DWORSHAK DAM IMPACTS ASSESSMENT AND FISHERIES INVESTIGATION

KOKANEE DEPTH DISTRIBUTION IN DWORSHAK RESERVOIR AND IMPLICATIONS TOWARD MINIMIZING ENTRAINMENT

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ABSTRACT

We measured the day and night depth distribution of kokanee *Oncorhynchus nerka kennerlyi* directly upstream of Dworshak Dam from October 1993 to December 1994 using split-beam hydroacoustics. At night most kokanee (70%) were distributed in a diffuse layer about 10 m thick. The depth of the layer varied with the season and ranged from 30 to 40 m deep during winter and from 15 to 25 m deep during summer. Nighttime depth of the kokanee layer during summer roughly corresponded to a zone where water temperatures ranged from 7°C to 12°C.

Daytime kokanee distribution was much different with kokanee located in dense schools. Most kokanee (70%) were found in a 5-I5 m thick layer during summer. Daytime depth distribution was also shallowest during fall and deepest during winter.

Dworshak Dam has structures which can be used for selective water withdrawal and can function in depth ranges that will avoid the kokanee layer. Temperature constraints limit the use of selective withdrawal during the spring, summer, and fall, but in the winter, water is nearly isothermal and the full range of selector gate depths may be utilized.

From October 1993 to February 1994, selector gates were positioned to withdraw water from above the kokanee layer. The discharge pattern also changed with more water being released during May and July, and less water being released during fall and winter. A combination of these two changes is thought to have increased kokanee densities to a record high of 69 adults/ha.

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INTRODUCTION

Fisheries for kokanee *Oncorhynchus nerka kennerlyi* in the Pacific Northwest are very popular (Wydoski and Bennett 1981; Rieman and Myers 1992). Kokanee feed low on the food chain and may reach densities in excess of 150 harvestable-sized fish/ha even in relatively sterile waters (Maiolie et al. 1991). They also appear to be an ideal fish in fluctuating reservoirs since they rear in the open pelagic zone and some strains spawn in tributary streams away from the potential impacts of water level fluctuations.

Kokanee, however, have one potentially serious drawback. In many reservoirs and lakes, kokanee tend to emigrate or become entrained in large numbers. Entrainment losses have been documented at Libby Reservoir in Montana, and Dworshak Reservoir in Idaho (Don Skarr, personal communication, Montana Department of Fish, Wildlife and Parks; Maiolie et al. 1993). At Dworshak Reservoir, entrainment losses have been high enough that the river below the dam has been opened to a salvage fishery which allows the netting of dead and dying fish. Entrainment losses of kokanee, predominately age 1, appeared to be driving the fishery in Dworshak Reservoir. Years with high discharge have been correlated with lower kokanee populations in the reservoir (Maiolie and Elam 1993).

In this study we used mobile split-beam hydroacoustics to determine the depth distribution of kokanee in the area upstream of Dworshak Dam, Idaho. Our hope was to use the selector gates and reservoir outlets on Dworshak Dam to withdraw water from depth strata that would avoid concentrations of kokanee thereby reducing losses. We also measured temperatures throughout the water column to determine if selective water withdrawal would conflict with downstream temperature considerations.

STUDY AREA

Dworshak Dam is located on the North Fork of the Clearwater River 3.2 km upstream from its confluence with the mainstem (Figure 1). The dam is about 5.2 km northeast of Orofino in Clearwater County, Idaho. At 219 m tall, it is the largest straight-axis concrete dam in the United States. Three turbines within the dam have a total operating capacity of 450 megawatts. Water can be discharged from the reservoir through the turbines spill gates, or reservoir outlets on the spillway.

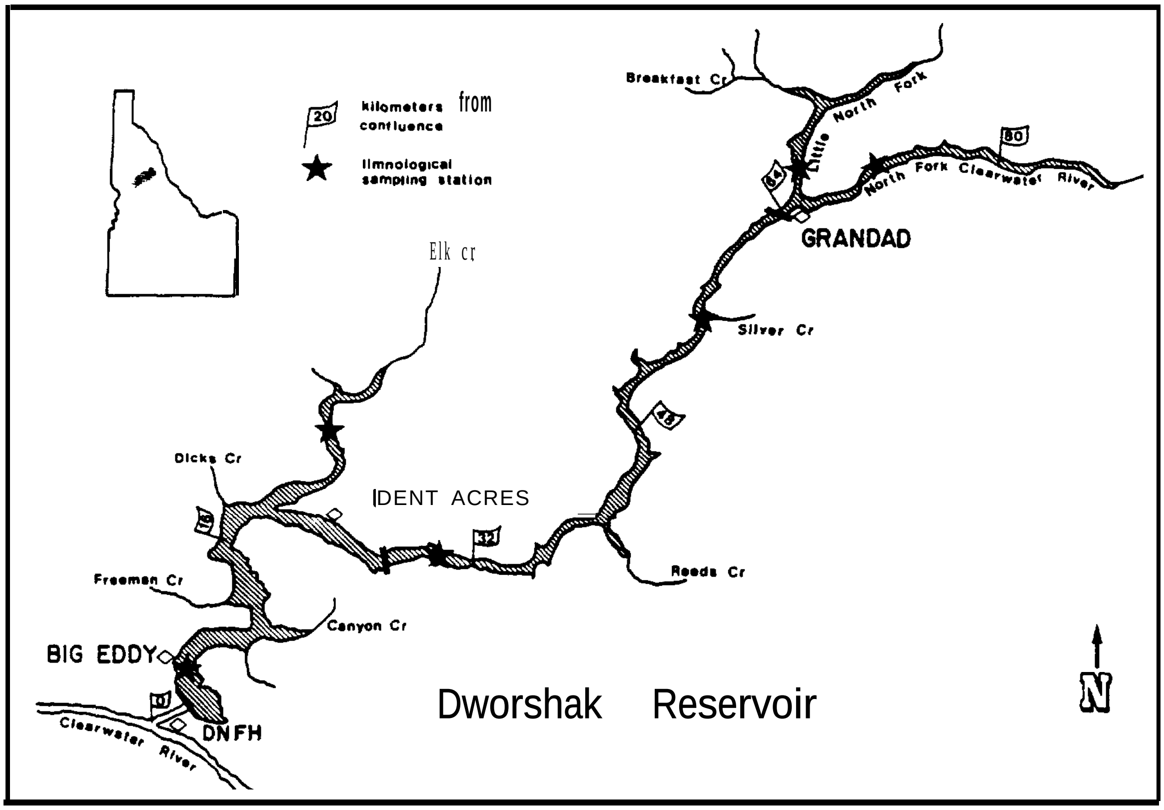

Figure 1. **Dworshak Reservoir and major tributaries, North Fork Clearwater River, Idaho.**

Dworshak Reservoir is 86.2 km long and has 295 km of mostly steep shoreline. Maximum depth is 194 m with a corresponding volume of 4.28 billion m^3 at full pool. Surface area when full is 6,644 ha and mean depth is 56 m. It contains about 5,400 ha of kokanee habitat (defined as the area over 15.2 m deep) depending on pool elevation. Mean annual outflow is 162 m^3/s. The reservoir has a mean retention time of 10.2 months. Retention time is variable depending on precipitation and has ranged from 22 months in 1973 to 6 months during 1974 (Falter 1982). Drawdowns of 47 m reduce surface area as much as 52% (3,663 ha). Dworshak Reservoir initially reached full pool on July 3, 1973.

The magnitude and timing of Dworshak Reservoir drawdown changes annually depending on the need for flood control or power production. During the summer of 1994, the pool elevation dropped markedly between May and August as water was released to augment summertime flows in the lower Clearwater and Snake rivers (Figures 2 and 3). The reservoir was then held stable throughout the fall and winter.

GOAL

To maximize the sport fishery potential of Dworshak Reservoir.

OBJECTIVE

To reduce the entrainment losses of kokanee so that densities of 30 to 50 adult kokanee/ha can be maintained on an annual basis.

METHODS

Hydroacoustic Equipment

We used a Simrad EY500 split-beam scientific echosounder with a 120 kHz transducer to document the depth distribution of kokanee upstream of Dworshak Dam. Echograms collected in the field were later analyzed using Simrad EP500 software, versions 4.0 and 4.5. Boat speed was 1.5 to 2.3 m/s. The echosounder was set to ping at 0.7 s intervals, with a pulse width of 0.3 milliseconds. Appendix A contains a complete list of echosounder settings.

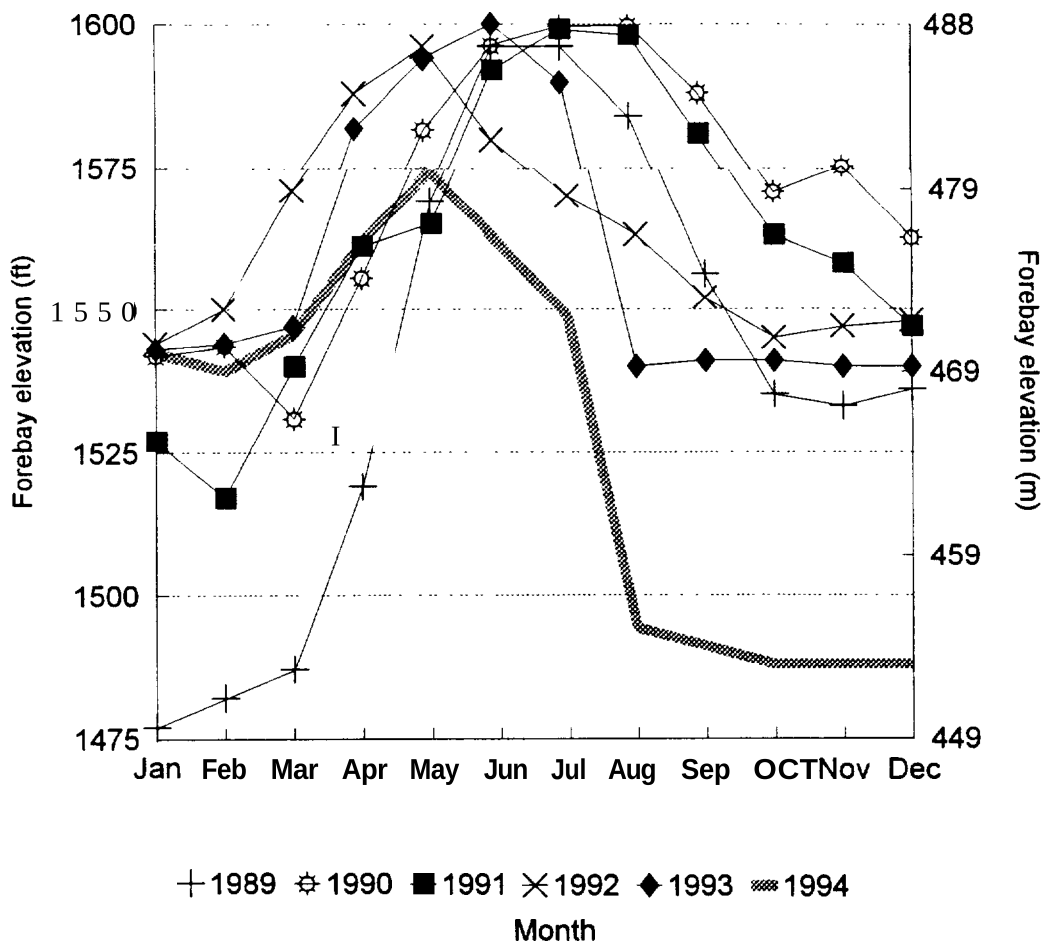

Figure 2. Elevation of Dworshak Reservoir, Idaho, 1988 to 1994.

