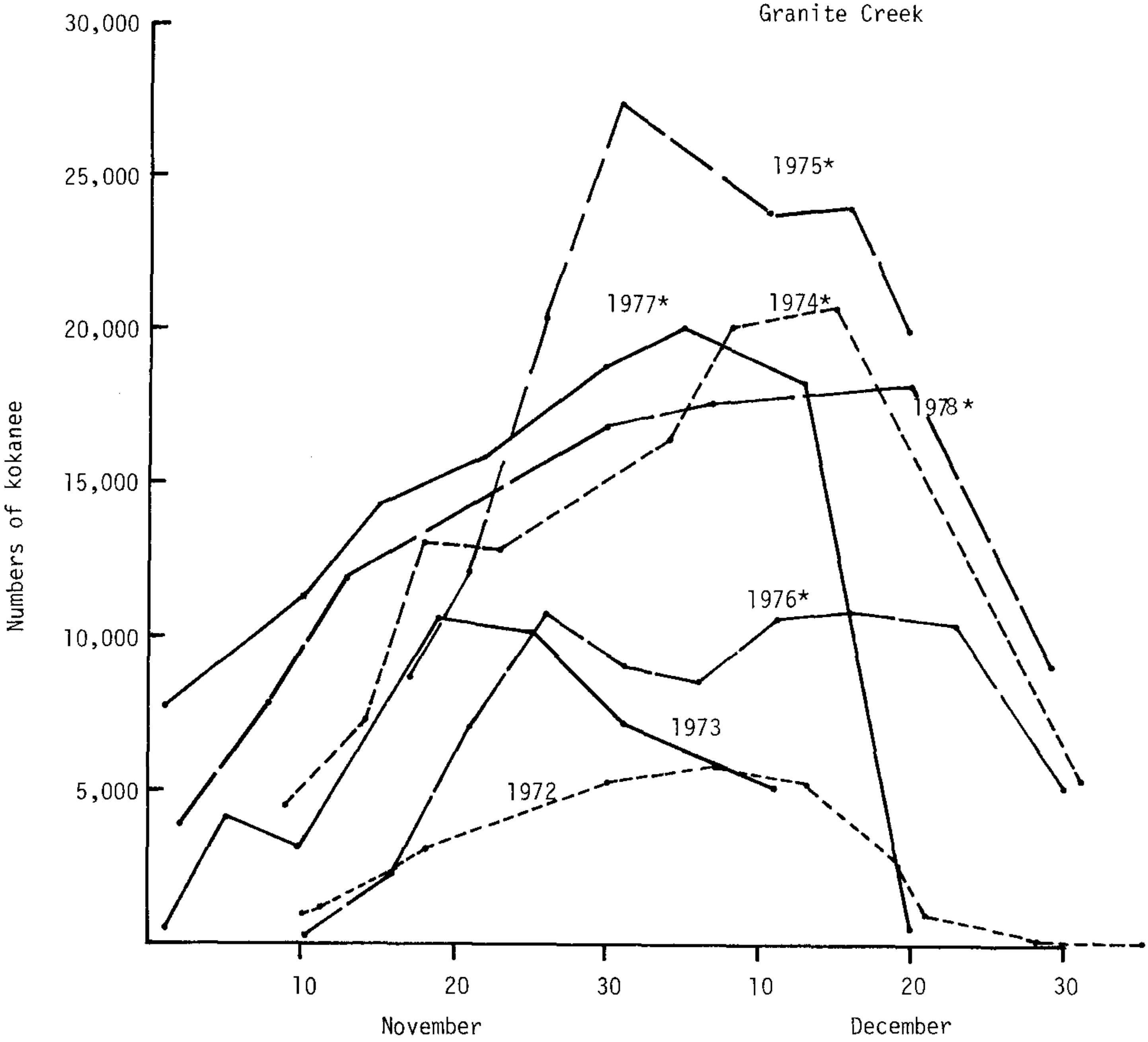

Figure 5. Numbers of spawning kokanee counted in Granite Creek (including Sullivan Springs) during the 1972 through 1978 late-spawning seasons in Pend Oreille Lake.

*The 1974-1978 counts include the accumulated Sullivan Springs weir count.

We counted a total of 16,875 kokanee through the weir at the mouth of Sullivan Springs Creek from 2 November to 19 December 1978 (Table 2). We also collected 1.4 million kokanee embryos during 1978 from Granite Creek that were incubated at the Clark Fork Fish Hatchery. The resultant fry will be released back into Sullivan Springs during mid-summer of 1979 when plankton abundance becomes favorable. We released 1.6 million kokanee fry from the 1977 year-class into Sullivan Springs from 22 June to 31 July 1978 (Table 2).

Lake Water Levels

The level of Pend Oreille Lake measured 625.69 m (2,052.27 ft) on 15 November 1978. By 20 November the lake stabilized at 625.44 m (2,051.45 ft) but fluctuated + 0.15 m (0.5 ft). Very little shoreline spawning was observed in Pend Oreille Lake during 1978. Coupled with minimal drawdown and few spawners there should be very little impact on incubating kokanee embryos in shoreline gravels during 1978.

Comparing Kokanee Escapement Trends from 1972 through 1978 with Trends of the 1950s

I compared maximum single counts of kokanee throughout the 1978 spawning season with the same counts made during the spawning years 1972 through 1977 (Table 3). The general trend in escapement is expressed in Figure 6. These trend estimates are similar to the maximum single counts as expressed by Table 3 but they exclude the Clark Fork River counts because we were unable to obtain comparable annual counts from the Clark Fork. As trend comparisons they indicate that the strength of the 1972 and 1976 spawning population were less abundant than the 1973, 1974, 1975, 1977 and 1978 spawning populations. Also the trend indicates the 1977 and 1978 spawning populations were not replaced based on the strength of the spawning populations in 1973 and 1974, suggesting a population decline (Fig. 6).

It is difficult to compare spawning escapement trends during the 1950s with those of present trends because much of the early data is spread over several years and is not consistent from year to year in the same areas. Jeppson (1960) found that during the 1950s kokanee spawned in 27 different shoreline areas with some areas averaging more than 1,000 kokanee annually. Gibson (1973) noted kokanee spawning trends in 1972 were consistently lower than those found in the 1950s. Although there is some variability in escapement estimates during the 1970s the general trend appears considerably less than those observed in the 1950s.

Length of Late-Spawning Kokanee

Mean total lengths of late-spawning kokanee in Pend Oreille Lake have fluctuated from 31 cm (12.2 in) in 1951 when data was first recorded to 24 cm (9.4 in) in 1976 (Table N, Appendix, Job I this report; Fig. 7). Larger kokanee than had been observed in the spawning runs since the early 1950s were seen during 1977 and 1978 in the Bay-view and Granite Creek spawning populations. Males ranging to 54 cm (21.3 in) and females ranging to 43 cm (16.9 in) were measured in Granite Creek during 1978. Mean size of large males measured 38.6 cm (15.2 in) and large females measured 37.8 cm (14.9 in). The larger kokanee (over 30.0 cm, 11.8 in) represented less than 0.5% of the total run into Granite Creek for both 1977 and 1978. The length frequency of 161 aged kokanee from Granite Creek is described in Figure 8.

Age at Maturity (Late-Run Kokanee)

The age at maturity of late-spawning kokanee in Pend Oreille Lake appears to

Table 2. Weir counts of kokanee entering Sullivan Springs Creek and foot survey estimates of upper (above the mouth of Sullivan Springs) and lower Granite Creek taken during the 1978-79 spawning season. Also the weir counts from 1974 through 1978 including embryo collections and subsequent fry releases are listed.

Date	Weir count	Upper and Lower Granite Creek
November		
2	2,130	
8	3,825	1,700
13	2,900	2,100
22	3,000	3,220
30	2,720	2,250
December		
7	1,300	1,780
19	1,000	1,350
Total	16,875	

Year	Weir count	Embryos collected	Fry released (date)
1974	13,549	985,000	
1975	14,198	--	629,222 (5/8 to 6/19)
1976	10,151	913,000	
1977	17,650	2.04 million	757,720 (7/11 to 7/28)
1978	16,875	1.4 million	1.6 million (6/22 to 7/31)

Table 3. Maximum single (late-run) kokanee counts made during the 1972 through 1978 spawning seasons on Pend Oreille Lake and its tributaries.

Area	Maximum single counts						
	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79
Lakeshore							
Bayview	2,626	17,156	3,588	9,231	1,525	3,390	798
Farragut	25	0	0	0	0	0	0
Idlewild Bay	13	0	25	0	0	0	0
Lakeview	4	200	18	0	0	25	0
Ellisport Bay and Hope	1	436	975	0	0	0	0
Trestle Creek Resorts	0	1,000	2,250	0	115	75	138
Sunnyside	0	25	0	0	0	0	0
Fishermen Island	0	0	75	0	0	0	0
Anderson Point	0	0	50	0	0	0	0
Camp Bay	0	617	0	0	0	0	0
Garfield Bay	0	400	20	0	0	0	0
Subtotal	2,669	19,834	7,001	9,231	1,640	3,490	936
Tributaries							
South Gold Creek	1,030	1,875	1,050	440	0	30	--
North Gold Creek	744	1,383	1,068	663	130	426	--
Cedar Creek	0	267	44	16	11	0	0
Granite Creek	5,733	10,631	20,672	27,453	10,717	20,075	18,225
Johnson Creek	0	0	1	0	0	0	0
Twin Creek	0	0	135	1	0	0	0
Mosquito Creek	0	503	0	0	0	0	0
Clark Fork River	539	3,520	6,180	0	--	--	--
Lightning Creek (Lower)	350	500	2,350	995	2,240	1,300	44
Spring Creek	2,610	4,025	9,450	3,055	910	3,390	4,020
Trestle Creek	1,293	18	1,210	15	0	40	0
Garfield Creek	0	0	25	0	0	0	0
Subtotal	12,299	22,722	42,185	32,638	14,008	25,261	22,289
Grand Total	14,968	42,556	A9,186	41,869	15,648	28,751	23,225

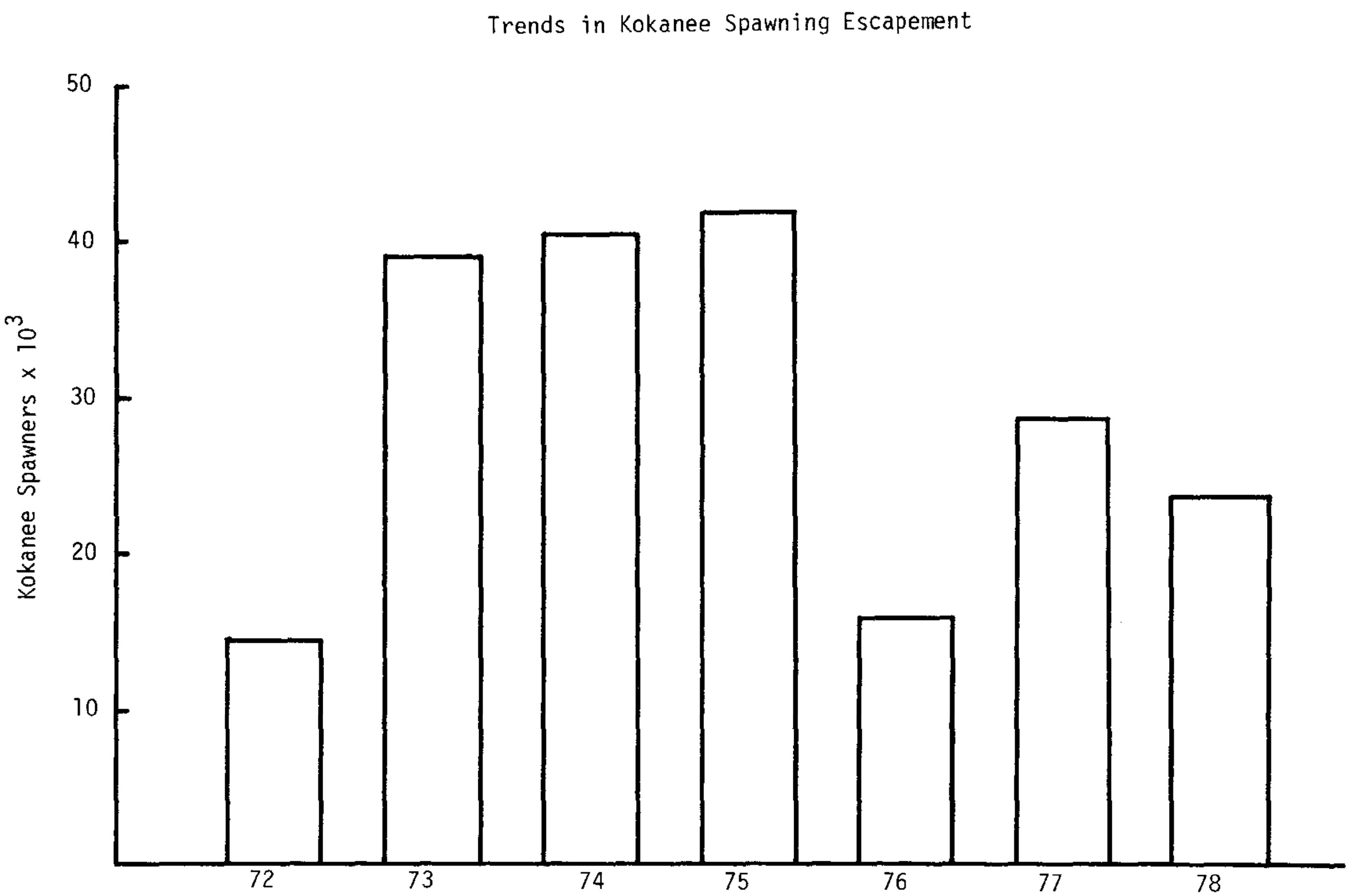

Figure 6. Trend estimates (maximum single counts) of kokanee spawning escapement in Pend Oreille Lake from the spawning years 1972-1978.

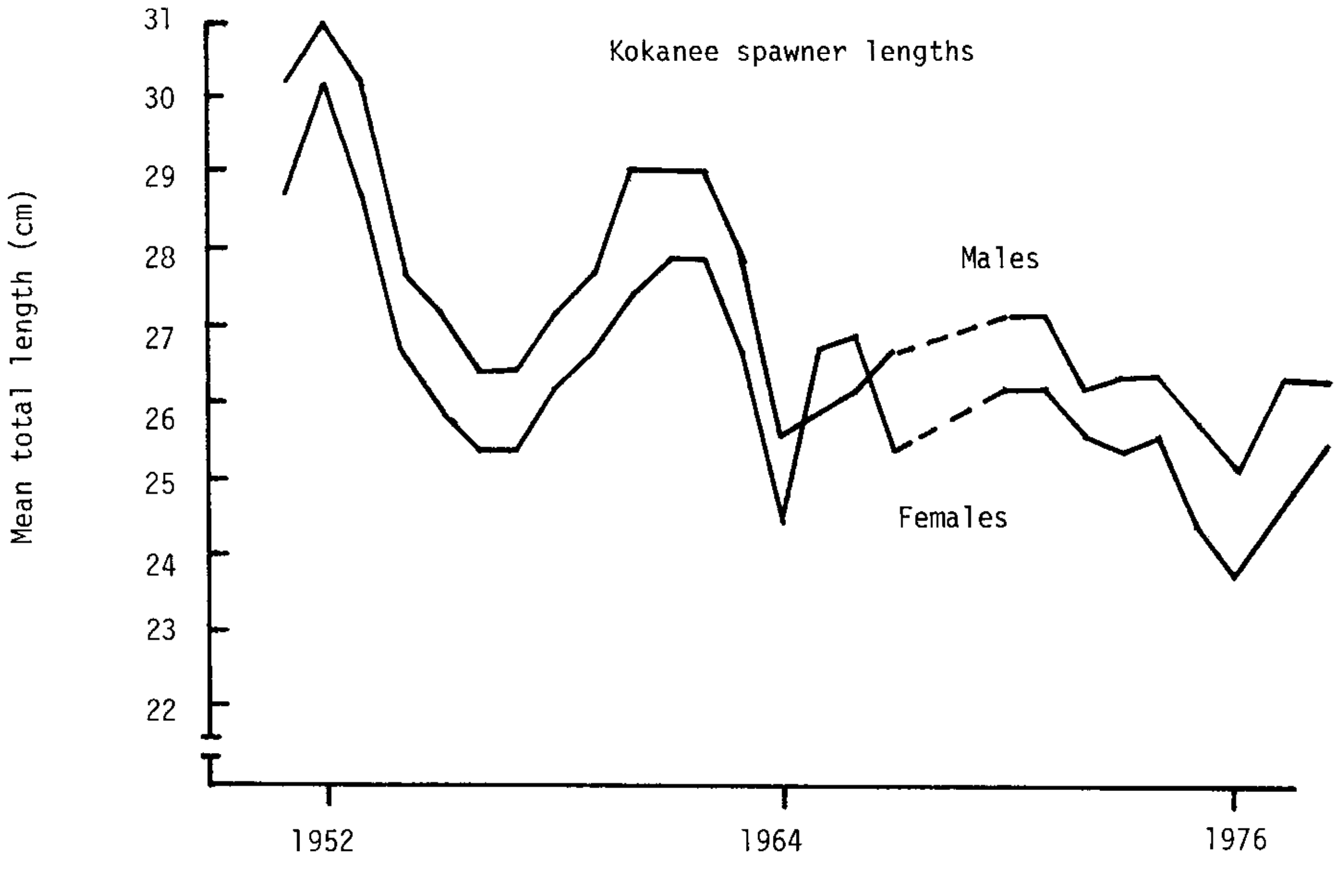

Figure 7. Mean lengths of kokanee spawners measured in Pend Oreille Lake from 1951 to 1978.

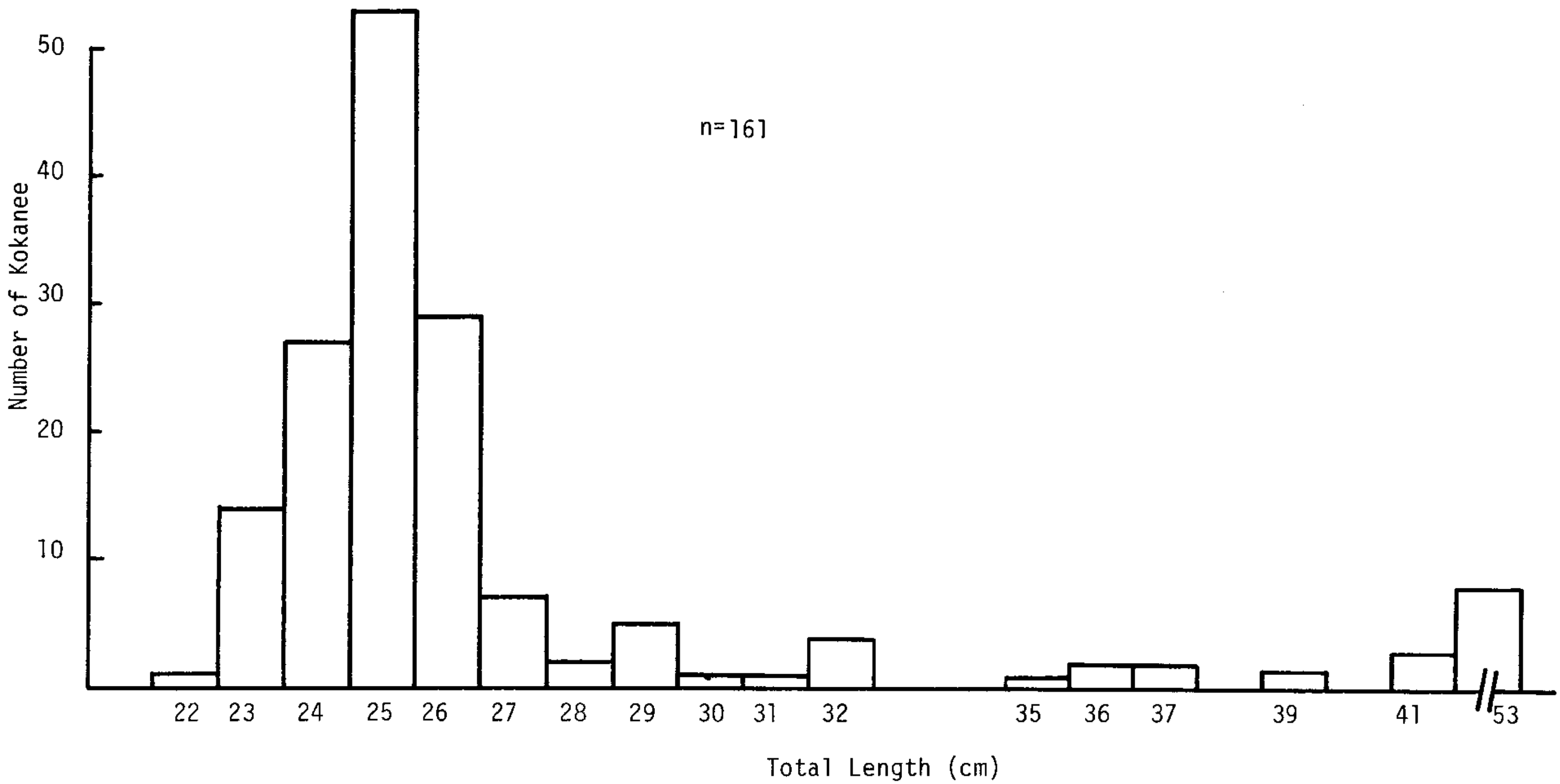

Figure 8. Length frequency of 161 aged kokanee spawners collected in Granite Creek during 1978. Aging was done with otoliths.

vary from year to year. The spawning population consists primarily of age 4 (3+) and 5 (4+) kokanee with the percentages of each varying from year to year. We have collected most of the Pend Oreille age at maturity data from two areas; Granite Creek (tributary) and Bayview (shoreline). Since Bayview has been erratic in spawner abundance it has been difficult to collect fish every year.

The kokanee age composition in Bayview varied considerably from 1974 through 1977. The percentage of age 4 (3+) kokanee ranged from 23% in 1974 to 71% in 1977 (Fig. 9). The increase in age 4 fish in 1977 was likely the result of a very strong 1973 year-class compared to a weak 1972 year-class (Fig. 2). Age composition in Granite Creek also varied from 1974 through 1978. Age 4 (3+) kokanee ranged from 32% in 1978 to 85% in 1976 (Fig. 10). In 1977 age 4 (3+) and 5 (4+) fish comprised about 50% of each age of the spawning population. All of the years examined in Granite Creek with the exception of 1977 had small percentages of age 6 (5+) kokanee in the spawning run (Fig. 10).

We collected 23 kokanee larger than 30.0 cm (11.8 in) in the Granite Creek spawning run during 1978. Eighty-three percent were males ranging in length from 31.0 cm (12.2 in) to 53.0 cm (20.9 in). Of those 23 kokanee, 13% were age 4 (3+), 52% were age 5 (4+), 31% were age 6 (5+) and 4% were age 7 (6+) (Table 4).

Potential Spawning Escapement Based on Trawl Data

It was apparent from the 1978 trawl estimates of the potential spawning population in Pend Oreille Lake that the trend estimates can account for only a small percentage of the total escapement in the lake. We estimated that the lake supported 988,000 kokanee larger than 22 cm (8.7 in) during September 1978. Those fish larger than 22 cm were mature while those less 22 cm were immature.

DISCUSSION

Early-Spawninq Kokanee

The low returns in 1977 and 1978 of early-spawning kokanee to the creel and to the spawning tributaries from where they were released suggests they have contributed little to the Pend Oreille kokanee population. Less than 0.1% of the early-spawning kokanee were recovered in mid-water trawl samples. The 3.5 million fry released were introduced mostly during the spring months of 1974 and 1975 (Bowler 1976) which may have resulted in poor survival due to poor food conditions in the lake at that time (Rieman 1978). Although Trestle Creek has supported a sustained kokanee population, it has been very erratic in spawner numbers ranging from several hundred to 15,000 in recent years. Also, early-spawning kokanee have contributed very little to kokanee abundance in Coeur d'Alene Lake with numerous introductions (Bowler 1975). Because late-spawning kokanee are more accessible to anglers during a longer period of time (January-October) they are more desirable to the angler than the early variety which commences spawning in September.

Overall, I would suggest that early-spawning kokanee provide little benefit to the Pend Oreille anglers. Enhancement efforts should be confined to the late-spawning variety.

Late-Spawninq Kokanee, Size and Age at Maturity

The length of late-spawning kokanee in Pend Oreille Lake from 1951 to 1978

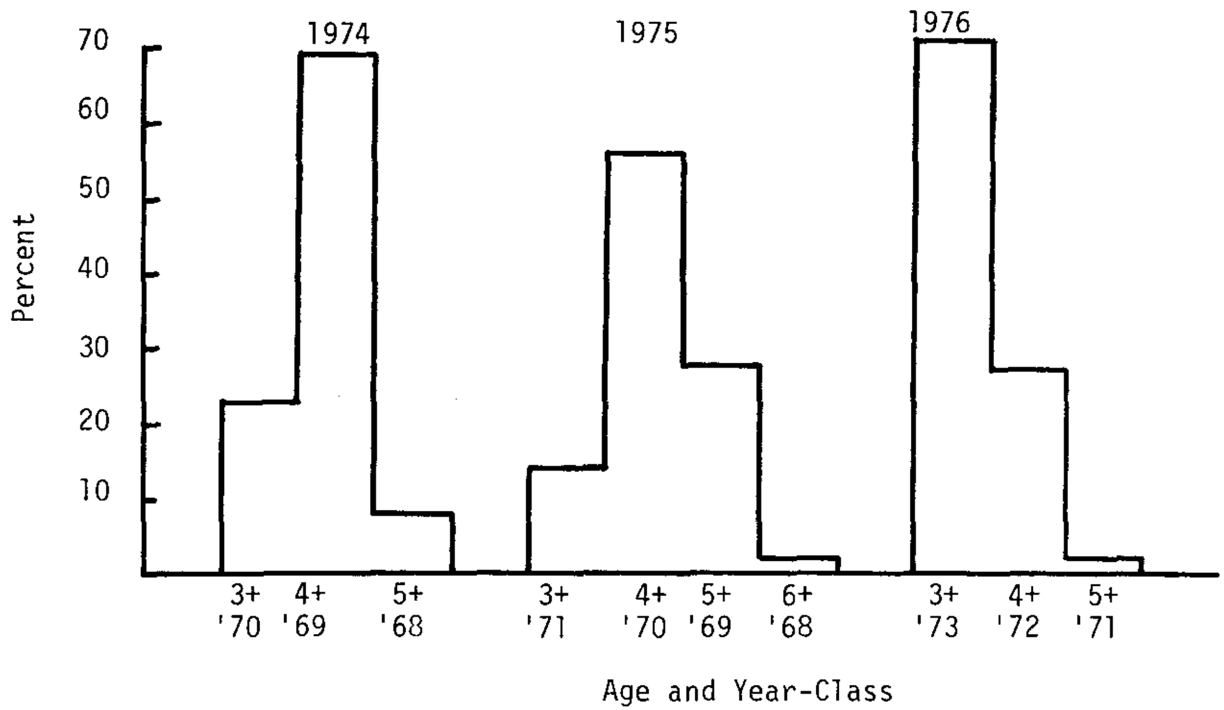

Figure 9. Age and year-class composition of late-spawning kokanee collected from Bayview in 1974, 1975 and 1977.

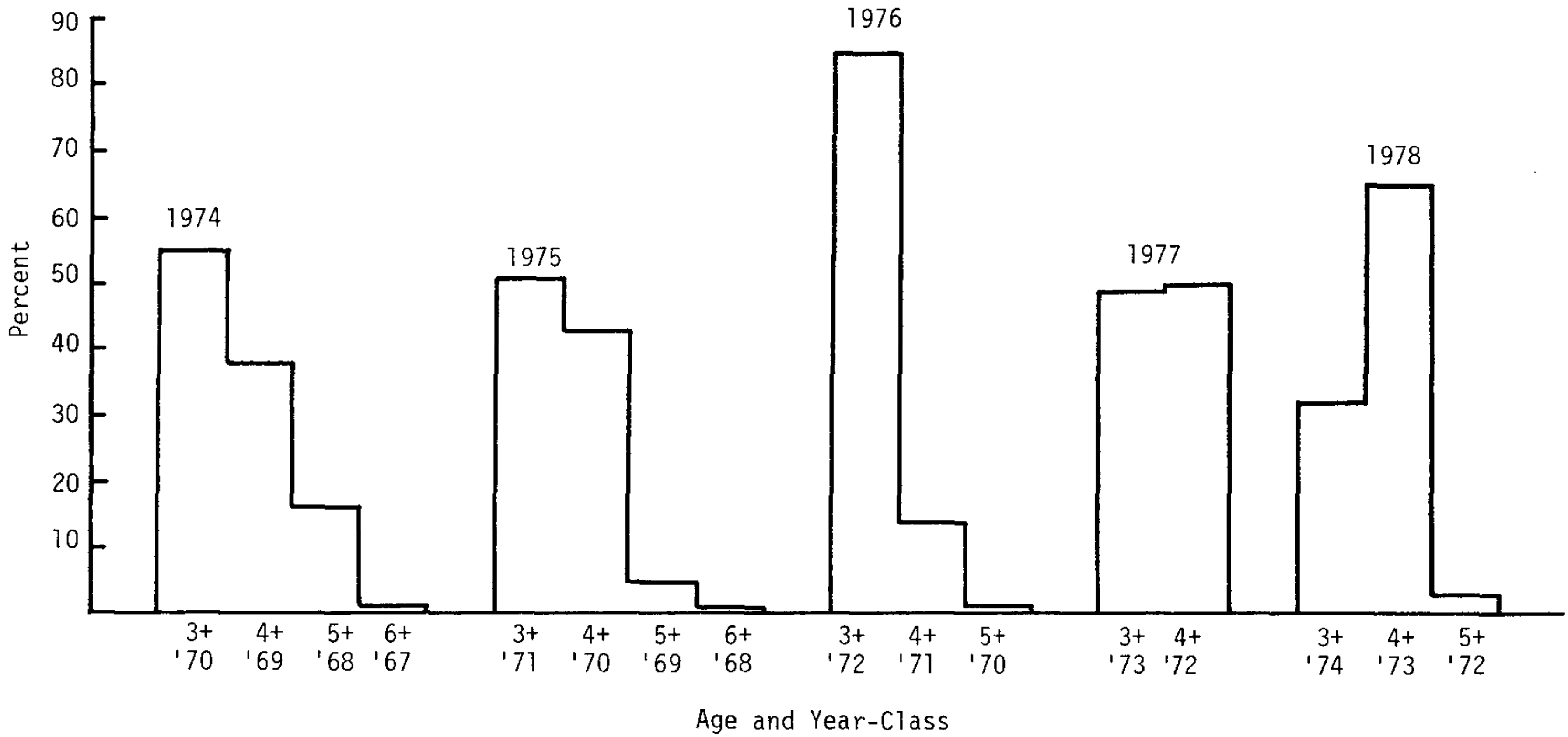

Figure 10. Age and year-class composition of late-spawning kokanee collected from Granite Creek during 1974 through 1978.

