KOKANEE ABUNDANCE AND DISTRIBUTION IN DWORSHAK RESERVOIR AND IMPLICATIONS TOWARD MINIMIZING ENTRAINMENT

DWORSHAK DAM IMPACTS ASSESSMENT AND FISHERIES INVESTIGATION PROJECT

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ABSTRACT

We measured the day and night depth distribution of kokanee *Oncorhynchus nerka kennerlyi* directly upstream of Dworshak Dam from January 1995 to October 1995 using split-beam hydroacoustics. At night, most kokanee (70%) were in a layer 10 to 20 m thick. The depth of the layer varied with the season and ranged from 15 to 35 m deep during January to 2 to 10 m deep during May. The nighttime kokanee layer during summer covered a zone where water temperatures ranged from 7 to 12°C.

Daytime kokanee distribution was much different with kokanee located in dense schools. Most kokanee (70%) were found in a 5 to 15 m thick layer during summer. Daytime kokanee depths were the shallowest during May and October and were the deepest during January.

Kokanee densities in the forebay declined from 770 kokanee/ha in January to 330 kokanee/ha in October. Lower densities near the dam were the result of kokanee moving up the reservoir throughout the summer. We calculated kokanee abundance at 1.9 million age 1 and 2 fish (± 19%, 90% confidence interval) during June. Age 2 densities were estimated at a record high of 110 kokanee/ha based on hydroacoustics. This converted to a trawl catch estimate of 97 age 2 kokanee/ha; well above our objective of 30-50 fish/ha.

Selective water withdrawal was used to discharge water from below the kokanee layer from February through June. The discharge pattern also changed from the pre-1991 years. More water was released during May, July, August, and November, and less water was released during fall and winter of 1994-95. A combination of these two changes was thought to have increased kokanee abundance to record high levels.

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INTRODUCTION

Dworshak Reservoir is the largest body of water in the Clearwater River drainage of Idaho. It provides a very popular fishery for kokanee *Oncorhynchus nerka kennerlyi* with angler effort exceeding 140,000 hours in some years (Mauser et al. 1989). The problem has been that the kokanee population, and the resulting fishery, was extremely variable. Kokanee densities have ranged from 3 to 70 adults/ha (Fredericks et al. 1995). Densities of kokanee were highly, and negatively, correlated to the amount of water discharged through Dworshak Dam (Maiolie and Elam 1995). This strongly indicated that losses of fish through the dam were influencing kokanee abundance and the resulting fishery.

In recent years, 1993 to 1995, the kokanee population has been at an all time record high level. Two changes appeared to be responsible for the recent increase in kokanee abundance. First, the reservoir has been drawn down in mid-summer (instead of the fall) to provide water for anadromous fish flows. Flows out of the dam during the fall and winter (periods of the year when adult kokanee are concentrated near the dam) were subsequently reduced. Secondly, the dam's selector gates and reservoir outlets have been used to withdraw water from depths which would avoid depths utilized by kokanee (Maiolie and Elam 1996).

Our studies in 1995 were to determine if the kokanee population would maintain high densities for another year even with changes in the operation of Dworshak Dam. We also wanted to quantify kokanee losses from the reservoir during the mid-summer drawdowns. Lastly, we monitored the depth of the kokanee population in front of the dam and made recommendations to the Army Corps of Engineers as to where water could be withdrawn to avoid kokanee losses.

GOAL

To maximize the sport fishery potential of Dworshak Reservoir.

OBJECTIVE

To maintain densities of 30 to 50 adult kokanee/ha, annually by reducing entrainment losses.

Subobjective #1

To optimize the use of selective water withdrawal so that kokanee entrainment is minimized and reservoir productivity is maximized.

Subobjective #2

To determine the impact on kokanee abundance of shifting reservoir drawdowns from the fall to mid-summer.

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 northwest of Orofino in Clearwater County, Idaho. At 219 m tall, it is the largest straight-axis concrete dam in the United States, and is owned and operated by the United States Army Corps of Engineers. 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.

Dworshak Reservoir initially reached full pool on July 3, 1973. It is 86.2 km long and has 295 km of steep shoreline. At full pool, maximum and mean depths are 194 m and 56 m, respectively. Surface area when full is 6,644 ha with a volume of 4.28 billion m^3. It contains about 5,400 ha of kokanee habitat (defined as the area over 15 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).

The magnitude and timing of Dworshak Reservoir drawdowns changes annually depending on the need for flood control, power production, and releases for anadromous fish. Between August 1994 and February 1995, the reservoir elevation was low and stable with only minimal flows released from the dam (Figures 2 and 3). The reservoir filled during the spring run-off of 1995. Surface elevation then dropped markedly between July and October as water was released to augment summertime flows in the lower Clearwater and Snake rivers and for repairs on Dworshak Dam. The reservoir elevation then increased from November to December 1995 during a rain-on-snow event (Figures 2 and 3).

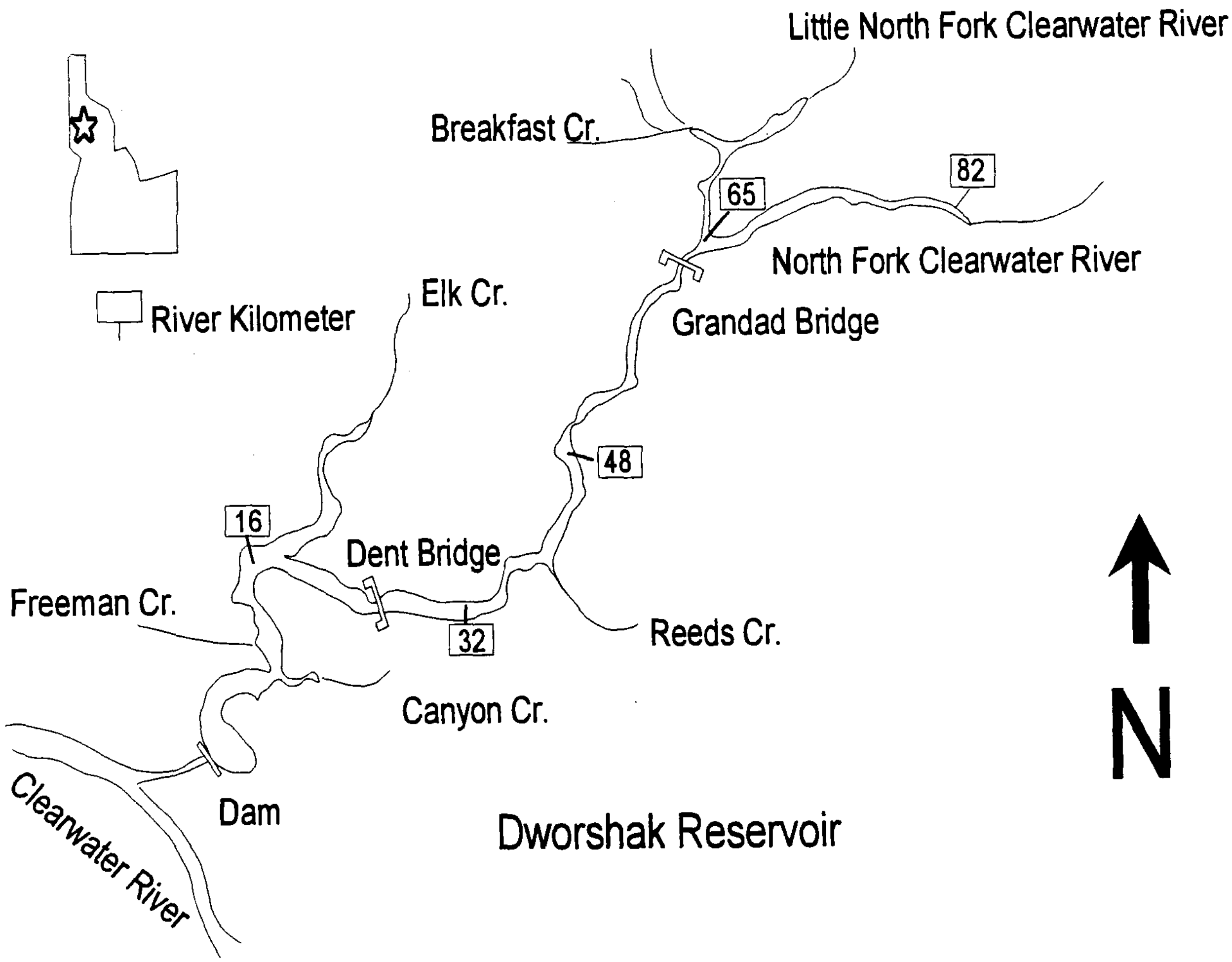

Figure 1. Dworshak Reservoir and major tributaries, North Fork Clearwater River, Idaho.

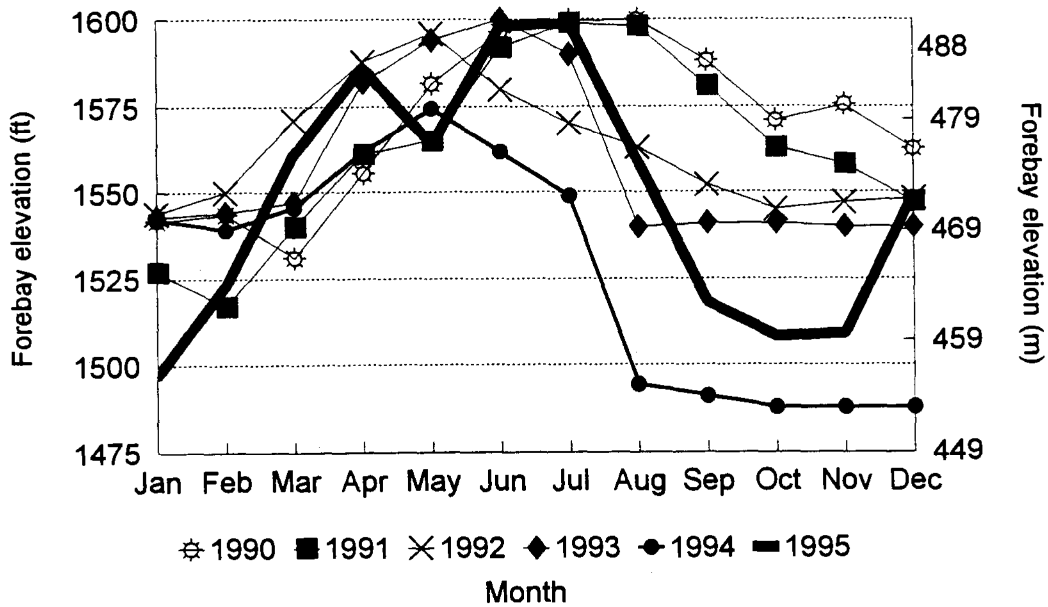

Figure 2. Elevation of Dworshak Reservoir, Idaho, 1990 to 1995.

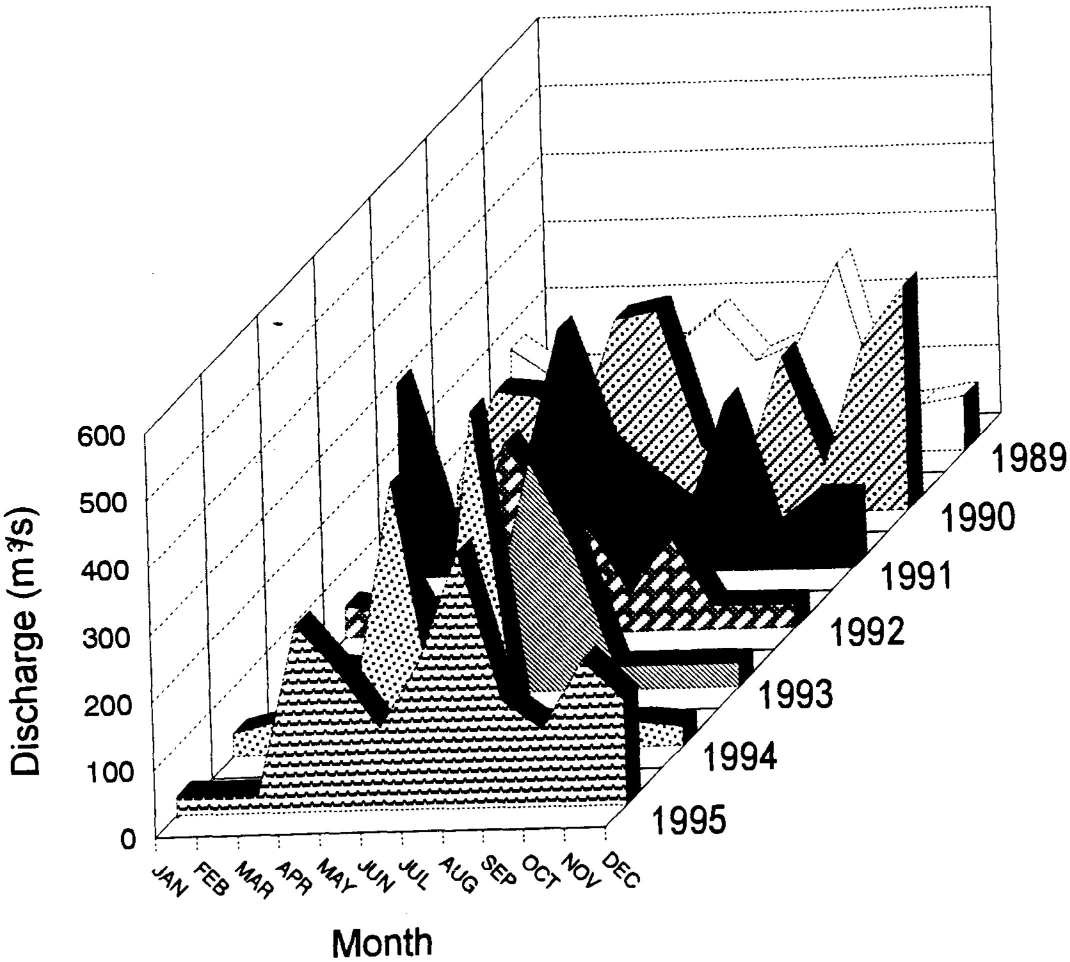

Figure 3. Mean monthly discharge from Dworshak Dam, Idaho, 1989 to 1995.

The reservoir was found to contain 21 different species of fish (Maiolie et al. 1993). Sport fisheries target three of these species: kokanee, smalimouth bass *Micropterus dolomieu* and rainbow trout *Oncorhynchus mykiss.* Based on annual July trawling, the pelagic zone of the reservoir contains kokanee almost exclusively. In rare instances, the trawl catch included young-of-the-year smallmouth bass, Pacific lamprey *Lampetra tridentata,* redsided shiner *Richardsonius balteatus,* or black crappie *Pomoxis nigromaculatus.* These other species, however, made up less than 1% of the trawl catch.

METHODS

<u>Hydroacoustic Equipment</u>

We used a split-beam echosounder made by Simrad (model EY500) with a 120 kHz transducer to document the abundance and distribution of kokanee in Dworshak Reservoir. Echogram data collected in the field were later analyzed using Simrad EP500 software version 4.5. Boat speed was 1.5 to 2.3 mIs. The echosounder was set to ping at 0.7 s intervals, with a pulse width of 0.3 milliseconds. Data were collected with a time varied gain constant of 20 log R (range). Appendix A contains a complete list of echosounder settings. We calibrated the echosounder at the beginning of the year using a 23 mm copper calibration sphere with a target strength of -40.4 dB (decibels) (at 23°C). Calibration was checked prior to each monthly survey, and the transducer gains were adjusted if needed.

Target Strength Analysis

We configured the echosounder so that only echos meeting certain criteria would be considered a fish. First, the returned echo had to be greater than -60 dB. The length of the returned echo had to be between 0.8 and 1.8 times the length of the echosounder's ping. The echo also could not need a correction of more than 4.0 dB for being off the acoustic axis. Echos meeting this criteria were classified as a fish "trace" (a single returned echo from a single fish).

EP-500 software, version 4.5, was used to analyze the data during post-processing. The fish traces were analyzed by three different methods to determine the size and, ultimately, the age classes of kokanee. First, we plotted the frequency of target strengths of all returned traces along a survey route made up of multiple transects across the reservoir.

Our second method was to analyze fish tracks. A fish track was a series of traces believed to be from a single fish. To be considered a fish track, the object had to return three or more echos, not change depth more than 30 cm between pings, and could not be missed by more than one ping in the track. Once defined as a fish track, the dB level of all traces were plotted in a frequency distribution. Again, survey routes of multiple transects across the reservoir were used so that a sample size of approximately 1,000 traces could be graphed.