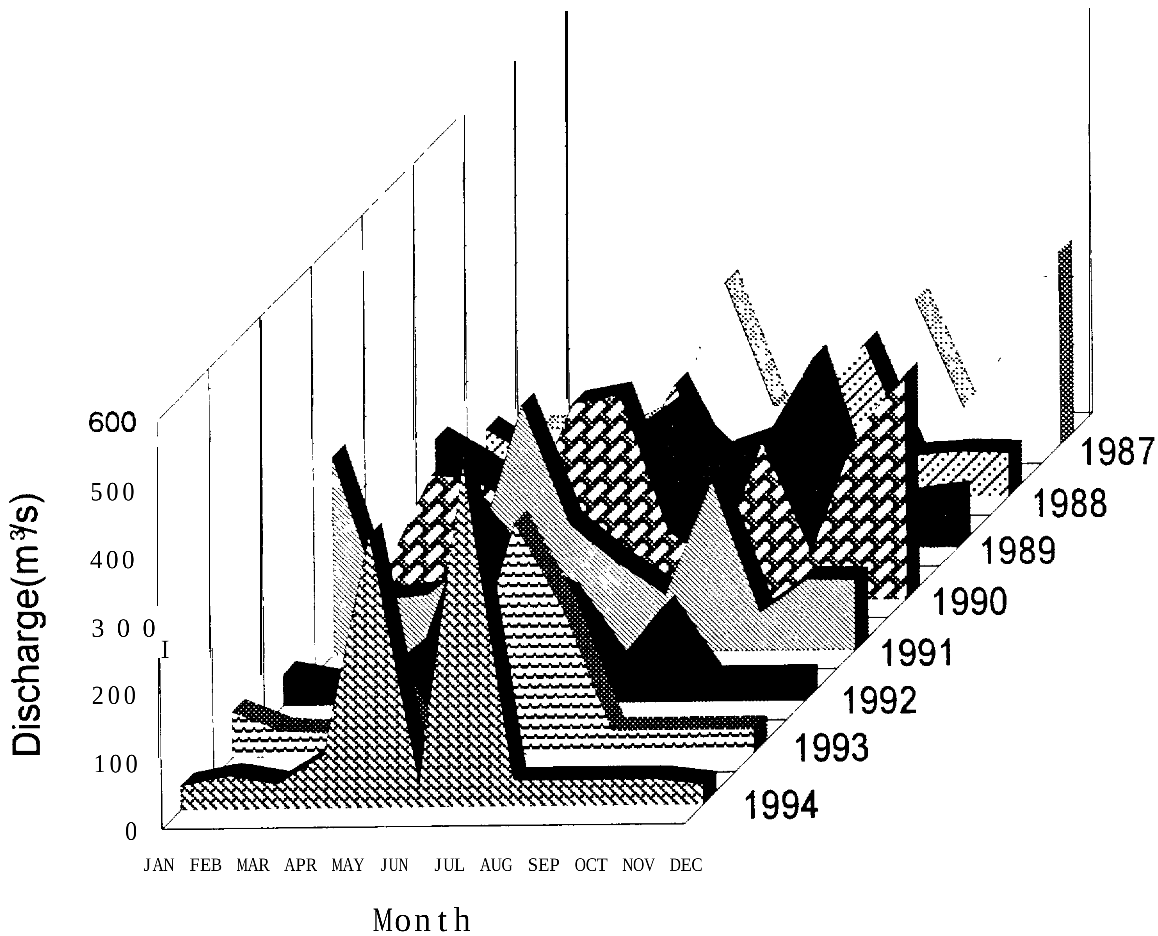

Figure 3. Discharge from Dworshak Dam, Idaho, 1985 to 1994.

We calibrated the echosounder at the beginning of the year using a 23 mm copper calibration sphere with a target strength of about -40.4 db (decibels), depending on temperature. This allowed the echosounder to compensate the returned signal based on the degrees off-axis for a given target. We also checked the calibration of the echosounder prior to each monthly survey, and adjusted the transducer gains if needed.

Forebay Surveys

A series of seven transects, perpendicular to the axis of the dam, were surveyed during the middle of each month from October 1993 through December 1994 (Figure 4). Surveys were conducted during the day and at night. These transects covered the entire width of the reservoir, beginning and ending at the 10 m depth contour and were uniformly spaced. We piloted the boat by visual landmarks, compass headings, Global Positioning Systems (GPS) locations, and/or radar. One transect was directly in line with the center of the dam structure. This transect was used to characterize the kokanee depth distribution (all transects had very similar distribution patterns).

From December 1993 to June 1994, we extended our surveys inside the log boom to include the area immediately in front of the turbine intakes. We found the noise generated by the turbines prohibited accurate hydroacoustic identification of kokanee so these surveys were discontinued.

We measured temperature profiles of the reservoir near the dam in conjunction with the hydroacoustic surveys. We used a Yellow Springs instrument Company temperature/oxygen probe to measure temperatures to a depth of 60 m by 1 m intervals.

Echograms were divided into 5 m depth intervals from the surface to a depth of 80 m. EP-500 software, versions 4.0 and 4.5, were used to determine the percent of the population in each 5 m band. All targets between -57 db and -33 db were used in determining depth distributions.

Reservoir-Wide Surveys

We conducted reservoir-wide surveys to document the movement of young-of-the-year kokanee down the reservoir from the headwaters to the vicinity of the dam. Transects were surveyed at 3.2 km (2 mile) intervals throughout the length of the reservoir during the night, monthly, between May and August. A different

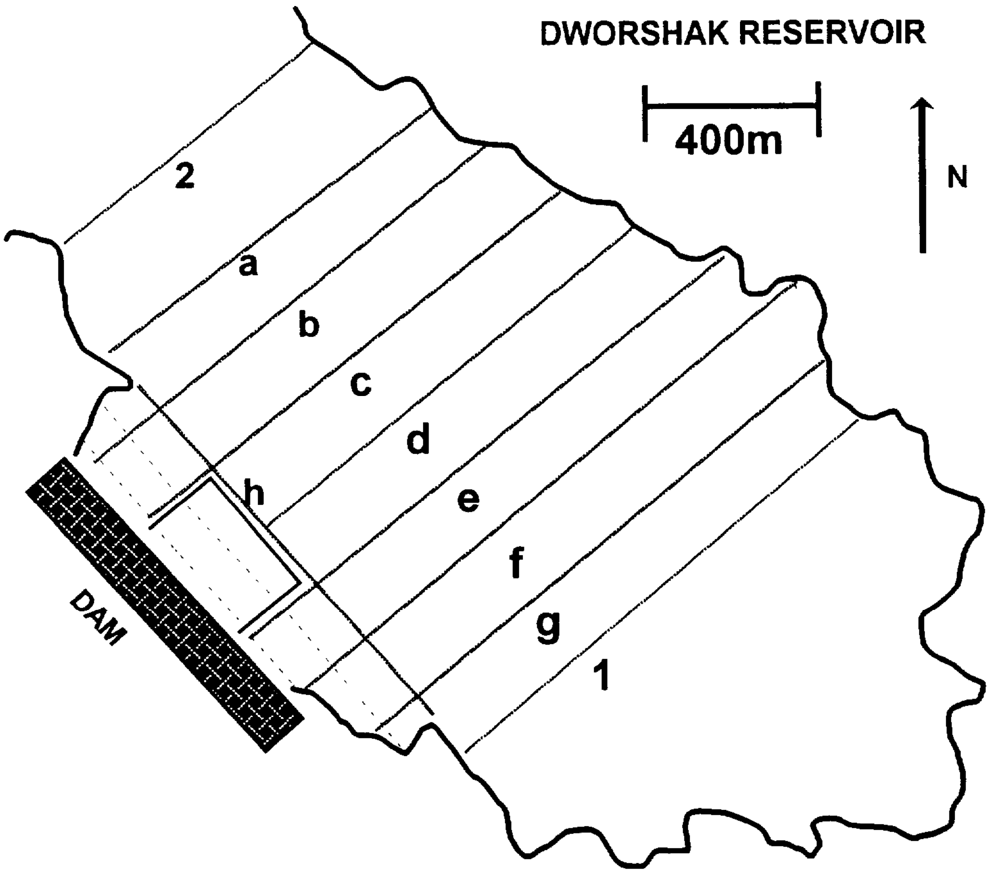

Figure 4. **Hydroacoustic transects used for intensive forebay area surveys of kokanee distribution.**

survey design was conducted in July when hydroacoustic surveys were paired with mid-water trawling. Sixteen paired trawling and hydroacoustic surveys were run parallel with the long axis of the reservoir from the dam to the headwaters.