Table 4. Length, sex and age of 23 late-spawning kokanee over 30.0 cm (11.8 in) collected in Granite Creek during 1978.

Length (cm)	Sex	Age
32.6	M	4 (3+)
32.6	M	4 (3+)
37.6	M	4 (3+)
31.0	M	5 (4+)
32.9	M	5 (4+)
36.6	M	5 (4+)
36.7	M	5 (4+)
37.4	M	5 (4+)
39.5	F	5 (4+)
41.2	M	5 (4+)
41.5	F	5 (4+)
41.7	F	5 (4+)
46.0	M	5 (4+)
49.6	M	5 (4+)
51.0	M	5 (4+)
32.0	M	6 (5+)
32.1	F	6 (5+)
35.6	M	6 (5+)
45.0	M	6 (5+)
49.6	M	6 (5+)
51.1	M	6 (5+)
53.0	M	6 (5+)
50.5	M	7 (6+)

fluctuated about 7 cm (2.8 in) (Fig. 7). When kokanee first entered the Pend Oreille system in the early 1930s they ranged to 61 cm (24 in) in length. It appeared that the kokanee population stabilized by the late 1940s. Since then, kokanee spawner lengths have ranged from 31 cm (12.2 in) to 24 cm (9.4 in), possibly the result of density dependent factors. Because the lake supports five age-classes of kokanee, it is difficult to speculate about how the density of spawning age fish could effect size at maturity. Perhaps competition from strong year-classes of age 0 or 1+ kokanee could effect size at maturity of the spawning age fish in any given year. Also, the change in length in the last 25 years may be the result of changes in age at maturity.

Although in recent years, length does not appear directly related to age at maturity (Fig. 3, Job I this report) there may have been a more direct relationship in the 1950s and 1960s. Spawner lengths from 1974 through 1978 correlate well with food abundance in the lake, suggesting a cause and effect relationship between food and length at maturity in the past 4 years. The available population data would indicate that the recent length changes are independent of density.

The larger kokanee, ranging to 55 cm (21.7 in), that appeared in the catch and in the spawning population were the result of established Mysis relicta populations in the lake. An increase in size of kokanee also occurred in Priest Lake which supports a Mysis population. Kokanee ranging to 3.0 kg (6.6 lb) have been taken from Priest Lake. The kokanee spawners from Granite Creek in Pend Oreille Lake that measured over 30 cm (11.8 in) were predominantly age 5 (4+) and 6 (5+) suggesting that an older age at maturity is required to obtain the large size. Limited work on Priest Lake also indicates the same age and size relationship.

Escapement Trends

Because of Pend Oreille Lake's size and diversity of spawning areas, it is impossible to obtain a total estimate of escapement by direct observation. In past years we relied on trend estimates to compare escapement from year to year. Aided by the trawl, we were able to make an estimate of potential escapement in September of 1978. We estimated 988,000 mature kokanee in the lake during early fall which suggests the trend estimates account for only approximately 3% of the potential escapement. Distribution of emergent fry also indicates that more of the spawning occurs in the south end of the lake along the shoreline (Bowler 1978).

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JOB PERFORMANCE REPORT

State of Idaho

Project No. F-73-R-1

Study No. II

Job No. III

Period Covered: 1 March 1978 to 28 February 1979

Name: LAKE AND RESERVOIR INVESTIGATIONS

Title: Pend Oreille Lake Limnology

ABSTRACT

A 2-year limnological project was initiated on Pend Oreille Lake in 1974 to describe environmental factors potentially important to the kokanee population, and to delimit any long-term changes in the system. The project was extended through 1978 to describe the effects of the recent establishment of a mysid population and the interactions of the kokanee population with its macro-zooplankton prey base.

Pend Oreille was classed as a temperate, oligotrophic lake. There was no evidence of cultural degradation. Though the system appeared to be stable in terms of physical, chemical and trophic conditions, we did observe some important changes in the macro-zooplankton. Mysis relicta was introduced to Pend Oreille in 1966 and increased in abundance dramatically in 1975 and 1976. A temporal delay in the seasonal occurrence of Daphnia and Bosmina and the replacement of Daphnia thorata by Daphnia galeata mendotae was associated with the establishment of the mysids. Mysids have not contributed a large part of the kokanee diet and the net impact may be a reduction of available food during the spring, early summer period. Available data suggests that survival of emergent fry has been reduced resulting in a declining population.

Artificial incubation and delayed release of large numbers of hatchery reared fry has been suggested for enhancement. The kokanee population did not appear to be using a major portion of available food. A discussion of the theoretical density-dependent response of the kokanee population and carrying capacity of the lake is presented and suggests an increase in the population size should not aggravate current problems of wild survival. However, the compensatory factors will be understood only as they become important. Any enhancement attempts should proceed with a complete evaluation to determine the most effective procedures and optimum capacity of the system.

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RECOMMENDATIONS

1. Artificial enhancement should proceed with evaluation to describe the most effective methods and optimum stock size.

2. The feasibility of lake fertilization to enhance fry production in localized areas should be explored.

3. More intensive research on the early life history of kokanee fry including mechanisms of dispensal, the relationship of recruitment timing density to early growth and survival, and factors affecting timing of recruitment, should be conducted in relation to the first two recommendations.

4. Data on stock density, growth and lake productivity should be collected from as many kokanee lakes as possible in an effort to develop a lake productivity-carrying capacity model that could be used for management decision processes.

5. Mysids should not be introduced to any lake supporting an important population of planktivarous fish. If introductions are made in other cases, complete preliminary information should be collected on the system. Introductions might be most successful in lakes supported through artificial recruitment, where early juvenile survival is not dependent upon planktonic food sources.

6. Other lakes throughout the state that received mysid introductions should be surveyed to see if populations have become established and if so whether significant alteration of the macro-zooplankton community has occurred.

OBJECTIVES

To describe seasonal trends in limnological characteristics of Pend Oreille Lake, including water temperatures, primary and secondary production and changes in macro-zooplankton composition, distribution, density and biomass.

To estimate abundance and describe distribution of Mysis relicta.

To examine food habits of kokanee and the relationship of food production to kokanee growth and abundance.

INTRODUCTION

This portion of the report is a discussion of the limnological portion of the work conducted on Pend Oreille Lake during the 5 year period 1974-1978. An emphasis has been placed on the dynamics of the macro-zooplankton community and its role as the food base for the kokanee population. All of the specific data collected during the study is available in earlier progress reports. All of it has not been represented here, in the sake of brevity, but referenced when necessary for discussion.

TECHNIQUES

USED Physical-Chemical Parameters

Limnological sampling stations were established at three sites (Fig. 1) chosen to best represent the limnetic area of Pend Oreille (Rieman and Falter 1976).

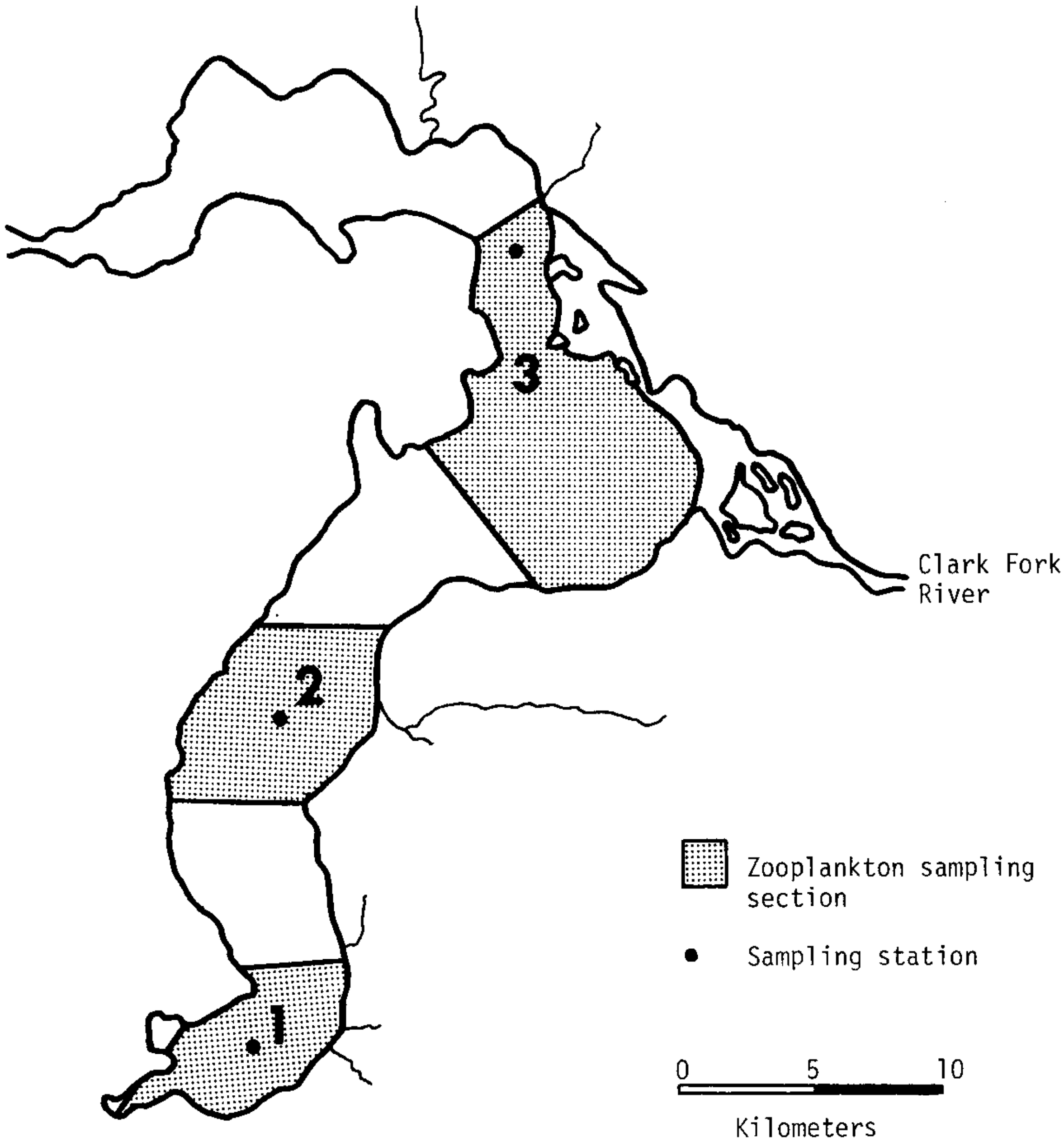


Figure 1. Limnological sampling stations and zooplankton sampling sections on Pend Oreille Lake, Idaho.

Temperature profiles were recorded with a bathythermography and transparency with a standard 20 cm (7.9 in) Secchi disk at biweekly intervals from May to October. Samples for analysis of total phosphorous, orthophosphate, nitrate and total nitrogen were collected in late spring, early summer and late fall and analyzed by the US Environmental Protection Agency Seattle Lab as described by EPA (1976).

Phytoplankton

Cell density and chlorophyll 'a" in the uppermost 12 m (39.4 ft) were used as indices of primary production. Samples were taken at biweekly intervals as composites from the surface at 3 m (9.8 ft), 6 m (19.7 ft), 9 m (29.5 ft), and 12 m (39.4 ft). Phytoplankton samples were preserved with lugols solution and analyzed for cell density and composition with an inverted microscope counting method (Rieman and Falter 1976). Samples for chlorophyll were analyzed as described by EPA (1973). Use of a digital spectrophotometer was provided by the Idaho Department of Health and Welfare Regional Lab in Coeur d'Alene.

Zooplankton

We partitioned zooplankton samples into three sampling areas on the lake (Fig. 1) using a stratified random sampling scheme based on the size of each sampling area and the variability of zooplankton density (Rieman and Falter 1976). A total of 17 samples were collected at each sampling interval. Samples were collected with a Miller plankton sampler calibrated by a General Oceanics flow meter and equipped with a 130m net and bucket. Oblique hauls were made towing the sampler at approximately 1.5m/sec and simultaneously raising it from 45 m to the surface at 0.15 m/sec with an electric winch. Further description of the sampling method, calibration and associated statistics is in Rieman and Falter (1976).

Samples were enumerated using standard dilution and sub-sampling methods. Entire samples were sorted for enumeration of Leptodora Kindtii.

Biomass estimates of total zooplankton were made using three to six samples from each interval. Samples were collected on a pre-dried and weighed filter paper, dried @ 60 C (140 F) for 16 to 24 hours and re-weighed on a micro-balance to the nearest 0.1 mg. The contribution of individual species biomass was estimated by measuring approximately 50 individuals of each species from each sampling section during the interval with a calibrated scale projector. Live weight was calculated from established length-weight relationships (Pechen 1965, Klekowski and Shuskina 1966; both cited from Edmondson 1971). Dry weight was assumed to be 10% of live weight (personal observation).

Mysids

Prior to 1976 the relative abundance of mysids was sampled using a small trawl towed near the surface at night (Irizarry 1974). We made estimates of mysid abundance with a Miller sampler during June 1976, 1977 and 1978. Sampling was the same as the standard zooplankton collections except done entirely at night during the "dark" phase of the moon. Mysids migrate vertically at dusk and most of the population is found above 45 m (148 ft) when thermal stratification or high light intensity does not alter their vertical distribution (Rieman 1977).

All mysids in each sample were counted and differentiated by age (length distribution). Twenty to 50 individuals of each age class were dried @ 60 C (140 F) and weighed to the nearest 0.1 mg.

Kokanee Food Habits

We collected kokanee stomachs from fish taken by mid-water trawl. Fish were grouped by age class from length frequency distribution. Stomachs were removed and preserved in 10% formalin.

Data on feeding periodicity of kokanee and sockeye suggests that maximum feeding intensity occurs at dusk and dawn with reduction or cessation of feeding during full darkness and full daylight (Doble 1974, Rieman 1977). Maximum stomach content should then occur at or following dusk and dawn. Therefore, for quantitative analysis only stomachs collected in the first trawl of each evening (within 1 hour of dusk) were used. All stomachs collected throughout the night were examined for evidence of mysid utilization.

For analysis the material from stomach and esophagus of at least ten fish in each age class was pooled as a single sample. A sub-sample was removed and counted under the dissecting scope to determine the composition of prey items. The relative contribution of each species to total mass was estimated by measuring a sample of each species present and converting length to weight as with zooplankton samples. The entire sample was collected on a filter paper dried at 60 C (140 F) and weighed to estimate mean dry weight of contents per stomach.

In 1977 we estimated total food consumption for kokanee on the basis of maximum stomach content and assumed feeding periodicity (Rieman 1978). However, when that data was compared to the observed growth of kokanee that year, estimates of gross growth efficiency (growth/ingestion) were higher than those normally observed in planktivorous fish, indicating that our 1977 estimates of food consumption were approximately one half what might be expected. Such comparison indicates that the kokanee were consuming more food than could be explained by assuming only two short feeding periods (at dusk and dawn) per day. Therefore food consumption for 1977 and 1978 was assumed to yield at gross growth efficiency (K=growth/ingestion) of 0.3 (Eggers et al. 1978) for dry weight. Kokanee dry weight was estimated from an emperically determined relationship of length to dry weight as a percent of wet weight. Summer food consumption, daily meal and daily ration was thus estimated from growth data for 1977 and 1978.

By combining estimates of daily meal with kokanee abundance and age class distribution data from the trawl, we were able to estimate the total food consumed by kokanee on a real basis. Comparison of food consumption with zooplankton standing crop (food available) was made to determine the magnitude of cropping.

Kokanee-Zooplankton Distribution

During 1977 and 1978, the relative distribution of kokanee and key food items was examined throughout the summer. Sonar transects were run simultaneous to all zooplankton tows with an echosounding system described by Bowler (1976). Zooplankton samples were collected at night on half of the sampling intervals so that actual fish density could be estimated from the echograms (Bowler 1976). The night sampling intervals were scheduled to coincide with the mid-water trawl sampling. We trans-formed density estimates from echograms to estimates of biomass from size distribution information from the trawl. The relationship of abundance of key food items and kokanee biomass was then plotted for each sampling interval. In addition, measurements of Daphnia length from each sample collected in September were made for comparison of kokanee abundance with mean length of the most perferred prey item.

FINDINGS

Nutrients

Analysis of nitrogen and phosphorous was provided by the US Environmental Protection Agency (EPA) during 1977. Throughout the year total P ranged from 8 to 12 µg/l (Table 1). Total N ranged from 90 to 182,µg/1. Nitrate N ranged from 10 to 80µg/1 and orthophosphate P ranged from 2 to 4,µg/1. The data from 1 April re-presents nutrient concentrations during spring mixing,, prior to any significant algal growth, and should be indicative of the lake's nutrient load. The N:P ratio was consistently high (712) and suggests that primary production may be primarily P limited. Nutrient bioassays conducted by the EPA in April and May, 1976 also indicated P limitation (W. Trial, personal communication).

Table 1. Nitrogen and phosphorous concentrations (ug/1) at 12 m depth for two stations on Pend Oreille Lake and the mouth of the Clark Fork River, 1977.

Date	Station	0-PO_4P	P Total	NO_3N	N Total	N:P
1 April	1	2	12	80	180	15
	3	2	10	50	120	12
	Clark Fork River	2	12	70	150	13
6 June	1	2	8	10	--	--
	3	2	10	10	--	--
	Clark Fork River	2	12	20	--	--
26 Sept	1	4	10	8	158	15
	3	2	10	22	162	14
	Clark Fork River	4	12	24	174	13

Temperature

Initial warming of the water column may very slightly from year to year (Fig. 2) and appears to be directly related to spring weather conditions. During the study initial warming was most rapid during 1974 and 1977 and slowest during 1976. Warming normally occurs earlier on the north end of the lake (Sta 3) (Fig. 3), perhaps in response to inflow of the Clark Fork River. Maximum heat content and stratification of the water column normally occurs from mid-August to early September (Fig. 2 & 3). The degree of stratification is never strong and varies from year to year. Depth of the thermocline during August is generally between 3 and 10 m (Fig. 4). Extremely large variations in the depth of isotherms can occur in a relatively short period, often destroying the thermocline in a matter of hours, due to strong internal seiches (Rieman 1976). Summer mean temperature has ranged from 11.9 to 14 C in the 0-15 m strat and 8.2 to 9.6 C in the upper 45 m (Table 2).

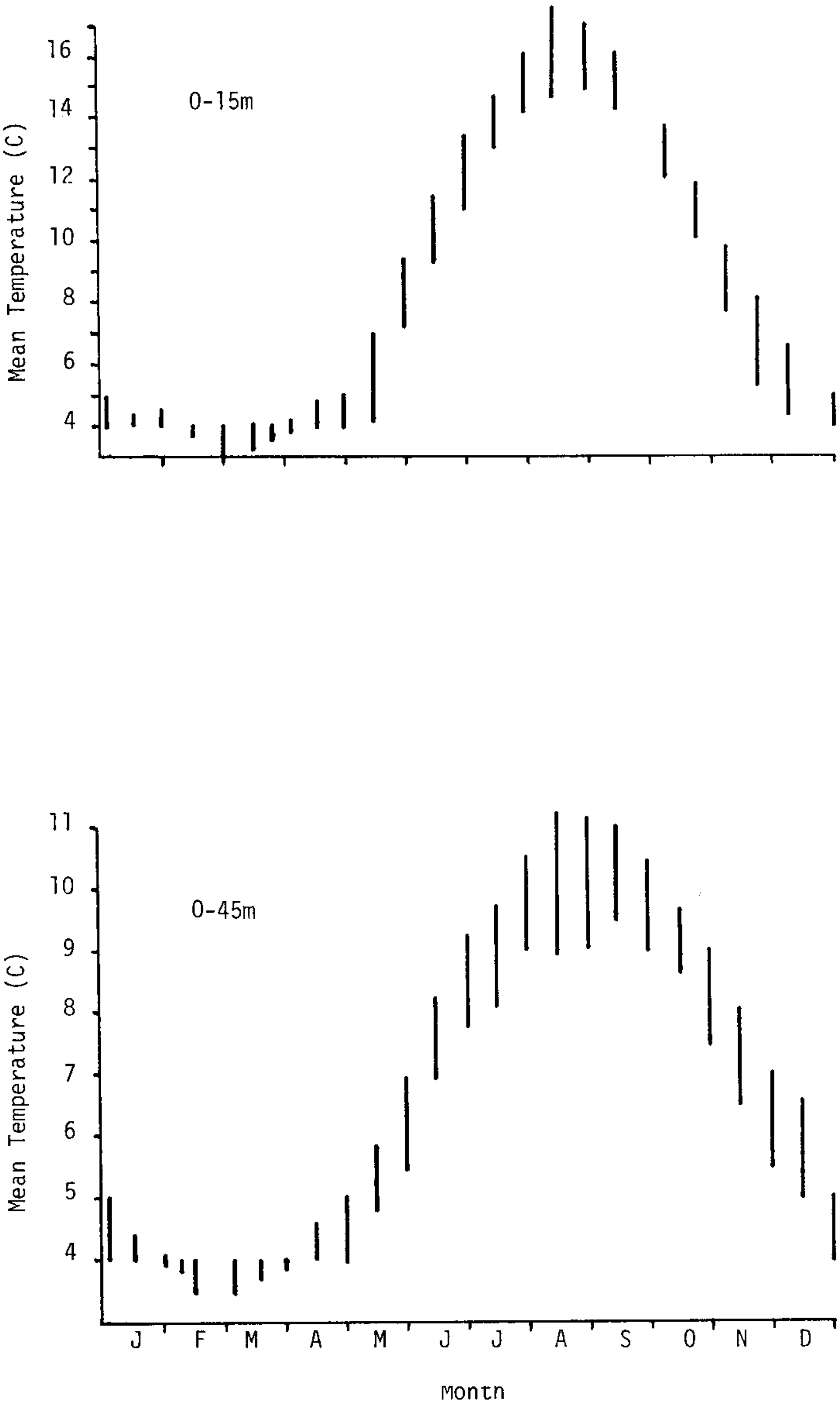


Figure 2. Range of mean temperatures in the upper 15 m and upper 45 m of Pend Oreille Lake, Idaho, 1974-1978.

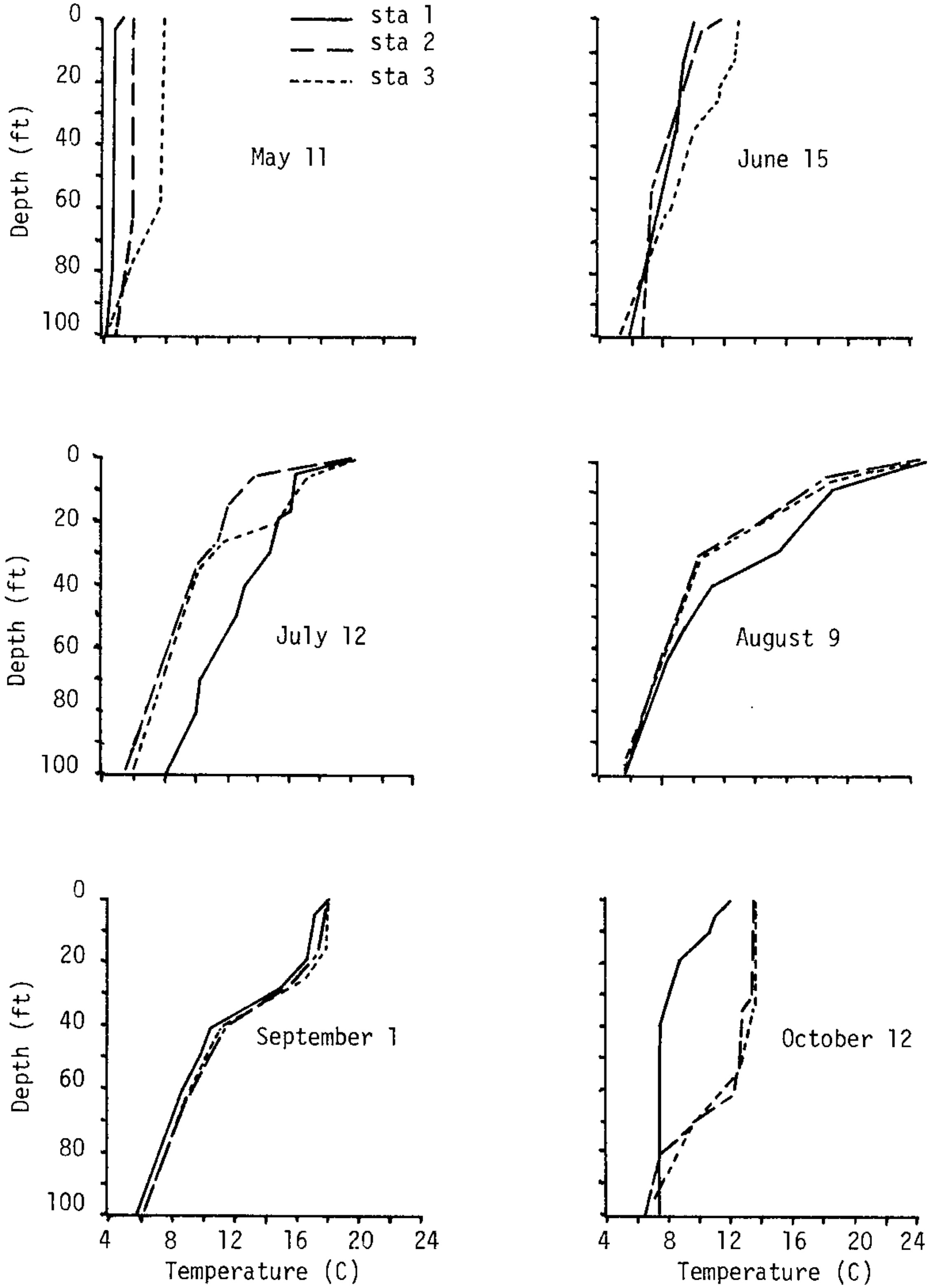


Figure 3. Development of thermal gradients at three stations on Pend Oreille Lake, Idaho, 1978.

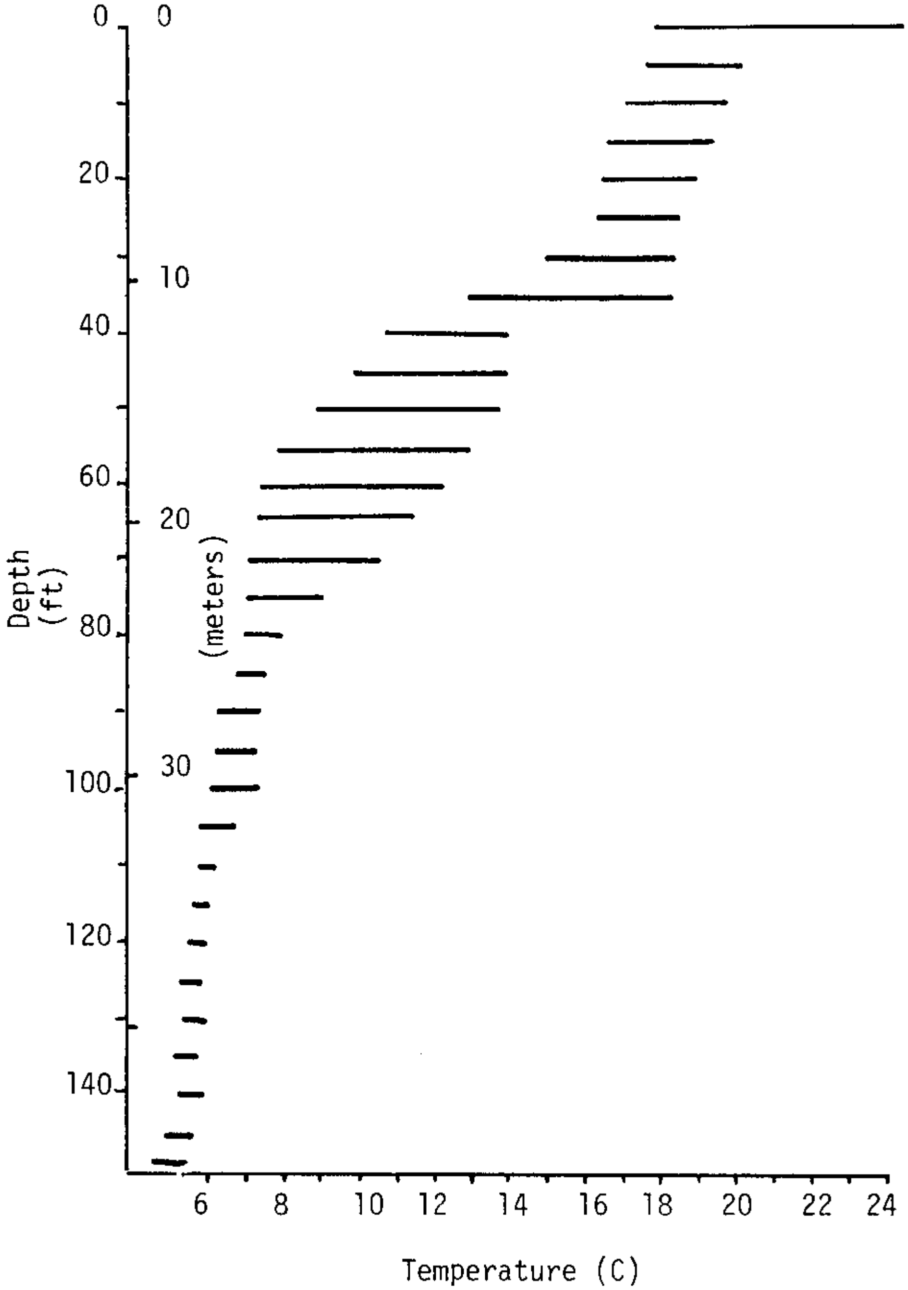


Figure 4. Range of temperature profiles during late August at station 2 on Pend Oreille Lake, Idaho, 1974-1978.