The third method to determine kokanee size was to take the data base of fish tracks, remove any tracks which were not in a straight line (which indicate the track was from two fish), and to remove any tracks in which target strengths varied more than 10 dB. The post-processing software then averaged the target strength from each echo on the fish track. We then constructed a frequency distribution of the mean target strengths from about 300 fish tracks.

We used Love's (1971) relationship between target strength and fish length to estimate kokanee size. All conversions between decibel level and total length in this report were based on his equation.

Forebay Surveys

We conducted hydroacoustic surveys along eight forebay transects during the middle of each month from January 1995 through October 1995 (Figure 4). Surveys were conducted during the day and at night. Transects were uniformly spaced, perpendicular to the axis of the dam, and covered the entire width of the reservoir beginning and ending at the 10 m depth contour. We piloted the boat by visual landmarks, compass headings, Global Positioning System (GPS) locations, and/or radar. Prior to May we characterized the depth distribution of kokanee solely from transect D, which was directly in line with the middle of the dam. Fish distribution on this transect was representative of the other transects in the forebay. Beginning in May, we combined the data from the eight transects into a single file to characterize this depth distribution.

During field surveys, the water column was viewed on the echograms to a depth of 100 m. Few, if any, fish were seen below 80 m. We therefore divided the echograms into 5 m depth intervals from the surface to a depth of 80 m. The EP-500 software was used to determine the percent of the population in each 5 m band. All returned traces (single ping signals) between -57 dB and -33 dB were used. In general, most kokanee were in a defined layer with a few fish scattered both deeper and shallower. We plotted the depth of the densest 70% of the fish to define this layer. We also plotted the depths where 90% and 100% of the fish occurred to characterize the dispersion around this layer.

The eight transects in the forebay were split into ten equal horizontal sections. Kokanee density in each of the 80 sections was then plotted on a map of the forebay. Our intent was to note concentrations of fish that may have been attracted to the dam.

Mean kokanee density in the forebay was calculated by averaging the density from the eight transects. Ninety-five percent confidence intervals were calculated using a Students's T distribution (Hoel 1971).

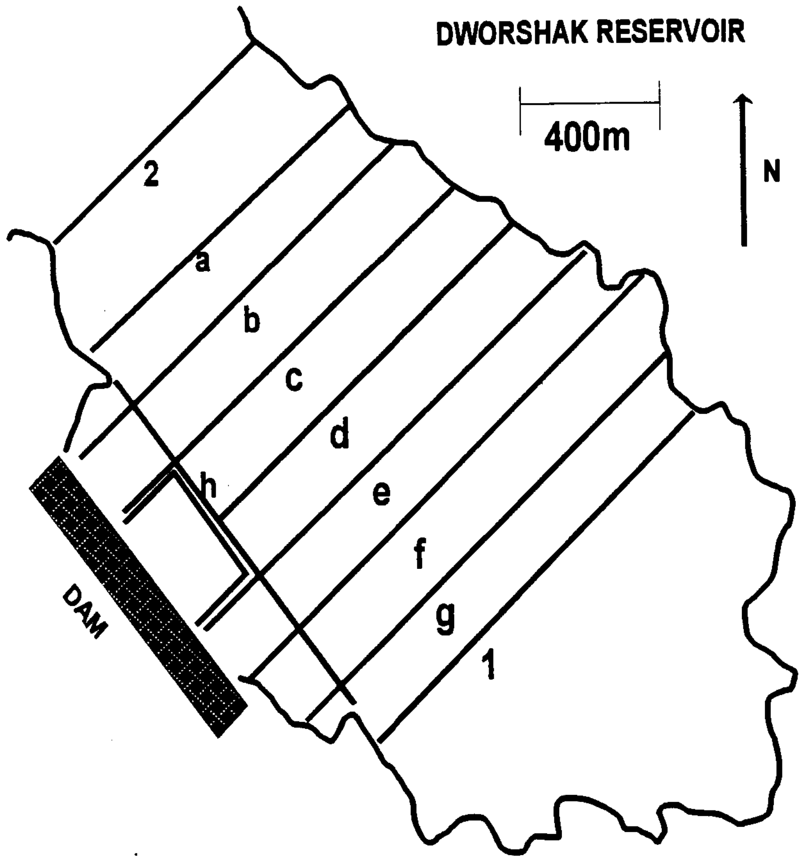

Figure 4. Hydroacoustic transect locations in the forebay area upstream of Dworshak Dam, Idaho.

We measured temperature profiles of the reservoir using a Yellow Springs Instrument Company temperature/oxygen meter. Temperatures were recorded to a depth of 60 m by 1 m intervals and were collected at a floating weather station about 1 km upstream from the dam.

Reservoir-Wide Surveys

Reservoir-wide hydroacoustic surveys were conducted to estimate kokanee abundance before, between, and after the large releases of water in May and August. We used a systematic, stratified survey design (Scheaffer et al. 1990). The reservoir was stratified into three sections: from the dam to Dent Bridge, Dent Bridge to Grandad Bridge, and Grandad Bridge to the headwaters (Figure 1).

All density estimates were based on echo integration results to account for fish in schools which could not be resolved as individuals. Integrated density estimates were provided by the EP-500 software. We analyzed only the pelagic region of each transect. In deep sections of the reservoir, this was defined as water over 50 m deep. In the shallow upper end of the reservoir, the pelagic zone included water over 10 m deep. Mean densities in each reservoir section were multiplied by the area of that reservoir section and totaled to obtain population estimates. Variances were calculated without a finite population correction factor since it was essentially one (.9993 and .9994 in the lower and middle sections of the reservoir). Ninety percent confidence limits were placed on the total kokanee population estimates using formula for stratified systematic design (Scheaffer et al. 1990).

Survey transects were spaced at 3.2 km (2 mile) intervals throughout the length of the reservoir. Surveys were conducted at night on April 10 and 11, June 13 and 14, and August 15 and 16, 1995. Moon phase was not taken into account when choosing the survey date since it appeared to have little effect on density estimates. Kokanee population estimates based on hydroacoustics were multiplied by 88% to obtain a trawler based population estimate based on past gear comparisons (Maiolie and Elam, unpublished data).

We also mapped the distribution of the age classes of kokanee in the reservoir. For this purpose only, we defined age 0 kokanee as fish between -60 and -57 dB (about 25 to 45 mm) in April, and -60 and -54 dB (about 25 to 50 mm) in June and August. (These conservatively small targets were used to eliminate age 1 fish from the data.) Age 1 and 2 kokanee could not readily be separated on the basis of target strength. We therefore mapped the location of all traces between -48 dB and -33 dB (75 mm to 405 mm) to note the movements and distribution of age 1 and 2 fish together.

RESULTS

Temperatures

The forebay of Dworshak Reservoir was warm monomictic (Wetzel 1975) in 1995. The water column was nearly isothermal between January and March 1995 with temperatures between 4 and 5°C (Figure 5). Between May and October, the reservoir thermally stratified. Temperatures in the metalimnion ranged from 10 to 18°C. Surface temperatures peaked at 22°C in July. During summer, kokanee could select for water temperatures anywhere from 4 to 22°C.

Kokanee Target Strength

During April 1995, a graph of the target strengths of fish traces in the lower end of the reservoir appeared to be one large normal distribution (Figure 6). No break points could be distinguished between low decibel level noise and small kokanee nor small kokanee and adult kokanee. A similar target strength-frequency plot of fish traces in August did show a single break at the -48 dB (75 mm) level (Figure 6). However we expected to see three peaks corresponding to the target strengths of age 0, 1, and 2 kokanee.

Plotting the target strength of single fish traces off of fish tracks provided a different appearance to the target strength-frequency distribution (Figure 7). These data from each month appeared to be bimodal. Plots of the mean target strength on each fish track also appeared bimodal in June, August, and October, but unimodal in April (Figure 8).

Kokanee Depth Distribution

Nighttime Depths

Most kokanee (the densest 70% of the distribution) were in a narrow band approximately 10 to 20 m wide at night (Figure 9, Appendix B). Depth of this band varied from 0 to 35 m deep throughout the year, with kokanee being the deepest during January 1995. The nighttime depth distribution which included all fish (the 100% band) was much wider. Kokanee were shallowest in April and May when most fish were found above 15 m in depth. The greatest dispersion occurred during June when fish ranged from 5 m deep to 70 m deep.

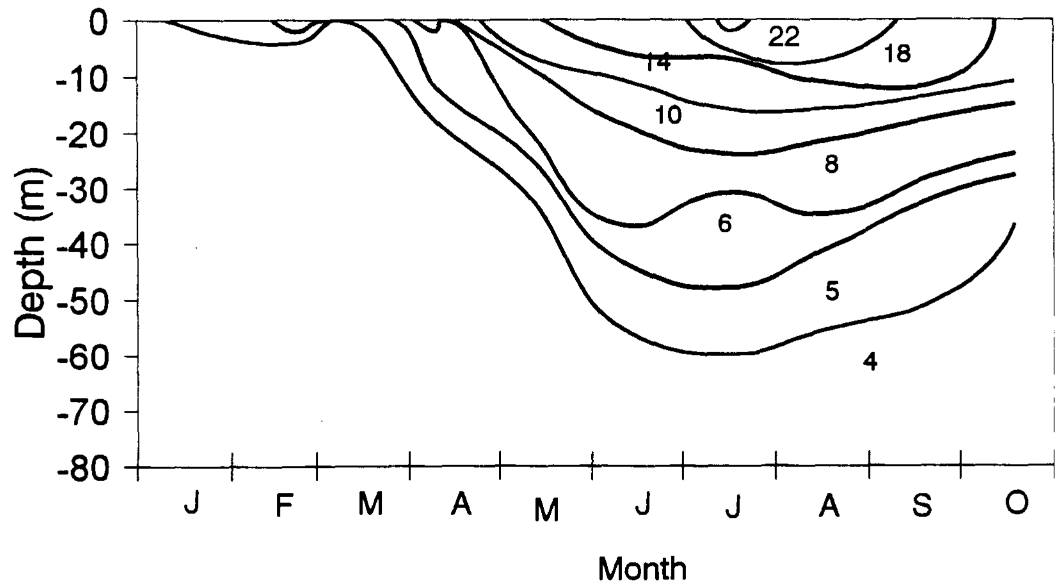

Figure 5. Isopleths of temperature for the lower end of Dworshak Reservoir, Idaho, January 1995 to October 1995.

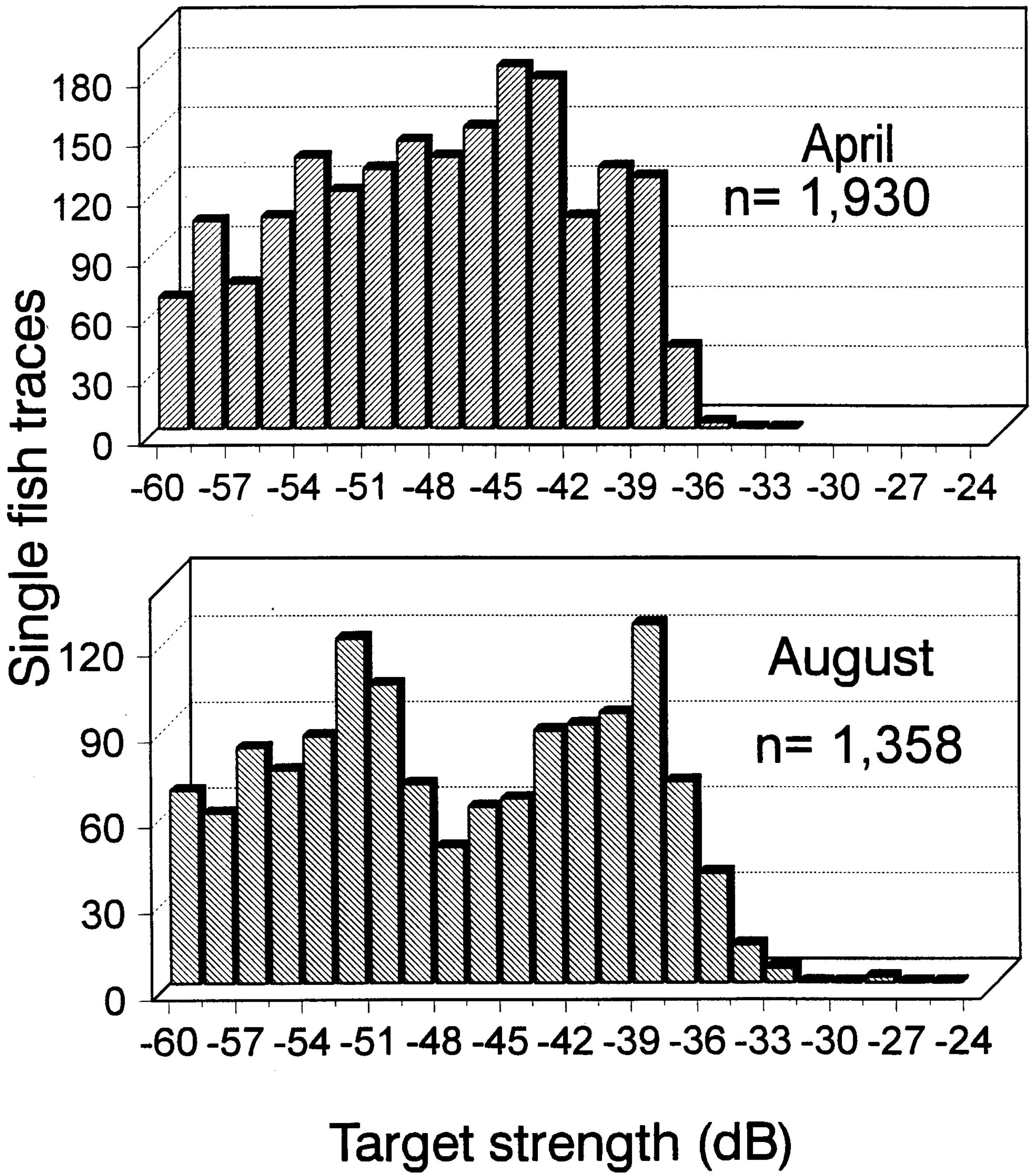

Figure 6. Target strength of all returned echos from individual fish (traces) in Dworshak Reservoir, April and August 1995.

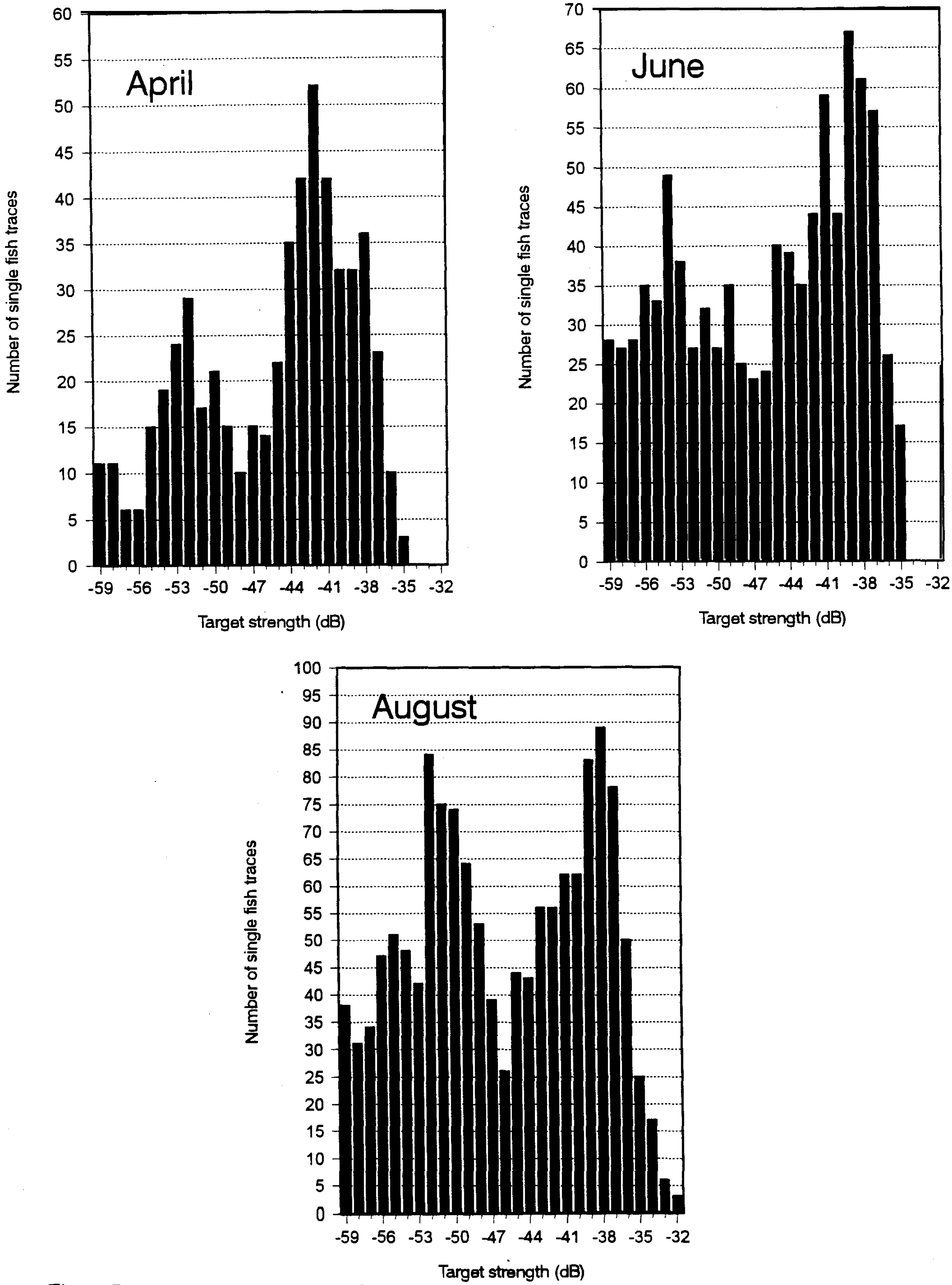

Figure 7. Target strength of all returned echos from fish tracks in Dworshak Reservoir, April, June, and August 1995.