Age 0 kokanee were defined as fish with a target strength of -60 decibels (db) to -51 db. Survey data were collected with a 40 log r (range) gain setting. We later determined these data could not be used to calculate fish density estimates. Therefore we expressed the relative abundance of age 0 kokanee on each transect by calculating the number of traces (returned signals from fish) received during a standard 5 min survey (429 pings).

RESULTS

Kokanee Depth Distribution

At night, most kokanee were in a narrow layer approximately 10 to 20 m thick (Figure 5, Appendix B). We characterized this layer by plotting the depth where 70% of the fish signals occurred. Depth of this layer varied from 15 to 45 m deep throughout the year with kokanee being the deepest during January and February 1994. The depth distribution of 100% of the fish was much thicker; up to 70 m from the shallowest to deepest fish. Fish covered a much narrower depth range in the summer and spread more widely during the winter (Figure 5).

During the day fish were very tightly schooled with some transects showing no fish. Daytime fish distribution showed two distinct patterns. During July, August, September, and October, fish were located in the top 25 m of water (Appendix B; Figure 6). Daytime distribution in January, February, April, November, and December showed fish split into two groups; one shallow group above 40 m and a deeper group below 45 m (Figure 6; Appendix B).

Temperatures

We classified the forebay of Dworshak Reservoir as warm monomictic based on its temperature stratification (Wetzel 1975). The water column was nearly isothermal between January and March 1994, with temperatures between 4°C and 5°C (Figure 7). Between May and October, the reservoir was thermally stratified. Temperatures in the metalimnion ranged from 10°C to 18°C. Surface temperatures peaked at 24°C during August. Thus, during summer, kokanee could select for water temperatures anywhere from 4°C to 24°C.

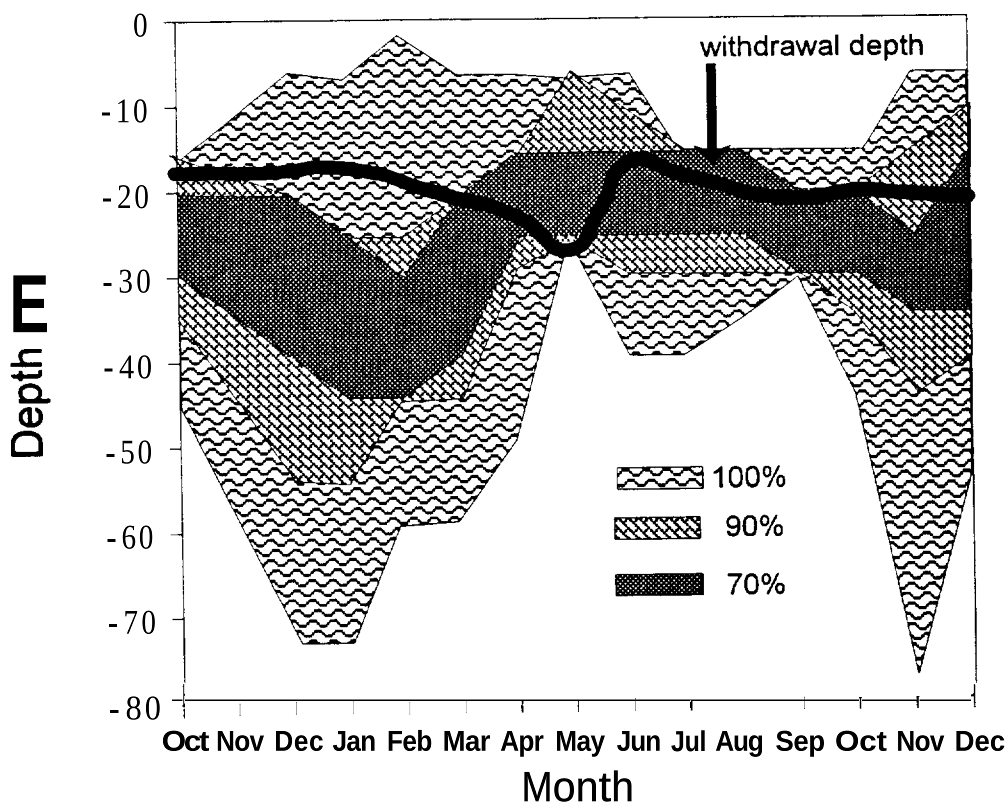

Figure 5. Nighttime vertical distribution of fish directly in front of Dworshak Dam, October 1993 to December 1994. One hundred percent band shows depth distribution of all fish, 70% and 90% band show distribution of that proportion of the population.

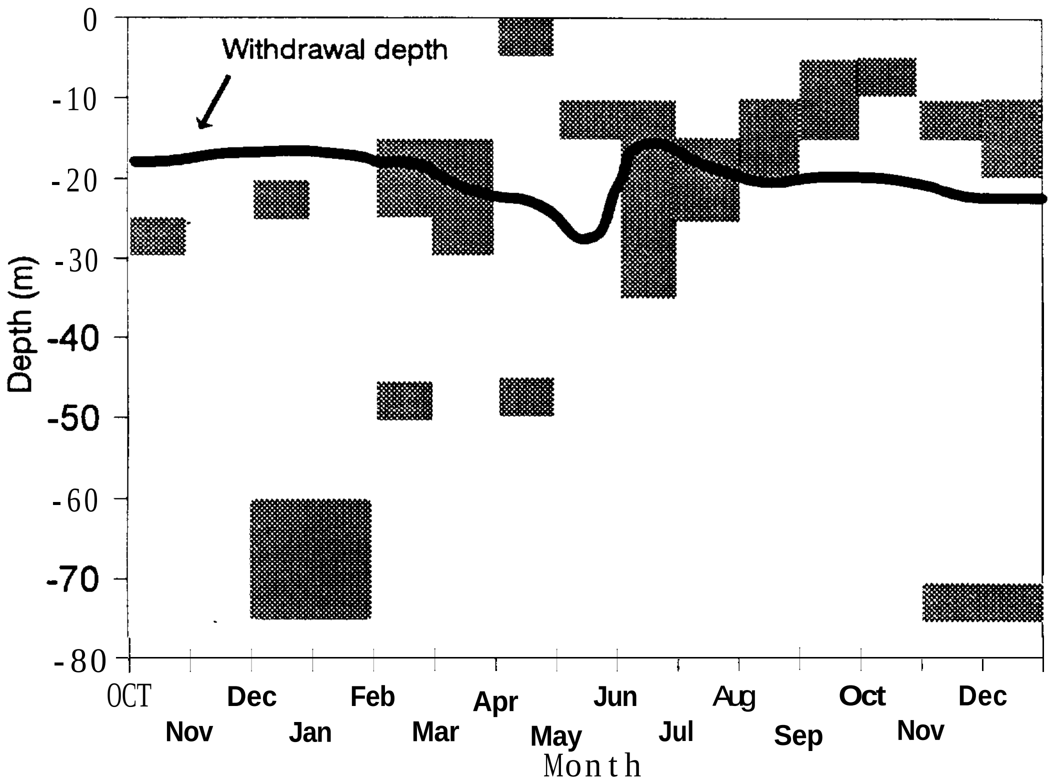

Figure 6. Daytime vertical distribution of fish directly in front of Dworshak Dam, October 1993 to December 1994. Band shows depth distribution of 70% of the population.

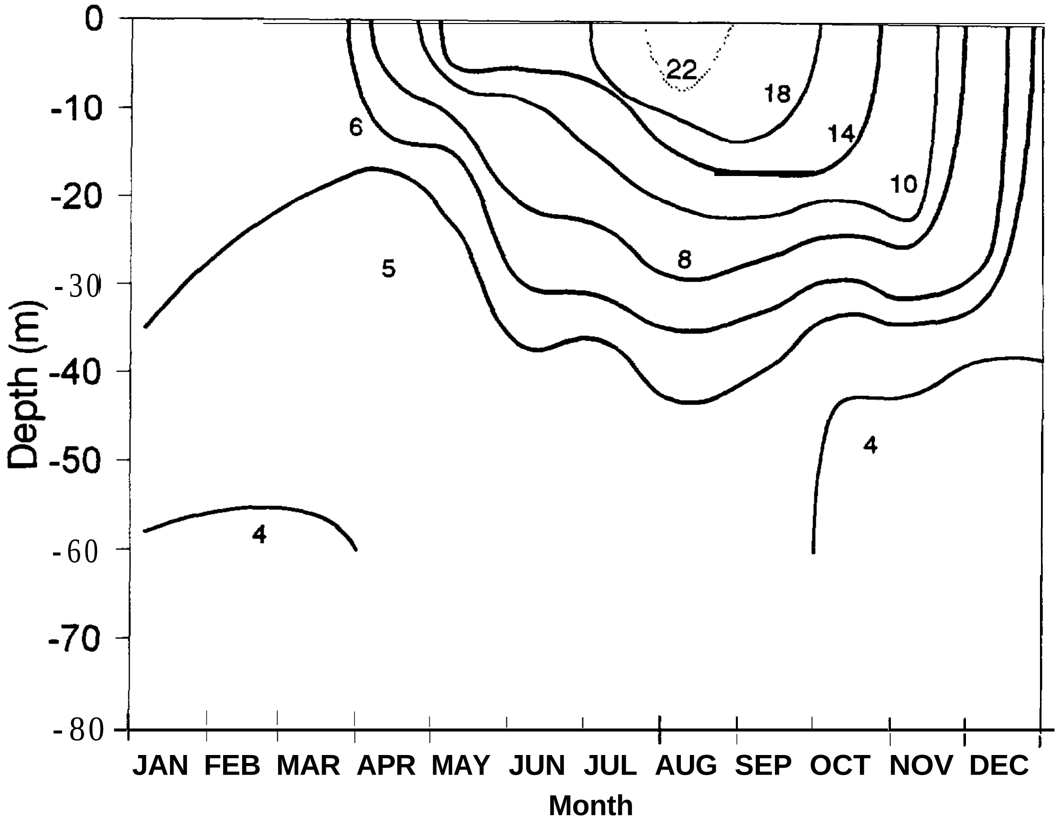

Figure 7. **Isopleths of temperature for the lower end of Dworshak Reservoir, October 1993 to December 1994.**

Age 0 Kokanee Distribution

We plotted the distribution of age 0 kokanee (all signals with a target strength between -60 db and -51 db) for each of the reservoir-wide surveys (Figure 8). At least some small targets were detected throughout the reservoir in each of the surveys. During June we noted a large increase in small targets above river kilometer (rkm) 55 (Figure 8). By July small targets had moved down the reservoir to about rkm 40, and by August they had moved down to about rkm 15.