Table 2. Summer mean temperature (°C) in Pend Oreille Lake, Idaho, 1974-1978.

Strata	1974	1975	1976	1977	1978
0-15 m	14.0	13.0	12.6	12.9	11.9
0-45 m	9.6	8.8	8.7	8.6	8.2

Chlorophyll

The concentration of chlorophyll "a" in the upper 10 m varied seasonally in Pend Oreille during 1977 and 1978, ranging from 0.1 to 5.2 μg/l. Peak concentrations occurred in May and June 1977, and June-July 1978 (Fig. 5). Chlorophyll declined during August both years followed by a modest pulse in the fall. Chlorophyll data available over the 5-year period indicates no major change from year to year (Table 3). Summer mean chlorophyll was 2.1 μg/l in 1977 and 1.8 μg/l during 1978. Mean annual chlorophyll was approximately 1 to 1.5 μg/l.

The phytoplankton in Pend Oreille is dominated by diatoms (Rieman 1978).

Table 3. Summer mean chlorophyll "a" (μg/l) in Pend Oreille Lake, Idaho, 1974-1978 (observed range in parentheses).

	1974 (June-Nov)	1975 (June-Nov)	1976 (May-Sept)	1977 (May-Sept)	1978 (May-Sept)
Sta 1	-- (0.0-3.6)	-- (0.2-4.5)	1.5 (0.7-4.5)	1.9 (0.1-3.7)	1.7 (0.1-3.3)
Sta 3	-- (0.4-2.1)	-- (1.2-2.5)	-- (0.4-1.5)	2.3 (0.7-5.2)	1.9 (0.3-4.2)

Transparency

Transparency varied dramatically in Pend Oreille and appeared to be directly related to chlorophyll and suspended material introduced by the Clark Fork River (Rieman 1976, 1978). Seasonal trends were similar with minimum transparency (1.8-3.4 m) normally occurring in June and maximum transparency ($\geq$11 m) occurring during the winter (Fig. 6). Transparency was consistently less on the north end (section 3) of the lake. Mean transparency was similar each year with the exception of 1977 (Table 4). During that year drought conditions substantially reduced the flow in the Clark Fork River and the introduction of suspended inorganic material to the lake (Rieman 1978).

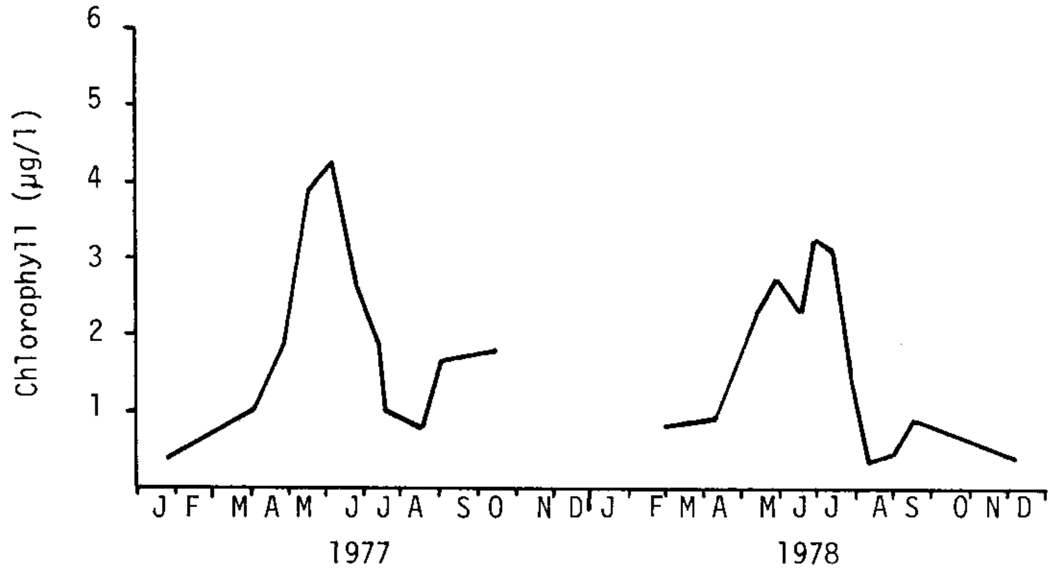


Figure 5. Mean chlorophyll "a" in the upper 10 m of Pend Oreille Lake, Idaho, 1977-1978.

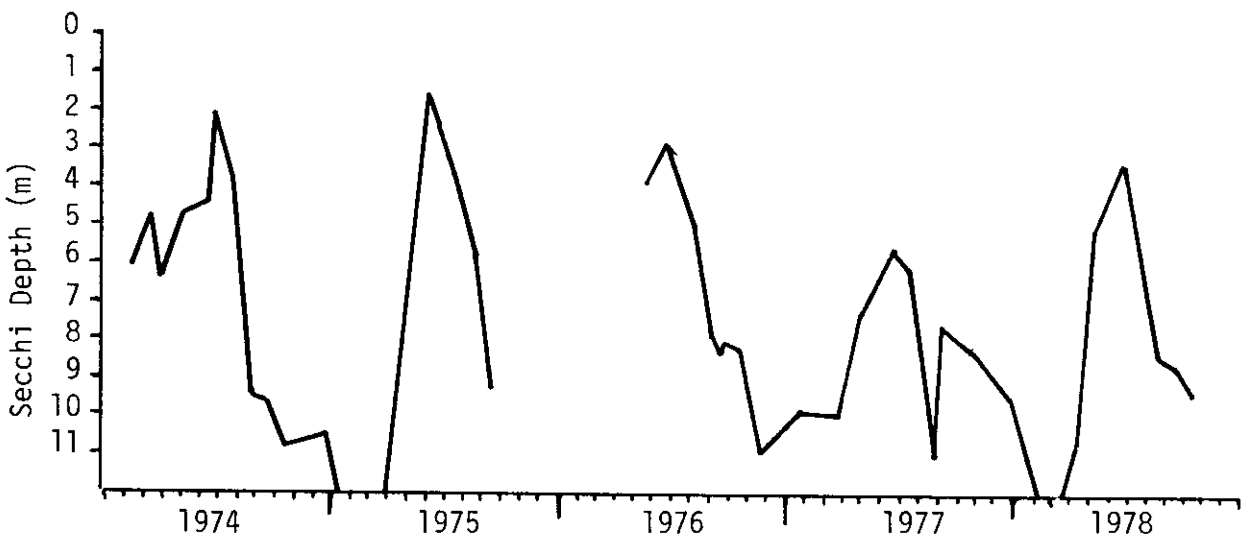


Figure 6. Secchi disk transparency in Pend Oreille Lake, Idaho, 1974-1978.

Table 4. Summer mean Secchi disk transparency (m) in Pend Oreille Lake, Idaho, 1974-1978.

Sampling section	1974	1975	1976	1977	1978
1	6.2	5.4	6.4	8.2	6.5
2	6.0	5.6	6.1	8.0	6.1
3	5.2	3.9	5.1	7.0	5.2

Macro-Zooplankton

Eleven species of crustacean zooplankton have been identified from Pend Oreille (Table 5). Bosmina was the smallest member of the macro-zooplankton community and Mysis the largest. Only those species that were common in our samples are discussed.

Table 5. Crustacean zooplankton identified from Pend Oreille Lake, Idaho with approximate size.

Species	Approximate mean Length (mm)	Dry Weight ($mgx10^3$)
Copepoda		
Cyclops bicuspidatus thomasi	0.6	1.0
Diaptamus ashlandi	0.8	3.0
Epischura nevadensis	1.6	16.0
Cladocera		
Daphnia thorata	1.1	7.0
Daphnia galeata mendotae	1.1	7.0
Bosmina longirostris	0.4	0.5
Diaphanasoma leuchtenbergianum	1.0	9.0
Chydorus sphaericus	--	--
Ceriodaphnia sp.	--	--
Leptodora kindtii	4.0	--
Malacostraca		
Mysis relicta	4.0-20.0	200-8000

Table 6. Average June zooplankton biomass (mg/m^3) in Pend Oreille Lake, Idaho, 1974-1978.

1974	1975	1976	1977	1978
220	7.1	14.0	40.3	16.0

Total zooplankton biomass varied considerably within each season and to a lesser extent among years (Fig. 7). Biomass observed in 1978 was similar to that in 1974 and 1976. The mean summer standing crop for the 5 years of study was 34.1 mg/m^3. Annual variation in the temporal development of total zooplankton biomass was evident. With the month of June used as a reference point, biomass (average for the month) has ranged from 7.1 mg/m^3 in 1975 to 40.3 mg/m^3 in 1977 (Table 6). There has been a consistent trend of greatest mean biomass in the south end of the lake (section 1) and lowest in the north (section 3), though the magnitude of difference has varied annually (Fig. 8). The difference in zooplankton standing crop between north and south areas has been attributed to difference in flushing rate and turbidity between those areas (Rieman 1976).

The copepods Cyclops bicuspidatus thomasi and Diaptomus asblandi have dominated the zooplankton throughout the study. During summer 1978 Cyclops composed 55% of total numbers and 37% of biomass. Diaptomus made up 34% of numbers and 47% of biomass Appendix A). Cyclops generally became abundant during July though it was very abundant during June 1977 (Fig. 9). Diaptomus increased in numbers during July peaking in August. Mean summer density of Cyclops was 8.64/1 for the 5 years of study. Diaptomus averaged 4.98/liter over the 5 summers.

The copepod Epischura nevadensis was relatively consistent in temporal distribution and abundance over the 5-year period (Fig. 9). Epischura usually was present from late May into December or January. It was never important numerically (5 summer average 0.06/1) and made up only 0.3% of total summer zooplankton in 1978. It was relatively large however, and contributed 3.0% of biomass during the same year.

We observed several major changes in the Daphnia species during the 5-year period. Daphnia thorata was the dominant species during 1974, and probably so in previous years (Rieman 1976). However D. thorata declined dramatically in 1975 and did not recover in following years (Fig. 9). D. galeata mendotae apparently replaced D. thorata and was moderately abundant during 1977 and 1978. Total Daphnia biomass varied quite a bit annually. It was estimated to be 9.9 mg/m^3 (30% total zooplankton) in summer 1974, 0.3 mg/m^3 (2.0% total) in 1975, 1.5 mg/m^3 (4% total) in 1976, 6.8 mg/m^3 (13% total) in 1977 and 2.3 mg/m (7% total) in 1978. The temporal distribution of Daphnia has also varied considerably during the 5-year period and relative to that observed in earlier studies. The cladoceran was present in samples by May in 1953, 1958 and 1974. Daphnia were absent from samples until late July in 1975, 1976 and 1978 but were present by mid-June during 1977 (Fig. 10).

The small cladoceran Bosmina sp. has not fluctuated a great deal in average summer density during the study. Summer means ranged from 0.95/1 in 1978 to 1.44/1 during 1975 (Appendix A). Bosmina composed 6% of total numbers in 1978, but since it is relatively small, only 1.6% of total biomass. There was some variation in the peak

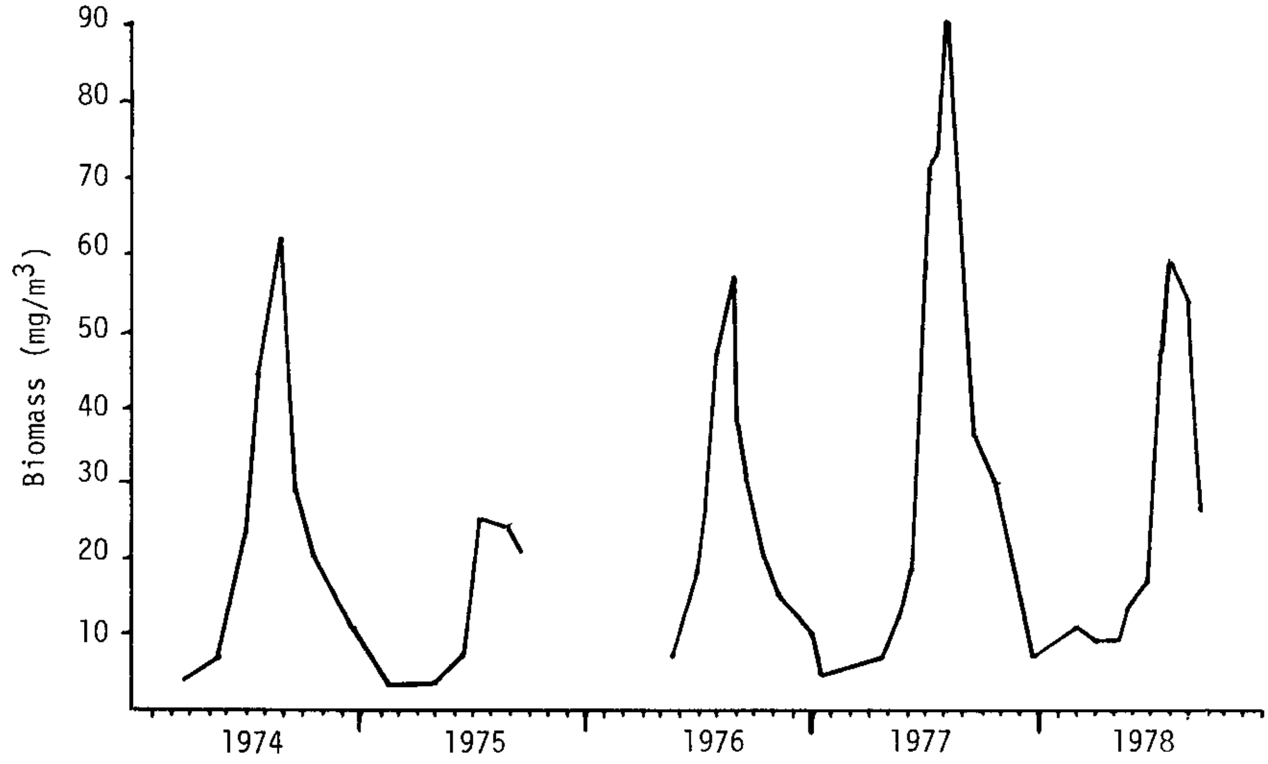


Figure 7. Mean zooplankton biomass in Pend Oreille Lake, Idaho, 1974-1978.

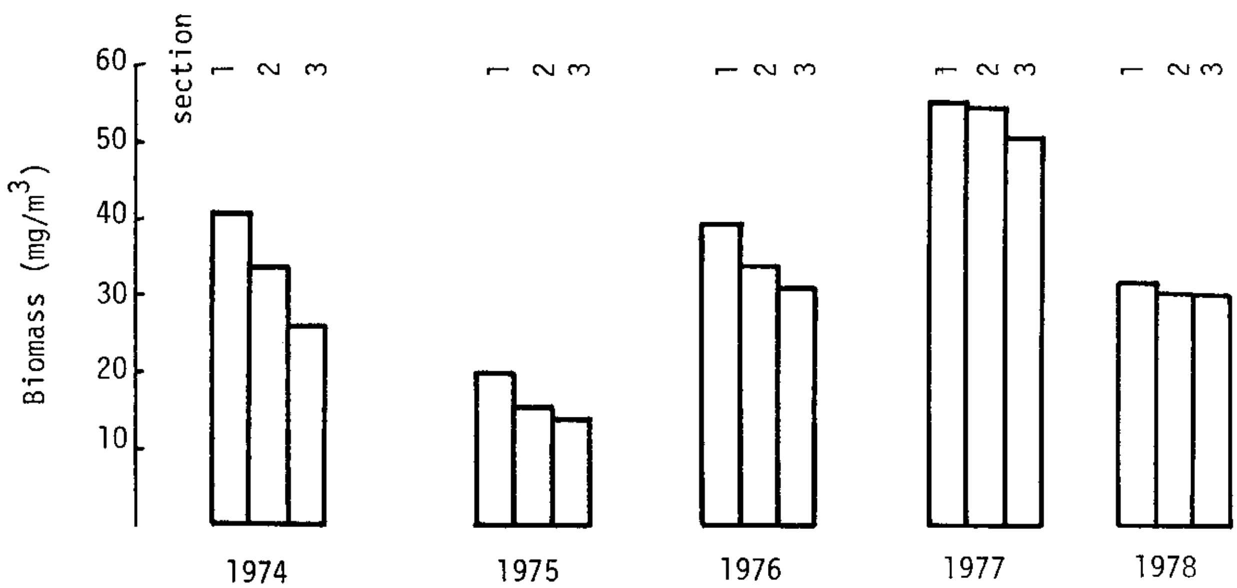


Figure 8. Summer mean zooplankton biomass in three sections of Pend Oreille Lake, Idaho, 1974-1978.

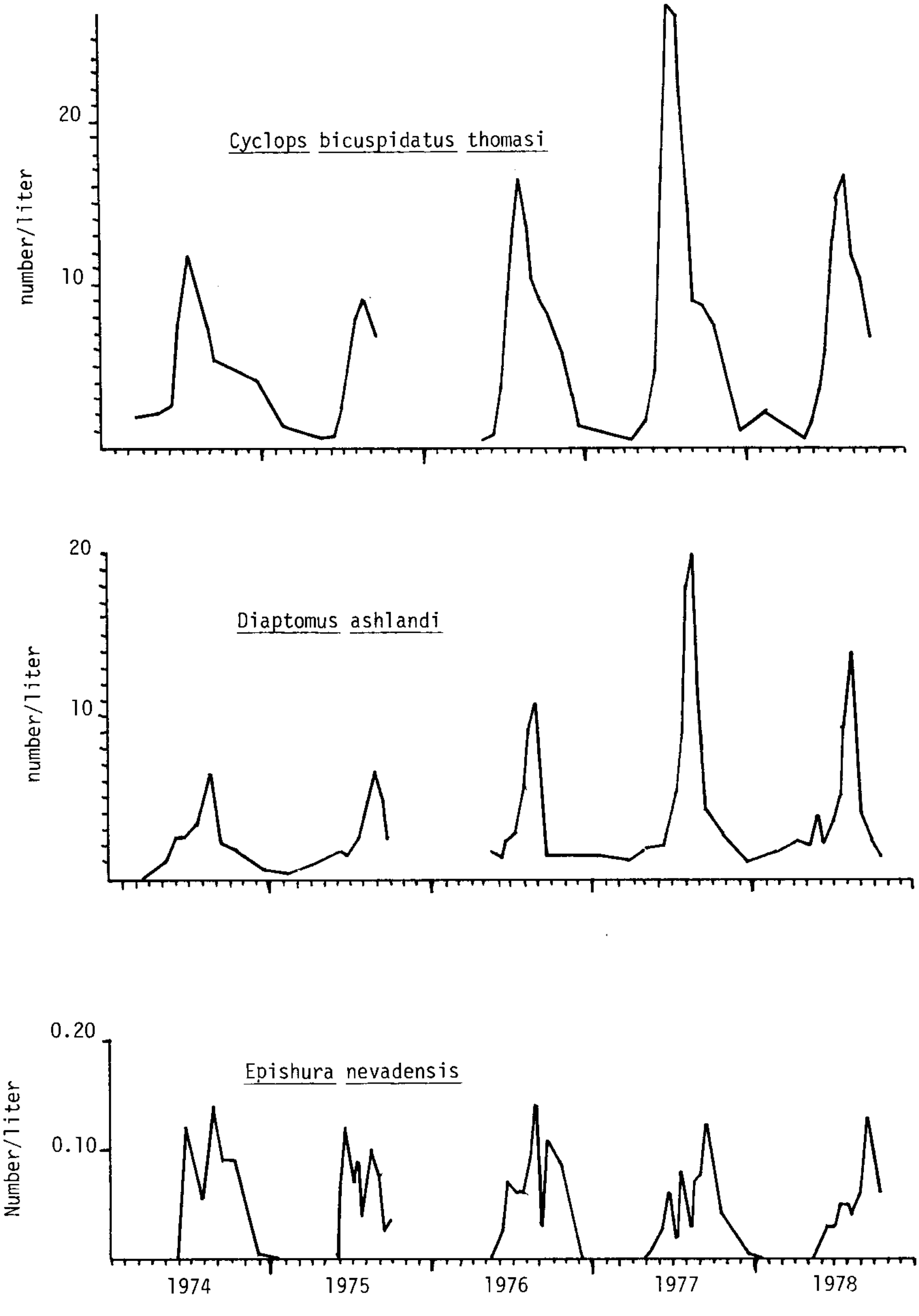


Figure 9. Mean zooplankton density, by species, in Pend Oreille Lake, Idaho, 1974-1978.

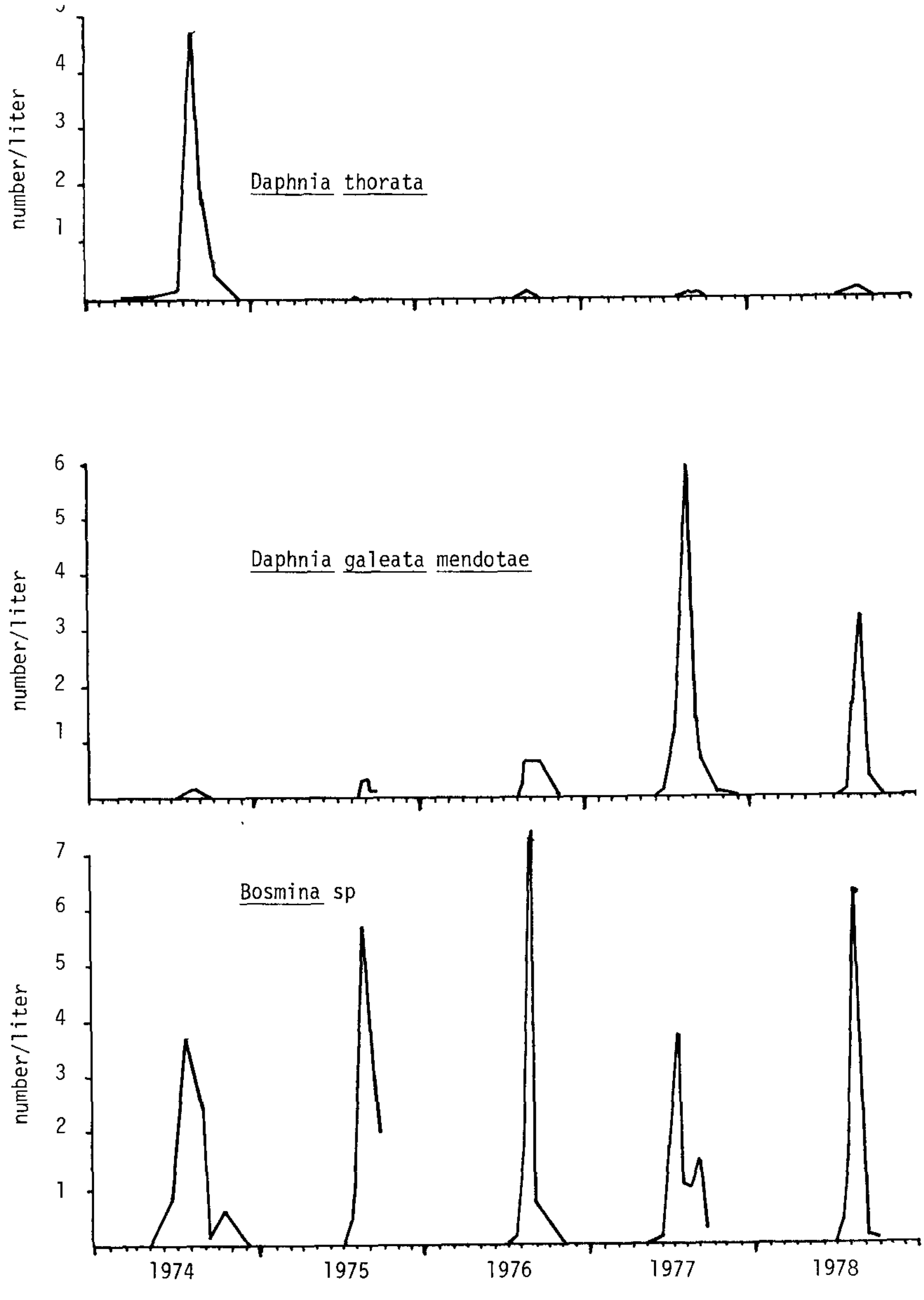
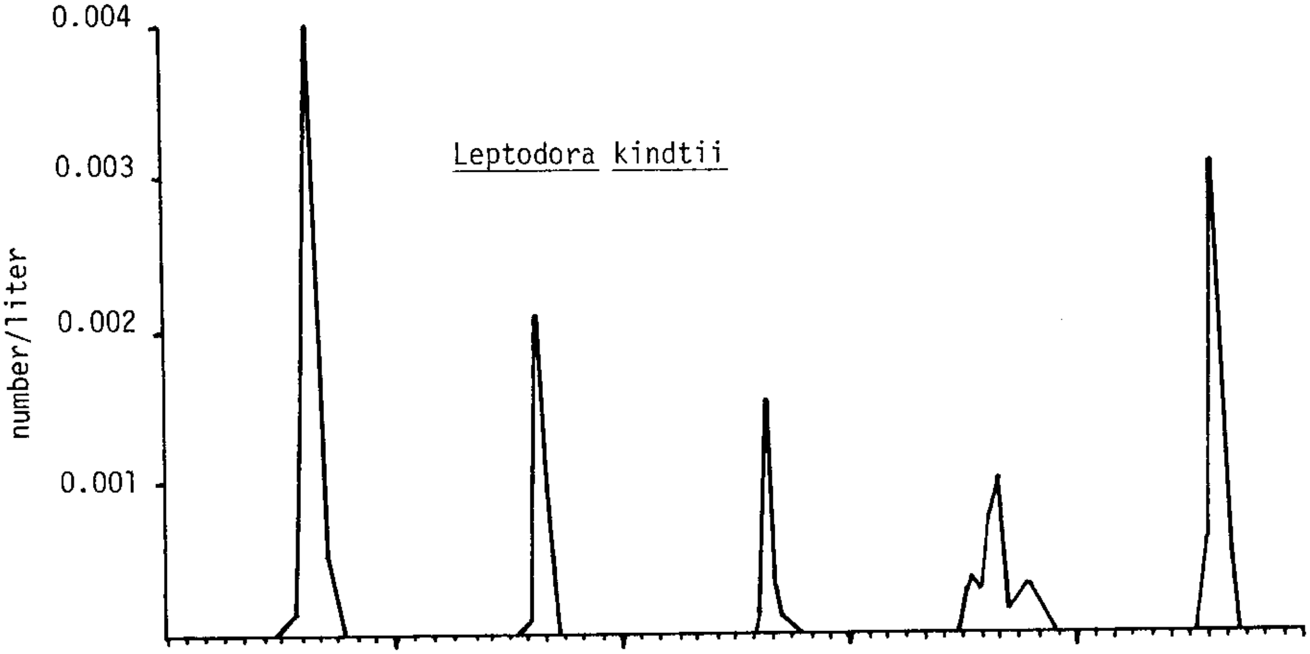


Figure 9 (Cont'd). Mean zooplankton density, by species, in Pend Oreille Lake, Idaho, 1974-1978.