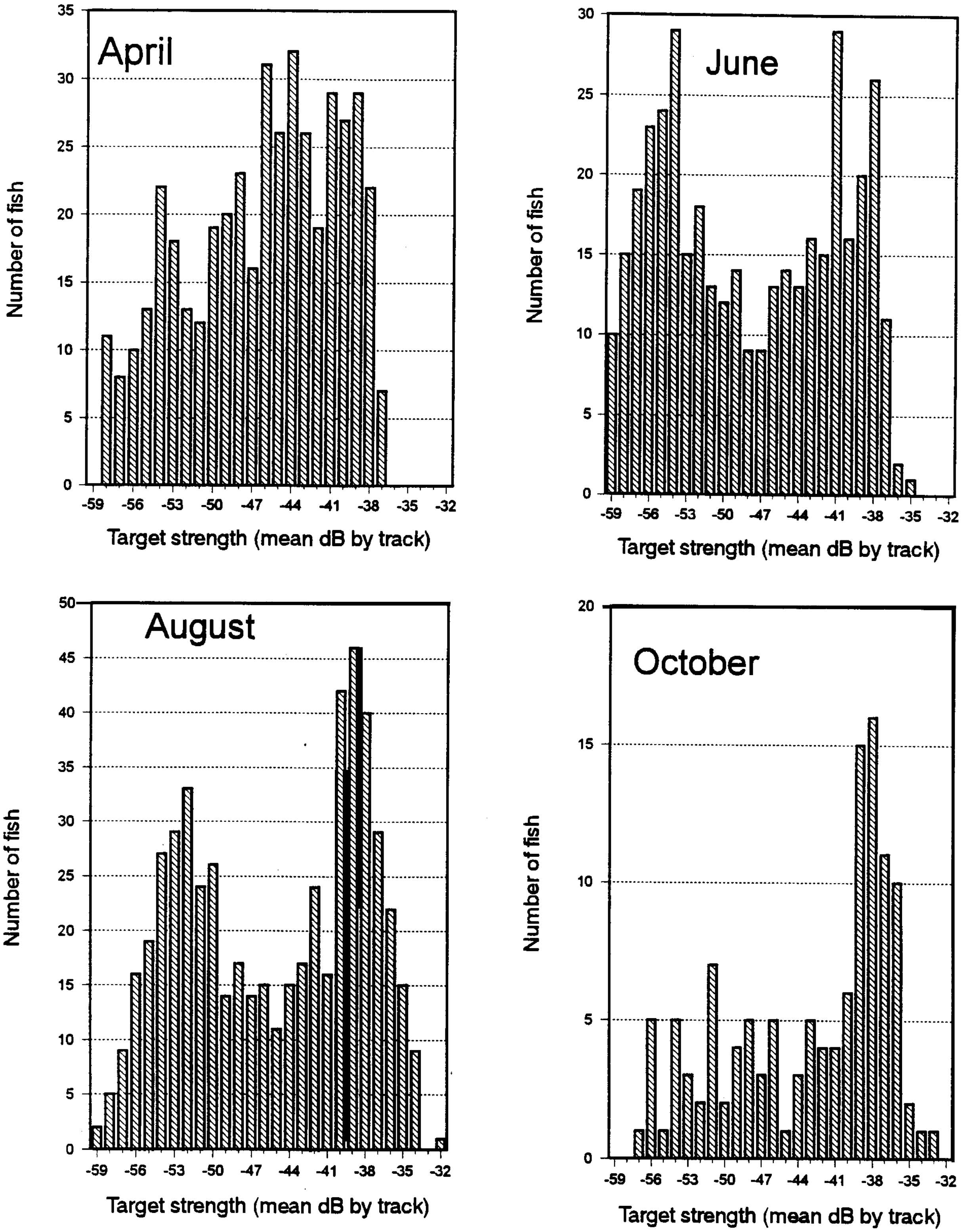

Figure 8. Mean target strength of returned echos on fish tracks in Dworshak Reservoir, April, June, August, and October 1995.

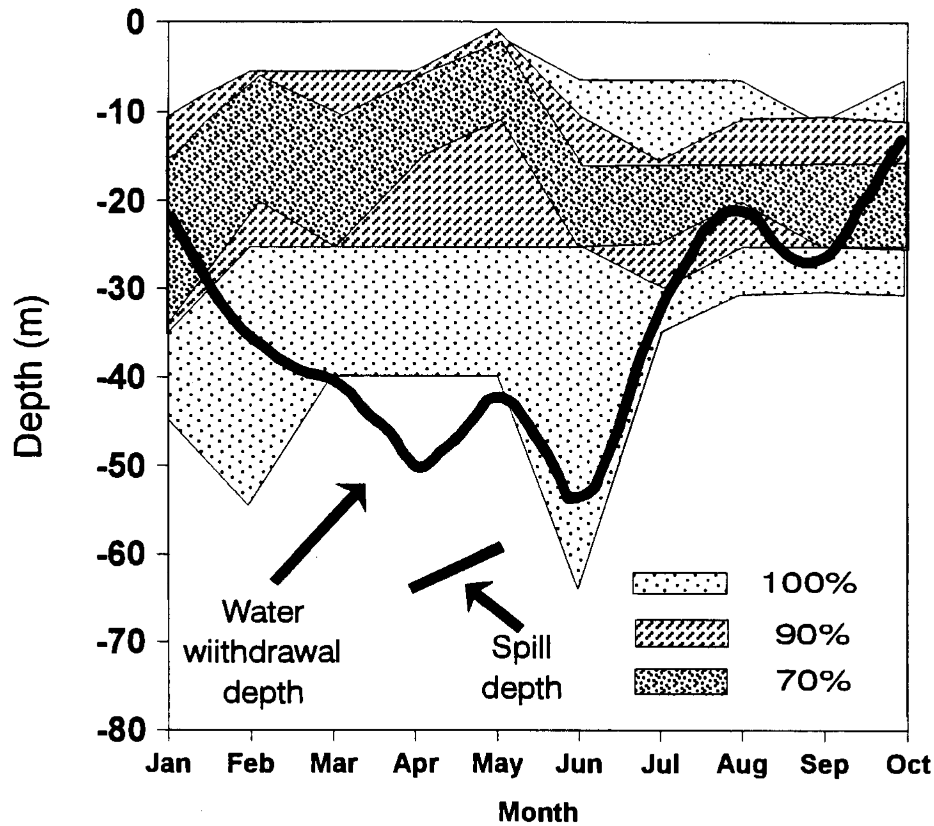

Figure 9. Nighttime vertical distribution of fish directly upstream of Dworshak Dam, January to October 1995. One hundred percent band shows depth distribution of all fish, 70% and 90% bands show distribution of that proportion of the population. Dark line shows the depth water was withdrawn into the penstocks.

Daytime Depths

Often the daytime depth distribution of kokanee was split into two distinct segments (Appendix B). During January, for example, fish were mostly located at a depth of 50 to 75 m, with a second group of fish located at 20 to 25 m (Appendix B). This split distribution was evident in most months of the year except April.

Kokanee were deepest during the winter, shallowest in the spring and fall, and occupied mid-depths during the summer (Figure 10).

Kokanee Densities and Distribution in the Forebay

Kokanee densities in the forebay for all fish, -57 dB to -33 dB, declined from 768 kokanee/ha in January to 330 kokanee/ha in October (Figure 11). The exception to this gradual decline occurred in June when density estimates increased to over 1,000 fish/ha. The June increase in kokanee density was concurrent with a reduction in flows to a mean monthly outflow of 122 m^3/s.

Maps of kokanee density displayed a clumped distribution pattern (Appendices E and F). Although the patchiness of their distribution was evident during both day and night, their schools were much tighter during the day (Appendix E). We did not fmd areas of high fish densities directly in front of the dam. Thus, we did not document large numbers of fish staging to emigrating from the reservoir (Appendices E and F).

Reservoir-Wide Kokanee Distribution and Abundance

Age 0 Kokanee Distribution

We plotted the distribution of small objects (the size of conservatively small kokanee fry; 25 to 50 mm) for each of the three reservoir-wide surveys (Figure 12). Some small objects were detected throughout the reservoir in April even before age 0 kokanee were thought to emerge. We do not know whether these were the fry of other species or debris in the water column. During June we noted a substantial increase in small objects in the reservoir. We believed this increase was due to kokanee fry recruiting to the open water. These fry had moved down the reservoir to river kilometer (rkm) 41 by June. By August they had moved down to rkm 35, with the highest densities remaining upstream of rkm 54 (Figure 12).

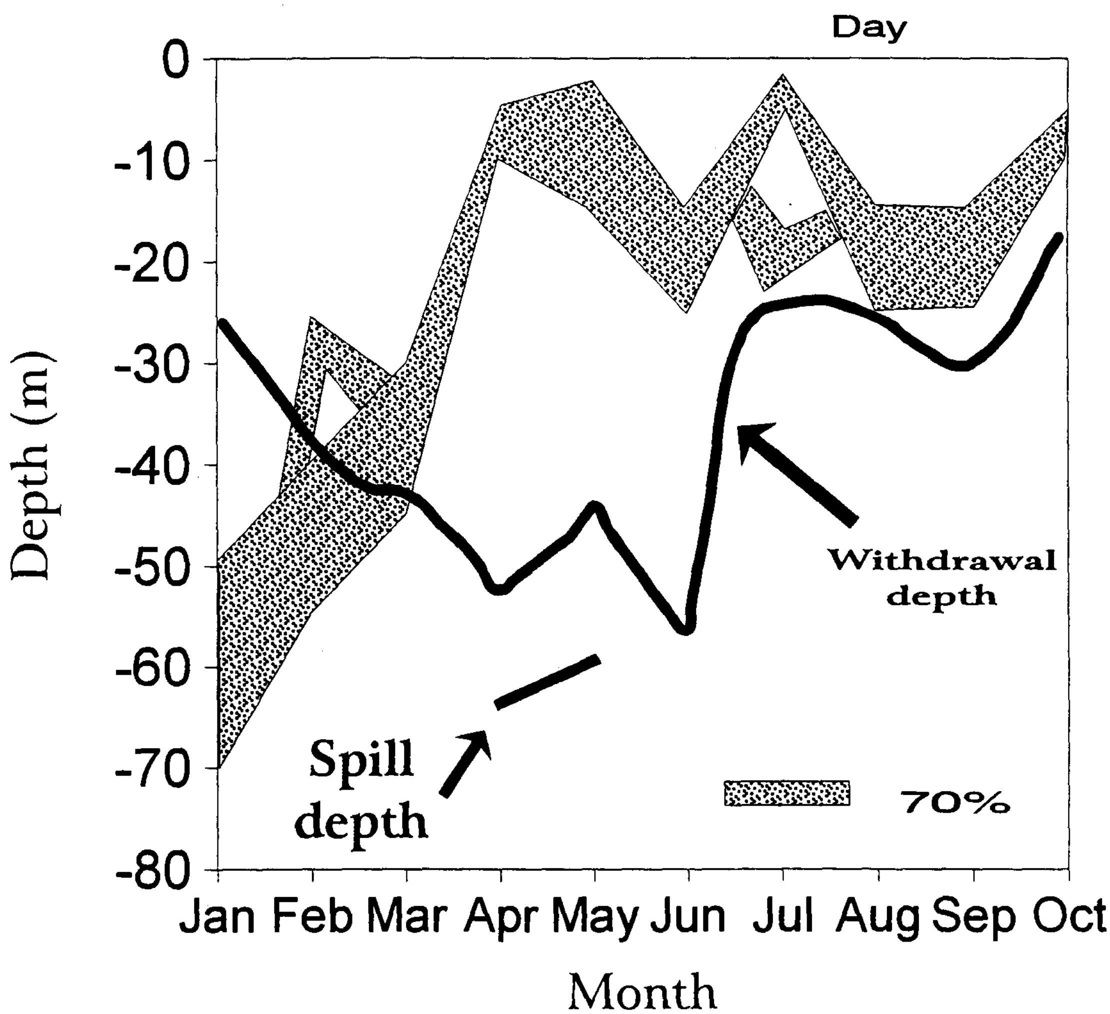

Figure 10. Daytime vertical distribution of fish directly upstream of Dworshak Dam, January 1995 to October 1995. Shaded area shows depth distribution of 70% of the population during the monthly survey. Dark line shows the depth water was withdrawn into the penstocks.

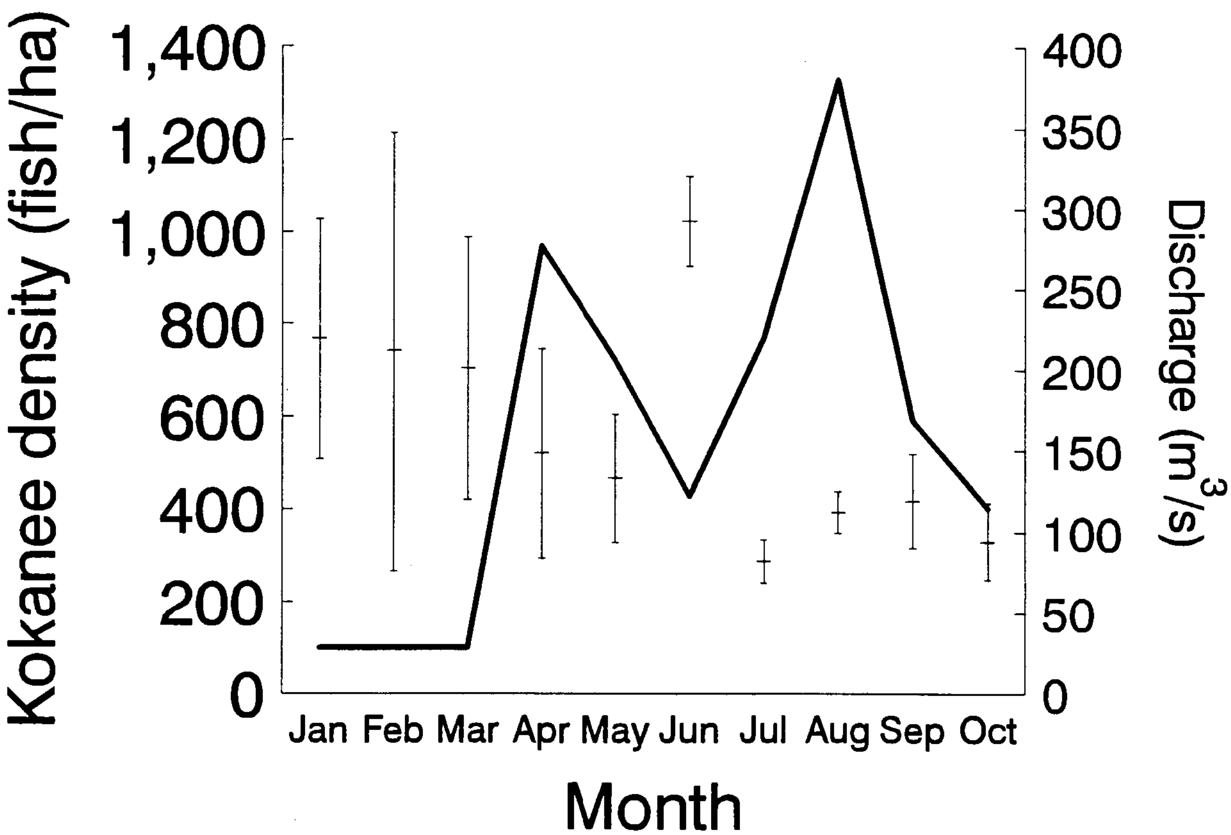

Figure 11. Mean nighttime kokanee densities in the forebay of Dworshak Reservoir, Idaho, 1995. Confidence intervals of 95% were placed on the means. Solid line depicts mean monthly discharge rate.