We also documented the distribution of age 0 kokanee by mid-water trawling (Fredericks et al. 1995). Trawling substantiated echosounder findings in that age 0 kokanee were primarily found in the upper half of the reservoir above rkm 45 during July. No age 0 kokanee were netted between the dam and rkm 35.

Water Withdrawal Options

Five routes exist for discharging water from the dam. Each route operates over a finite range of depths (Figure 9). The top of the selector gate, on each of three penstock intakes, could be set between 475 and 447 m (1,560 and 1,465 ft) elevation above mean sea level (msl). At this range of settings, water would flow over the top of the gate. The top of the gate must be at least 12 m below the reservoir's surface during operation. Alternately, the gates could be raised and water would flow into penstocks 1 and 2 at an elevation of about 433 m (1,420 ft), and penstock 3 at an elevation of 430 m (I ,412 ft). A flow of 283 m^3/s (10,000 ft^3/s) can be withdrawn through the turbines.

Water could be withdrawn from the spill gates between elevations of 488 m (1,600 ft) and 471 m (1,545 ft). Lastly, reservoir outlets on the spillway could be opened to discharge up to 425 m^3/s (I 5,000 ft^3/s) at an elevation of 415 m (1,361 ft).

The surface of the reservoir may fluctuate as much as 47 m during the course of a year. Reservoir elevations below 471 m renders the spillway gates inoperable. Reservoir elevations below 457 m (1,500 ft) renders the selector gates inoperable. Also, water will always be withdrawn through the turbine intakes as a first priority. If flows exceed 283 m^3/sec (10,000 ft^3/s) then an additional route will be required.

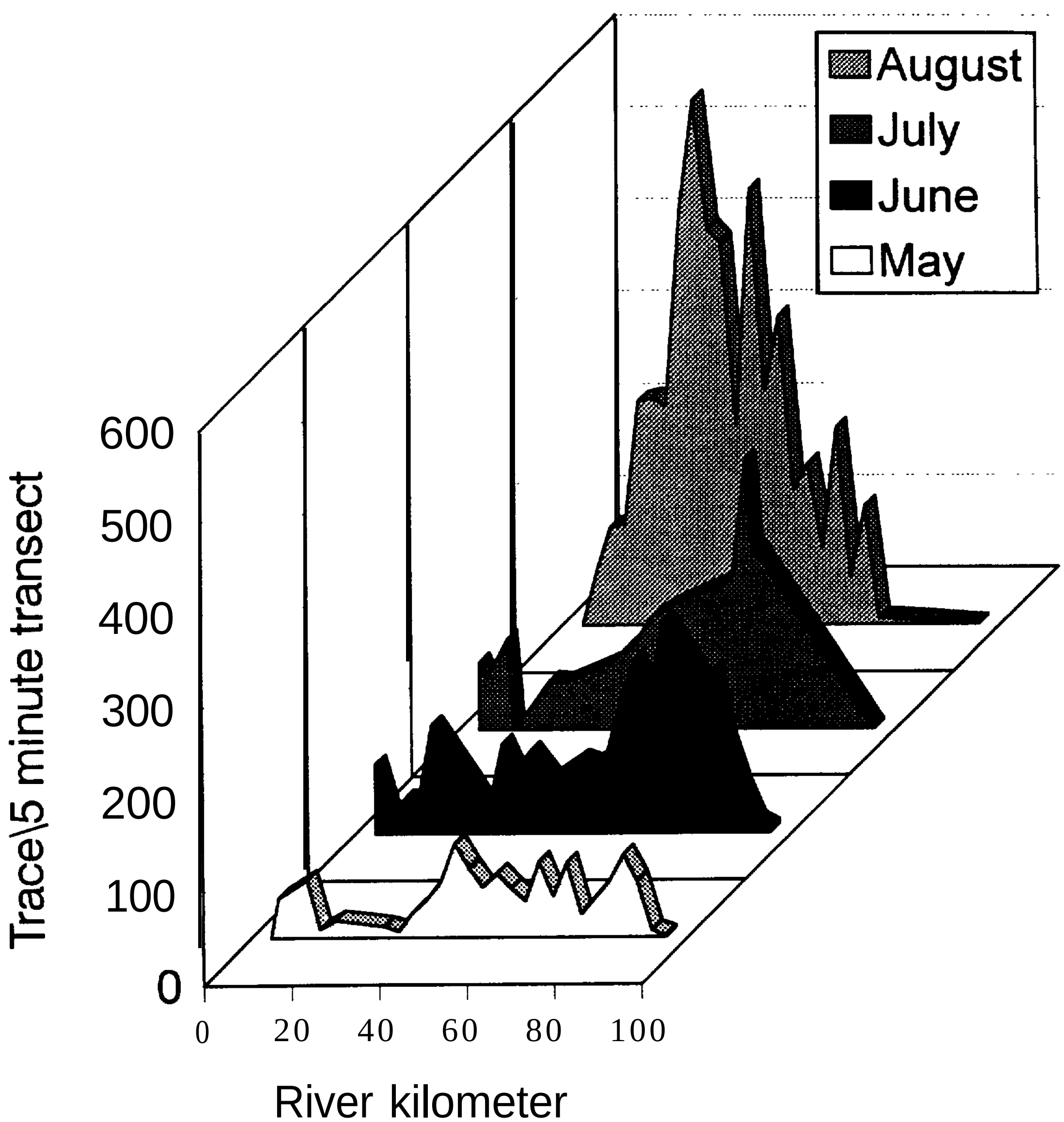

Figure 8. **Number of traces (returned echos) from small fish (-60 to -51 db) throughout the length of Dworshak Reservoir. River kilometer 2 is Dworshak Dam.**

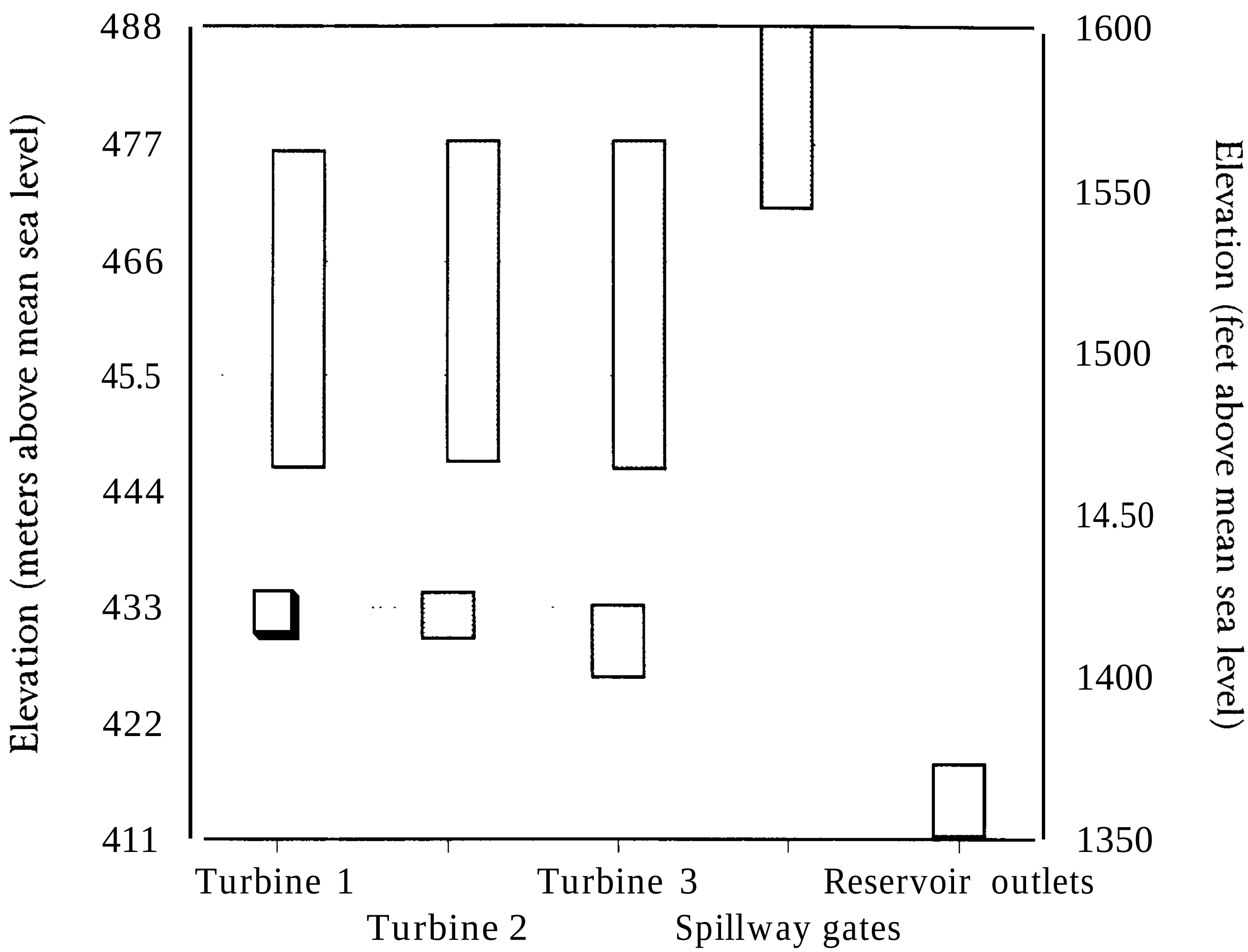

Figure 9. **Possible elevation where water could be withdrawn from Dworshak Reservoir, Idaho.**

DISCUSSION

Selective Withdrawal

Kokanee showed a rather consistent pattern from month to month in their vertical distribution during 1994 (Figures 5 and 6). The depths of kokanee were such that water could be withdrawn from above or below most of the fish during most of the year depending on reservoir elevation (Figure 9).