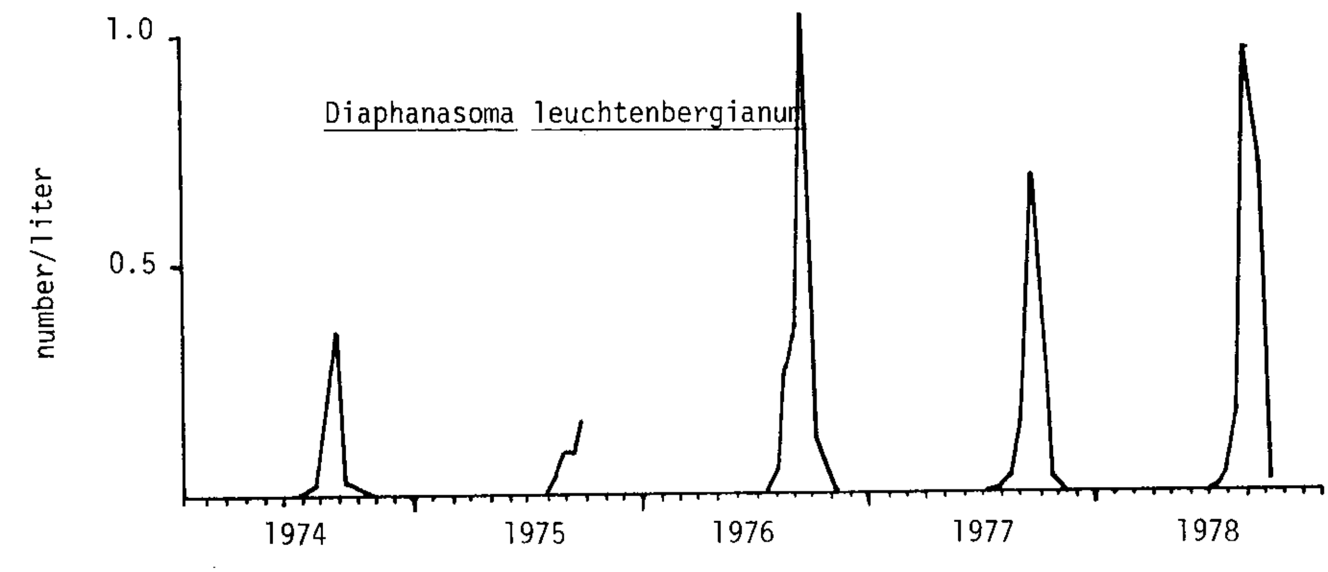


Figure 9 (Cont'd). Mean zooplankton density, by species, in Pend Oreille Lake, Idaho, 1974-1978.

abundance of Bosmina (Fig. 9) and also in temporal distribution (Fig. 11). During 1953, 1958 and 1974 Bosmina was present in samples by May and became abundant during June peaking in density during June or July. In 1975, 1976 and 1978, Bosmina was absent from samples until July and did not peak in abundance until August. In 1977 we found Bosmina to have a temporal distribution more similar to that of earlier years.

Diaphanasoma leuchtenbergianum fluctuated in numbers during the study and was more abundant during the last 3 years (Fig. 9). Diaphanasoma was not reported in the plankton of earlier work on Pend Oreille (Kemmerer et al. 1923, Stross 1954, Platts 1958) and may be a new member of the community, just becoming established. Although Diaphanasoma was relatively unimportant numerically (1% of 1978 numbers) it is one of the largest zooplankton in Pend Oreille and made up 4. 5% of biomass during 1978. We found some variation in the time Diaphanasoma appeared in our samples (appeared late in 1975, 1976 and 1978), though peak abundance occurred from mid-August to late September.

Leptodora kindtii occurred at very low densities during the 5-year period and did not make up a significant portion of the total zooplankton. Peak density ranged from 0.001/1 in 1977 to 0.004/1 during 1974 (Fig. 9). Leptodora also exhibited some variation in temporal distribution similar to the other cladocerans appearing in June during 1974 and 1977, but not until late July during 1975, 1976 and 1978.

The vertical distribution of the macro-zooplankton was examined periodically throughout the study. Nearly 100% of the zooplankton (excluding mysids) is found in the upper 50 m throughout the day (Rieman 1975). Vertical migration was more pronounced with the copepods Cyclops and Diaptomus (Rieman 1975) while the cladocerans and Epischura were generally restricted to the upper strata. During 1978 from 45 to 74% of the total zooplankton biomass was found in the upper 10 m of the water column. Daphnia, Bosmina, Diaphanasoma and Epischura were found almost exclusively in that strata (Table 7).

On 25 July 1978 we conducted some zooplankton sampling in the shallow (<15 m) heads of three bays (Button Hook, Garfield, Ellisport) to see if there were any obvious differences in zooplankton composition in shallow inshore areas relative to the open lake. All species occurred at densities similar to the open lake except Bosmina which was found at densities from 2 to 5 times that at the same depths in open water.

Mysids

Mysis relicta was introduced to Pend Oreille in 1966. Mysids were first collected in night-time trawl samples near the surface in 1972 and the apparent density of animals increased dramatically during 1975 and 1976 (Fig. 12). Beginning in 1976 we made estimates of the absolute density of mysids during June using the Miller sampler.

During 1977 the density of mysids in section 3 was much higher than in the other two sections, but during 1976 and 1978 density in that area was lower than other parts of the lake (Fig. 13). Also, during 1976 the abundance of mysids increased dramatically in section 3 from June to December, while it declined in other areas (Rieman 1977). The density of mysids in section 3 may fluctuate as a function of flushing. During periods of high runoff flushing in the north arm is undoubtedly greater than other areas of the lake (Rieman 1976). Mysids will be lost from that area by physical export, resulting in reduced numbers. During 1977 runoff was very low, which may partially explain the high density of mysids in section 3 that year. At any rate, because of

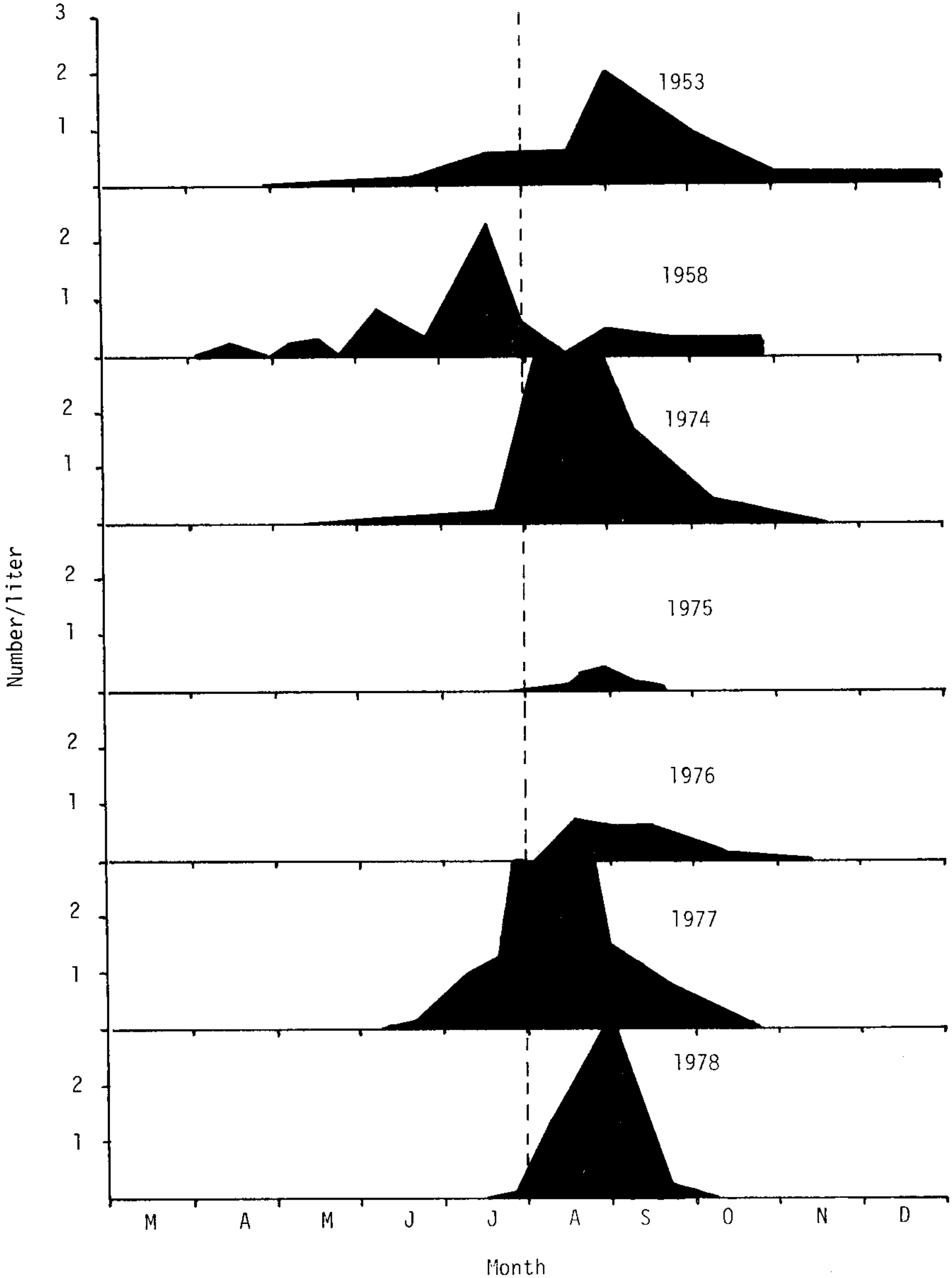


Figure 10. Temporal distribution of Daphnia in Pend Oreille Lake, Idaho, for 1953, 1958, 1974-1978. June 30 is shown as a point of reference.

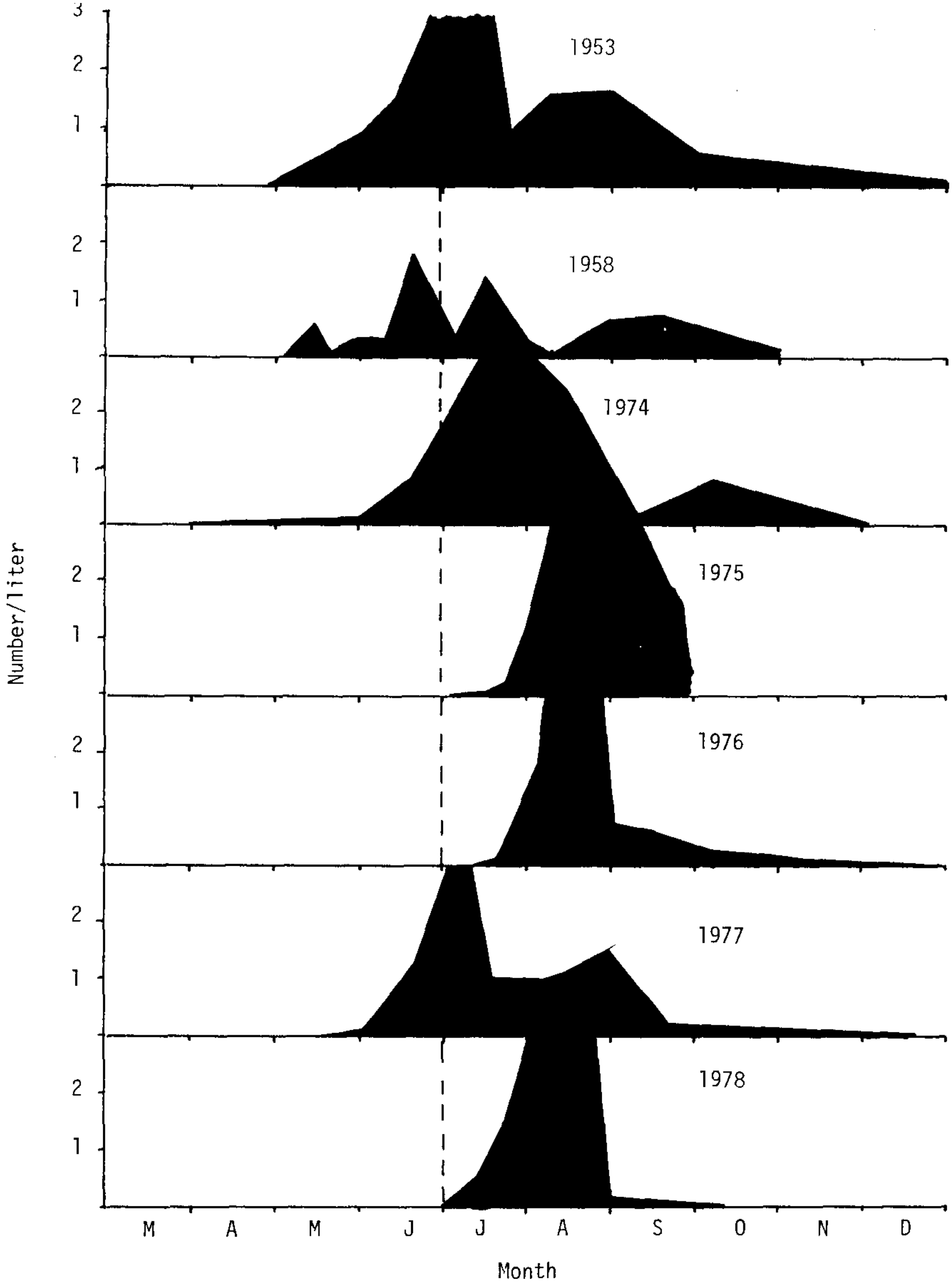


Figure 11. Temporal distribution of Bosmina in Pend Oreille Lake, Idaho, for 1953, 1958, 1974-1978. July 31 is shown as a point of reference.

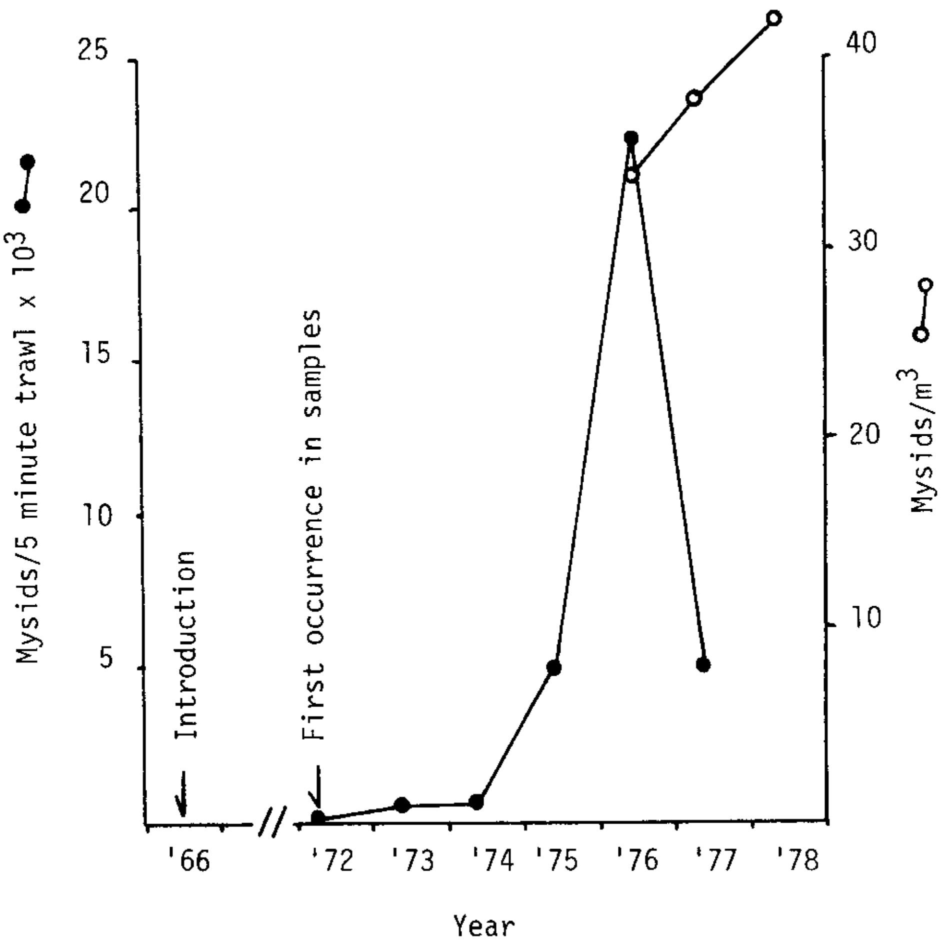


Figure 12. Relative abundance of mysids collected with a small trawl and estimated density of mysids sampled with a Miller plankton sampler in Pend Oreille Lake, Idaho.

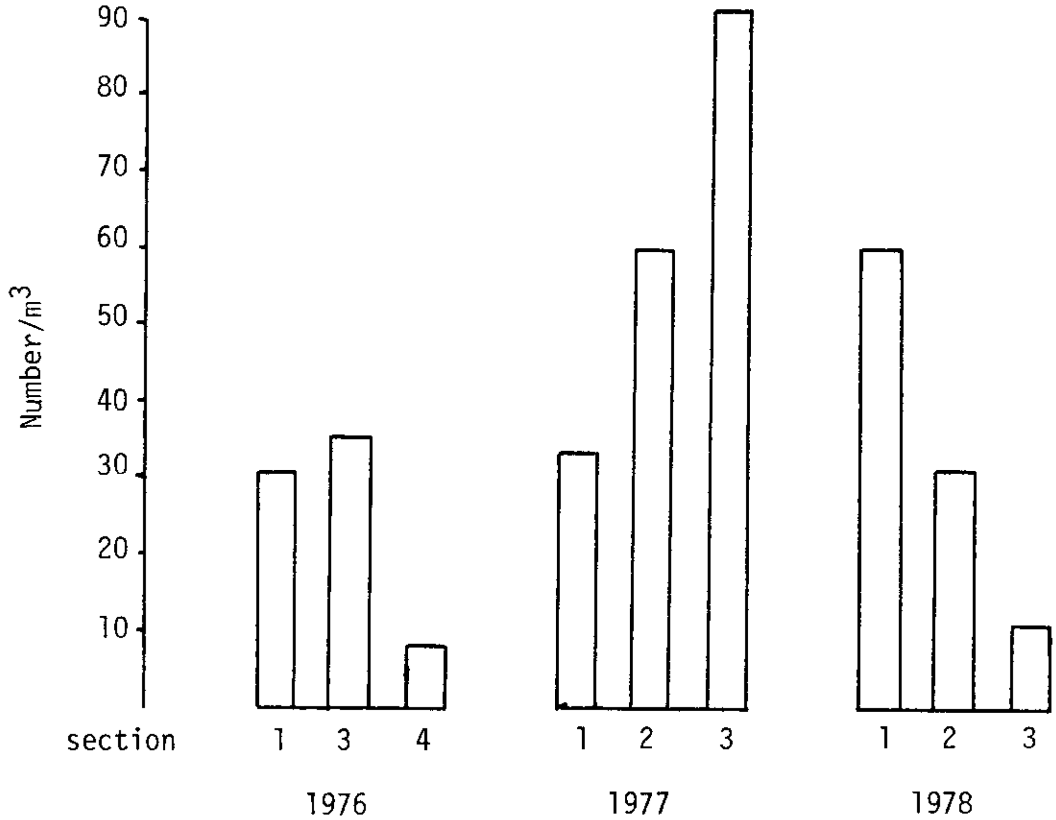


Figure 13. Density of mysids in three sections of Pend Oreille Lake, Idaho, during June 1976-1978.

the variability of numbers in that area, annual comparisons of mysid density are made only for sampling sections 1 and 2.

Density of mysids in sections 1 and 2 increased modestly from 1976 ranging from a mean of $34/m^3$ in 1976 to $44/m^3$ in 1978. Samples from the trawl indicated a substantial decline in mysid numbers during 1977. The change appeared to be due to an earlier vertical isolation of mysids deep in the water column that year due to unusual physical conditions thus reducing the numbers of "shrimp" in the upper strata sampled by the trawl (Rieman 1978).

In June juvenile mysids dominated numerically, but the immature, 1 year old animals composed most of the biomass (Fig. 14). Mean June biomass in sections 1 and 2 has ranged from 32 mg/m in 1976 to 52 mg/m^3 in 1978. Abundance of mysids varied considerably throughout the lake and in 1978 individual samples ranged from 16 to 108 $mysids/m^3$. If these estimates are converted to areal estimates, density ranged from 500 to over 3,000 $mysids/m^3$ with a 1978 average of approximately 1,300/ m^2. Estimated density of mysids in Pend Oreille was high relative to other lakes. Carpenter et al. (1974) reported a maximum density of 847 $mysids/m^2$ in Lake Huron and $861/m^2$ in Lake Ontario. The maximum population in Lake Tahoe approximated $300/m^2$ (S. Threlkeld, Tahoe Research Group, personal communication). The density of mysids in Pend Oreille was similar to that reported in Kootenay Lake (Zyblut 1967).

The vertical distribution of mysids varied diurnally and through the season. In general the animals migrated toward the surface at dusk and returned to deep water at dawn. Few individuals were ever taken in samples above 50 m during day-light except in areas where turbidity was very high. As summer progressed the upper limit of vertical migration became deeper in the water column (Fig. 15). The upper limit is probably determined by thermal stratification and increasing transparency (Beeton 1960, Bowers and Grossnickle 1978, Rieman 1978). Normally the population was isolated below 10 m by August though isolation may have occurred as early as June in 1977 (as mentioned earlier) due to much greater transparency and earlier warming than normal that *year.*

Table 7. Proportion of zooplankton biomass occurring in the upper 10 m at night in Pend Oreille Lake.

Date	Cyclops	Diaptomus	Epischura	Bosmina	Daphnia	Diaphanasoma	Total
5/12/78	37%	51%	--	--	--	--	47%
6/27/78	73%	43%	100%	75%	--	--	47%
8/9/78	28%	45%	--	82%	100%	100%	45%
9/1/78	50%	60%	100%	81%	100%	100%	74%

<u>Kokanee Feeding</u>

Kokanee in Pend Oreille fed almost exclusively on crustacean zooplankton, though terrestrial insects and midge larvae did make up a small component of the food at times

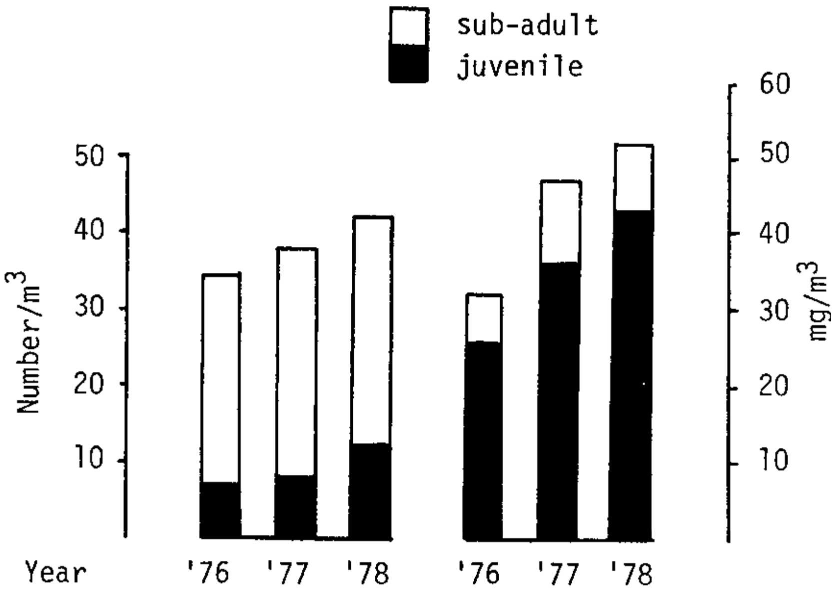


Figure 14. Mean biomass and density of two age classes of mysids in sections 1 and 2 of Pend Oreille Lake, Idaho, during June 1976-1978.

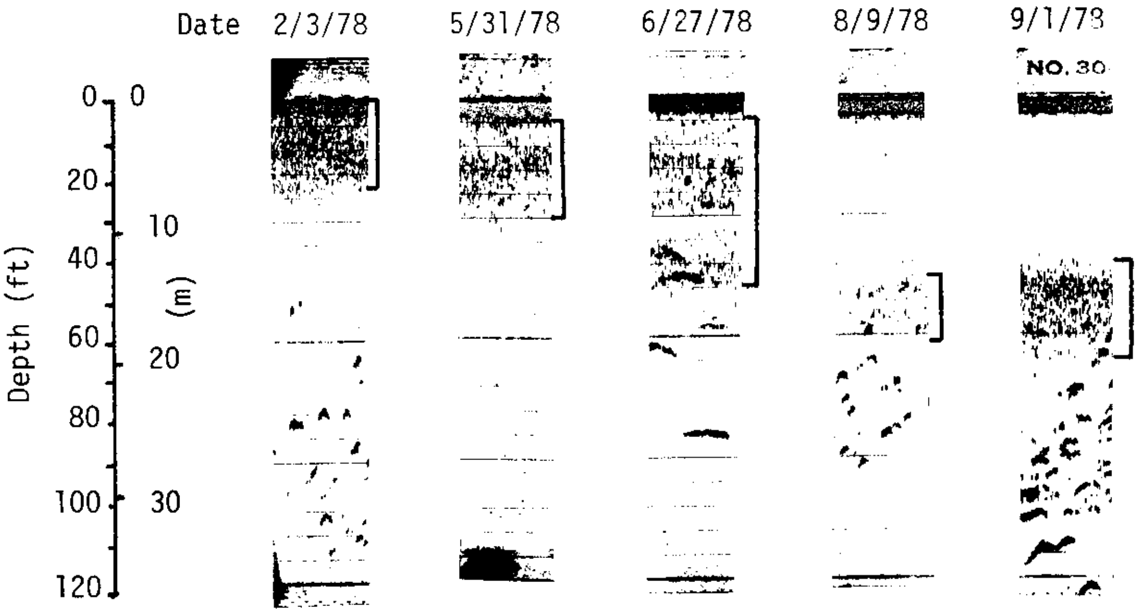


Figure 15. Night-time vertical distribution of mysids in Pend Oreille Lake, Idaho, 1978, from echograms. Vertical bars encompass the vertical range of mysids.

in the spring. During winter and early spring Cyclops was the major component of the diet but the small cladoceran Bosmina was an important food item during some spring and early summer periods when it was available (Rieman 1977, Platts 1958, Stross 1954). Bosmina was not used extensively in 1977 when Cyclops was extremely abundant (Rieman 1978). Daphnia was the most preferred food of all kokanee as it became available, and during periods of peak abundance kokanee fed almost exclusively upon it (Fig. 16). During periods when Daphnia was not abundant kokanee also used the large Epischura and Diaphanasoma or the much more abundant but smaller Cyclops. Mysids were used by kokanee though they did not make up a large component of the diet. Throughout 1977 mysids composed 7% of all the food consumed by kokanee and from 4 to 12% during 1978. Some fish were found to have fed almost exclusively on mysids, but the actual contribution to the total food consumed by the population was small since only a fraction of the fish used them. In 1977, 19% of all the stomachs examined (n = 2,555) contained the remains of mysids (Rieman 1978). In 1978, 23% of the total (n = 927) contained mysids (Appendix B). The actual contribution of mysids to the food of kokanee is probably even less than that represented here. The food habit data comes from stomachs collected just after dusk. Mysids do not occur to a significant extent in stomachs collected during the day (Rieman 1977, 1978) and are apparently not available to fish at that time. If a significant portion of kokanee feeding occurs during daylight, the dusk stomach samples would represent an over-estimate of the actual contribution of mysids to the daily meal.

The food habits of all age classes of kokanee appeared to be very similar, though Bosmina may at times have been more important to age 0 kokanee than to the larger fish (Rieman 1977). Age 0 fish also apparently did not use mysids early in the year (Appendix B) and only the larger age 0 fish used them later in the season (Fig. 17). There was also a trend of greater utilization of mysids by the older (3+) kokanee during 1978 (Appendix B) though it was not obvious in 1977.

Estimates of summer food consumption ranged from 0.3 g for age 0+ kokanee to approximately 52 g for age 3+ and older fish in 1977 (Table 8). The daily meal varied throughout the season (Table 9). Summer mean daily meal ranged from 2.1 mg/ day for age 0+ individuals to 440 mg/day for 3+ and older fish. Mean daily ration (food consumed as % body weight) ranged from 5.5% for age 0+ to 1.1% for 3+ and older.

Estimates of total food consumption were made using the kokanee density and age class composition data from the trawl and acoustic work. From these we estimate the population consumed a total of 765 mg/m^2 in 1977 and 542 mg/m^2 in 1978 The rate of food consumption varied during each season and ranged from 2.0 mg/m^2/day to 7.9 mg/m^2/dy. The mean summer rate was approximately 4.2 mg/m^2/day during 1978 and 6.5 mg/m^2/day in 1977 (Table 10).

Estimates of cropping for preferred food items are available by using estimates of feeding rate and zooplankton biomass. Maximum estimated cropping was with Daphnia and amounted to 3.4% of Daphnia biomass/day in July 1977 and 2.0% biomass/day during August 1978 (Table 10). Cropping of the major food item early in the summer appeared to be relatively insignificant. Kokanee used approximately 0.6% of Cyclops biomass/ day in June 1977 and 0.7%/day in June 1978.