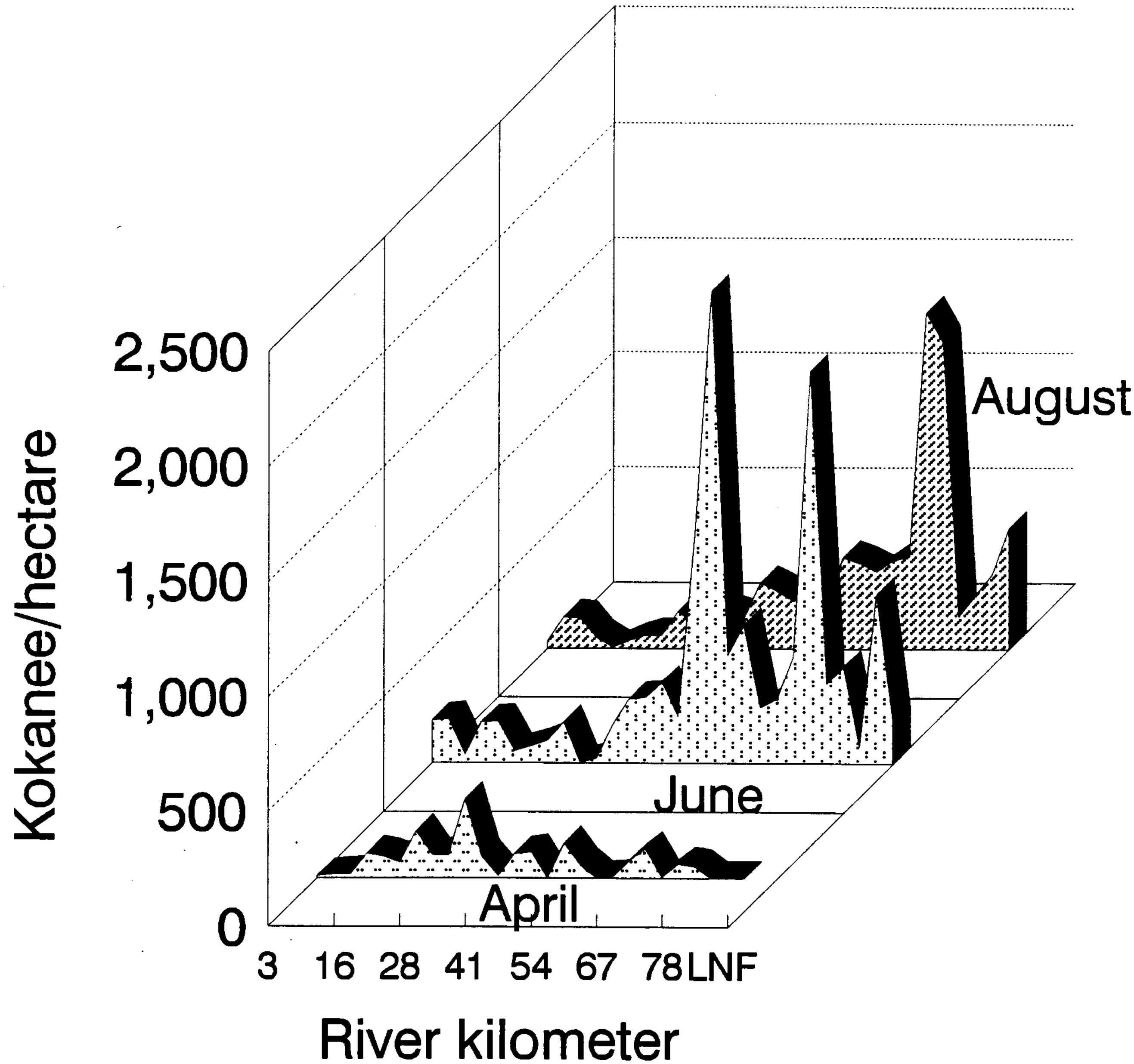

Figure 12. Age 0 kokanee distribution (target strength -60 to -57 dB in April, -60 to -54 dB in June and August) in Dworshak Reservoir, Idaho, April, June, and August 1995.

Our abundance estimates for objects with target strengths between -57 and -48 dB (25 mm to 75 mm) was 1.64 million ± 34% (90% CI) in June and 1.56 million ± 26% in August. Thus, we did not document a significant decline of age 0 kokanee throughout the summer.

Age 1 and 2 Kokanee Distribution

Age 1 and age 2 kokanee were difficult to separate based on frequency plots of target strength. Distribution of both age classes were therefore described together. In April, age 1 and 2 kokanee concentrated in the lower reservoir below rkm 41, leaving the middle and upper portions of the reservoir nearly devoid of fish (Figure 13). By June, these kokanee spread throughout the reservoir with peak densities occurring at rkm 3, 42, and 71. During the August survey, we recorded very high densities of 500 to 2,600 fish/ha at the upper end of the reservoir above rkm 74 (Figure 13). This movement was likely to have been a spawning migration towards the inflowing tributaries. Fish densities in the lower third of the reservoir were relatively low during August.

We estimated the abundance of age 1 and 2 kokanee (-48 to -33 dB; 70 to 380 mm) in April at 1.7 million fish ± 17% (Figure 14). Our June abundance estimate was 1.9 million ± 19%, and our August estimate was 1.6 million ± 25%. The three estimates, therefore, showed little change in response to high spring discharges or late summer drawdowns.

We converted the June hydroacoustic estimate of kokanee into a trawl estimate for comparison to past data (Figure 15). We split age 1 and age 2 kokanee at the -39 dB level, although this was not a clear break in the frequency distribution (Figure 8). Reanalyzing the data gave estimates of 1.30 million age 1 kokanee (243 fish/ha) and 0.60 million age 2 kokanee (110 fish/ha). Considering the trawl is 88% efficient relative to the echosounder, a density estimate based on trawling would have been about 97 age 2 kokanee/ha.

Selective Water Withdrawal

During January 1995 the reservoir surface level was too low for the selector gates to operate. Thus water was withdrawn from a depth that was in the densest part of the kokanee layer at night and above the kokanee layer during the day (Figures 9 and 10). Our recommendation was to keep the selector gates raised as the reservoir filled in late winter and spring (Figure 2). This recommendation was followed and the selector gates remained raised until July. Between February and June, water was withdrawn at an elevation of 433 m (1,420 feet), which was well below the depths utilized by kokanee either during the day or at night (Figures 9 and 10). The selector gates were operated for temperature control of the discharge water from July through October. Temperature of the river is critically important to the Dworshak National Fish Hatchery, which is located below the dam and uses river water in its

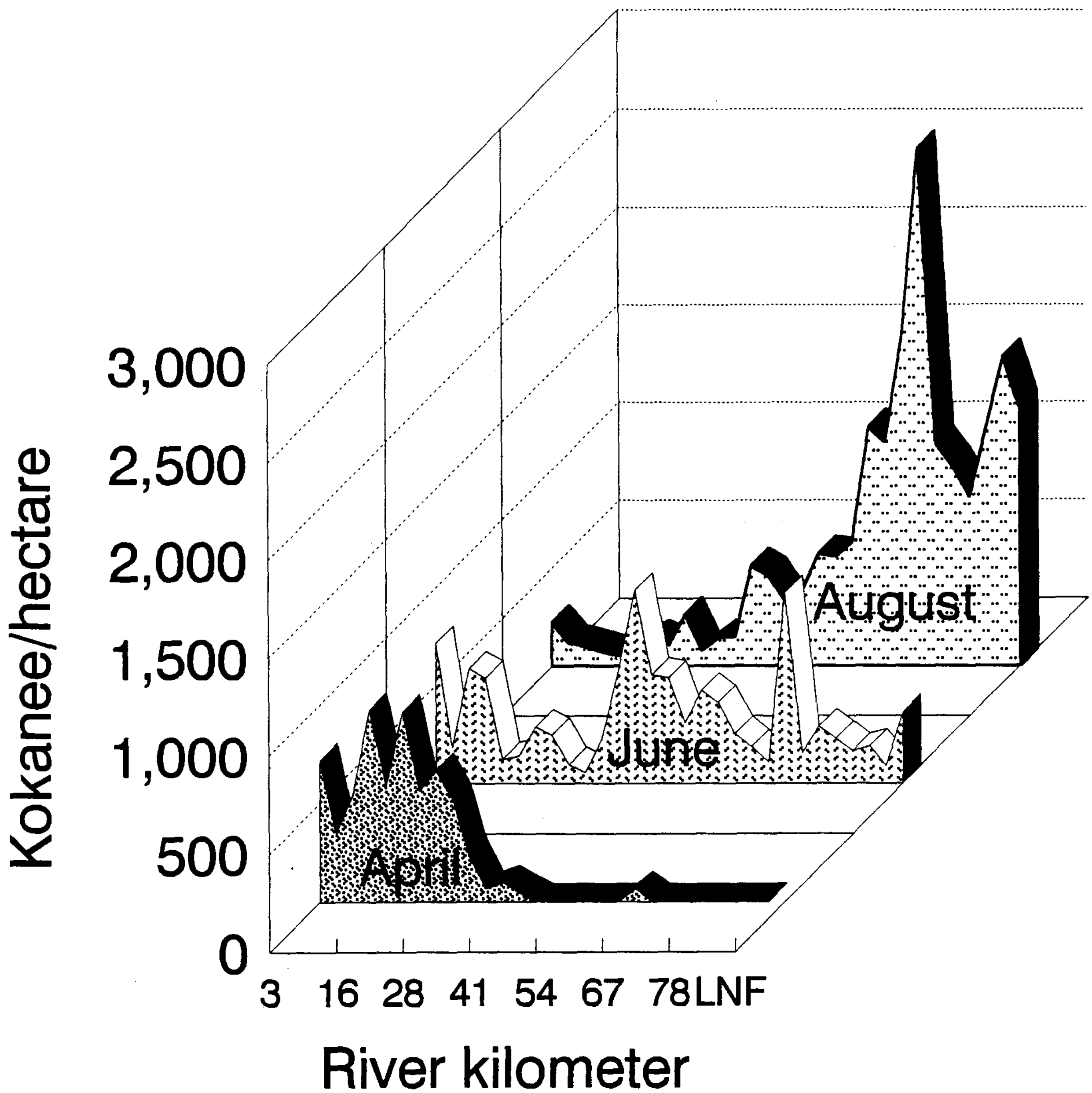

Figure 13. Age 1 and 2 kokanee distribution (target strength -48 to -33 dB) in Dworshak Reservoir, Idaho, for April, June, and August 1995.

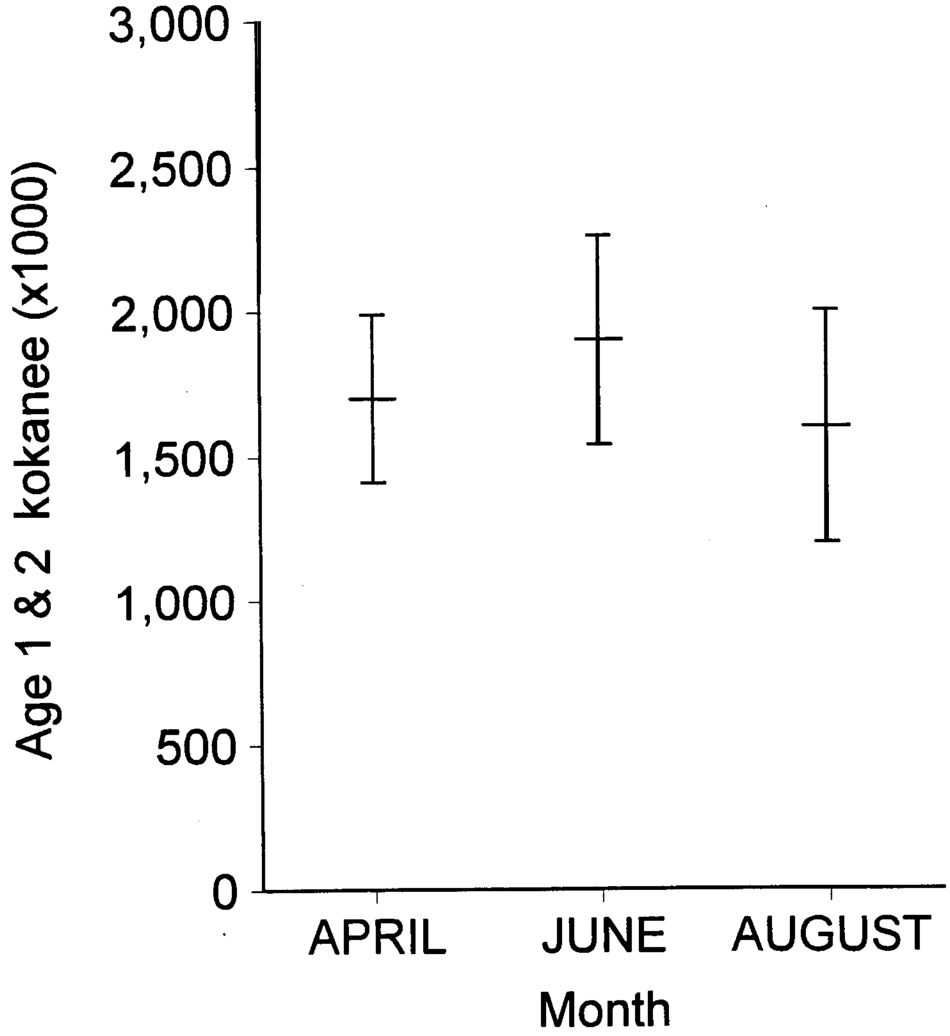

Figure 14. Population estimates of age 1 and 2 kokanee in Dworshak Reservoir, April, June, and August 1995. Bar depicts 90% confidence intervals.

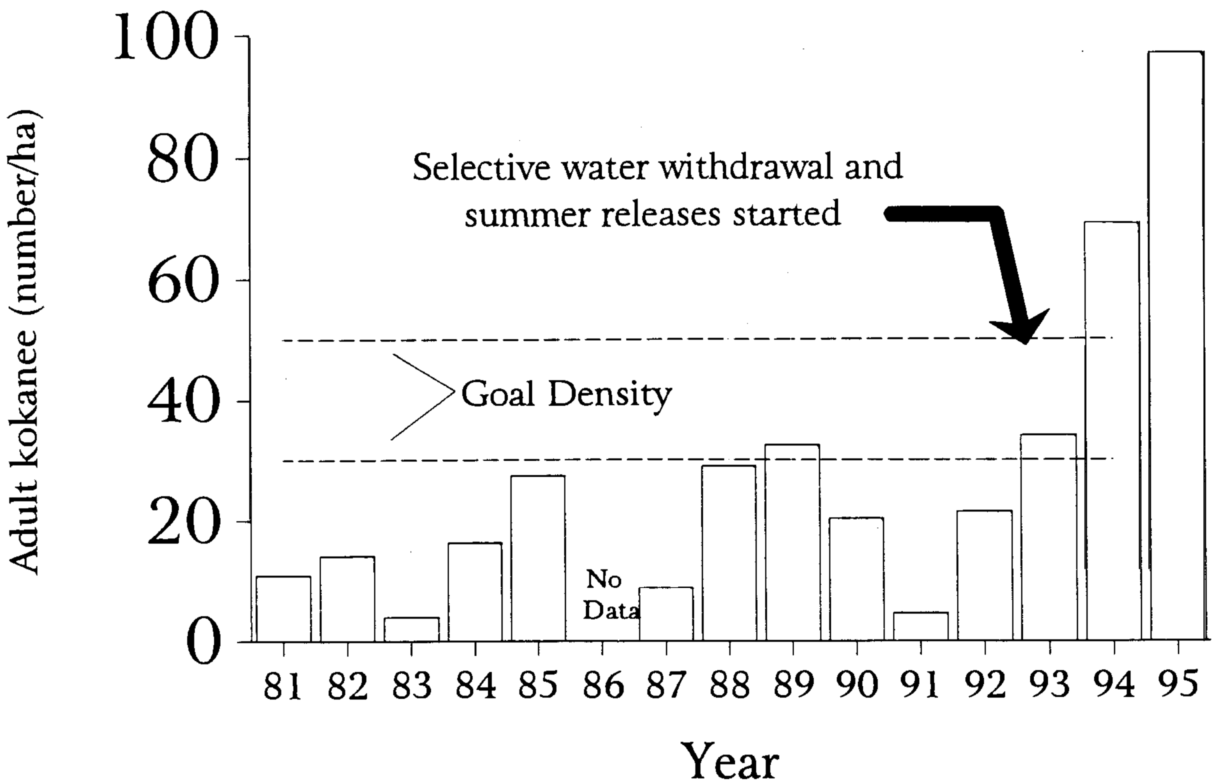

Figure 15. Adult kokanee densities from 1981 to 1995 in Dworshak Reservoir, Idaho.

outdoor raceways. From July to October, water was withdrawn from a depth heavily utilized by kokanee during the night and just below depths where kokanee concentrated during the day (Figures 9 and 10).