During summer, Dworshak Reservoir was found to be thermally stratified. Water was released from the metalimnion to keep the North Fork of the Clearwater River cool, which was needed for optimum fish production in the Dworshak National Fish Hatchery (DNFH). Currently, all the water used in the outside raceways at DNFH comes directly from the river. Therefore there was no opportunity to use selective withdrawal to avoid kokanee entrainment during summer.

Water in the reservoir was nearly isothermal during winter. Thus, selective withdrawal was used to avoid fish entrainment with little impact to water temperatures at DNFH. Water was withdrawn from above the 70% kokanee layer during the winter of 1993-94 (Figures 5 and 6). Also, the reservoir outlets were used during May 1994 to withdraw deep water rather than using the shallower spill gates. Adult kokanee abundance in 1994 reached a record high of 308,000 fish, and age 1 abundance also reached a record high of 984,000 fish (Fredericks et al. 1995). Our objective was to reach an adult density of 30-50 kokanee/ha. In 1994, we exceeded this amount with 69 adult kokanee/ha. Exceeding this objective caused adult kokanee to decline to a modal length of 230 mm in July.

We encountered one potential problem in using selective withdrawal when the reservoir elevation was low. The selector gates could not be used if the reservoir dropped below 457 m msl (1,500 feet). The selector gates had to remain at least 12 m below the reservoir's surface or the pressure of the reservoir's water could damage the gates. During December 1994, the reservoir elevation was 454 m (1,488 ft msl) and the selector gates could not be used to avoid the kokanee layer.

Age 0 Kokanee Distribution

Most of Dworshak Reservoir's kokanee spawn in the North Fork of the Clearwater River and its tributaries above the reservoir. Kokanee fry would be expected to emerge during May and June. Fry would then travel downstream to the reservoir and then down the reservoir to the dam. Our reservoir-wide surveys indicted that high numbers of age 0 kokanee did not reach the dam until after August 18, 1994. Also, the bulk of this cohort were still above rkm 18 during August.

This would imply that entrainment of age 0 kokanee would be minor until after August. The shifting of the release of some of the reservoir's water from late fall (August to November) to mid-summer (May and July), as they did in 1994, could have caused a substantial increase in survival of fry. This is likely to be one of the main reasons for the increase in kokanee abundance.

Our trawling revealed that very few age 0 kokanee were in the lower third of the reservoir in July. We did, however, find some small targets there during hydroacoustic surveys. Possibly these small targets were age 1 kokanee not age 0. But, we were unable to avoid this apparent problem even by reducing the signal strength used to define age 0 kokanee (signals were lowered to -60 to -54 db). Averaging the returned signals from each fish (trace tracking) also did not eliminate these small targets. Another possibility was that the hydroacoustic surveys could have been showing small debris or insects that were small enough to pass through the trawl net.

CONCLUSIONS

Based on results from 1993 and 1994, we are optimistic that the project objective can be met. Water can be withdrawn from the dam at depths which will avoid most of the kokanee. Current temperature considerations limit the use of selective withdrawal to winter and spring when water in the reservoir is nearly isothermal, Using selective water withdrawal from October to February, along with the change from fall drawdowns to mid-summer drawdowns, appeared to be capable of minimizing kokanee entrainment sufficient to meet or exceed our objective.

RECOMMENDATIONS

1. We recommend the Corps of Engineers continue to use the selector gates and reservoir outlets on Dworshak Dam to minimize kokanee entrainment losses. This may greatly enhance future fisheries. Continued use of the gates during different water years and discharge patterns will greatly aid our understanding of entrainment losses.

2. **Trawling should be conducted annually to determine changes in kokanee abundance that are attributable to dam operation.**

3. **Studies should be undertaken to determine if selective water withdrawal impacts reservoir productivity and fish growth.**

4. **Data on the use of selective withdrawal should be incorporated into a series of "rule curves." These should then be meshed with the other operating criteria of the dam to begin the development of integrated rule curves for Dworshak Reservoir.**

5. **The entrainment rate of kokanee should be measured at various selector gate positions to determine their effectiveness at avoiding losses. This would require installing fixed location hydroacoustics on at least one turbine intake.**

6. **A study should be undertaken to develop temperature.criteria for the dam's discharge water. The study should define the optimum temperature ranges, throughout the year, to meet the needs of the hatchery, resident fish and anadromous fish. Having a defined temperature range would simplify options of selector gates settings.**

ACKNOWLEDGMENTS

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Appendix A.
List of echosounder settings used during hydroacoustic surveys of Dworshak Reservoir.

Settings for hydroacoustic transceiver.

Operation Menu

Ping Mode	Normal
Ping Auto Start	Off
Ping Interval	0.7s

Disk Menu

Log	Off
Max File Size	1-2Mb

Telegram Menu

Status	Off
Parameter	On
Annotation	On
Navigation	On
Depth	On
Echogram	On
Echo-trace	On
sv	Off
Sample Angle	Off
Sample Power	Off
Sample Sv	Off
Sample Ts	Off
Vessel-Log	On
Layer	On
Integrator	On
TS Distribution	On

Echogram Menu

Range	100 m
Range Start	0 m
Auto Range	Off
Bottom Range	0 m
Bot. Range Start	0 m
No. of Main Val.	250
No. of Bot. Val.	75
TVG	40 log R

Display Menu

Colour Set	Light, Dark
Event Marker	Off
Echogram Speed	1:1
Echogram	On
Echogram Menu	

Echogram Menu

Transd. Number	1
Range	100m
Range Start	0m
Auto Range	Off
Bottom Range	0m
Bot. Range Start	0 m
Bot. Range Pres.	Off

Sub. Bottom Gain	0.0 dB/m
Presentation	Normal
TVG	40 log R
Scale Lines	10
Bot. Det. Line	On
Layer Lines	On
Integration Line	Off
TS Colour Min.	-50, -65
Sv Colour Min.	-70, -60

Printer Menu

Navig. Interval	0
Event Marker	Off
Annotation	Off
Naut. Mile Marker	Off
TS Distribution	Off
Integr. Tables	Off
Echogram Speed	1:l
Echogram	Off
Echogram Menu	

Echogram Menu

Transd. Number	1
Range	100 m
Range Start	0 m
Auto Range	Off
Bottom Range	10 m
Bot. Range Start	5 m
Bot. Range Pres.	Off
Sub. Bottom Gain	0.0 dB/m
Presentation	Normal
TVG	40 log R
Scale Lines	10
Bot. Det. Line	On
Layer Lines	Off
Integration Line	Off
TS Colour Min.	-50, -65 dB
Sv Colour Min.	-60, -70 dB

Transceiver Menu 120 kHz

Mode	Active
Transducer Depth	.5, .53 m
Transd. Sequence	Off
Absorption Coef.	38,0 dBkm
Pulse Lenth	Medium
Bandwith	Wide
Max. Power	63 W
2-Way Beam Angle	-18.5 dB
Sv Transd. Gain	-23.0, -27.6 dB
TS Transd. Gain	-23.0, -27.6 dB
Angle Sensitiv.	17.0
3 dB Beamwidth	10.7 dg
Alongship Offset	0.04 dg
Athw.ship Offset	-0.05 dg

Bottom Detection Menu

Minimum Depth	0.0 m
Maximum Depth	0,300 m
Min. Depth Alarm	0.0 m
Max. Depth Alarm	0m
Bottom Lost Al.	Off
Minimum Level	-50 dB

Log Menu

Mode	Off
Ping Interval	100
Time Interval	60,240 sec
Dist. Interval	1.0,.5 nm
Simulator Speed	5.0 knt
Distance	0.0,2.5

Layer Menu

Super Layer	I0

Layer-X Menu

Type	Pelagic
Range	10m
Range Start	0,90 m
Margin	1m
Sv Threshold	-60,-80 dB

TS Detection Menu

Min. Value	-50,-65 dB
Min. Echo Length	0.8
Max. Echo Length	1.8
Max. Gain Comp.	4.0
Max. Phase Dev.	2.0,4.0

Serial Corn. Menu

Telegram Menu

Format	Binary
Modem Control	On
Remote Control	On
Status	Off
Parameter	On
Annotation	Off
Navigation	Off
Depth	Off
Echogram	Off
Echo-Trace	Off
sv	Off
Vessel Log	Off
Layer	Off
Integrator	Off
TS Distribution	Off

USART Menu

Baudrate	9600
Bits Per Char.	8

Stop Bits	1
Parity	None

Echogram Menu

Range	100 m
Range Start	0 m
Auto Range	Off
Bottom Range	15 m
Bot. Range Start	I0 m
No. Of Main Val.	250
No. Of Bot. Val.	75
TVG	40 log R

Annotation Menu

Event Counter	0
Time Interval	0 min
Text	

Navigation Menu

Start Sequence	SGPGLL
Separation Char.	002c
Stop Character	OOOD
First Field No.	2
No. of Fields	4
Baudrate	4800
Bits Per Char.	8
Stop Bits	1
Parity	None

Utility Menu

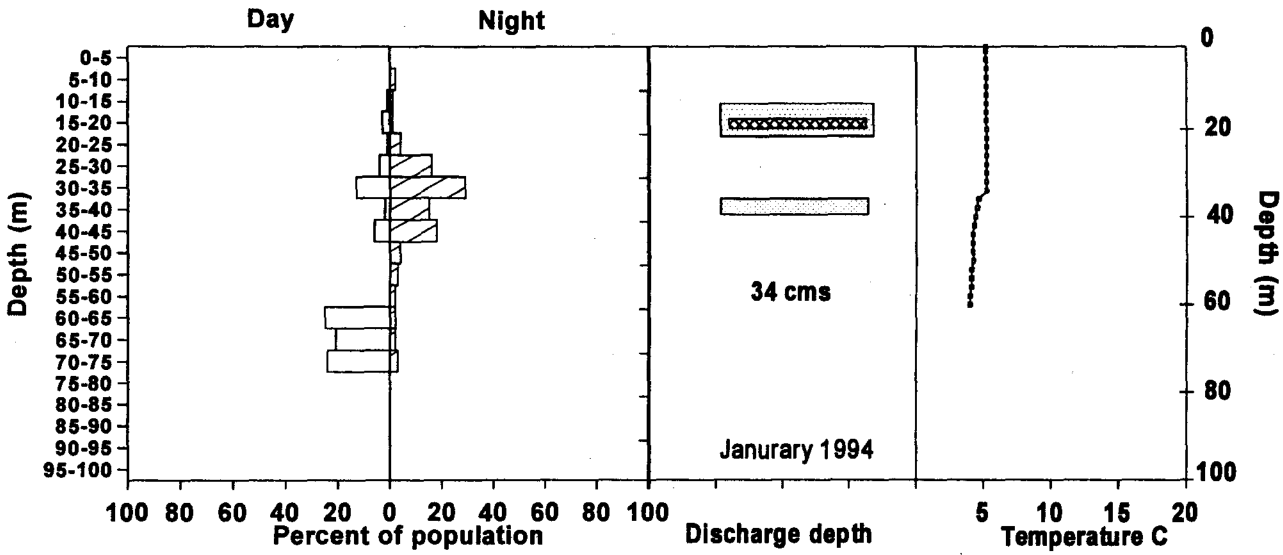
Beeper	On
Status Messages	On
Date	yy.mm .dd
Time	hh.mm.ss
Password	0
Default Setting	No
Sound Velocity	1420,1488 m/s
COMI /COM2 Switch	Off