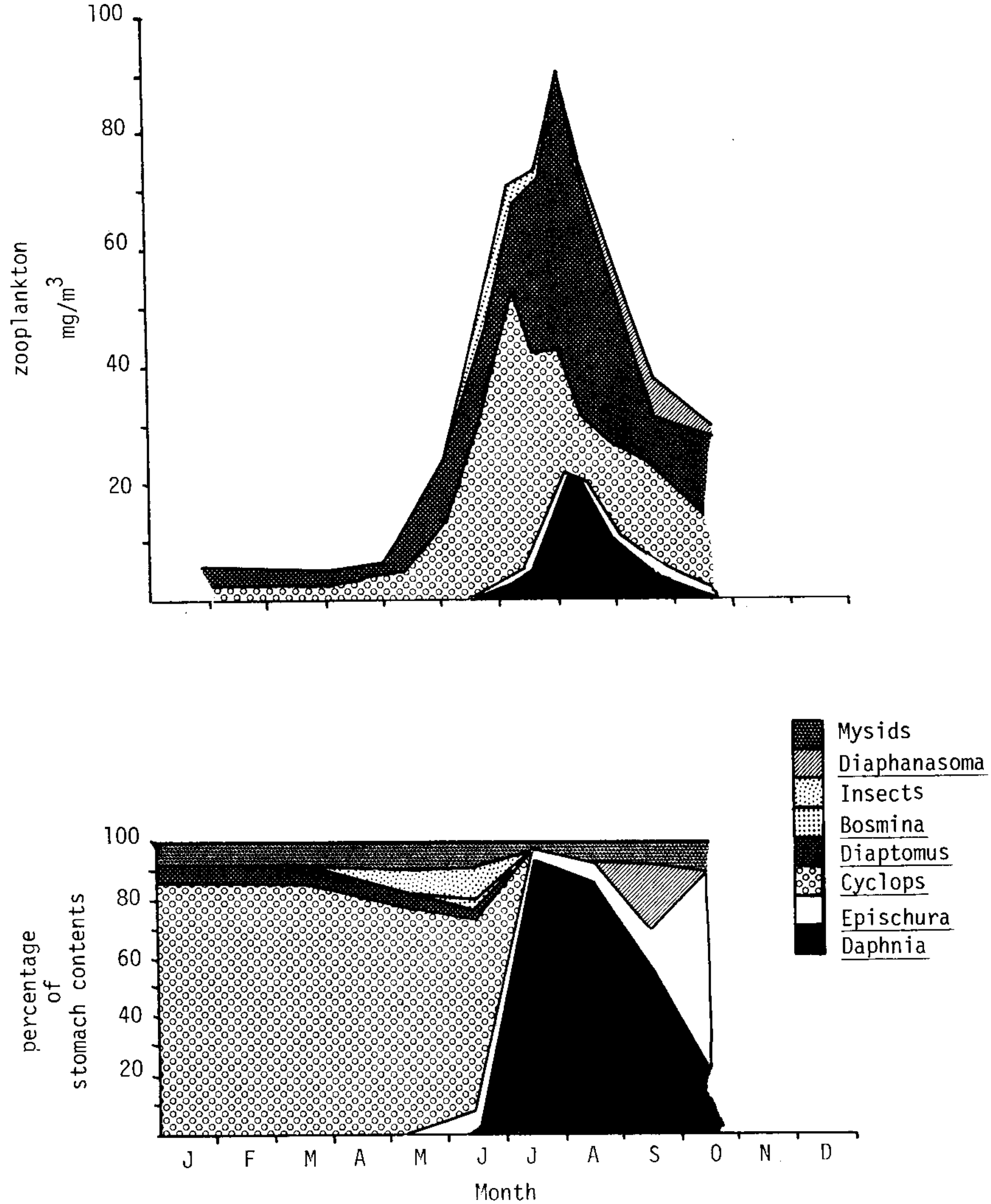


Figure 16. Zooplankton biomass and the relative contribution (by weight) of food items in kokanee stomachs in Pend Oreille Lake, Idaho, 1977.

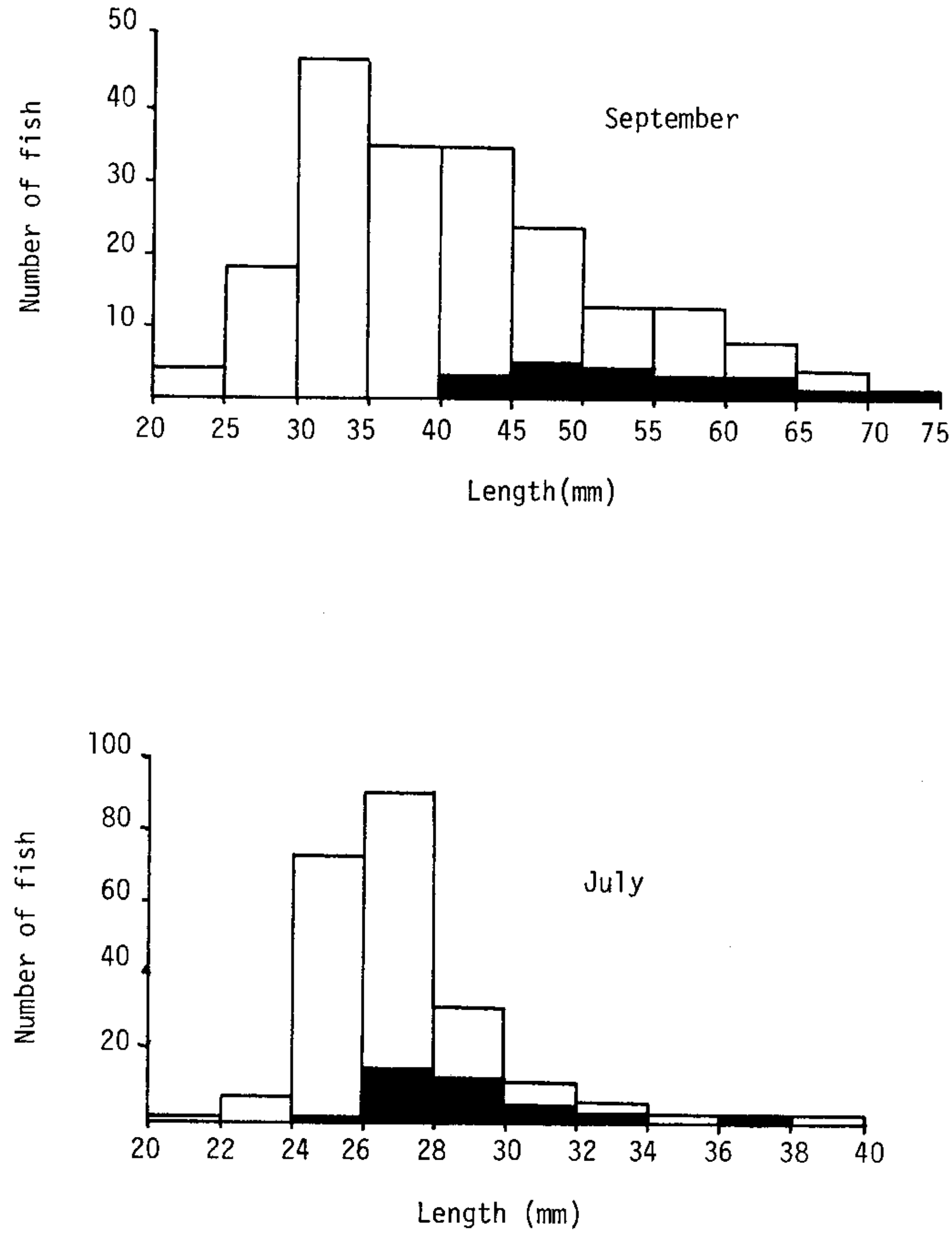


Figure 17. Length frequencies of age 0 kokanee with (black) and without mysids in the gut from Pend Oreille Lake, Idaho, during July and September 1978.

Table 8. Estimated summer food consumption (g/fish) for kokanee in Pend Oreille Lake, 1977 and 1978.

	Age Class/0+	1+	2+	3+ and older
1977	0.3	11.9	30.3	51.9
1978	0.3	13.0	30.9	38.2

Table 9. Estimated daily meal (mg/fish/day) for kokanee in Pend Oreille Lake, 1977 and 1978. Mean daily ration (% of body weight consumed in food/day) is in parentheses.

Period	Age Class/0+	1+	2+	3+ and older
1977				
May-June	1.1	102.1	493.9	266.4
June-July	0.4	135.7	349.6	547.9
July-Aug	1.9	79.2	105.8	200.4
Aug-Sept	3.7	89.4	110.6	716.9
Summer Mean	2.3	100.6	256.4	440.1
	(5.5%)	(4.0o)	(1.9%)	(1.6;)
1978				
May-July	0.2	138.3	173.3	75.0
July-Sept	4.5	78.3	340.0	561.7
Summer Mean	2.1	100.0	237.7	293.8
	(4.8%)	(4.3%)	(2.2%)	(1.1%)

Table 10. Estimated daily food consumption of the total kokanee population and cropping rate of total zooplankton and the predominant prey item in Pend Oreille Lake, 1977 and 1978.

Period	Total daily food consumption by kokanee ($mg/m^2/day$)	Portion of total zooplankton biomass consumed/day	Portion preferred prey biomass consumed/day
1977			
June	7.9	0.5%	(Cyclops) 0.6%
July	5.7	0.3%	(Daphnia) 3.4%
August	4.9	0.2%	(Daphnia) 0.7%
September	3.6	0.3%	(Daphnia) 1.5%
Summer Mean	6.5		
1978			
June	2.0	0.3%	(Cyclops) 0.7%
August	6.6	0.4%	(Daphnia) 2.0%
Summer Mean	4.2		

We also looked for potential cropping effects by examining the relative distribution of kokanee and their key prey items, during 1977 and 1978. Early in the year we found no relationship between density of kokanee and abundance of prey items such as Cyclops (Fig. 18). However, we did observe a significant ($p = .05$) positive relationship with Daphnia abundance and kokanee biomass during both years (Figs. 19 & 20). We also compared the density of kokanee with the size of Daphnia and found a possible cropping effect during September 1977 (Fig. 21). Since kokanee are very size selective in feeding (Rieman 1978) the apparent reduction in mean Daphnia length at kokanee densities above, approximately, 30 kg/ha may be indicative of a high cropping rate. We did not observe a similar effect in 1978, but unfortunately we did not find an area with kokanee density exceeding 42 kg/ha (only two samples were above 30 kg/ha). Thus the observed distributions of fish may not have been dense enough at any point to have a significant effect on the prey composition.

A comparison of the length distribution of Daphnia was also made for the 5 years of study (Fig. 22). Complete seasonal data was available only during 1977 and 1978. In those years the size of Daphnia tended to increase through the season. There appeared to have been very little difference in the size of Daphnia among August samples of each year.

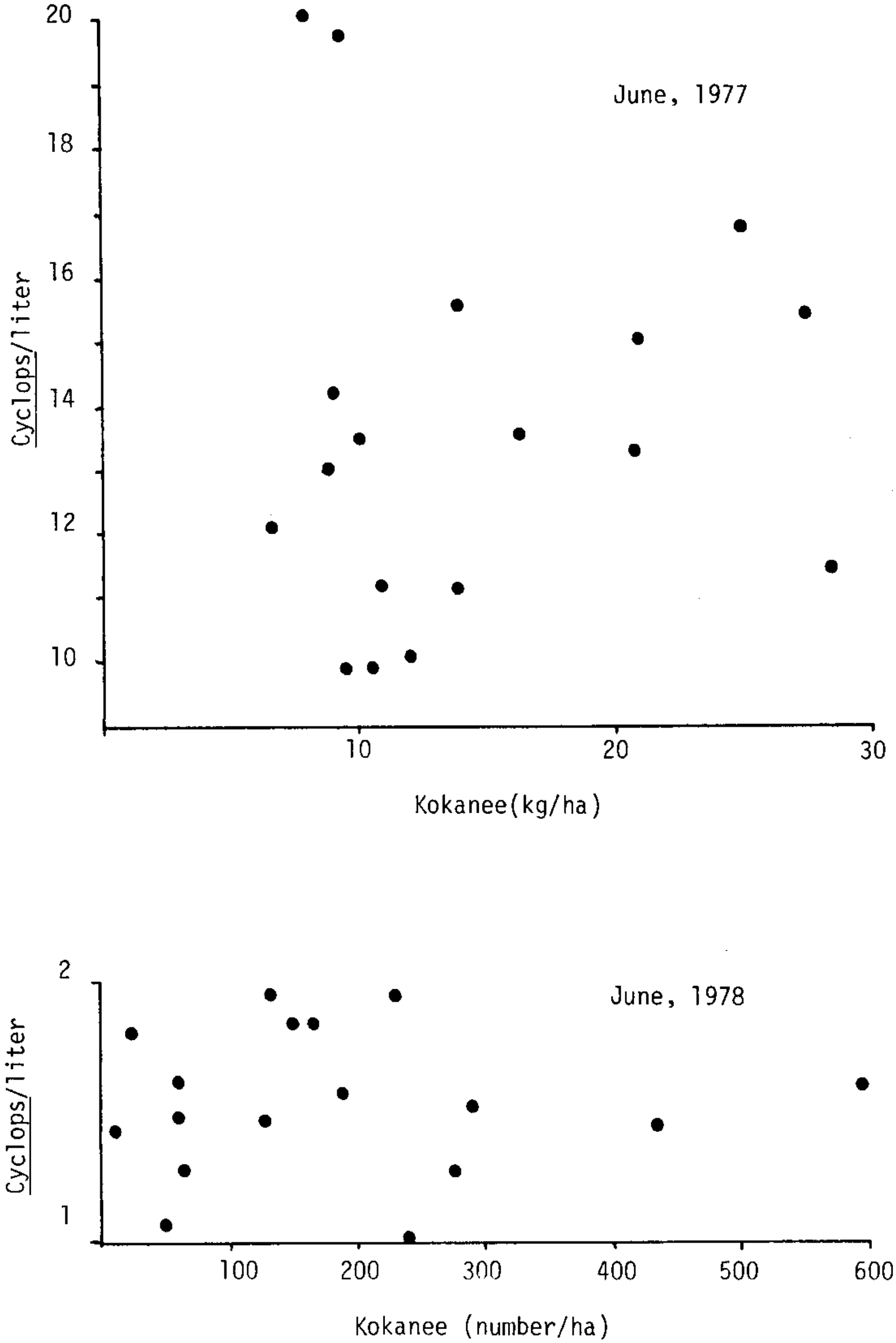


Figure 18. Relationship of kokanee density and primary prey (*Cyclops*) density in Pend Oreille Lake, Idaho, during June 1977 and 1978.

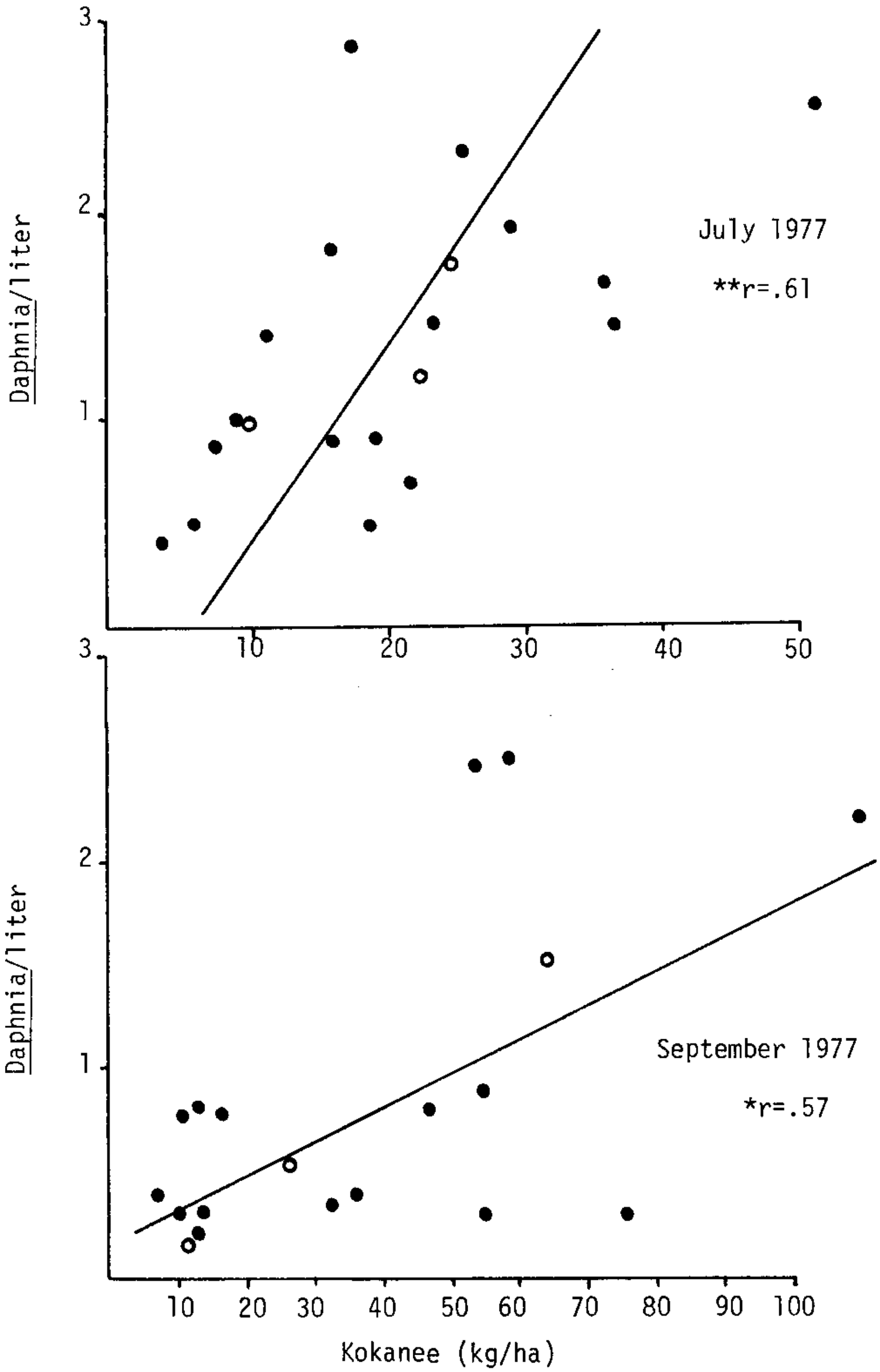


Figure 19. Relationship of kokanee density and primary prey (Daphnia) density in Pend Oreille Lake, Idaho, during July and September 1977. *denotes significance at p = .05 **denotes significance at p = .01

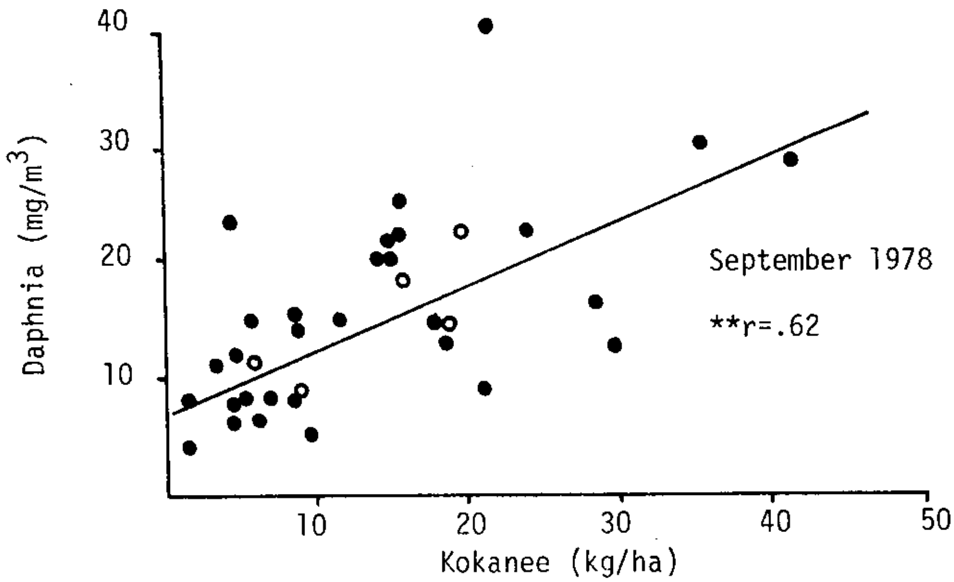


Figure 20. Relationship of kokanee density and primary prey (Daphnia) density in Pend Oreille Lake, Idaho, during September 1978. **denotes significance at p = .01.

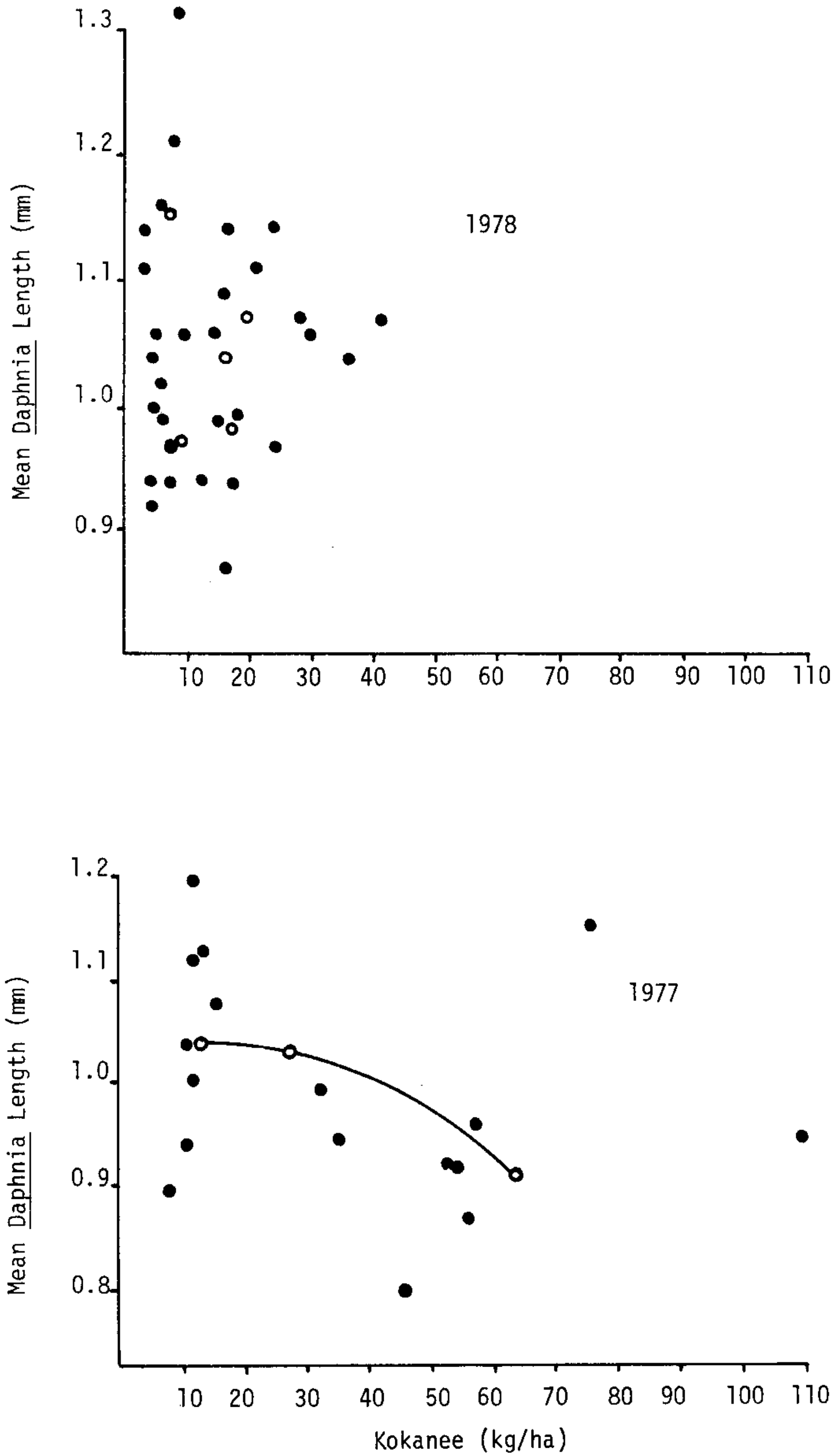


Figure 21. Relationship of kokanee density and mean Daphnia length in Pend Oreille Lake, Idaho, during September 1977 and 1978.

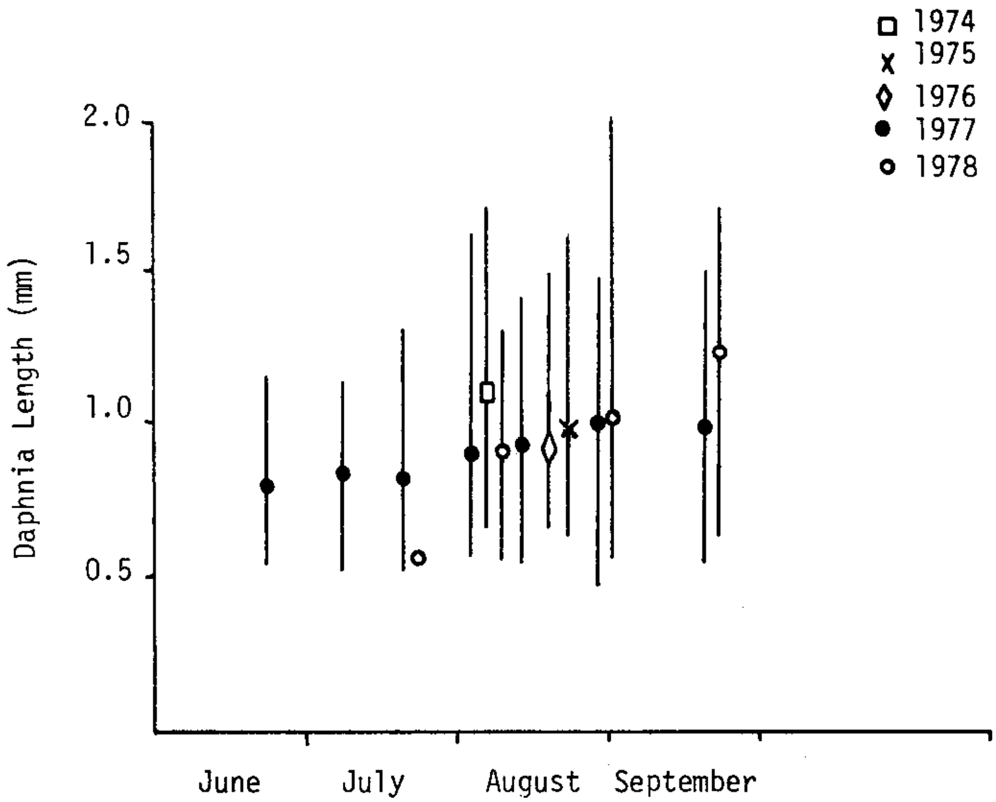


Figure 22. Mean length and length range of Daphnia from Pend Oreille Lake, Idaho, 1974-1978.

DISCUSSION

Pend Oreille may be considered a temperate dimictic lake (Rieman 1976). Though no dramatic changes have occurred in thermal conditions over the 5 years of study, the degree and timing of initial warming and fall cooling varied due to changing weather conditions. Such changes could influence the vertical distribution of kokanee, the vertical distribution of mysids and the production of zooplankton as will be discussed later. Thermal conditions in the lake may also have an influence on the time of emergence of fry from shoreline spawning areas, though we do not know how important it might be.

The Clark Fork River has an important and often dramatic influence on Pend Oreille. The spring run-off influences transparency and flushing throughout the lake. Because of the proximity of the Clark Fork to the north end of the lake, turbidity was usually greatest in that area, and residence time of the water mass was much less than in the main body of the lake (Rieman 1976). As a result primary and secondary production may have been depressed on the north end of the lake (Rieman 1976). During 1977 flows in the Clark Fork River were unusually low due to drought conditions. Transparency throughout the lake was much greater that year and differences in plankton production between ends of the lake were less than had been previously observed (Rieman 1978).

The annual chlorophyll concentrations in Pend Oreille appear to have been relatively stable throughout the study. The level of chlorophyll and early estimates of productivity (27-390 mgC/m^2/day) provided by the Army Corps of Engineers (Rieman 1977) suggest the lake is an oligotrophic system. The oligotrophic nature is probably maintained by the great depth (mean = 164 m) of the lake since nutrients are not extremely low (total P = 8-12 µg/l). There was no indication of cultural degradation in Pend Oreille since earlier work (Rieman 1976).

Though the Pend Oreille system appeared to be stable in terms of physical chemical and trophic conditions, we did observe some important changes in the macro-zooplankton community. Mysis relicta increased dramatically in abundance during 1975 and 1976 and apparently became established at densities as high as those known for any other lake. The increase in mysids apparently had an impact on the composition and temporal distribution of other macro-zooplankton. The most important changes occurred with the cladocerans. Daphnia were sparse during 1975 and 1976. Daphnia thorata was nearly eliminated, replaced in importance by D. galeata mendotae which was common in 1977 and 1978. Except for 1977 both Bosmina and Daphnia were absent from plankton samples collected in spring and early summer following the establishment of mysids.

It appears that the cladoceran populations have been negatively affected by some interaction with the mysids that may be a function of their spacial distribution. The night time vertical distribution of Mysis relicta is probably regulated by thermal stratification and light (Beeton 1960). As the lake warms and transparency increases through the season the mysids will not migrate into near surface strata avoiding light and thermal gradients. Since the cladocerans exists primarily in the upper 10 m, spacial segregation from mysids will occur as the season progresses reducing any potential interaction. Thus Daphnia and Bosmina did not become abundant until late in the summer when the mysids were isolated below the surface to 10 m strata. Vertical isolation of mysids apparently occurred much earlier than normal during 1977, probably a result of earlier warming and greater transparency (Rieman 1978). As a result Bosmina and Daphnia were abundant during the early summer period in 1977.

The conclusion that mysids are responsible for the recent changes observed in the cladoceran populations in Pend Oreille is admittedly based on circumstantial evidence. However, in light of data from other systems that conclusion is appropriate. In Lake Tahoe, California-Nevada, Daphnia and Bosmina were essentially eliminated following the establishment of Mysis relicta (Richards et al. 1975, Morgan et al. 1978). Daphnia declined in abundance in Kootenay Lake following the introduction and establishment of mysids (Zyblut 1967, 1970) and occurred only during a restricted period late in the summer (Cloern 1976, Al Martin, UBC personal communication). Furst (1978) noted that Daphnia were typically reduced in abundance with the introduction of mysids in Swedish lakes. In Lake Washington, the recent re-establishment of Daphnia may be the result of a decline in the numbers of Neomysis (Eggers et al. 1978). We have also observed changes in the macro-zooplankton of Priest Lake, Idaho similar to those described for Pend Oreille following establishment of a mysid population (Rieman 1979).