DISCUSSION

Selective Water Withdrawal and Entrainment

During the fall of 1994 and the winter of 1994-95, flows through Dworshak Dam were very low (Figure 3). This fact alone would have tended to minimize kokanee entrainment at a time of year when kokanee are concentrated in the lower reservoir. Flows out of the dam increased between April and June, which had the potential to entrain large numbers of kokanee. However, depth of water withdrawal was about 50 m whereas most kokanee were above the 15 m depth at night (Figure 9). Thus, the depth of water withdrawal should have helped to minimize losses of kokanee during the first large discharges in 1995. The benefits of utilizing selective withdrawal, however, have not been quantified. This should be considered for future work. In the meantime, we recommend utilizing selective water withdrawal, assuming positive benefits, particularly during the winter and early spring.

Kokanee Distribution and Entrainment Potential

A second increase in discharge occurred during July and August. During this time, water was withdrawn at the depth heavily utilized by kokanee (Figures 9 and 10). However, by this time of year age 1 and 2 kokanee had dispersed throughout the reservoir and age 0 kokanee were still in the upper section (Figures 12 and 13). Thus entrainment losses were minimized by the fish's horizontal distribution. We documented this lack of entrainment losses in our hydroacoustic population estimates (Figure 14). Age 1 and 2 kokanee densities remained high before, during, and after the large water releases in May, June, and July. We could determine no significant decline attributable to these drawdowns.

The result of avoiding these entrainment losses was a record high year class of fish. Our objective was to maintain kokanee densities at 30 to 50 adults/ha (based on trawling), with a mean size of 265 mm. This year it was 97 adults/ha. The consequence of exceeding this objective was that kokanee were smaller than desired (234 mm, mean total length of kokanee in the spawning run, n= 366 fish [Ralph Roseburg, United States Fish and Wildlife Service, unpublished data]). Under these conditions (high densities but smaller size) we would have expected no corresponding increase in angler catch-per-unit-effort (Rieman and Maiolie 1995).

This year's fish distribution would imply that entrainment of age 0 kokanee would be minor until sometime after August. Shifting the release of some of the reservoir's water from the August to November period to the May to July period, as they did in 1993 and 1994, could have caused a substantial increase in survival of fry for the last 3 years (Figure 3). The similar population estimates of age 0 fish in June and August also supported the conclusion that entrainment of fry was minimal during this time. Minimizing the winter discharges was likely to be one of the main reasons for the recent increase in kokanee abundance.

The critical period for the entrainment of age 1 and 2 kokanee appears to be between January and May when kokanee were concentrated in the lower section of the reservoir (Figure 13). This may be why historic releases of water in late winter and early spring entrained large numbers of kokanee (Horton 1981).

Target Strength Analysis

Age classes of kokanee proved to be difficult to interpret based on target strengths. We expected to see two peaks in the target strength-frequency distribution for April which corresponded to age 1 and age 2 kokanee. Multiple peaks were noted (Figure 8), but the smaller peak (-54 dB) was at a size which corresponded to a 40 mm fish; too small for age 1 kokanee, and too early in the year for age 0 kokanee. Burczynski and Johnson (1986) showed that age 0 sockeye salmon (45 mm fork length) had a target strength of -52 dB. Identity of these smaller objects remains unknown. Future studies should consider tows with larval fish nets when trying to analyze target strength distributions that include small fish. By August, three peaks in the target strength-frequency distribution were expected (Figure 8). The peak of the smallest group (-52 dB, the estimated size of a 44 mm fish based on Love's (1971) equation) appeared to be the correct size for age 0 kokanee. The other two peaks at -42 dB (140 mm) and -39 dB (200 mm) were close to what would be expected for age 1 and 2 kokanee.

The best method to analyze target strengths appeared to be by graphing the mean target strength of individual fish tracks (Figure 8). This method defined kokanee age classes better than a plot of all single fish traces.

The problem of distinguishing age classes of kokanee may have been caused by having a weak year class of age 1 fish. In Figure 8, the August data appears to show a small peak at -42 dB. Possibly this year class was so low that they did not show up as a distinct peak in the target strength-frequency distributions. Also, age 2 kokanee were small because of their high densities, which caused them to be less distinguishable from age 1 fish.

Kokanee Depth Distribution

It was our hope that the depth distribution of kokanee would be rather consistent from year to year. If that were the case, choosing future selector gate settings would be a simple matter of referencing figures of kokanee depth distribution, examining the water temperatures, and setting the gates accordingly.

However, depth distributions have shown marked differences between years. During February and March 1994, kokanee were very deep; 25 to 45 m (Maiolie and Elam 1994). This year (1995) they were shallow during these months; 5 to 25 m (Figure 9). Differences also occurred during spring run-off. In May 1994, fish were predominantly between 15 and 25 m, but in 1995 they were from 3 to 10 m. Our recommendation is to measure kokanee depths monthly before deciding on selector gate settings.

CONCLUSIONS

Results from 1993, 1994, and 1995 were very promising. Water can be withdrawn from the dam at depths that are above or below most kokanee. Current temperature considerations do not limit the use of selective withdrawal during the winter and spring when kokanee are concentrated in front of the dam. And lastly, the change in the timing of reservoir drawdown, along with the use of selective water withdrawal, has been shown to increase kokanee abundance beyond our project objectives. What remains to be tested, however, is whether or not kokanee densities can be maintained in wetter than normal water years when discharge is high.

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. Continued use of the gates during different water years and discharge patterns will greatly aid our understanding of entrainment losses.

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

3. Data on the use of selective withdrawal should be incorporated into a series of "biological 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.

4. Fish entrainment rates 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.

5. 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 Dworshak National Fish Hatchery, resident fish, and anadromous fish. This would simplify the choice of where to locate the selector gates.

ACKNOWLEDGMENTS

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

EY500 MENUS

Operation Menu

Ping mode	Normal
Ping Auto Start	Off
Ping Interval	0.7s

Disk Menu

Log	Off
Max File Size	2 Mb

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	20 log R

Display Menu

Colour Set	Light
Event Marker	Off
Echogram Speed	1:1
Echogram	On

Echogram Menu

Echogram Menu

Transd. Number	1
Range	100 m
Range Start	0 m
Auto Range	Off

Bottom Range 0 m Sot.
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	Off

Integration Line Off

TS Colour Min.	-60 dB
Sv Colour Min.	-60 dB

Printer Menu

Navig. Interval Event
Marker Annotation
Naut. Mile Marker TS
Distribution Integr.
Tables Echogram Speed
Echogram
Echogram Menu

Echogram Menu

Transd. Number
Range
Range Start
Auto Range Bottom
Range Bot. Range
Start Bot. Range
Pres. Sub. Bottom
Gain Presentation
TVG
Scale Lines
Bot. Det. Line
Layer lines
Integration Line
TS Colour Min. Sv
Colour Min.

Transceiver Menu 120 kHz

Mode
Transducer Depth
Transd. Sequence
Absorption Coef.
Pulse Length
Bandwidth
Max. Power
2-Way Beam Angle
Sv Transd. Gain
TS Transd. Gain
Angle Sensitiv. 3
dB Beamwidth
Alongship Offset
Athw.ship Offset

Bottom Detection Menu

Minimum Depth
Maximum Depth Min.
Depth Alarm Max.
Depth Alarm Bottom
Lost Al. Minimum
Level

Log Menu

Mode
Ping Interval
Time Interval
Dist. Interval
Simulator Speed
Distance

0
Off
Off
Off
Off
Off
1:1
Off

1
100 m
0 m
Off
10 m
5 m
Off
0.0 dB/m
Normal
40 log R
10
On
Off
Off
– 60 dB
-60 dB

Active
0.53 m
Off
0 dBkm
Medium
Wide
60 **W** -
20.8 dB
–26.1
dB*
–26.1
dB* 21.0
9.0 dg -
0.07 dg -
0.06 dg

0.0 m
300 m
0.0 m
0 m
Off
-50 dB

Time
100
300 sec
0.5 nm
5.0 knt

Layer Menu

Super Layer	10
Layer-X Menu	**1,2,3...**
Type	Pelagic
Range	10.0 m
Range Start	1,10,20m
Margin	1.0 m
Sv Threshold	-60 db

TS Detection Menu

Min. Value	-60 dB
Min. Echo Length	0.8
Max. Echo Length	1.8
Max. Gain Comp.	4.0 dB
Max. Phase Dev.	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

MART 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
Sot. Range Start	10 m
No. of Main Val.	250
No. of Sot. Val.	75
TVG	40 log R

Annotation Menu

Event Counter	0
Time Interval	0 min
Text	

Navigation Menu

Start Sequence	$GPGLL
Separation Char.	002C
Stop Character	000D
First Field No.	2
No. of Fields	4
Baudrate	4800
Bits Per Char.	8
Stop Bits	1
Parity	None

Utility Menu

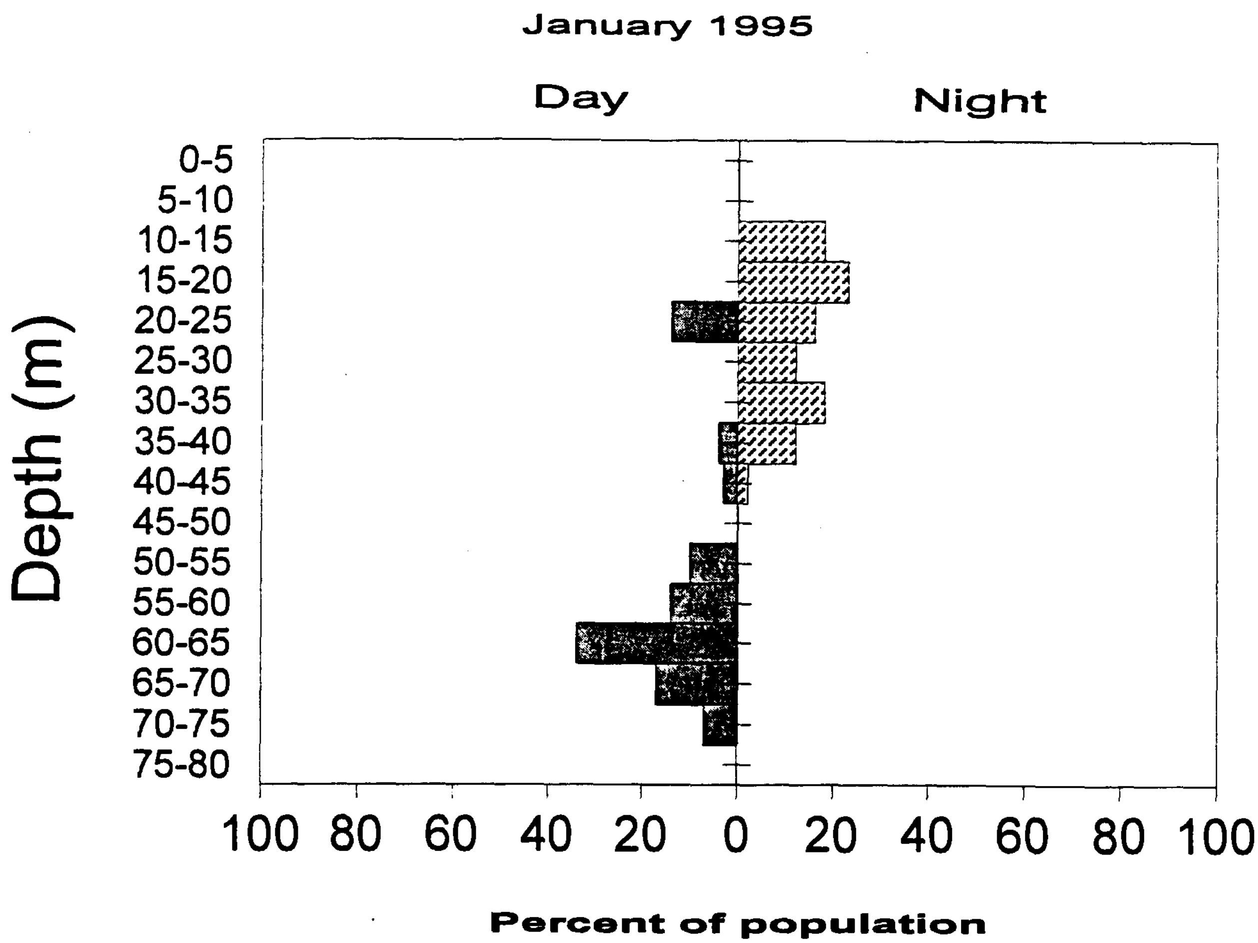
Beeper	On
Status Messages	On
Date	yy.mm.dd
Time	hh.mm.ss
Password	0
Default Setting	NO
Sound Velocity	1450 m/s
COM1/COM2 Switch	Off