Test Menu

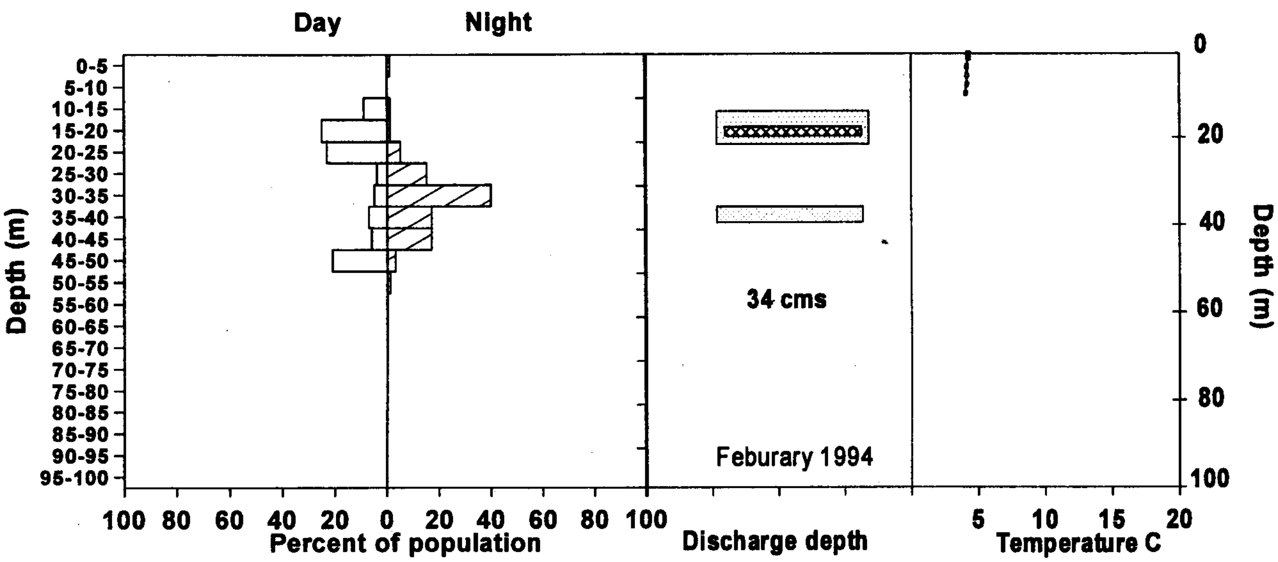
Message	
Transceiver	
Version	4.01
Scope	
Simrad	

Appendix B.

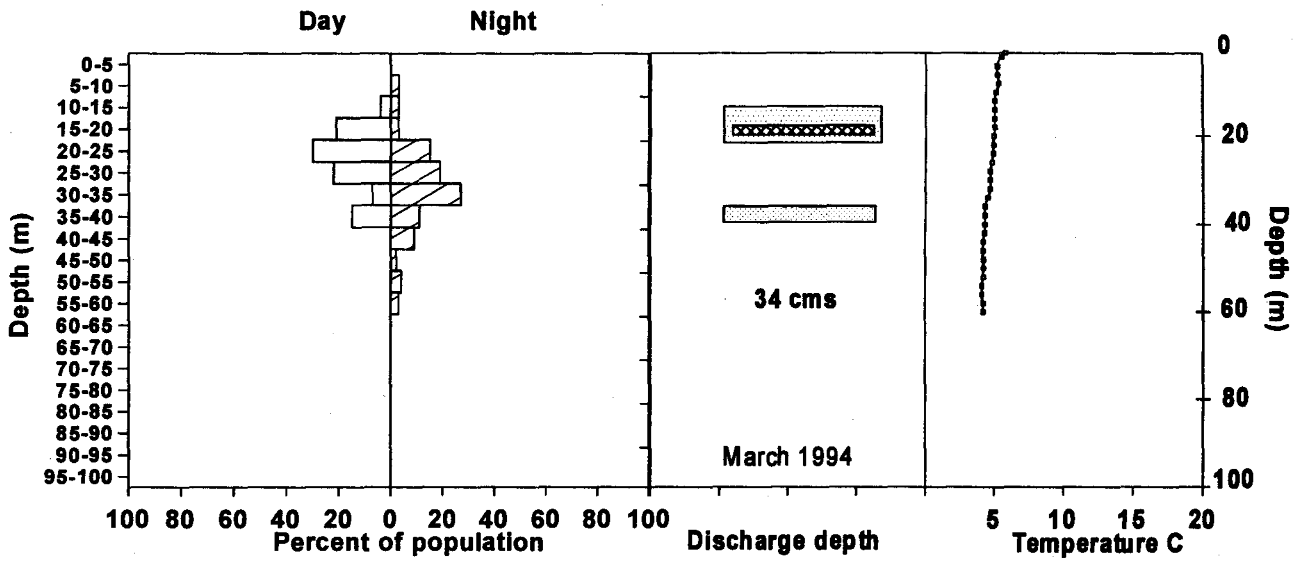
Monthly depth distributions of kokanee in front of Dworshak Dam during the day and at night, depth of water withdrawal (cross hatched area), possible depth of water withdrawal (shaded box), amount of discharge at the time of the survey, and temperature profile in the forebay.

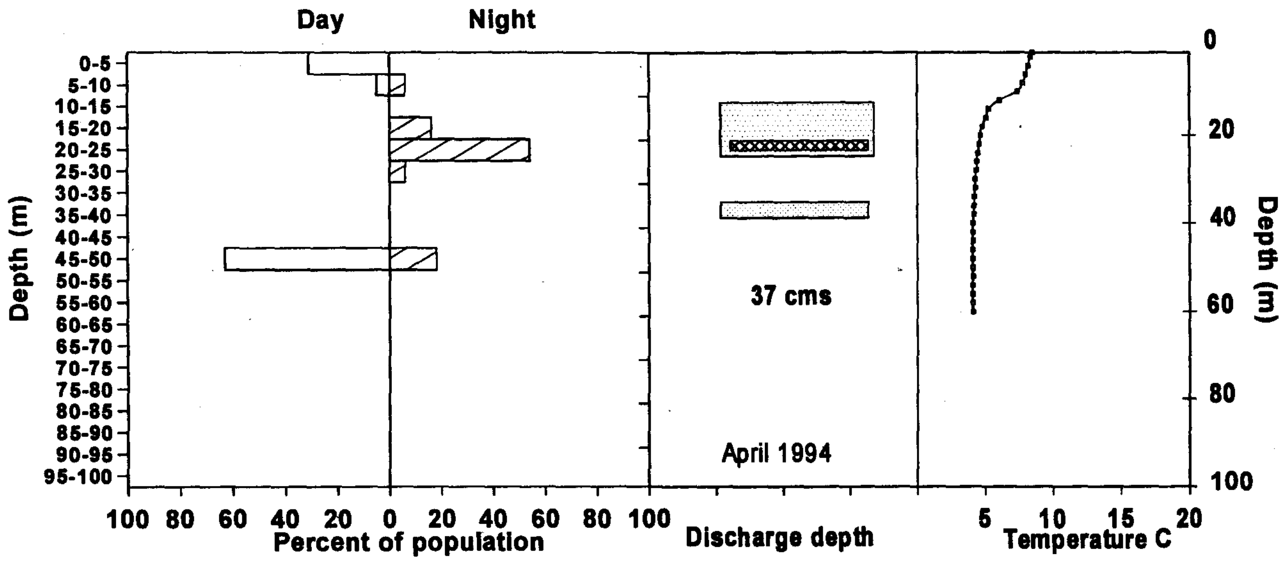


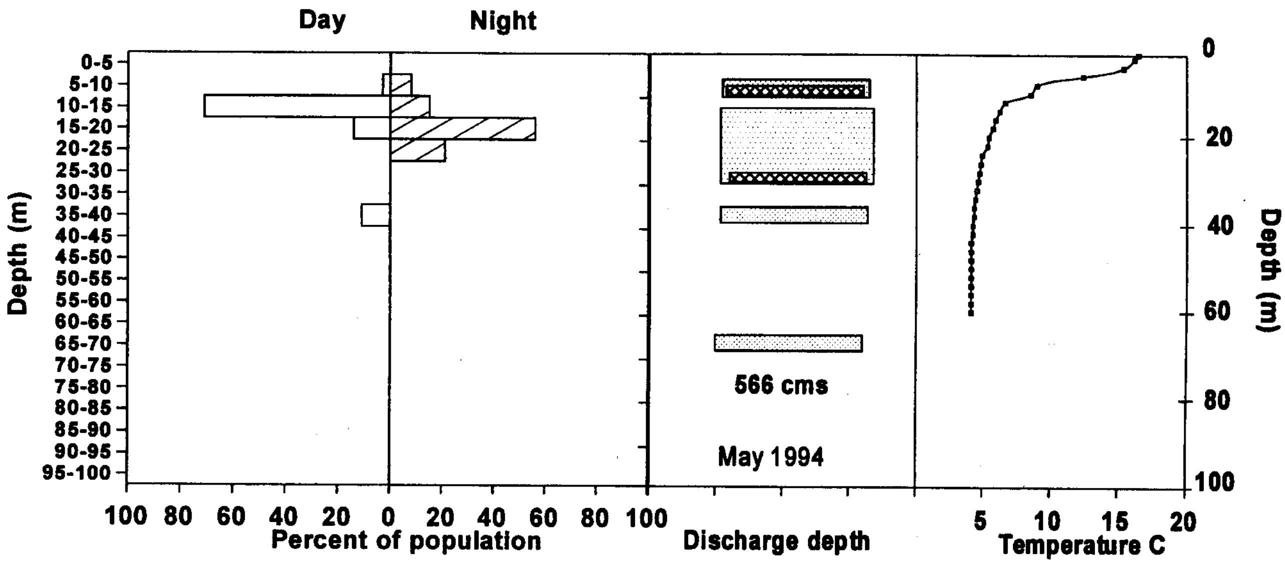
Day
Night
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
Depth (m)
100 80 60 40 20 0 20 40 60 80 100
Percent of population
34 cms
Janurary 1994
Discharge depth
5 10 15 20
Temperature C
0
20
40
60
80
100
Depth (m)