The actual mechanism of interaction between mysids and cladocerans is unclear and both predation and competition for food are potentially important (Lasenby and Langford 1973, Morgan et al. 1978, Zyblut 1967, Richards et al. 1975). The degree of interaction may also be dependent upon the trophic nature of the lake. In main Lake Tahoe, the cladocerans were completely eliminated though in a more productive bay Bosmina managed to coexist with the mysids (S. Thelkeld, personal communication) . In Kootenay Lake and Pend Oreille, both much more productive than Tahoe, Daphnia and Bosmina were not eliminated entirely.

Daphnia thorata was probably the dominant species of Daphnia prior to 1974 (Rieman 1976) and its replacement by D. galeata mendota suggests the latter is better able to coexist with mysids. The difference in body morphology between the two Daphnia may be important. D. galeata mendotae has a pronounced helmet spike, while D. thorata has a rounded helmet. Such appurtenances may be important in reducing invertebrate predation (Dodson 1974). It is possible that D. galeata mendotae gained an advantage over D. thorata due to a lower susceptibility to predation by mysids. D. thorata may also be more susceptible to predation by Leptodora kindtii once mysids are no longer limiting. It is interesting to note the D. galeata also replaced D. thorata in Kootenay Lake (Rieman 1976) which also had Leptodora (Zyblut 1967), but D. thorata is the only species found in Priest Lake which does not have Leptodora 'Rieman 1979).

The pattern of food selection by kokanee throughout the study has been consistent with optimal prey selection strategies described for other limnetic planktivores (Eggers 1977, Werner and Hall 1974). Kokanee appear to be visually selective for the largest and/or most abundant prey items. Daphnia is typically the most preferred prey item when it is available and its dominance in stomach contents generally mirrors its abundance in the lake. During years that Daphnia was delayed in seasonal appearance or reduced in abundance kokanee were forced to feed less selectively and used the large Epischura and Diaphanasoma, and the more abundant but smaller member of the macro-zooplankton was also an important food item when it was abundant in the spring (Stross 1954, Platts 1958, Rieman 1977). Even though small, Bosmina may have been readily available since it was concentrated near the surface where the fish are located in the spring. Bosmina may also be easier to capture than the faster swimming copepods.

This type of prey selection is well documented and should prove the most efficient for growth (Parsons and LeBrasseur 1970, Goodlad et al. 1974). Kerr (1971) showed that growth efficiency should decline both with declining abundance and size of prey. The recent establishment of a mysid population would then be expected to significantly enhance growth of kokanee since mysids are much larger than any of the other macro-zooplankton. Indeed that was the reason they were introduced to the system. Some unusually large kokanee have been taken in the catch and their enhanced growth may be attributed to mysids. However, the relative number of large fish has been minimal, contributing less than 0.5% of the 1977 and 1978 spawning runs at Granite Creek while the mean and modal size of spawners remained similar to past seasons. Growth of most fish was not enhanced by mysids and it was obvious that mysids did not contribute a major portion of the diet. Only a fraction of the population sample had mysid remains in the gut and newly recruited age 0 fish did not use them at all. Kokanee can obviously handle the mysids but utilization may be limited by availability. The vertical distribution of mysids coincided with that of actively feeding fish for only a short period at dusk and dawn as the shrimp migrated to or from the upper strata. The mysids were in deep water during daylight, well below most of the fish, and since kokanee are visual predators feeding ceased with darkness (Rieman, 1977). Since the vertical and horizontal distribution of kokanee did vary, mysids may have been available for any length of time only to fish located deep in the water column or in shallow water where mysids cannot escape vertically during the day. There was some indication that utilization of mysids increased with the age (and size) of fish during 1978. This could have been a function of different behavior and distribution or more efficient feeding with large prey items, by the larger kokanee. The absence of mysids in the diet of very small kokanee may also have been a function of size. Mysids might simply have been too large a food item for kokanee just beginning to feed.

It would appear then that recent changes in the temporal distribution and abundance of Daphnia and Bosmina could represent a reduction in available food uncompensated by the establishment of a mysid population. These types of changes may be especially critical for age 0 kokanee. Mortality related to slow growth is probably much greater for juveniles while older fish are less seriously influenced by food deprivation (Peterman 1978). Lewis (1974) found that year class strength of kokanee in Odell Lake was directly related to the mean density of Daphnia during the first year of life. There is some indication that the growth of juvenile kokanee did decline following the change in availability of Daphnia and Bosmina. Scale samples indicate that distance to the first annulus and the number of circuli to the first annulus declined dramatically for kokanee from the 1972-76 year classes compared to fish from the 1969-71 year classes. This type of index for first year's growth might under-represent the importance of such changes, however. Since the slower growing fish may experience a higher mortality they may be under-represented in the population sample collected the following year. Walters et al. (1978) commented that it may be difficult to observe changes in growth due to changing food availability since slow growing fish are eliminated from the population.

Though changing food availability can affect growth and result in higher mortality over time, reduced food availability very early in the year may result in high initial mortality of emerging fry. The importance of adequate food supplied as fish are just emerging and beginning to feed has been discussed extensively (Rosenthal and Hempel 1970, Cushing 1977, Baegnal and Braum 1971, Braum 1967, Hurley & Brannon 1969). Foerster (1968) suggested that mortality of emerging sockeye could be high if appropriate food items such as Bosmina were not available. LeBrasseur et al. (1978) have demonstrated a very close positive relationship of sockeye egg to fall fry survival and spring zooplankton biomass in Great Central Lake, British Columbia. Much of the sockeye enhancement work in Canada is now based on the idea that the very early period of initial feeding is critical to development of year class strength (J.G. Stockner, Canada Dept. Fish and Environ., personal communication). In Pend Oreille, fry emergence generally begins in May and peaks during June. The absence of food items such as Bosmina and Daphnia at that time is probably critical.

The declining population estimates in Pend Oreille may well be related to poor recruitment of fry. The population estimates declined from the previous year estimate in 1975, 1976 and 1978, all years of poor spring-early summer food availability. During 1977 a year of high food availability no decline was evident. The most significant mortality occurring each year is the loss of all adult fish after spawning. Failure of the population to build back to pre-spawning numbers following recruitment of the resultant progeny suggests that a major mortality is occurring between egg deposition and recruitment of fry to the population the following summer. The 1978 estimate of egg-to-fry survival was 1.2% indicating that survival during a year of poor spring food availability was indeed very low. That was the first actual estimate of survival, but comparison of relative spawning escapement in 1976 and 1977 and the resulting fry populations indicates that fry survival in 1977 (1976 year class) a year of good food availability was much better than in 1978 (1977 year class).

In short, the data we have indicates that the introduction of mysids to Pend Oreille may have resulted in a reduction in the availability of food for kokanee and may be responsible for recent declines in the population. The data is not conclusive as yet, but it is consistent with such a hypothesis. There are also supporting data from other lakes. The kokanee fishery in Priest Lake collapsed in 1976 and has not recovered. The data suggests a failure in recruitment beginning in about 1972, approximately the time mysids were established in that system (Rieman 1979). The recent decline of the kokanee population in Lake Tahoe has been attributed to the establishment of mysids (Morgan et al. 1978). The kokanee fisheries have also declined in Lake Chelan, Washington (Larry Brown, Wash. Dept. of Game, personal communication)and Okanagan Lake, British Columbia (Chris Bull, BC Fish and Wildlife, personal communication) following the establishment of Mysis relicta. Unfortunately there is no current zooplankton data available on these two lakes.

If recent changes in food availability are critical to kokanee fry survival, it may be possible to compensate through artificial means. Wild egg-to-fry survival has been enhanced in other systems through habitat improvement such as the Meadow Creek kokanee spawning channel on Kootenay Lake or those units used extensively by the International Pacific Salmon Fisheries Commission for sockeye. Artificial incubation has also been used. It is also possible to provide additional benefit by rearing fry in a hatchery before release. Since food availability may be delayed, releases of fry later in the season when food is abundant, rather than at the time wild fish move into the lake, could significantly improve survival. Our first release of hatchery reared fry, marked with tetracycline, showed substantially better survival (egg-to-fall fry) than occurred in the wild (Bowler 1979). These fish may also exhibit a higher survival throughout life because of a size advantage over wild fish of the same year class.

Aritificial enhancement of the population appears feasible. However, the apparent value of these procedures is based on data from a depressed population. Because of density-dependent factors, survival rates might well decline as large numbers of fish are introduced to the system making significant enhancement more difficult than might , be expected. Attempts to increase the population might only aggravate present problems associated with food availability. The role of density-dependent pressures have been well documented with salmon populations (Johnson 1965, Foerster 1968, Goodlad et al.

1974). Once fish are recruited to open water the mechanism of compensation is generally considered competition for food (Goodlad et al. 1974, Brocksen et al. 1970, Walters et al. 1978). In other words, as the fish increase in density they use more and more food, until at some point food is reduced in availability and growth of the fish declines. The point where this compensatory factor becomes significant to the population (i.e. further increase in abundance of fish results in a significant decline in growth or survival), might be defined as the minimum carrying capacity of a lake. The International Pacific Salmon Commission uses a simple model of this nature based on zooplankton biomass and fry growth to predict the carrying capacity of sockeye lakes (IPSFC 1972). In our case it has become very important to gain some understanding of what the carrying capacity of Pend Oreille is for kokanee, or at least whether the present densities of fish are approaching that critical point. Can the population be significantly enhanced without seriously aggravating present problems of growth and survival?

Of course the best understanding of these density related processes will come by studying the system at a wide range of population sizes over a long period of time. However, it may be possible to examine these interactions circuitously with present data. To do this we have assumed that food is the primary limiting factor in terms of density-dependent interactions once the fish recruit to the lake. As discussed earlier, this concept is well supported in the literature. It should be possible then to examine the pressure kokanee are exerting on the food supply at present to see if cropping is significant or potentially so.

Estimated cropping by kokanee during 1977 and 1978 appeared to be low over the season. Cropping averaged 0.2% zooplankton biomass/day in 1977 and 0.5% in 1978 though over shorter intervals cropping may have been more significant particularly for individual prey items. We estimated that kokanee consumed 3.4% of Daphnia biomass/day during July 1977 and 2.0%/day during August 1978. However, even these levels of cropping would seem insignificant. Hall (1964) considered a loss of 1% to 3% of Daphnia/day to be small in a natural lake. Noble (1975) suggested that a loss of 2.8% to 8.4% Daphnia/day to fish predation was negligible. Northcote et al. (1979) also felt a loss of 2% Daphnia/day by fish predation could not account for changes in the size structure of a population. The spring-early summer period may be most' critical in terms of food availability and kokanee survival since it may be a period of high food consumption and low zooplankton abundance. The June biomass of zoo-plankton was much less in 1978 than 1977 yet estimated cropping was 0.4%/day for Cyclops, the key food item in June 1977 and 0.3%/day in June 1978. Cropping did not appear to be more significant during the year of low zooplankton production. Feeding rate was apparently lower in the year during 1978 than 1977, perhaps as a response to lower food availability.

The density of kokanee varies throughout Pend Oreille. We examined the relative distribution of fish and zooplankton during 1977 and 1978 to see if cropping effects did occur in areas where fish were aggregated. Correlative analysis of these data showed no negative relationship between kokanee density and density of the prey. There was in fact, a significant positive relationship between kokanee density and abundance of the preferred prey, Daphnia, that could be explained by fish actively seeking areas of high food availability. During September 1977, we did observe a negative relationship of kokanee density and mean size of Daphnia. Size selective feeding may certainly alter the size structure of the prey population (Northcote and Clarotto 1975, Brooks 1978, Galbraith 1967), and may provide a more responsive indication of cropping pressure than absolute prey abundance. The observed relationship suggests that the kokanee may have exerted a significant cropping pressure at relatively high densities (exceeding 30 to 40 kg/ha). During September 1978 we repeated the correlative work with a much larger sample size, but found no relation-ship of kokanee biomass and prey size. We did not however encounter any fish density in excess of 42 kg/ha.

The comparison of Daphnia length among years did not show any change in size structure of the population during a period of declining kokanee abundance. This data suggests that at least within the range of kokanee numbers Pend Oreille has supported in the last 5 years (declining from approximately 12 million to 6 million) there was no effect on prey composition. In other words, 12 million fish did not have a greater cropping effect than did 6 million.

It is interesting to note that in the last 5 years on Pend Oreille, with a major decline in population size, there has been no obvious compensatory increase in growth of kokanee. A similar lack of compensatory response is apparent in Priest Lake (Rieman 1979). Priest and Pend Oreille have very similar zooplankton production, and the species composition is the same. The density of kokanee in Priest has declined dramatically in recent years and in 1978 it was 1/6 (50/ha) of that in Pend Oreille (300 fish/ha), yet growth of kokanee in these two systems was similar (Bowler 1979).

Our conclusion drawn from the data is that the observed density of kokanee in Pend Oreille Lake (13-17 kg/ha) did not have a significant cropping effect on avail-able food. Within the range of densities that the lake now supports, density-dependent interactions related to food do not appear to be important. Some modification of that conclusion may be important in light of historic information. When kokanee were first introduced to Pend Oreille,very large kokanee were taken in the catch. The size of mature fish obviously declined to the present range, 229-279 mm (9-11 in), as the population became established. Based on our present data we would suggest that the density-dependent response of kokanee might look something like the curve in Figure 23. When fish are first introduced to a system, densities are very low and growth is very good. As abundance increases with time, schools form and increase in size. Certainly there exists a very localized competition among fish within a school (Eggers 1976) and growth will decline as this process becomes important. However, there still may not be enough fish to negatively affect total food production in the lake. Schools will eventually reach an optimum size (begin to form more schools rather than larger ones) and the compensatory pressure will cease to increase if the schools do not interfer with each other. The total population might increase further without an accompanying increase in compensatory effects. The population would be operating along the flat portion of the curve until it reaches such a level where it begins to affect actual food production in the lake. That point might again be described as the functional carrying capacity of the lake. Biologists from the International Pacific Salmon Fisheries Commission have suggested that the density-dependent response of sockeye populations may be of the same nature described here (Jim Woody, IPSFC, personal communication).

This basic concept may describe the Pend Oreille system. We appear to be working on the flat portion of the curve, perhaps some distance below carrying capacity. It should be possible to significantly increase the population without seriously aggravating our present problems with growth and survival.

The Future

Further work on Pend Oreille should be coupled with the evaluation of potential enhancement methods. We should examine more closely the spring period of fry recruitment because of the potential for food limitation and major mortality at that time. If artificial enhancement is used the timing and distribution of fry releases

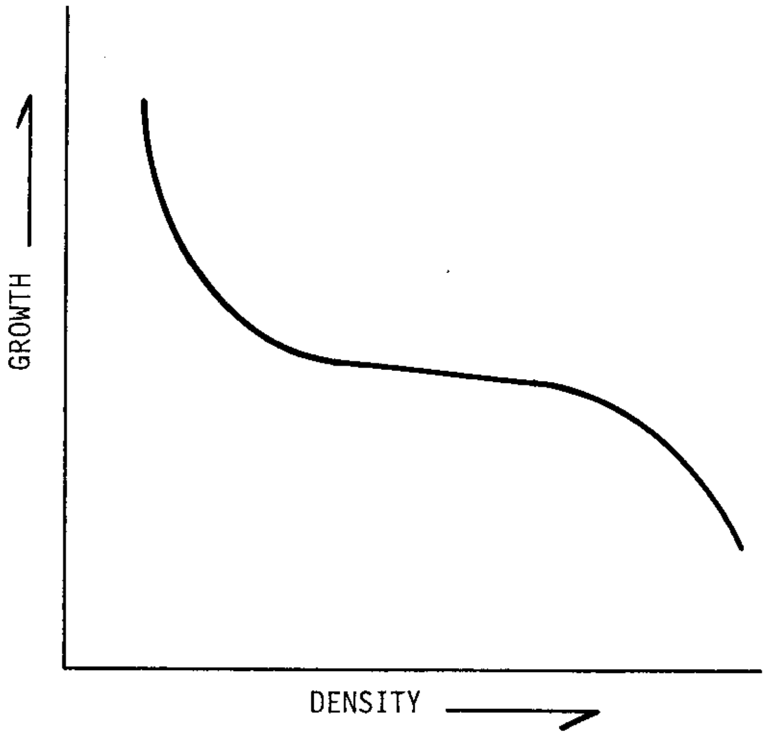


Figure 23. Theoretical density-dependent growth response of kokanee.

must be explored to provide maxumum survival with the least possible impact on wild stocks. New techniques are becoming available for studying more closely the early life history of limnetic fishes. The examination of early growth history and age on a scale of days rather than years is possible by daily growth ring analysis of otoliths (Ken Wilson, UBC IARE, personal communication). This technique could be extremely useful for examining the importance of time of recruitment, food availability and fish density to the early growth and survival of kokanee. Significant advances have also been made recently with lake fertilization. The technique has proven very effective in enhancing growth and fry survival of sockeye under certain conditions (J.G. Stockner, Canada Dept. Fisheries and Environment, personal communication). It is quite possible that fertilization could provide a boost to early food availability for fry in some localized areas of the lake. Again a better understanding of the early fry life history, distribution and behavior, as well as the physical and chemical limnology of important fry producing areas is important. Further work should explore the feasibility of fertilization.

Our work indicates that Pend Oreille can support a larger kokanee population. It is important that our conclusion be viewed only as a prediction from the best available data on the current system. The important density-dependent processes will be understood only as they begin to act. To be effective, artificial enhancement of Pend Oreille should be closely evaluated. Methodology can be modified in progress to provide optimum distribution and recruitment timing. There are too many examples of failure with major enhancement attempts simply because of inadequate understanding of the new problems that were created.

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APPENDICES

Appendix A. Summer mean zooplankton densities (number/1) and total biomass (mg/m^3) Pend Oreille Lake, Idaho, 1974-1978. Available biomass data for individual species is shown in parentheses.

Year	Cyclops	Diaptomus	Epischura	Bosmina	Daphnia	Diaphanasoma	Total	Total biomass mg/m^3
30 May-10 Sept 1974	6.98	3.42	0.09	1.39	1.39	0.08	13.34	33.8
					(9.9)			
22 May-10 Sept 1975	5.10	3.35	0.05	1.44	0.07	0.02	10.04	16.3
					(0.3)			
16 May-15 Sept 1976	8.62	4.73	0.06	1.20	0.22	0.20	15.03	34.8
	(12.1)	(13.2)	(1.3)	(0.8)	(1.5)	(1.6)		
13 May-19 Sept 1977	13.88	8.16	0.06	1.08	1.71	0.10	24.99	54.3
	(20.6)	(24.3)	(1.0)	(0.9)	(6.8)	(0.9)		
11 May-19 Sept 1978	8.63	5.28	0.05	.95	.54	.21	15.67	31.1
	(11.6)	(14.6)	(0.8)	(0.5)	(2.3)	(1.4)		
5 year mean	8.64	4.98	.06	1.21	.78	.12	15.80	34.1

Appendix B. Frequency of occurrence for mysids in kokanee stomachs from Pend Oreille Lake, Idaho, 1978. Same size (N) is in parentheses.

Month	Age Class 0+	1+	2+	3+	Total
May	(8) 0%	(75) 10%	(51) 20%	(48) 47%	(171) 22%
July	(151) 22%	(57) 7%	(63) 44%	(99) 54%	(370) 32%
September	(149) 13%	(68) 13%	(94) 11%	(75) 19%	(380) 14%
Total	(308) 17%	(200) 10%	(197) 23%	(222) 41%	(927) 23%

Appendix C. Composition of stomach contents (% of total contents by weight) for four age classes of kokanee from Pend Oreille Lake, Idaho, 1978.

Date	Age Class	(n)	Cyclops	Diaptomus	Epischura	Bosmina	Daphnia	Diaphanasoma	Insects	Mysids
May	0+	(8)	100%	0						0%
	1+	(15)	90%	5%						5%
	2+	(11)	70%	28%						2%
	3+	(12)	80%	3%					2%	14%
July	0+	(159)	82%	3%	1%	1%				13%
	1+	(17)	73%	12%	6%	7%				2%
	2+	(22)	78%	2%	1%	2%				17%
	3+	(42)	62%	1%	18%					19%
September	0+	(33)			22%		74%	1%		3%
	1+	(15)			2%		91%	1%		7%
	2+	(23)			0		95%	4%		0.6%
	3+	(20)			6%		82%	2%		10%

JOB PERFORMANCE REPORT

State of	Idaho	Name;	LAKE AND RESERVOIR INVESTIGATIONS
Project No.	F-73-R-1	Title:	Kokanee Life History Studies in Pend Oreille Lake
Study No.	II		
Job No.	IV		

Period Covered: 1 March 1978 to 28 February 1979

ABSTRACT

We used echosounding and mid-water trawling techniques to assess the status of the kokanee stock in Pend Oreille Lake during 1978. We measured peak abundance, assessed distribution and movement, monitored growth and survival and estimated year-class strength of the kokanee stock in the lake.

Peak fish abundance declined in the lake from 1974 to 1978. Acoustic estimates of 12.1 million were recorded in 1974 with 5.2 million in 1978. The trawl estimate dropped from 7.0 million in 1977 to 5. 8 million in 1978 with both trawl estimates lying within the 95% confidence limits of the acoustic estimates. Kokanee comprised 99.2% of those fish collected in the trawl suggesting changes in the acoustic estimates reflected changes in kokanee abundance.

Young-of-the-year kokanee were mostly recruited in the south end of the lake during 1977 and 1978. They moved northward as summer progressed. Age 1+ kokanee were the predominant age-class found on the north end of the lake.

We measured wild kokanee survival from potential embryo deposition to fry abundance the following fall at 1.2%. Hatchery survival was estimated at 15.3% from released fry in July to September. Based on the number of embryos collected to produce the July release, hatchery survival was increased 10 fold over wild survival. Releases were made in July to enhance survival by timing food production with lake residency.

Kokanee growth to the first annulus declined with the establishment of Mysis relicta in Pend Oreille Lake. Cladoceran production also declined with the onset of Mysis.

Estimates of year-class strength for the 1975, 1976 and 1977 kokanee year-classes suggest that fishing success will not improve through the 1981 fishing season. Stock abundance for those years indicates that the lake is understocked and operating below its carrying capacity. Natural recovery appears marginal with a declining population. Artificial enhancement of the kokanee stock appears to be a logical solution for restoring former levels of kokanee abundance to Pend Oreille Lake. Future enhancement efforts will need close evaluation to monitor success.

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RECOMMENDATIONS

Develop a program of kokanee enhancement on Pend Oreille Lake to bolster fry recruitment by;

1. Hatchery rearing kokanee fry and timing their release to peak occurrences of preferred food items (Bosmina, Daphnia) in the lake.

2. Developing an on-site incubation station in Sullivan Springs Creek to enhance recruitment and ensure returns for an egg source.

3. Assessing the feasibility of an experimental fertilization program in isolated bays of significant recruitment to enhance survival of kokanee fry.

Continue to tetracycline mark kokanee fry that are released into the lake and monitor their survival from mid-water trawl returns.

Continue to monitor peak fish abundance in Pend Oreille Lake acoustically in September.

Continue to make estimates of kokanee year-class abundance and distribution with mid-water trawling and make annual estimates of survival from September to September.

Continue to collect scales from age 0+ and 1+ kokanee to relate growth to annual survival.

Continue to relate growth, abundance, and distribution of kokanee to different limnological characteristics of the lake.

Begin to make comparisons of kokanee density, growth and food abundance and availability from Pend Oreille with Priest and Coeur d'Alene Lakes.

OBJECTIVES

To assess densities, abundance and movements of the kokanee population in Pend Oreille Lake by area, season and age-class.

To assess species composition of the fish populations in the lake.

To assess distribution of young-of-the-year kokanee as an indicator of shore-line spawning areas in the lake.

To make estimates of year-class strength and assess age class competition of the Pend Oreille Lake kokanee populations.

To assess survival of kokanee by year-class from season to season. To measure

kokanee growth rates by year-class.

To correlate kokanee abundance in the lake by year-class with growth rates and annual survival rates.

TECHNIQUES

USED Echosounding

We measured relative densities and assessed movement patterns of fish in Pend Oreille Lake during 1978 using echosounding. We used a Ross Fineline 200 A depth sounder (105 KHz) with a hull mounted transducer (22° beam angle) fixed in a 6.5 m (21 ft) fiberglass boat.

Echosounding for fish abundance measurements was done at night and during the dark phase of the moon for better interpretability of the echograms (Bowler 1975).

For sampling purposes, we stratified Pend Oreille Lake into seven sections. Each section was further divided into 804.9-m (0.5-mi) grids or transects (Fig. 1). During the sampling months of 1978, approximately 22% of the possible transects in each lake section were selected at random for echosounding. These totaled 137 transects for each month's survey for the entire lake. We traversed through the trans-sects using known boat speeds, compass headings and fixed landmarks. The average boat speed measured 2.4 m/sec (5.5 mph) at 1,000 rpm for echosounding each transect and 12.2 m/sec (27 mph) at 3,500 rpm for traveling between transects.

The total fish estimates were made by calculating the mean number of fish per transect from the echograms found in the volume of water sampled with the cone at 5-fathom (30 ft) intervals and expanding that value to the total volume of water in the lake to the depth at which fish were recorded on the echograms. The actual cone volume was computed from the 22° beam angle as the volume of a trapezoid (Bowler 1975). No estimates were made above the 2-fathom (12-ft) level.

To check the accuracy of the quantitative fish measurements collected on Pend Oreille Lake using echograms, we employed the use of a calibrated echosounding system (data acquisition system) in 1975 operated by the Fisheries Research Institute (FRI) from the University of Washington. With the resultant comparative data, correction factors were applied to the estimates for improved accuracy (Bowler 1976). All of the data was programmed on a calculator that yielded the corrected estimates with their respective confidence limits.

During the echosounding surveys we used a gain setting of 7 on the recorder because this setting allowed for the best resolution of fish targets found in the depth range at which kokanee were distributed (0 to 46 m; 0 to 150 ft) as assessed by vertical gill netting (Bowler 1975).

Trawling

We used mid-water trawling techniques as described by Lewis 1974, for sampling fish species in Pend Oreille Lake during 1978. We collected species and age composition information as well as scales, stomachs, lengths and weight data from the kokanee sampled. We also made estimates of kokanee abundance and year-class strength.

The trawling boat was an 8.5-m (28-ft) cruiser equipped with a 140-hp diesel engine, hydraulic winches, a Ross Fineline 200 A depth sounder and two hull mounted transducers (22° and 8° beam angles) (Fig. 2). The trawl system utilized hydro-dynamic otterboards, depressors and hydrofoils. The net measured 3.05 m (10 ft) square at the mouth and 13.7 m (45 ft) long, and contained mesh sizes (stretch measure) graduated from 32, 25, 19 and 13 mm (1 1/4, 1, 3/4 and 1/2 in) in the body

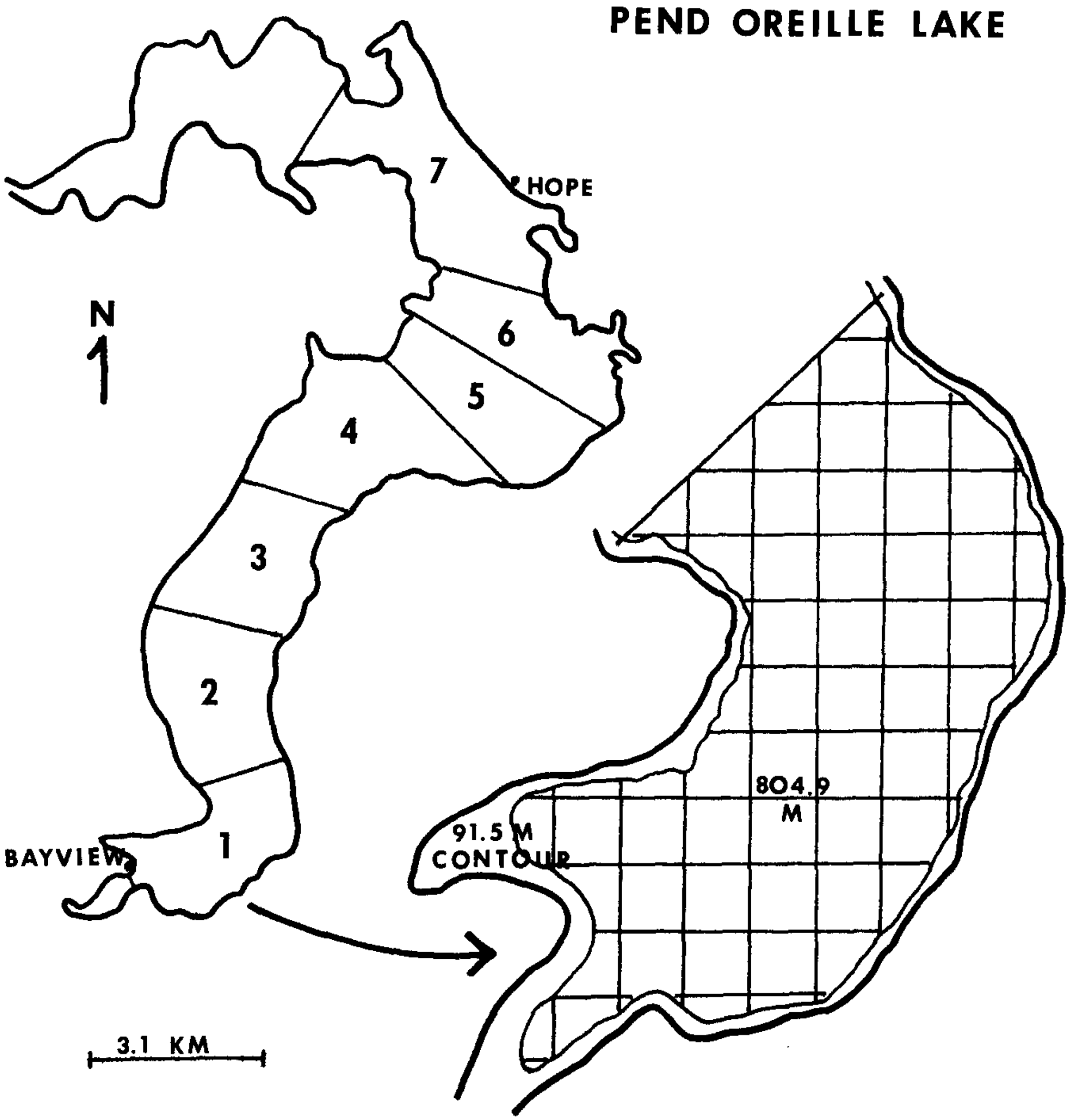

Figure 1. Stratified sampling sections used on Pend Oreille Lake during the 1978 acoustic and trawling surveys. Each lake section was divided into 804.9 m (0.5 mi) transects.

to 6 mm (1/4 in) in the codend. Towing speed of the net measured 1.5 mps (4.9 fps). Towing depth was estimated from angle-length relationships and was verified using a time-depth recorder.