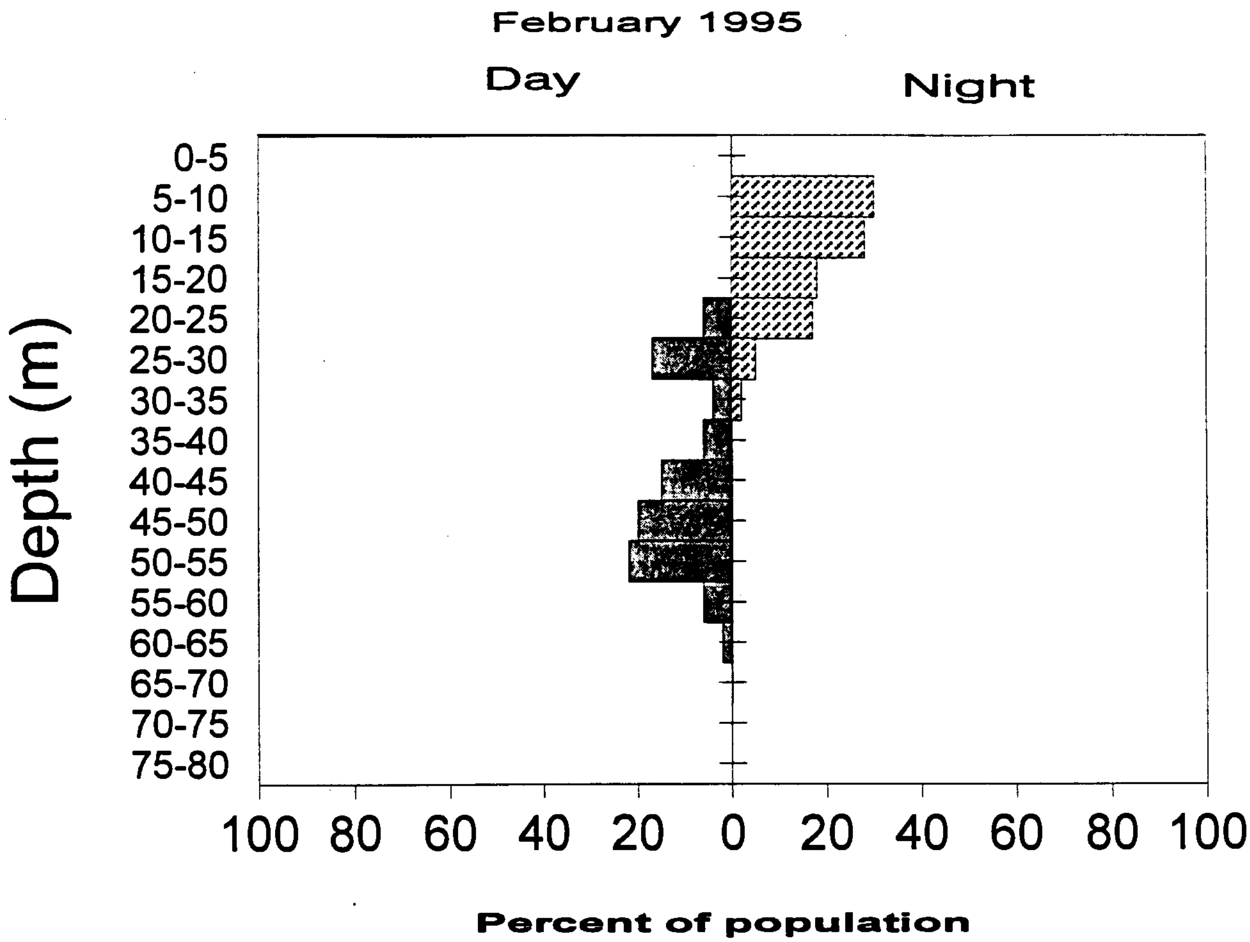
Test Menu

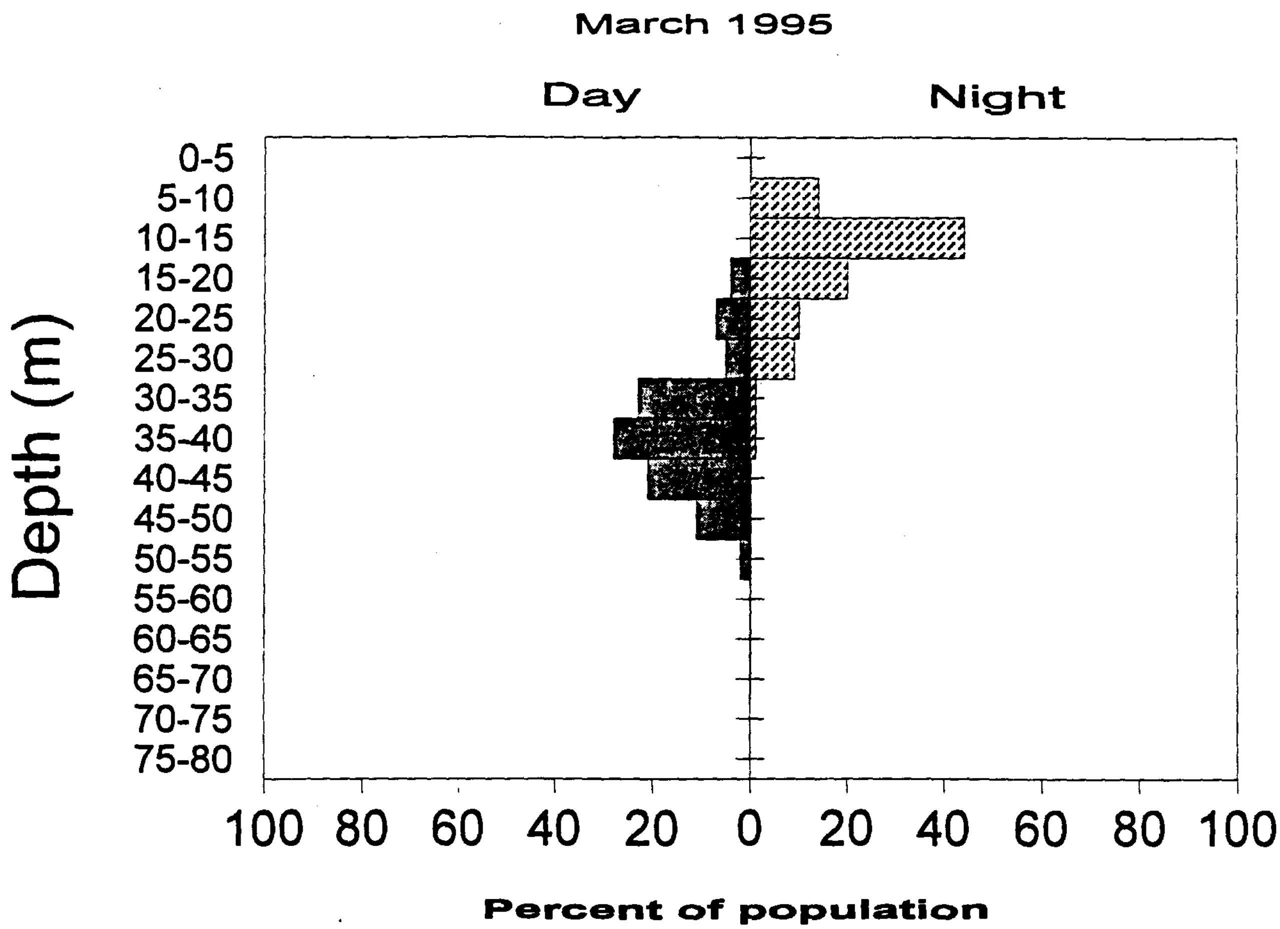
Message	
Transceiver	
Version	4.01
Scope	
Simrad	

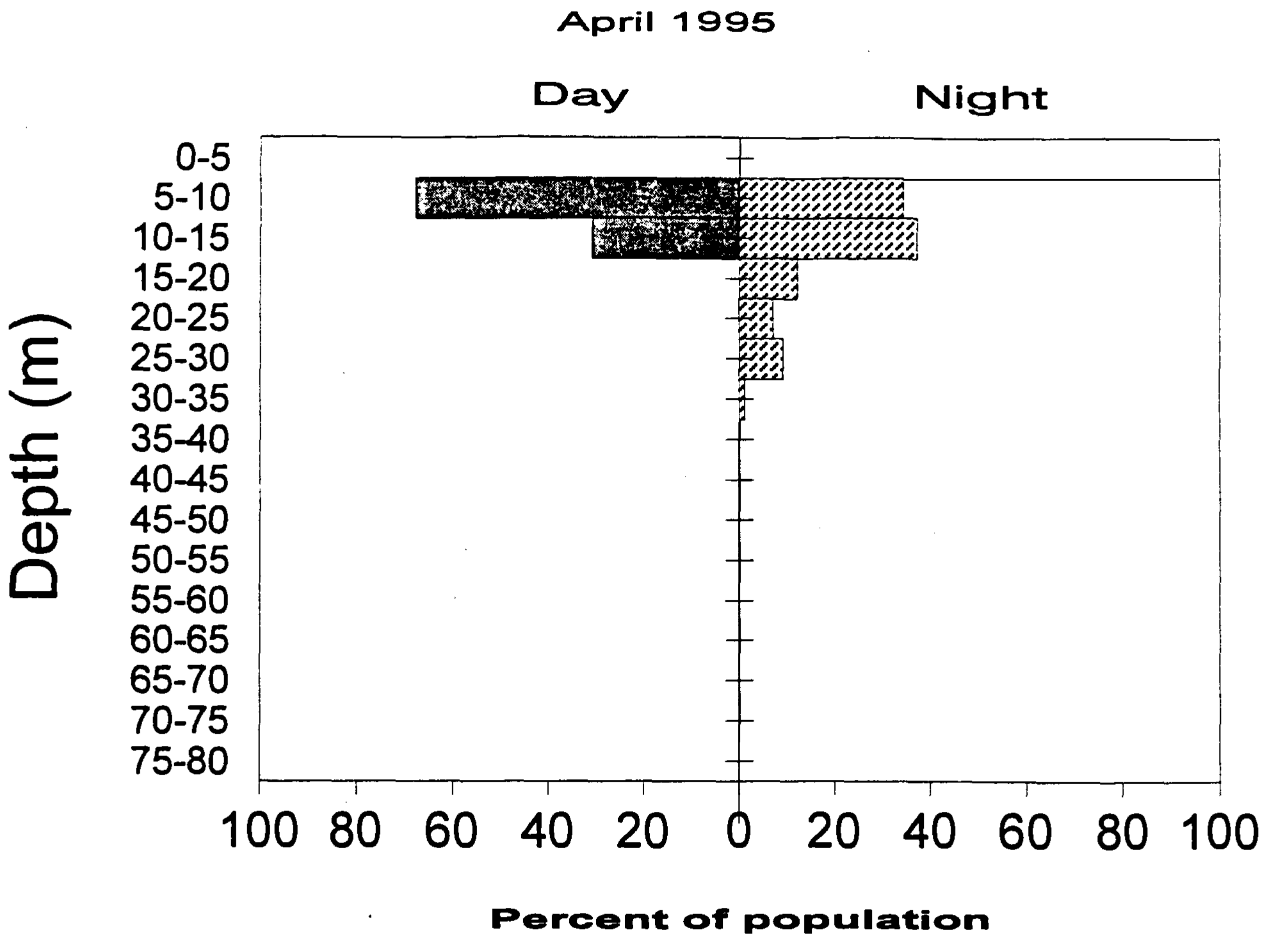
* - Setting changed by month depending on temperature.

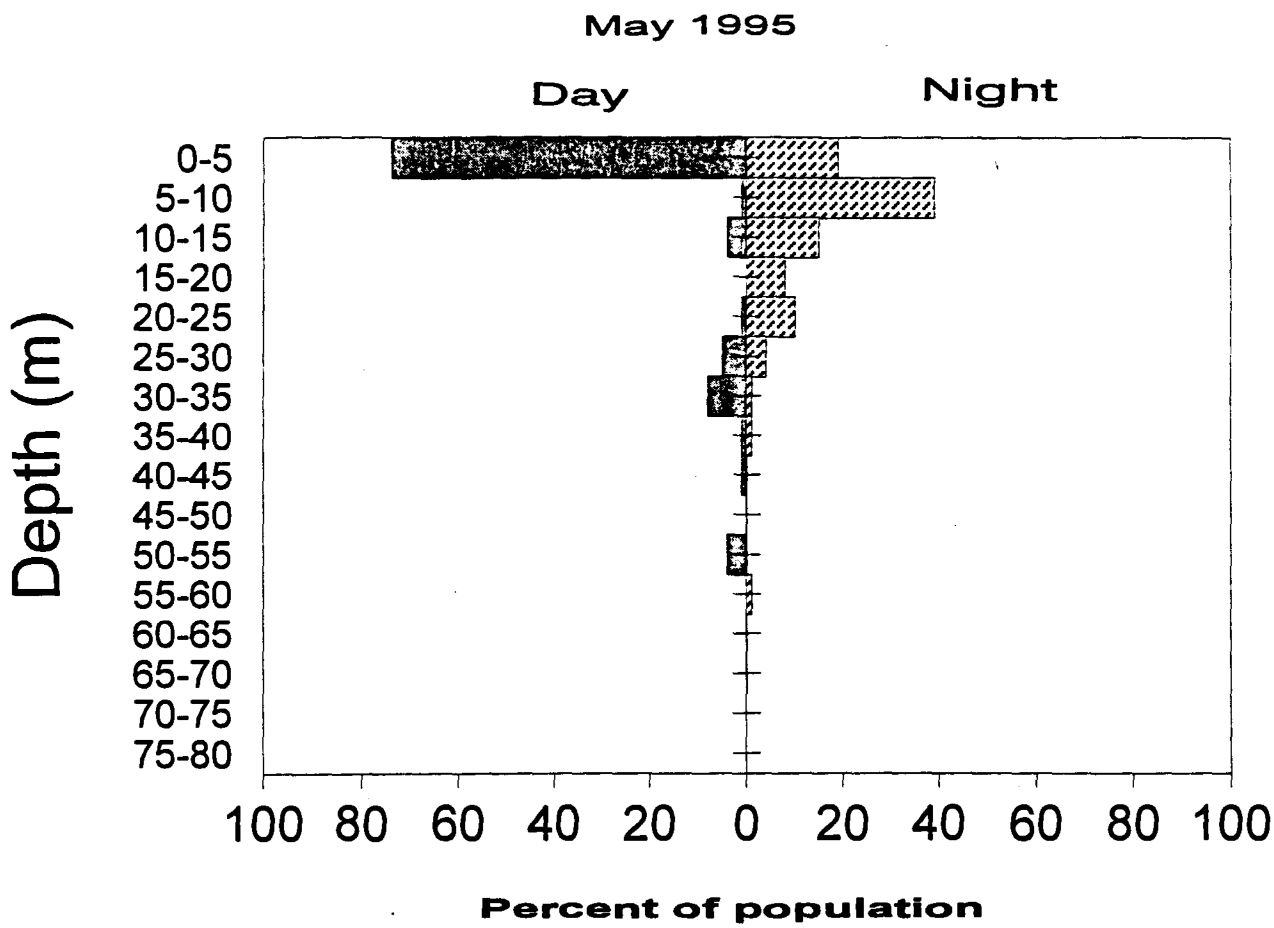
Appendix B.
Monthly depth distributions of kokanee near Dworshak Dam during the day and at night.


January 1995
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
Depth (m)
100 80 60 40 20 0 20 40 60 80 100
Percent of population

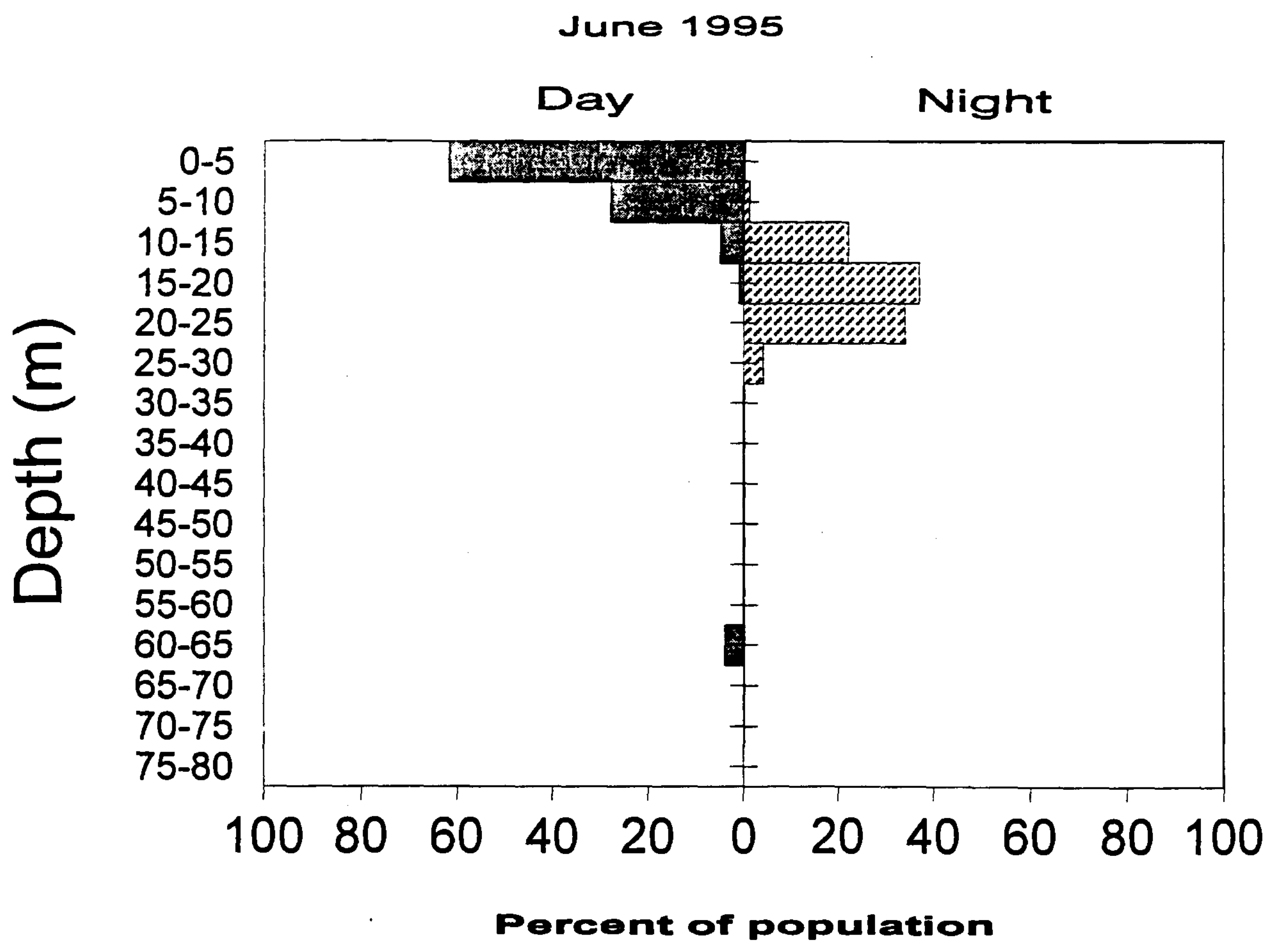

February 1995
Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
100 80 60 40 20 0 20 40 60 80 100
Percent of population