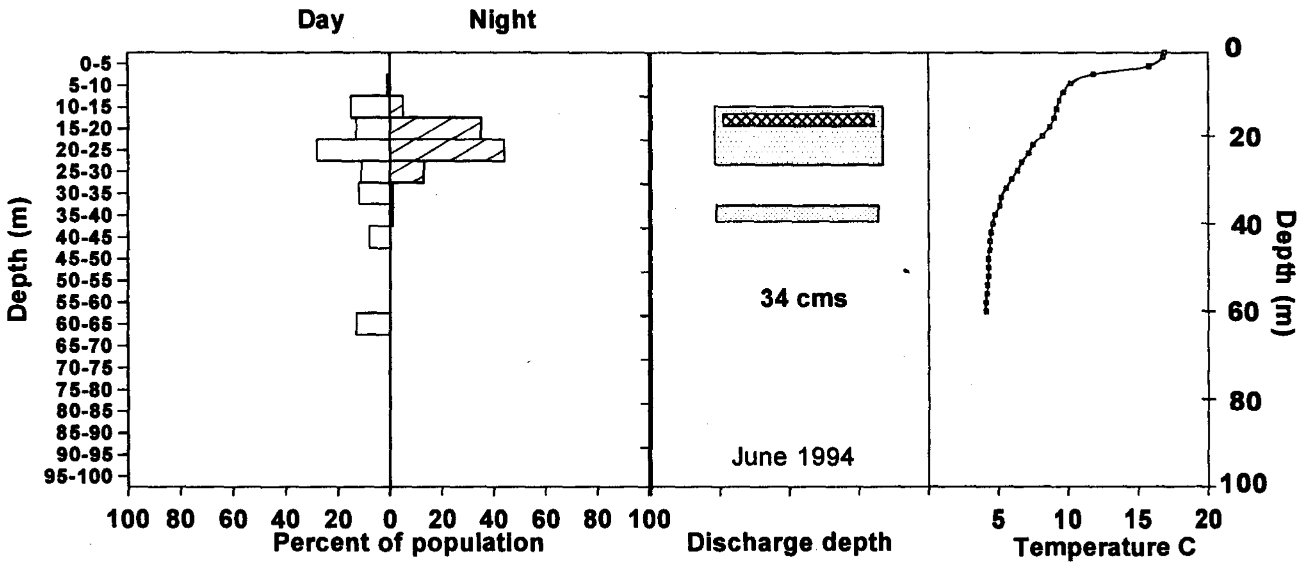


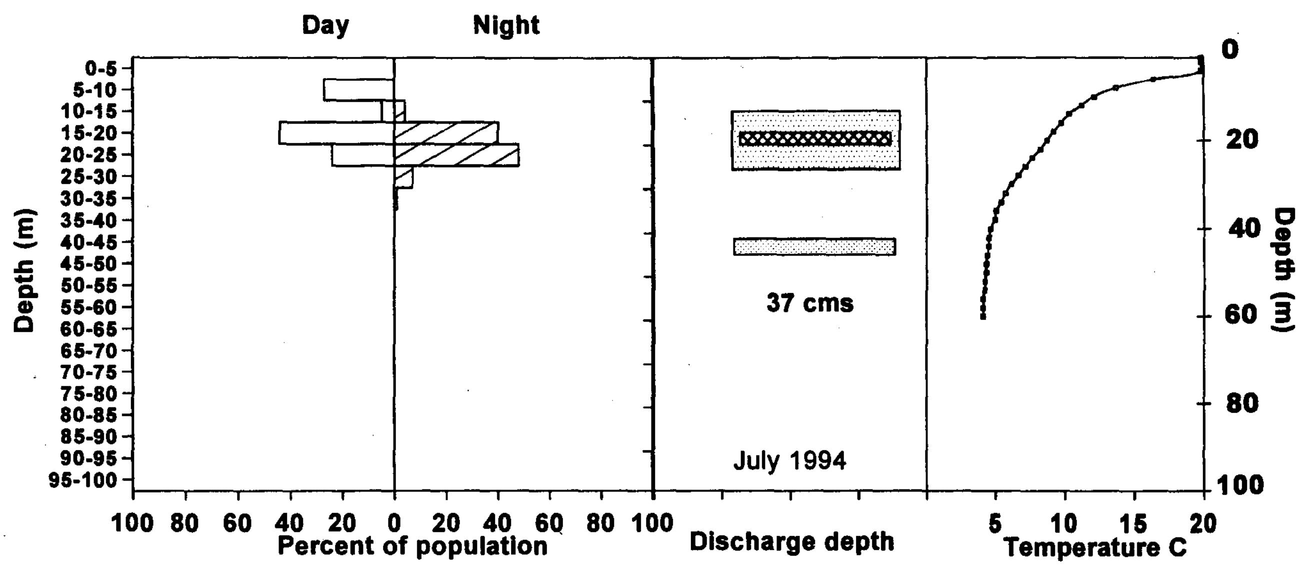
Day
Night
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
Depth (m)
100 80 60 40 20 0 20 40 60 80 100
Percent of population
34 cms
Feburary 1994
Discharge depth
5 10 15 20
Temperature C
0
20
40
60
80
100
Depth (m)


Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100 80 60 40 20 0 20 40 60 80 100
Percent of population
34 cms
March 1994
Discharge depth
5 10 15 20
Temperature C
0
20
40
60
80
100
Depth (m)

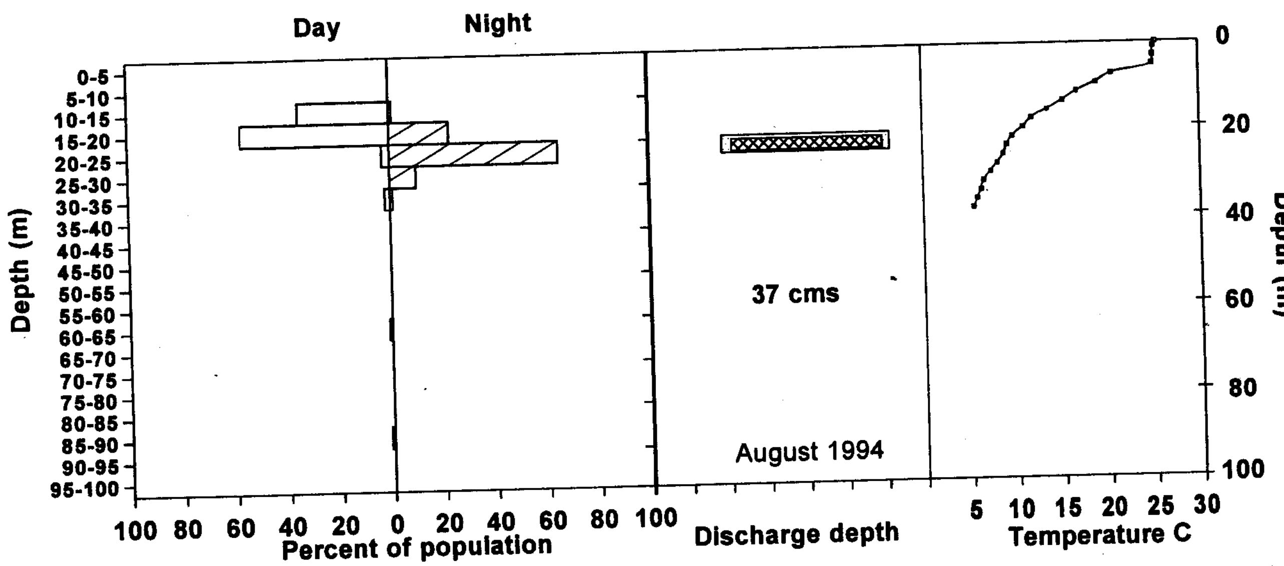

Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100 80 60 40 20 0 20 40 60 80 100
Percent of population
37 cms
April 1994
Discharge depth
5 10 15 20
Temperature C
0
20
40
60
80
100
Depth (m)


Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100 80 60 40 20 0 20 40 60 80 100
Percent of population
566 cms
May 1994
Discharge depth
5 10 15 20
Temperature C
0
20
40
60
80
100
Depth (m)