All trawling was done at night during the dark phase of the moon to increase capture efficiency. For making estimates of kokanee abundance we made oblique tows through the vertical distribution of fish targets as observed from the echo-grams in 3.7 m (12 ft) intervals. The distance traveled and volume sampled in a standard 3.5 minute haul was 305 m and 2,832 m^3 (334 yd, 3,702 yd^3), respectively. During each month's survey we trawled approximately 28 randomly selected transects throughout the lake which included an average of five oblique hauls depending on the vertical distribution of fish. This equalled approximately 140 hauls per sampling month.

We weighed and measured all kokanee and collected scale and stomach samples of the representative age-classes. All kokanee fry were preserved in 10% formalin. Lengths and weights of preserved fry were determined in the laboratory and adjusted to live values using correction factors (1. 06 x preserved length and .97 x preserved weight).

Tetracycline Marking Hatchery Fry

We marked all kokanee fry with tetracycline before releasing them into Pend Oreille Lake. Tetracycline (TM-50) was mixed with the fish feed at the rate of 11% by weight (i.e. 1 lb TM-50 to 9 lb feed) per day. All kokanee were fed the TM-50 mixture 10 days prior to release.

We examined all trawl caught kokanee fry for tetracycline marks just after they hauled aboard the boat. We used a battery powered ultraviolet light with long wave length (3,600 A°). When the marked fish were exposed to the UV light in total darkness a yellow sheen was observed around the mandibles, opercules, pelvic and pectoral fins. The external mark was evident for several months after the fish were fed TM-50. When the external mark faded the yellow sheen could be seen internally on the ribs and vertebrae.

Age and Growth

We analyzed scales from all age classes of kokanee collected during 1978 with an emphasis on the age 1+ fish. We made growth rate comparisons with previous scale collections by measuring the distance to the first annulus and also enumerating the number of circuli to the first annulus. Scales were cleaned and mounted dry between glass slides and analyzed on a microprojector with 41.6X magnification.

FINDINGS

Fish Abundance

Comparative acoustic estimates of peak fish abundance made in Pend Oreille Lake from 1974 to 1978 were collected during September. Reduced sampling variance due to the horizontal and vertical distribution of kokanee during September resulted in the best comparative estimates (Bowler 1975, 1976). The peak estimates declined from 12.1 million (534 fish/ha, 216 fish/acre) in 1974 to 5.2 million (230 fish/ha, 93 fish/ acre) in 1978 (Fig. 3). The respective confidence limits on the estimates indicate there has been a significant ($p = 0.05$) decline in the population from 1974 to 1978 (Fig. 3).

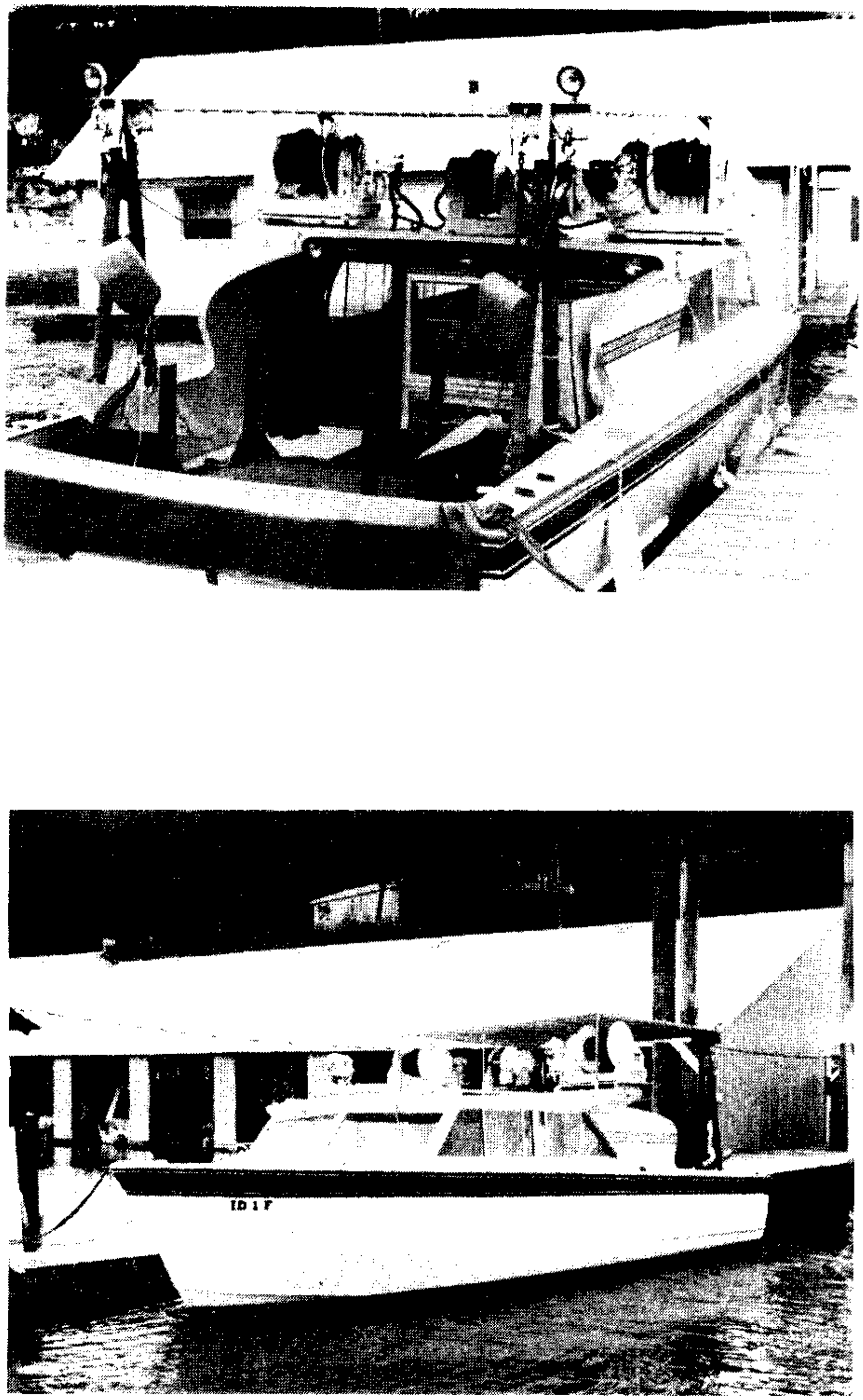

Figure 2. Mid-water trawling vessel used on Pend Oreille Lake during 1976, 1977 and 1978.

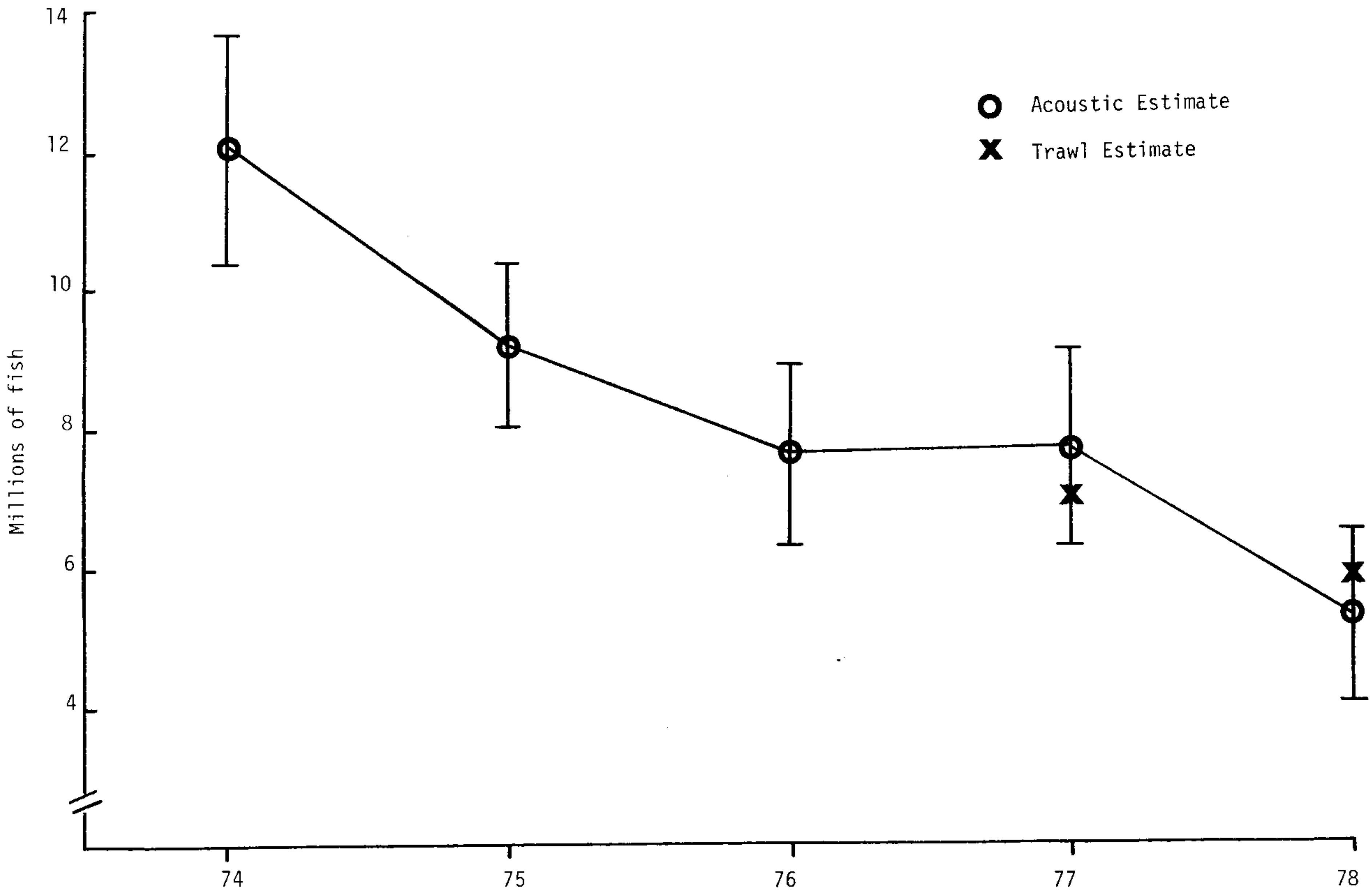

Figure 3. Annual fish population estimates including confidence intervals (p=.05) obtained from acoustic and trawl surveys during September of 1974 through 1978 in Pend Oreille Lake.

Species Composition

Kokanee made up 99.2% of the 1,532 fish collected in trawl hauls during May, July, September and November 1978 in Pend Oreille Lake. The remaining 0.8% were 9 lake whitefish and 4 unknown fry. None of the kokanee collected were of the early-spawning variety.

Kokanee Fry Emergence

Kokanee begin to emerge from tributary and shoreline gravels in Pend Oreille Lake in early April and continue to early July (Jeppson 1960). We found from trawl data collected during 1977 that fry emergence extended into August with the peak occurring in June (Fig. 4). We also estimated the expected fry emergence from the Bayview and Granite Creek spawning areas by calculating the number of days needed to absorb 900 thermal units from the time of observed spawning in both areas. By that method emergence would have commenced in early May and peaked in June in Bayview (Fig. 5). Because of warmer water temperatures in Sullivan Springs than in the lake, emergence would have commenced in April and peaked in May in Granite Creek (Fig. 6).

Kokanee Distribution and Movement

Young-of-the-year kokanee were collected predominately on the south end of the lake during 1977 (Bowler 1978) and 1978. Distribution of fry suggests that most of the shoreline spawning occurs in the south end of the lake mostly in Idlewilde and Scenic Bays. Throughout the summers of 1977 and 1978 the fry moved northward (Bowler 1978). Trawl and gill net data indicate that most of the age 1+ kokanee spend their second summer rearing in the north end of the lake (lake sections 5, 6, 7) (Bowler 1975, 1976, 1977, 1978). The age 2+, 3+ and 4+ kokanee distribute themselves throughout the lake (Bowler 1978).

Kokanee Year-Class Strength

Mid-water trawling was used to make kokanee year-class during 1978 in Pend Oreille Lake. Total trawl estimates were made in July and September. The total estimate increased from 5.10 million in July to 5.82 million in September (Table 1).

Because of Pend Oreille's size it is difficult to sample the lake adequately enough to affix confidence limits to the trawl estimates. Estimates for both months indicate there was little difference between each year-class with the possible exception of the 1975 year-class (Table 1). The September estimate was likely more accurate because of the horizontal and vertical distribution of kokanee at that time (Bowler 1978). Also the September estimate lies within the 95% confidence limits of the acoustic estimate (Fig. 3). There appears to be a tendency to underestimate the abundance of age 1+ kokanee because of their uneven distribution in the lake.

Kokanee Growth

We physically measured kokanee growth by age-class during 1978 from trawl caught fish. We also collected a representative sample of the age 1+ kokanee for scale interpretation of growth to the first annulus.

We compared growth of each age class of kokanee caught with the trawl during 1977 and 1978. There appeared to be no difference between growth of young-of-theyear kokanee during the summers of 1977 ('76 year-class) and 1978 ('77 year-class) (Figs. 7 & 8). Also there appeared to be little difference in growth between the

Table 1. Estimates of kokanee year-class strength collected by mid-water trawling in Pend Orielle Lake during 1978. (Estimates are in millions of fish).

Year-class	July	September
1977	1.79	1.82
1976	0.65	.71
1975	1.29	2.00
1974 & 1973	1.37	1.29
	5.10	5.82

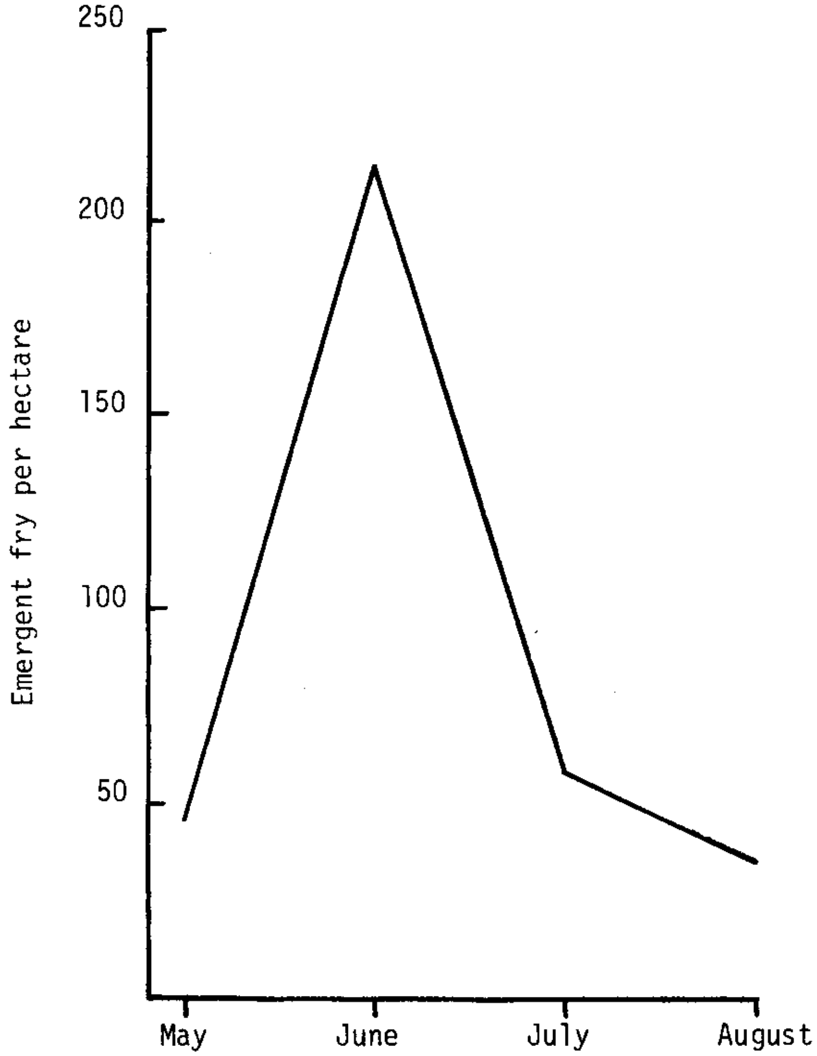

Figure 4. Kokanee fry emergence in Pend Oreille Lake as measured by mid-water estimates of emergent fry ($\leq$ 25 mm) during 1977).

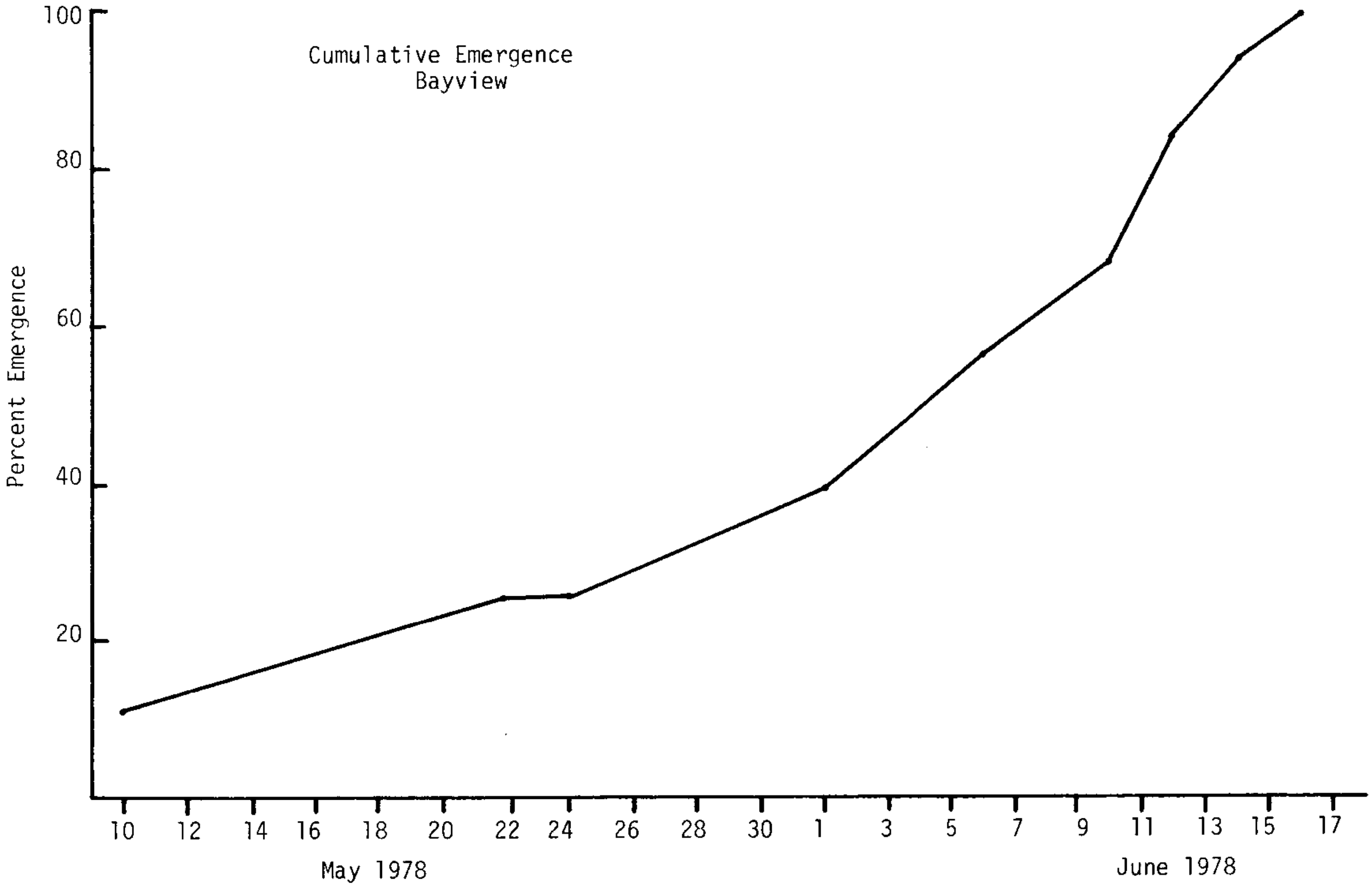

Figure 5. Expected fry emergence for shoreline spawning kokanee in Bayview based on embryo absorption of 900 thermal units from the 1977 spawning season.

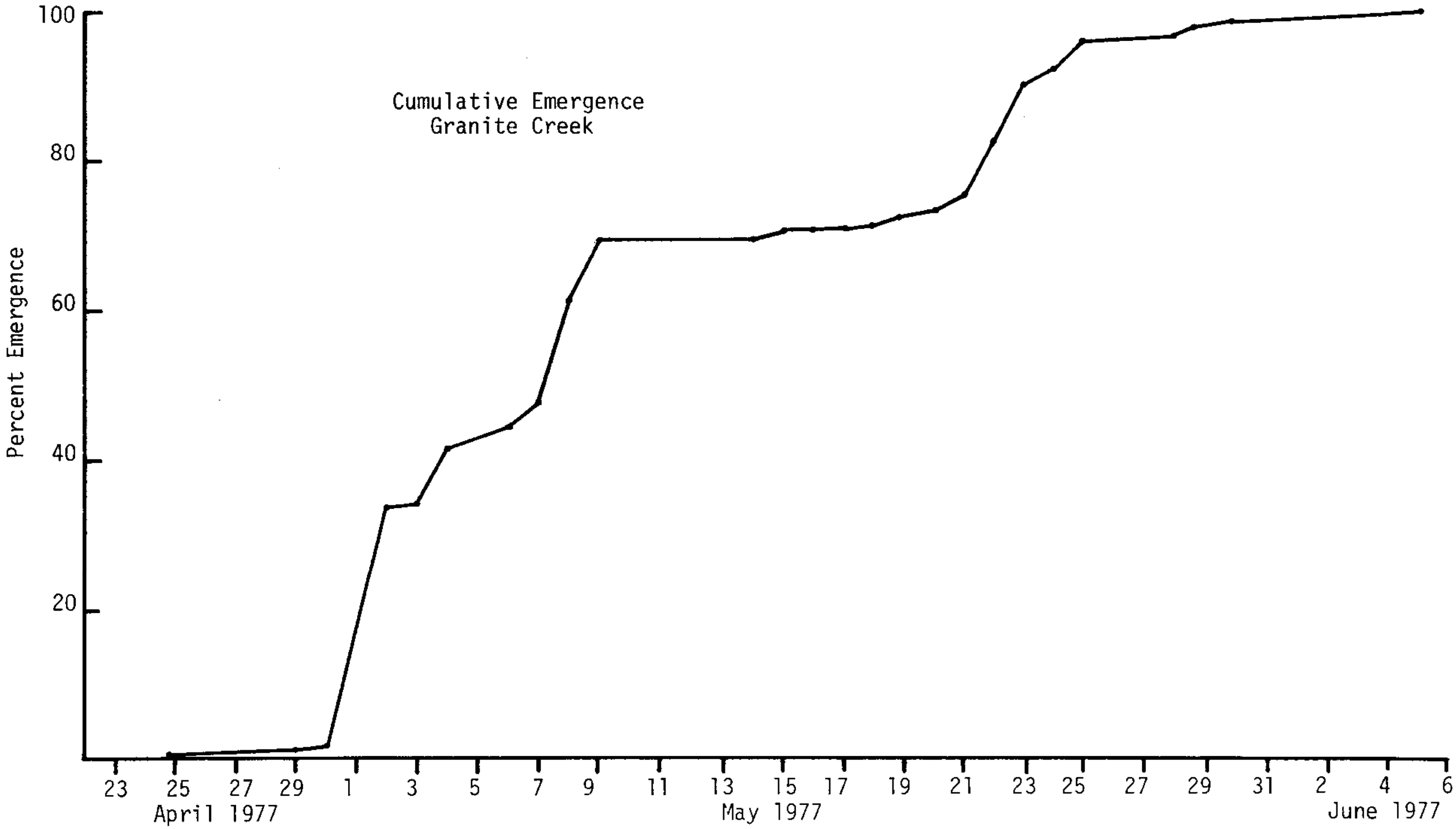

Figure 6. Expected fry emergence for tributary spawning kokanee in Granite Creek based on embryo absorption of 900 thermal units from the 1976 spawning season.

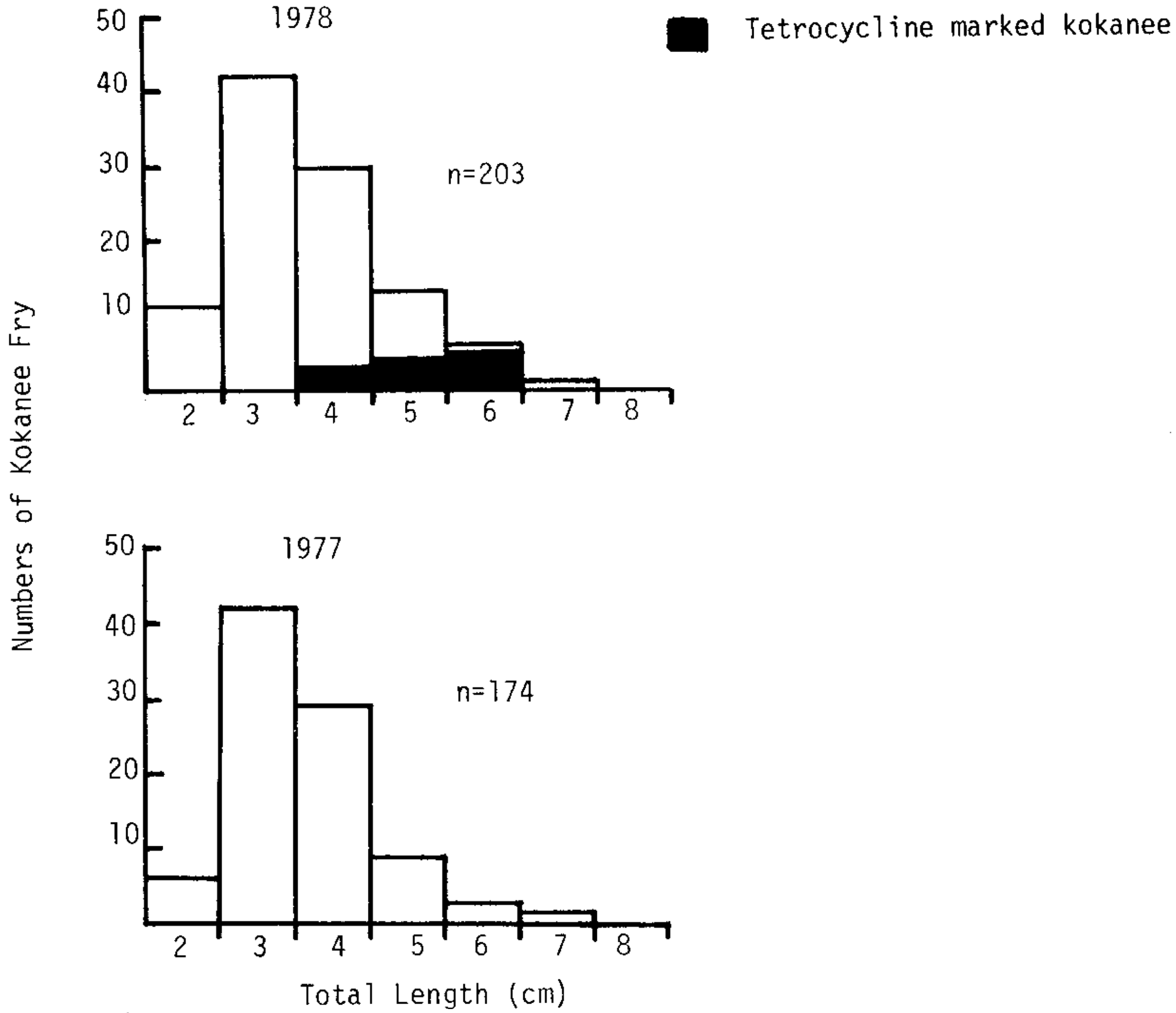

Figure 7. Length frequency of young-of-the-year kokanee collected by mid-water trawl during September 1977 and 1978 in Pend Oreille Lake.