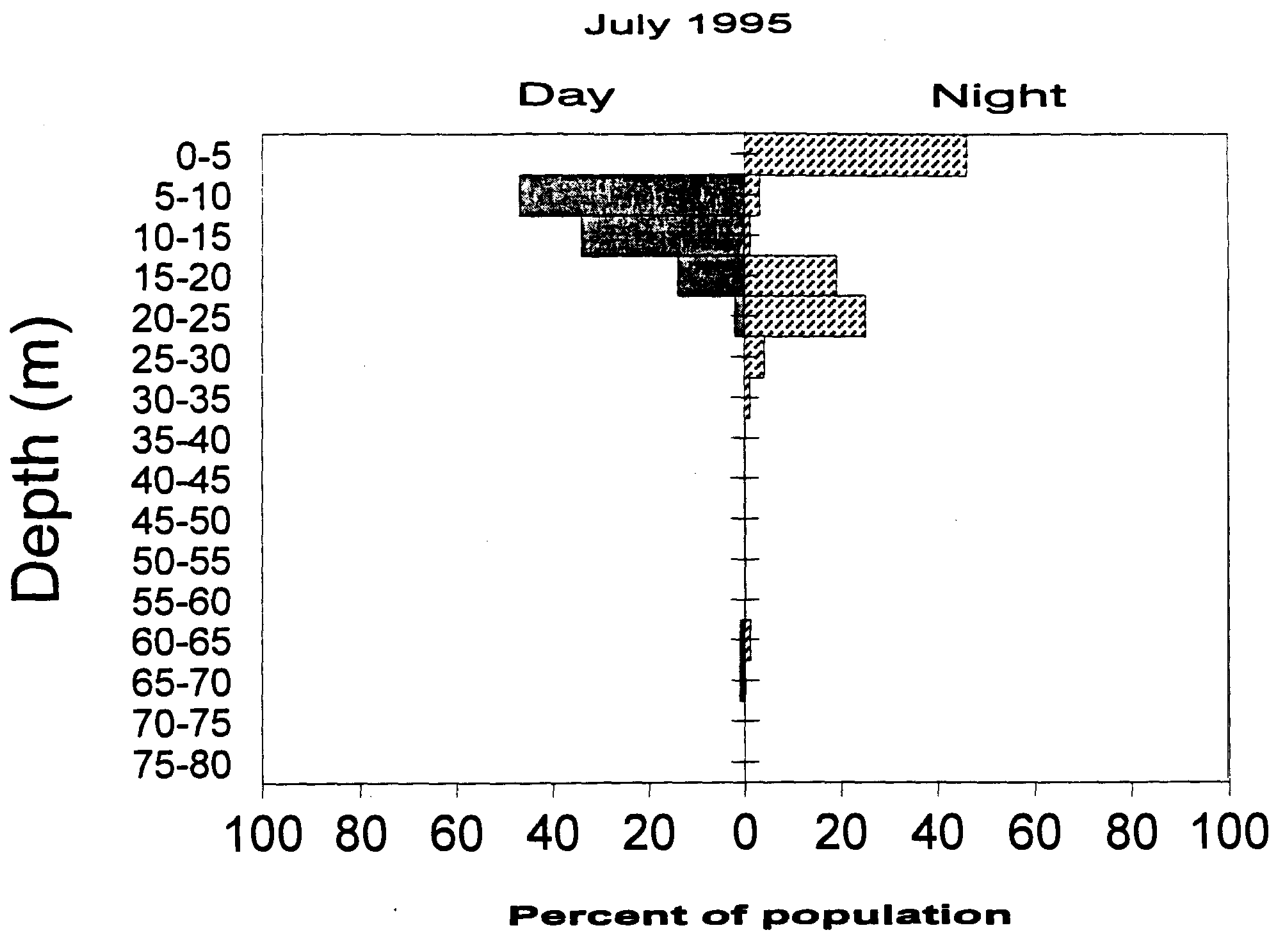

March 1995
Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
100 80 60 40 20 0 20 40 60 80 100
Percent of population

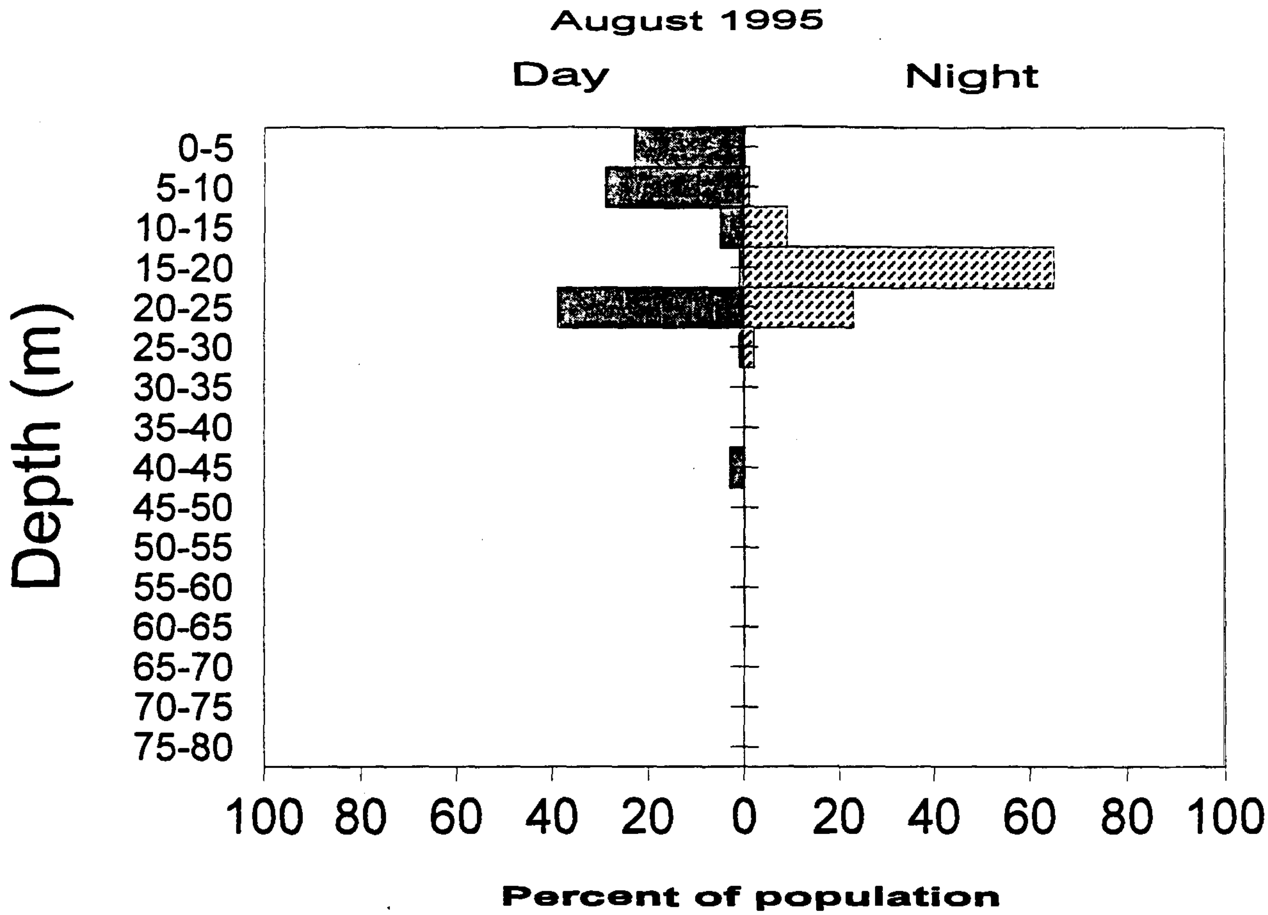

April 1995
Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
100 80 60 40 20 0 20 40 60 80 100
Percent of population

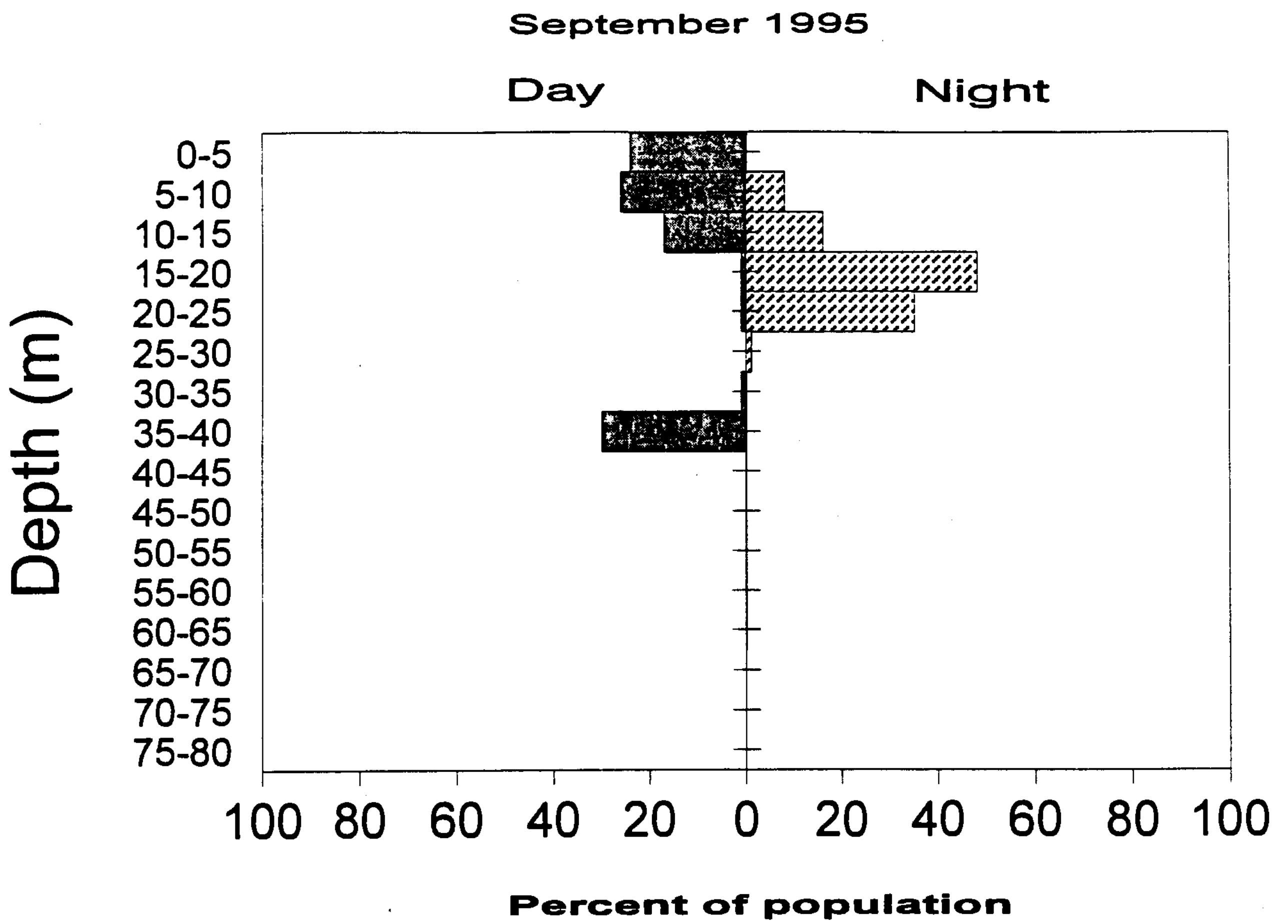


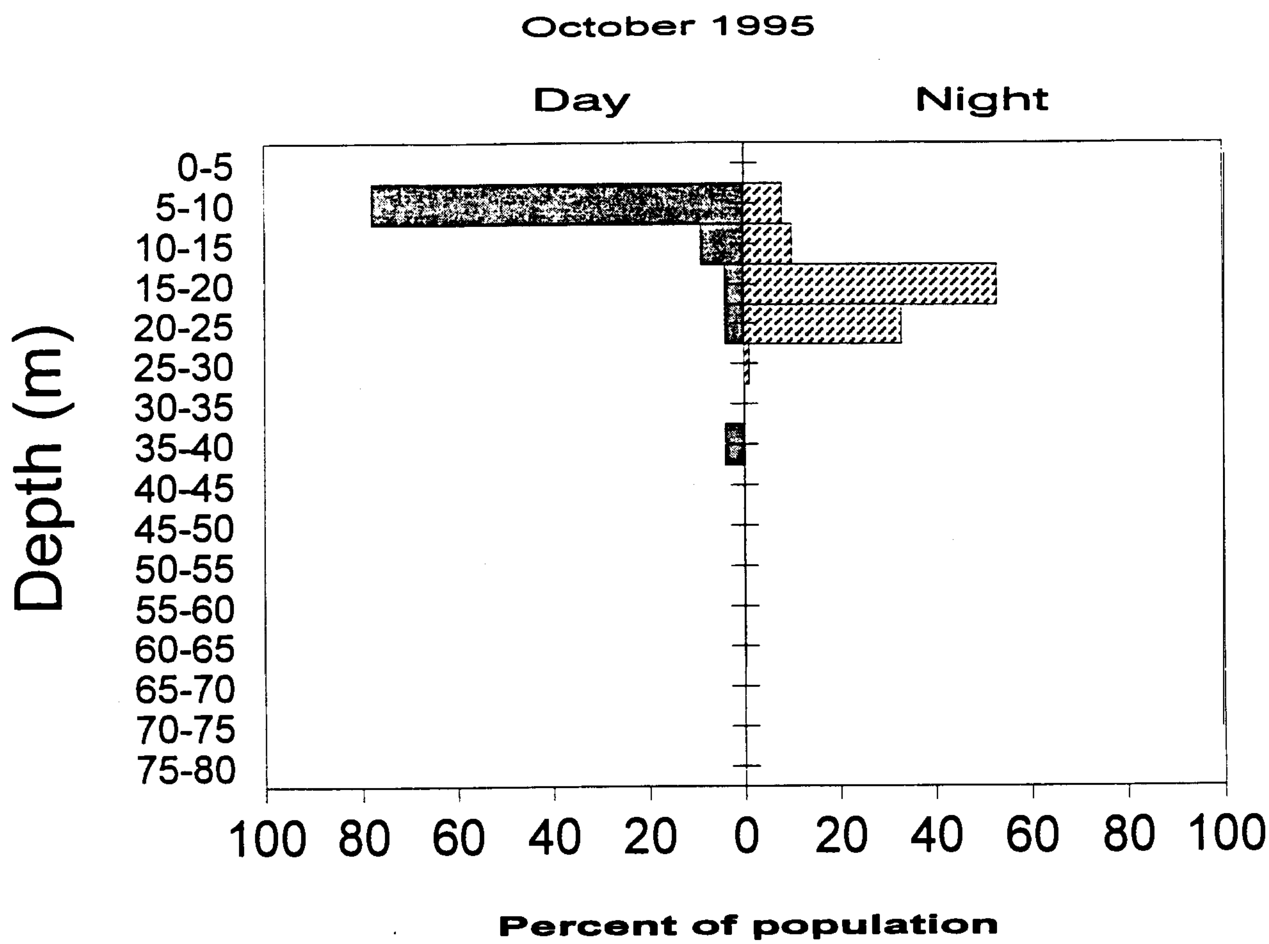
May 1995
Day
Night
Depth (m)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
100 80 60 40 20 0 20 40 60 80 100
Percent of population


June 1995
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
100 80 60 40 20 0 20 40 60 80 100
Percent of population


July 1995
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
100
80
60
40
20
0
20
40
60
80
100
Percent of population


August 1995
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
100 80 60 40 20 0 20 40 60 80 100
Percent of population


September 1995
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
100 80 60 40 20 0 20 40 60 80 100
Percent of population