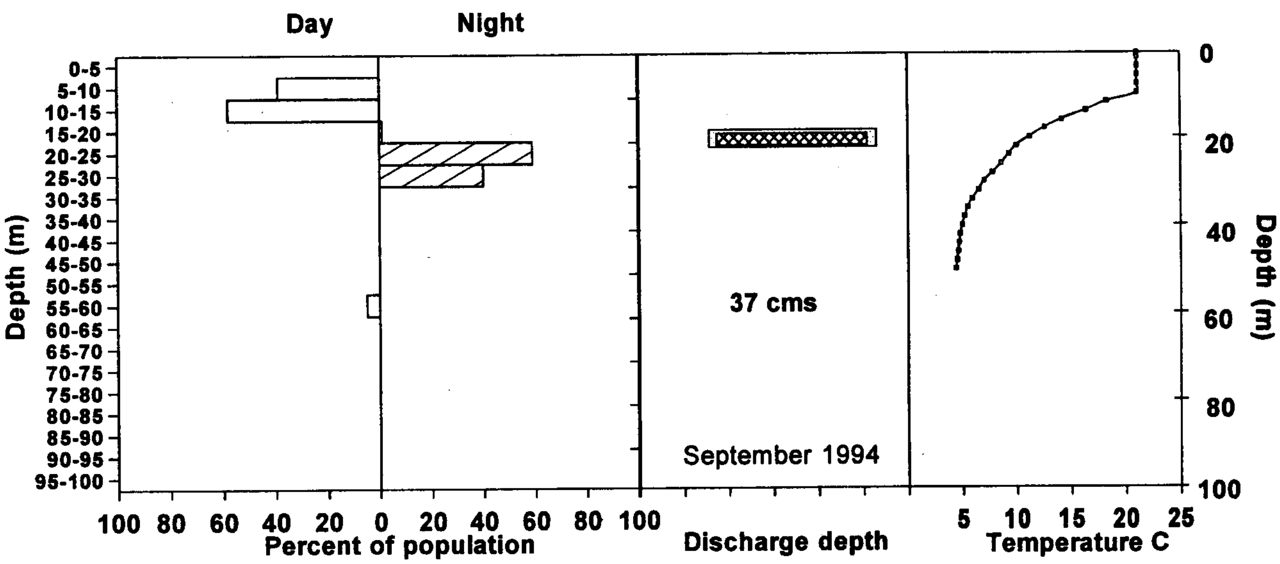

Day
Night
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
Depth (m)
100 80 60 40 20 0 20 40 60 80 100
Percent of population
34 cms
June 1994
Discharge depth
5 10 15 20
Temperature C
0
20
40
60
80
100
Depth (m)

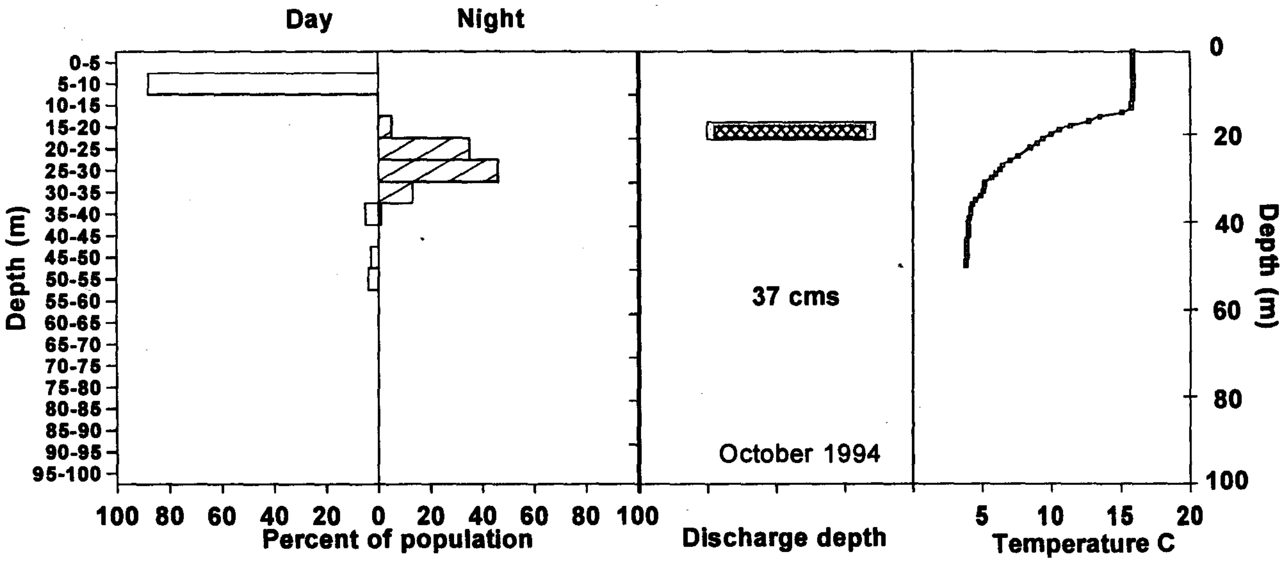


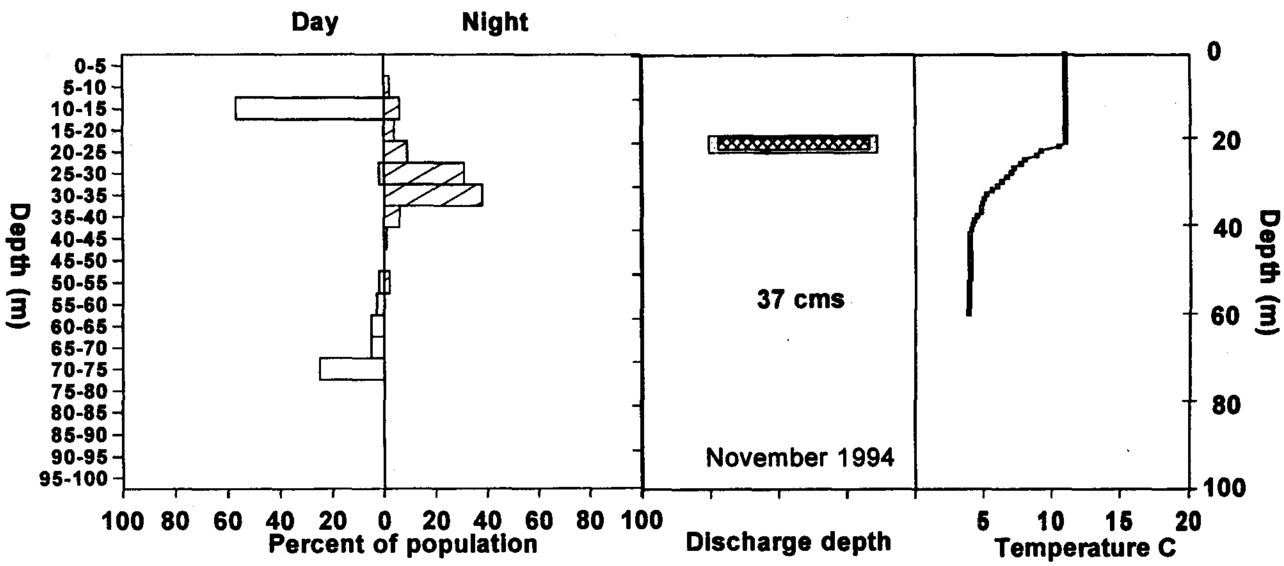
Day
Night
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
Depth (m)
100 80 60 40 20 0 20 40 60 80 100
Percent of population
37 cms
July 1994
Discharge depth
0
20
40
60
80
100
Depth (m)
5 10 15 20
Temperature C

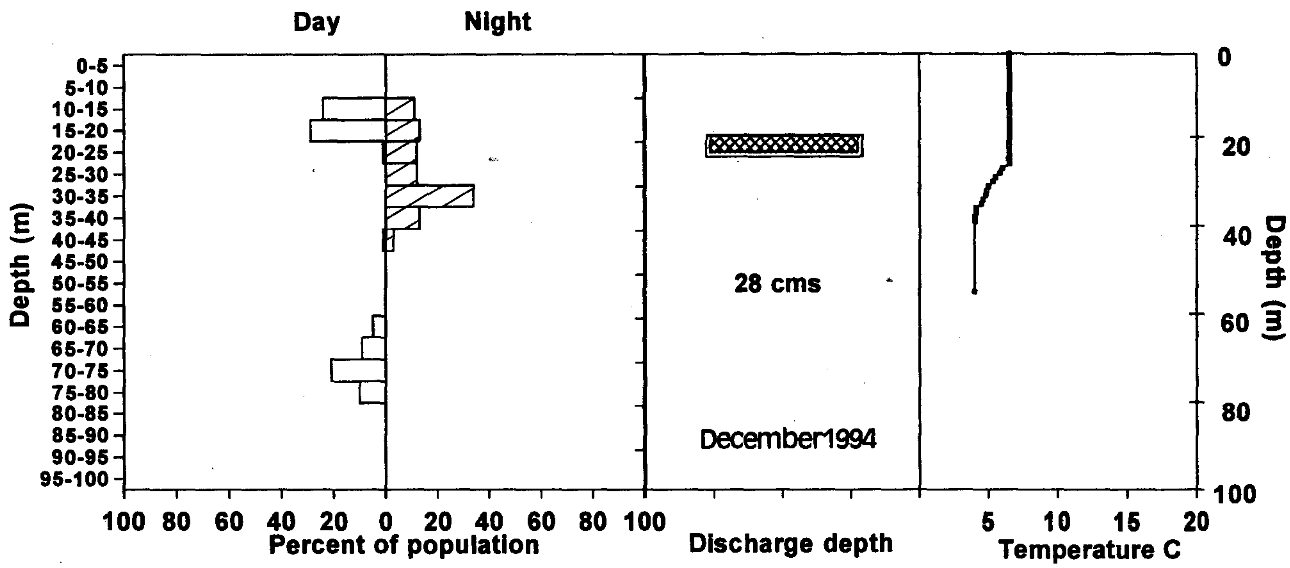


Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100 80 60 40 20 0 20 40 60 80 100
Percent of population
37 cms
August 1994
Discharge depth
5 10 15 20 25 30
Temperature C
0
20
40
60
80
100
Depth (m)


Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100 80 60 40 20 0 20 40 60 80 100
Percent of population
37 cms
September 1994
Discharge depth
5 10 15 20 25
Temperature C
0
20
40
60
80
100
Depth (m)


Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100 80 60 40 20 0 20 40 60 80 100
Percent of population
37 cms
October 1994
Discharge depth
5 10 15 20
Temperature C
0
20
40
60
80
100
Depth (m)


Day
Night
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
Depth (m)
100 80 60 40 20 0 20 40 60 80 100
Percent of population
37 cms
November 1994
Discharge depth
0
20
40
60
80
100
Depth (m)
5 10 15 20
Temperature C



Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100 80 60 40 20 0 20 40 60 80 100
Percent of population
28 cms
December1994
Discharge depth
5 10 15 20
Temperature C
0
20
40
60
80
100
Depth (m)

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