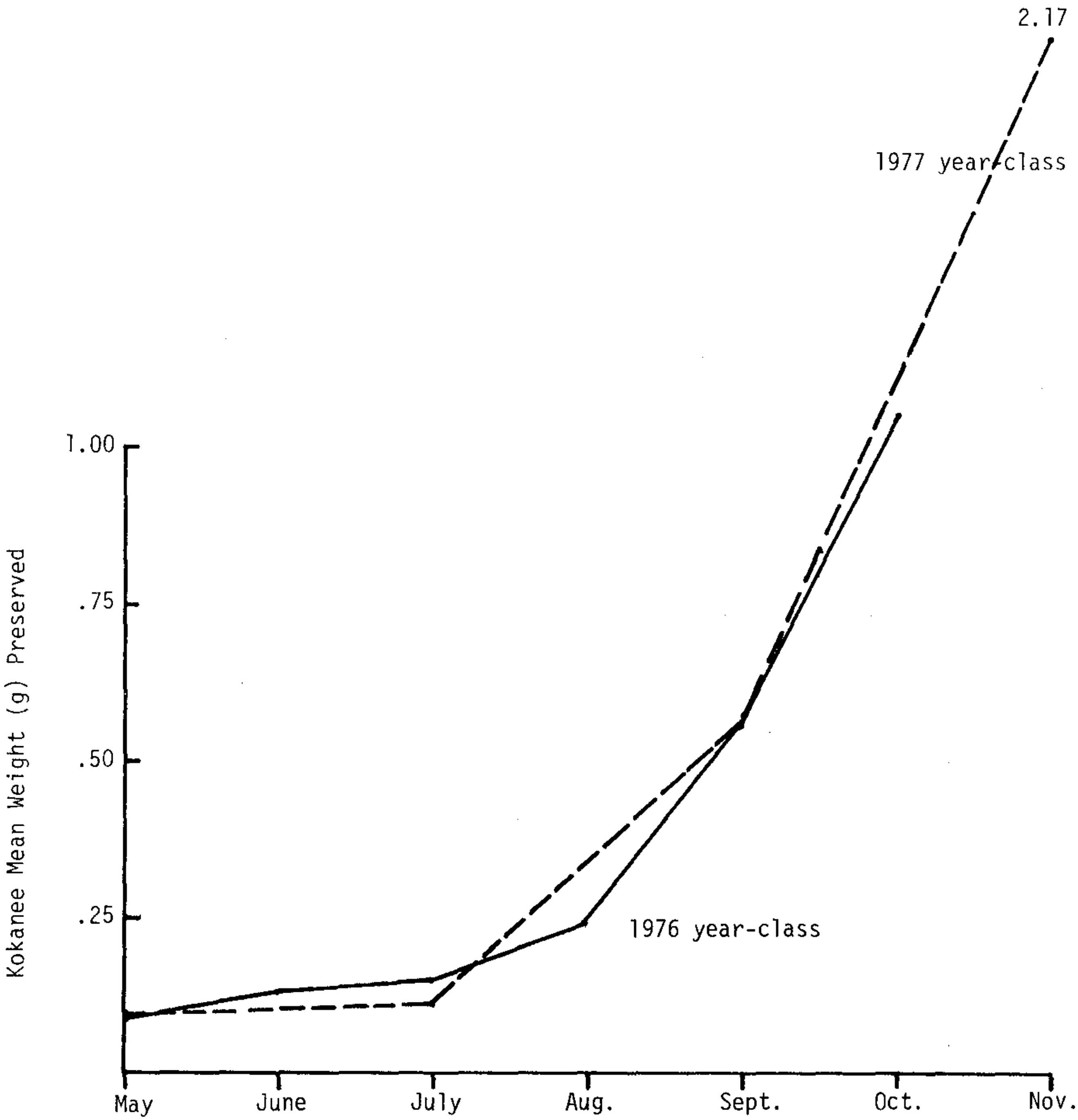

Figure 8. Mean preserved weight (g) of age 0+ kokanee collected by month in Pend Oreille Lake during 1977 and 1978 using a mid-water trawl.

age 1+ kokanee for both years. Perhaps the 1976 year-class demonstrated slightly better growth in the summer of 1978 than the 1975 year-class showed during the summer of 1977 (Fig. 9). The largest difference in growth appeared in the age 2+ kokanee for both years. The 1975 year-class gained less weight during the summer of 1978 than the 1974 year-class gained in the summer of 1977 (Fig. 9). We observed little growth differences in the age 3+ and 4+ kokanee for both summers (Fig. 9).

We examined first year growth from the 1969 to 1976 kokanee year-classes in Pend Oreille Lake by measuring the distance and enumerating the number of circuli to the first annulus. We hypothesized that changes in growth would be reflected by changes in first year survival. Several problems arose in the aging technique that may tend to mask changes especially in growth reductions. Because we did not have scale samples from age 1+ kokanee of all the year-classes aged we had to back calculate growth to the first annulus from older age fish. We found that measured growth to the first annulus increased as age increased suggesting that those fish showing slow growth during their first year also experienced higher mortality throughout life (Table 2).

We pooled and compared yearly increments of growth from back calculations of the 1969 to 1971 year-classes and the 1972-76 year-classes of kokanee. Growth to the first annulus showed a marked decline from the latter group compared to the former (Fig. 10) suggesting survival may have been better in the years before Mysis became well established in the lake. To help eliminate the bias of back calculating from older age fish it will be necessary in future years to compare growth of age 1+ kokanee of each year-class collected the same time of year.

We also compared growth increments of large kokanee (>30.0 cm, 11.8 in) with those less than 30.0 cm and found that the back calculated length at each annulus were generally larger among the kokanee exceeding 30.0 cm. The average length at each annulus of those 30.0 cm and longer ranged from 1.6 cm (0.6 in) for age 1+
kokanee to 13.7 cm (5.4 in) for age 5+ fish larger than those less than 30.0 cm. Also increments of growth to each annulus followed a similar pattern (Tables 2 & 3). The larger kokanee were the later maturing segment of the spawning population. They were predominantly age 4+ and 5+ (Bowler 1978).

Kokanee Fecundity

We examined egg skeins from 23 mature kokanee collected in Granite Creek during November 1978. We enumerated individual eggs and weighed each skein. Egg numbers ranged from 245 in a 236 mm (9.3 in) female to 545 eggs in a 268 mm (10.6 in) female. The average length of female kokanee spawner in Granite Creek during 1978 was 25.0 cm (9.8 in). A 25.0 cm kokanee yielded approximately 400 eggs (Fig. 11).

We also examined 21 egg skeins from mature females collected by trawling during September 1978. The females averaged 238 mm (9.4 in) in length and yielded a mean egg count of 382.

Kokanee Biomass

We measured kokanee biomass in Pend Oreille Lake in July and September 1978. The July estimate yielded 7.37 kg/ha (6.56 lb/acre) while September yielded 13.17 kg/ha (11.72 lb/acre). Peak biomass in 1977 was measured at 17.22 kg/ha (15.33 lb/ acre) in September.

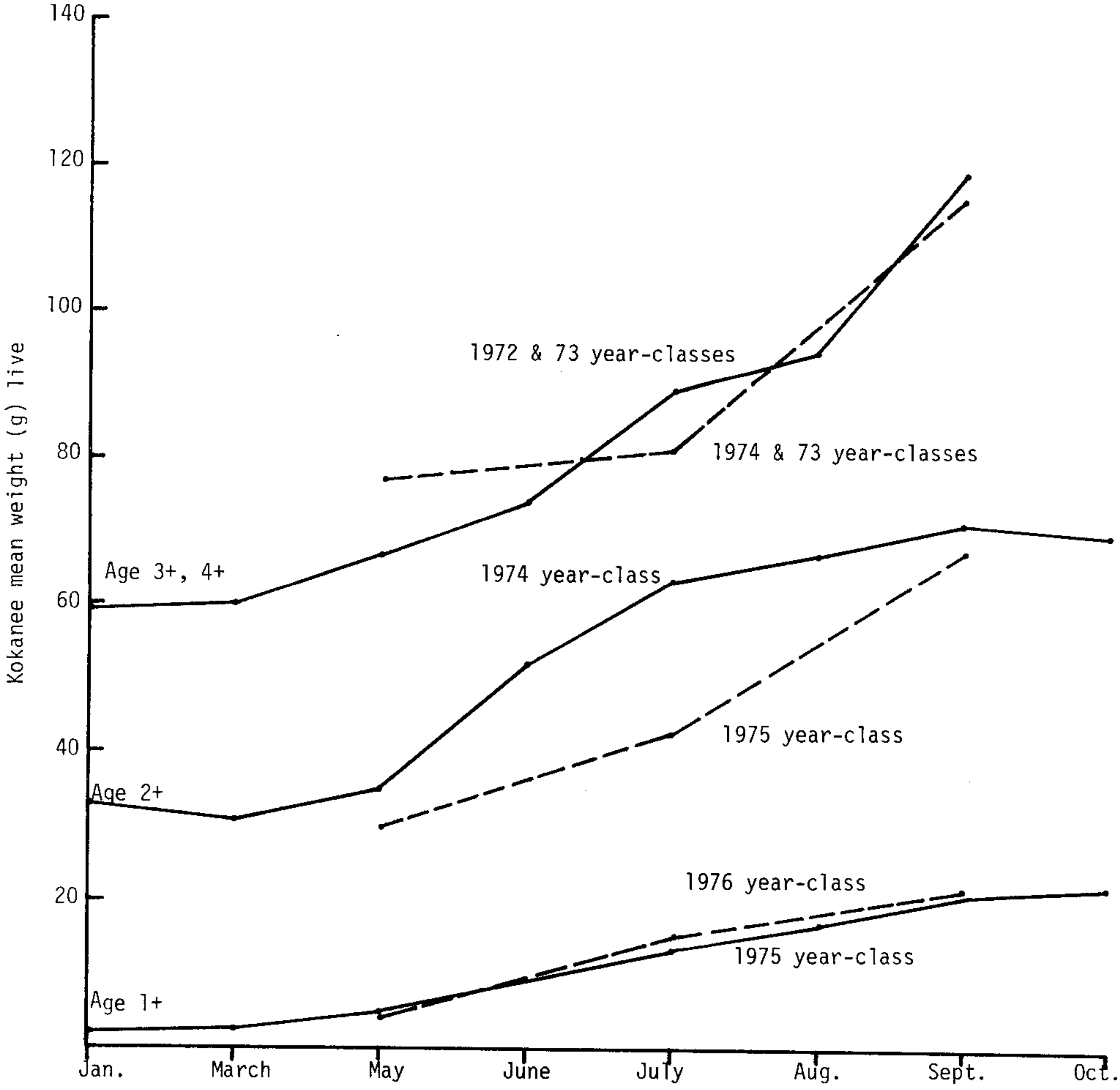

Figure 9. Mean live weights (g) of age 1+, 2+, 3+ and 4+ kokanee collected by month in Pend Oreille Lake during 1977 and 1978 using a mid-water trawl.

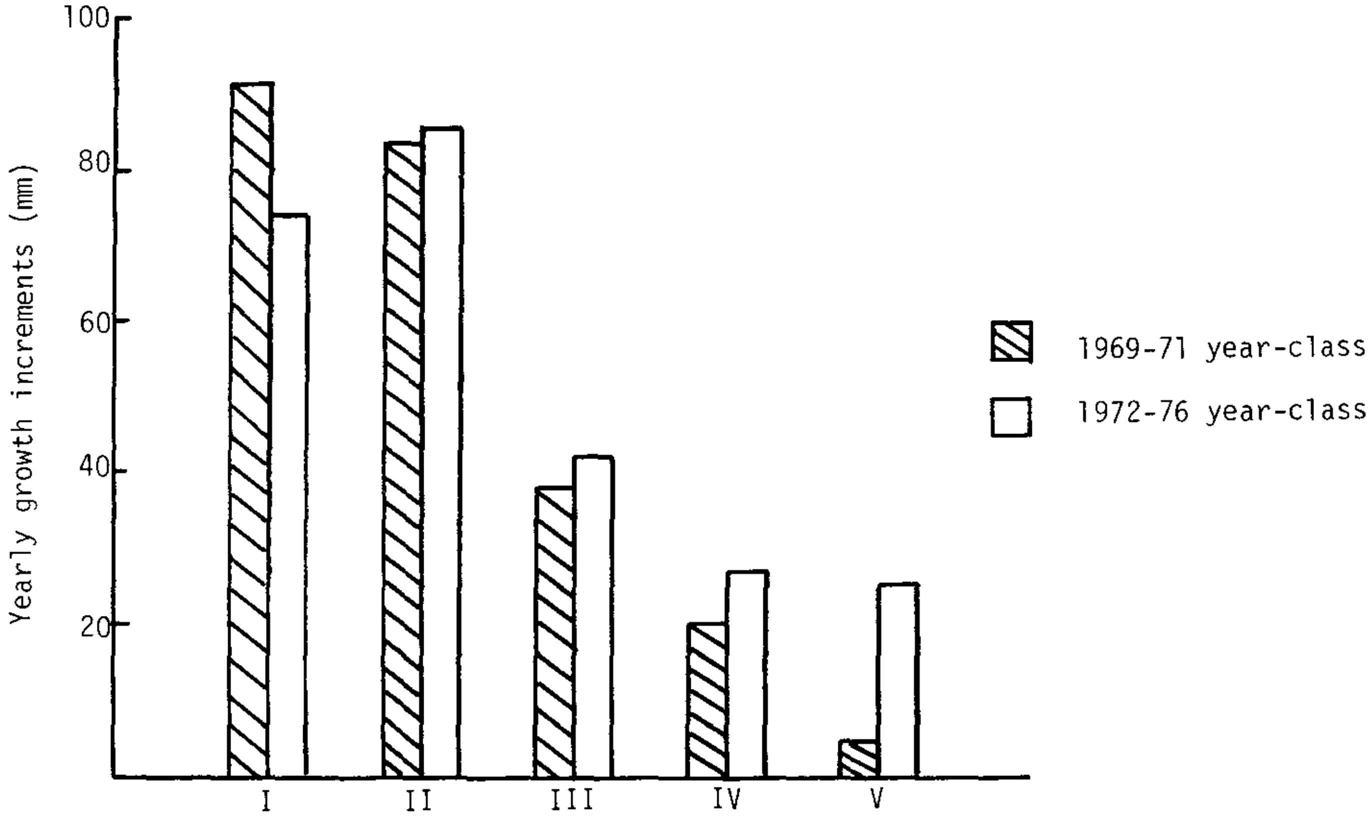

Figure 10. Yearly growth increments (by age) of 8 year-classes (1969 to 1976) of kokanee collected in Pend Oreille Lake.

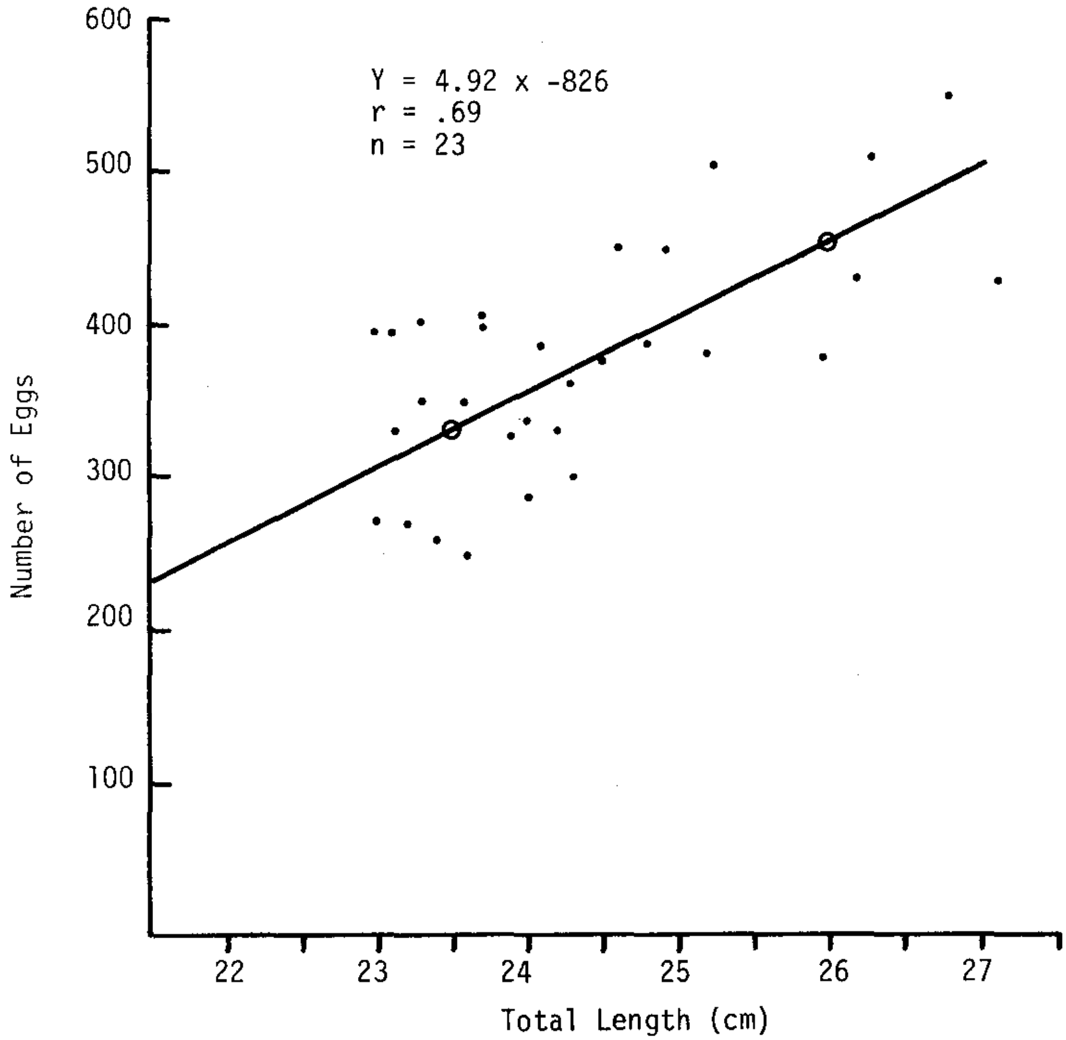

Figure 11. Fecundity vs. length of 23 mature kokanee collected in Granite Creek during 1978. (Y = 4.92 x -826)

Exploitation Rate (E) and the Force of Fishing Mortality (F)

The annual kokanee harvest in Pend Oreille Lake during 1978 was 168,000 fish. Of the total catch 10,000 were age 2+ (1975 year-class) and 158,000 were age 3+ and 4+ (1973-74 year-classes) . The exploitation rate (E) for the 1973-74 year-classes was estimated at 10%. For the 1972-73 year-classes during 1977 E was estimated at 15%. Also for both 1977 and 1978 we estimated exploitation rate for the mature fish only. The 1977 estimate equalled 19% while the 1978 estimate was 12%.

The force of fishing mortality was calculated for both years using the formula $F = \frac{EZ}{1-S}$ where F is fishing mortality, E is exploitation rate, Z is instantaneous rate^{I-S}of total mortality and S is annual survival rate. Annual survival was estimated at .67 from year-class strength data collected by trawl and Z was taken from Ricker's tables. We computed F at .12 in 1978 and a F of .18 in 1977.

Survival

We estimated wild fry survival in 1978 in Pend Oreille Lake by comparing potential embryo deposition from estimates of mature kokanee in the fall of 1977 to fall fry estimates in 1978. We assumed a potential embryo deposition of 130 million in 1977. The 1978 wild fry estimate was 1.6 million yielding a 1. 2% survival rate.

We also measured survival of hatchery reared kokanee in 1978 by comparing estimates of tetracycline marked kokanee fry in the lake in September to the known number of marked fry released in Granite Creek in July. Most of the marked fish were recovered in lake section 3 but several were captured in sections 1, 2 and 4. The modal length of the marked fry measured 65 mm (2.6 in) compared to 35 mm (1.4 in) for the wild fry (unmarked) (Fig. 7).

We released 1.6 million marked kokanee fry into Granite Creek from 22 June to 31 July 1978. All of the releases were made in the upper section of Sullivan Springs Creek about 2.4 km (1.5 mi) from the lake. Subsequent snorkeling evaluation indicated that the fry moved during darkness and spent a maximum of one night in the creek before entering the lake. We estimated that 245,000 marked fry were in the lake in September 1978 yielding a survival rate of 15.3%. Of the original 2.0 million embryos collected for the 1.6 million fry, 12.3% survived to fall fry which was 10 times the estimated wild survival.

Stock Recruitment

We calculated a hypothetical stock recruitment relationship for Pend Oreille Lake kokanee using catch statistics. We assumed a constant exploitation rate of 20% from 1951 to 1972 when commercial fishing was terminated and 10% from 1973 to 1978. Sport anglers were often more successful during the commercial season because commercial anglers located schools of fish. Total parent stock was then assumed to equal 5 times the catch from 1951 to 1972 and 10 times the catch from 1973 to 1978. Using both a 4 year and 5 year life-cycle we plotted parent stock against mature progeny 4 and 5 years later. Two curves were fitted by inspection to simulate stock recruitment relationships for the pre (before 1965) and post (after 1965) kokanee decline eras (Fig. 12). Based on the hypothetical curves it would appear that in recent years the kokanee population is not replacing itself which supports the stock decline.

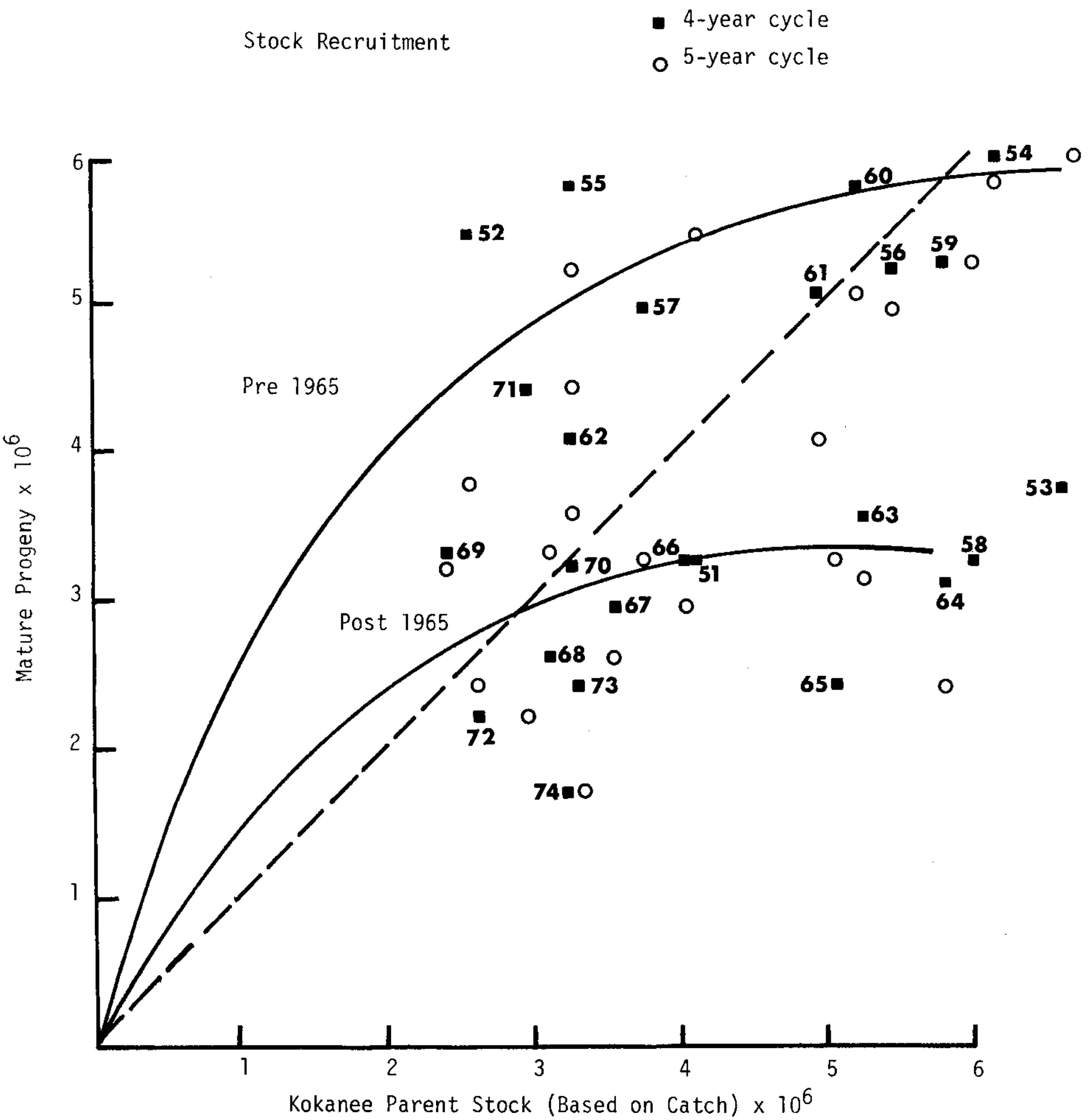

Figure 12. Hypothetical stock-recruitment curves for Pend Oreille Lake based on catch data using a constant exploitation rate 1951-72, 20%; 1973-77, 10%.

DISCUSSION

Kokanee Abundance

The kokanee population in Pend Oreille Lake has declined significantly from 1974 to 1978. The population trend measured acoustically has decreased from 12.1 million in 1974 to 5.2 million in 1978. The trawl estimate declined from 7.0 million in 1977 to 5.8 million in 1978 with both estimates lying within the 95% confidence interval of the acoustic estimates.

Kokanee abundance stabilized in 1976 and 1977 before declining in 1978. Trends in escapement for both years indicated a lower potential embryo desposition in 1976 than 1977 (Bowler 1978). Limited trawling completed in the fall of 1976 yielded a low abundance of the 1972 year-class corroborating the low escapement trend in 1976 (Bowler 1977). Fry estimates collected by trawling the following fall yielded a 2 million young-of-the-year estimate for 1977 (1976 year-class) and 1.6 million in 1978 (1977 year-class). This suggests differential survival for both years. Food availability in the lake was better in 1977 than in 1975, 1976 and 1978 indicating that the abundance decline from 1974 to 1978 may directly relate to young-of-the-year survival (Rieman 1979).

Growth and Survival

Although it was difficult to accurately measure first year growth of kokanee each year because of back calculating bias there is evidence that growth has been reduced after Mysis became established in the lake. Rounselfell (1958) found that growth was directly related to survival of sockeye smolts in Karluk Lake, Alaska.

We estimated a wild survival rate of 1.2% for Pend Oreille Lake kokanee from potential embryo deposition to fall fry one year later. LeBrasseur et al. (1978) estimated survival rates of juvenile sockeye ranging from 2.8% to almost 13% for the same period in Great Central Lake, BC. He correlated survival with spring levels of zooplankton biomass. Lewis (1974) reported a decline in kokanee survival from 7.4% to 1.9% in Odell Lake, Oregon. He measured survival from emergence to fall fry and related the decline to zooplankton density.

Hatchery survival was estimated at 15.3% from July released fry to September abundance in the lake. The survival estimate was 12.3% considering the number of embryos collected to produce the July releases. This represents a 10 fold increase over wild survival suggesting a significant increase. Zooplankton abundance had improved considerably in the lake by July from levels observed in May and early June (Rieman 1979). Overall it suggests that first year survival can be improved by mid-summer releasing kokanee fry into Pend Oreille Lake when zooplankton abundance is more favorable than May and June when wild fry emerge.

Kokanee Distribution and Movement

Catch, gill net and trawl data support a pattern of distribution and movement of kokanee in Pend Oreille Lake. Young-of-the-year kokanee appear to be mostly recruited on the south end of the lake resulting from shoreline spawning. They move northward their first summer and rear through their second summer as age 1+ fish on the north end of the lake. As age 2+ and older the kokanee disperse throughout the lake and begin recruiting to the fishery (Bowler 1978).

Presently enhancement efforts are directed toward bolstering the spawning run in Granite Creek to build an egg source. Subsequent fry are returned to Granite Creek thereby entering the lake well north of where most of the recruitment is occurring. Releasing mass numbers of hatchery fry mid-lake may help minimize impacts to wild fry emerging in the south end of the lake.

Kokanee Yield Predictability, Fishing Mortality and Stock Recruitment

Estimates of year-class strength made during 1978 for the 1975, 1976 and 1977 kokanee year-classes indicate that kokanee catch rates will likely not improve through the 1981 fishing year in Pend Oreille Lake. The annual yield for 1978 was 168,000 kokanee with a catch rate of 1.4 fish per hour, which is very low for Pend Oreille standards. Sport fishery catch rates of 2.5 to 3.0 kokanee per hour were enjoyed during the mid 1960s. The estimated exploitation rate for 1978 was 10%. The exploitation rate is probably relatively constant in a lake the size of Pend Oreille, perhaps 10 to 20% depending on stock size, suggesting that stock abundance will need to increase proportionally for catch rates to improve. If exploitation rates were doubled from 10% to 20% under present stock conditions annual survival would only decrease from 58% to 50%. This suggests that changes in exploitation and fishing mortality (even if it could be done presently in Pend Oreille) would likely not effect annual survival significantly but as the stock size gets critically low each fish becomes more important.

Stock abundance of the 1975 through 1977 kokanee year-classes would indicate that catch rates will not show improvement in the next few years and natural recruitment will not improve stock abundance. The theoretical stock recruitment curve (Fig. 12) describes a declining population that is not replacing itself. Overall, it suggests that natural recovery of the Pend Oreille kokanee stock is marginal and that a program of artificial enhancement will be necessary to improve stock abundance, yield and success rates. Also techniques such as lake fertilization of key recruitment areas to enhance fry survival should be examined.

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