October 1995
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
100 80 60 40 20 0 20 40 60 80 100
Percent of population

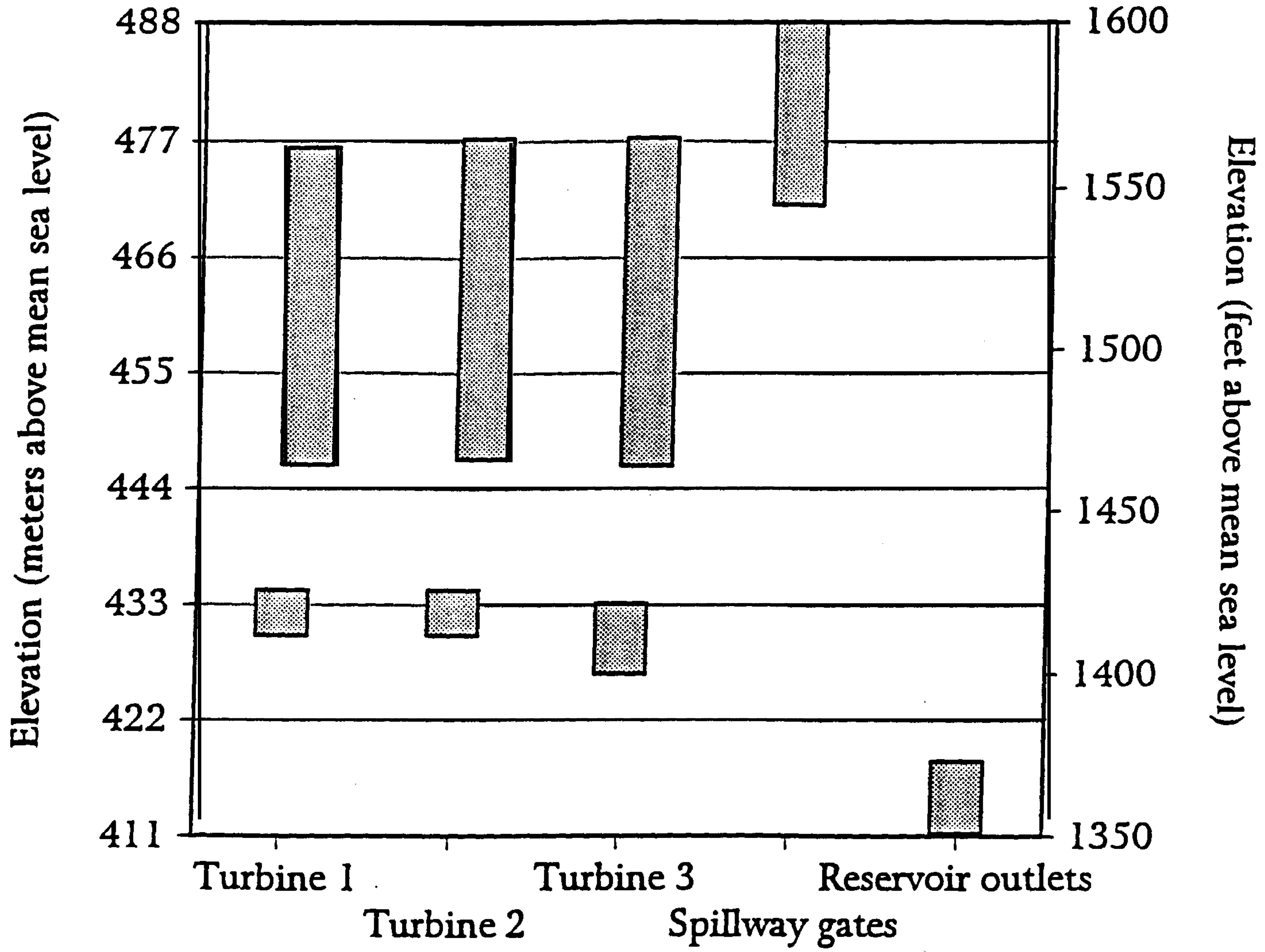
Appendix C.
Dworshak Reservoir forebay water temperatures for 1995.

Temperatures in Celsius

Depth (m)	Jan 95	Feb 95	Mar 95	Apr 95	May 95	Jun 95	Jul 95	Aug 95	Sep 95	Oct 95
Surface	4.2	5	5	7.8	13.3	17	23.2	20.5	16.5	13
1	4.2	5	4	6.9	12.5	17	23	20.5	16.5	13
2	4.2	5	4	6.2	12.1	16.8	22	20.5	16.5	13
3	4.2	4.5	4	5.9	11.9	16.2	21.8	20.5	16.5	12.9
4	4.2	4	4	5.8	11.2	16	21.2	20.5	16.5	12.8
5	4.2	4	4	5.8	10.8	15.2	19.4	20.5	16.4	12.8
6	4.2	4	4	5.8	9.6	14.6	15.4	20.3	16.3	12.7
7	4.2	4	4	5.8	9	13.5	14.1	20.3	16.3	12.7
8	4.2	4	4	5.8	8.2	12.2	13.5	17.4	16.3	12.6
9	4.2	4	4	5.8	7.5	11.8	13.2	15.9	16.3	12.5
10	4.2	4	4	5.6	7.3	11.7	12.3	14.8	14.8	12.3
11	4.2	4	4	5.5	7.2	10.7	11.8	13.9	12.2	10
12	4.2	4	4	4.9	7	9.4	11.2	12.5	11	9.3
13	4.2	4	4	4.5	6.9	9	11	12	10.2	8.7
14	4.2	4	4	4.2	6.8	8.8	10.8	11.1	9.2	8.1
15	4.2	4	4	4.2	6.5	8.5	10.3	10.8	8.9	8
16	4.2	4	4	4.2	6.2	8.3	10	10	8.4	7.7
17	4.2	4	4	4.1	6.1	8.2	9.9	9.5	8	7.2
18	4.2	4	4	4	6	8.1	9.5	9	7.8	7
19	4.2	4	4	4	6	8	9.2	8.8	7.4	7
20	4.2	4	4	4	5.9	7.8	9	8.5	7.2	6.9
21	4.2	4	4	4	5.8	7.8	8.9	8.2	7	6.8
22	4.2	4	4	4	5.8	7.5	8.6	8	6.9	6.4
23	4.2	4	4	4	5.6	7.3	8.2	7.9	6.8	6.1
24	4.2	4	4	4	5.2	7.2	8	7.7	6.6	6
25	42.	4	4	4	4.9	7.2	7.9	7.4	6.3	5.8
26	4.2	4	4	3.9	4.8	7.1	7.8	7.3	6.2	5.5
27	4.2	4	4	3.9	4.6	7	7.7	7.2	6	5.2
28	4.2	4	4	3.9	4.4	7	7.5	7	5.9	5
29	4.2	4	4	3.9	4.2	7	7.4	6.9	5.3	5
30	4.2	4	4	3.9	4.2	6.8	7.2	6.8	5.2	4.9

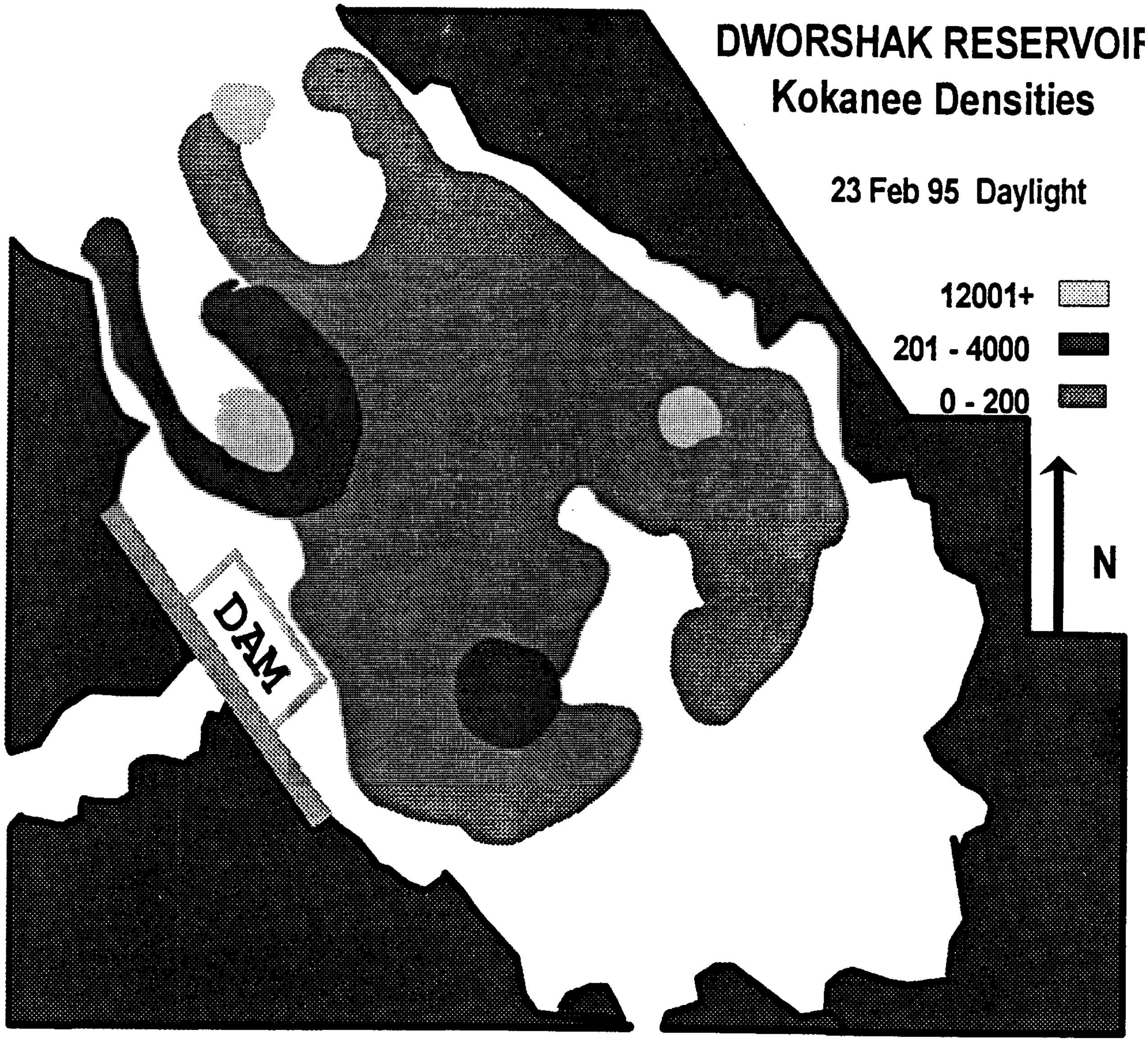
31	4.2	4	3.8	4	6.6	7.2	6.7	5	4.8
32	4.2	4	3.8	4	6.5	7.1	6.6	5	4.8
33	4.2	4	3.8	4	6.4	7	6.3	4.9	4.6
34	4.2	4	3.8	4	6.2	6.9	6.2	4.8	4.3
35	4.2	4	3.8	4	6.1	6.8	6	4.6	4.2
36	4.2		3.8	4	6	6.7	5.9	4.3	4.1
37	4.2	4	3.8	3.9	6	6.5	5.8	4.2	4
38	4.2	4	3.8	3.9	5.9	6.3	5.7	4.2	4
39	4.2		3.8	3.9	5.8	6.2	5.4	4	4
40	4.2	4	3.8	3.9	5.8	6.1	5.2	4	4
41	4.2		3.8	3.9	5.6	6	5.1	4	4
42	4.2		3.8	3.8	5.3	5.8	5	4	3.9
43	4.2		3.8	3.8	5.2	5.6	4.9	4	3.9
44	4.2		3.8	3.8	5	5.4	4.8	4	3.9
45	4.2		3.8	3.8	4.9	5.3	4.7	4	
46	4.2		3.8	3.8	4.8	5.2	4.5	4	
47	4.2		3.8	3.8	4.7	5.1	4.3	4	
48	4.2		3.8	3.8	4.5	5	4.2		
49	4.2		3.8	3.8	4.3	4.9	4.2		
50	4.2		3.8	3.8	4.2	4.7	4.1		
51	4.2		3.8	3.8	4.2	4.3	4		
52	4.2		3.8	3.8	4.2	4.2	4		
53	4.2		3.8	3.5	4.1	4.2	4		
54	4.2		3.8		4.1	4.1	4		
55	4.2		3.8		4.1	4.1	4		
56	4.2		3.8		4	4	4		
57	4.2		3.8		4	4	3.9		
58	4.2		3.8		4	4	3.9		
59	4.2		3.8		3.9	4	3.9		
60	4.2		3.8						

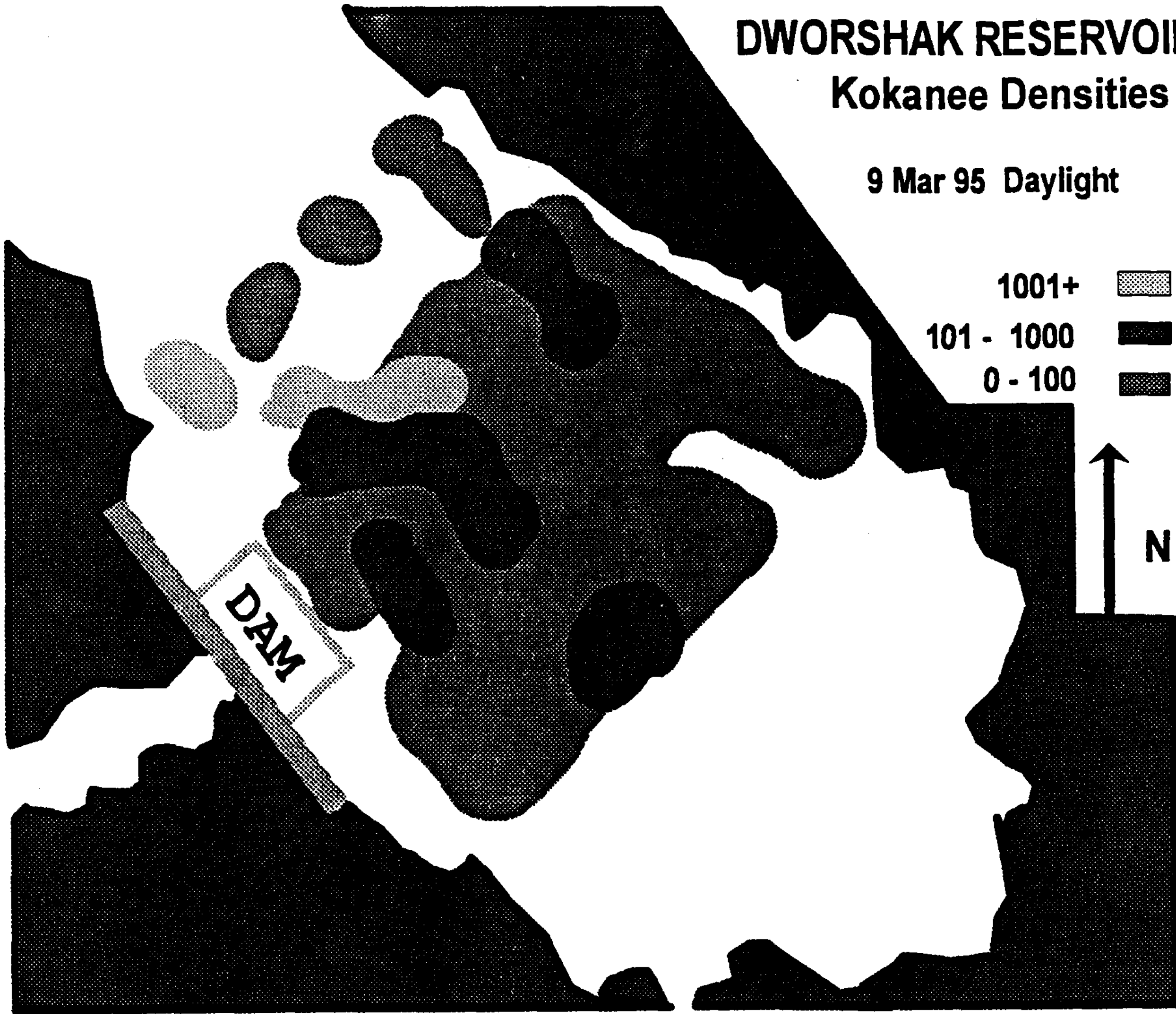
Appendix D.
Possible elevations (shaded squares) where water could be withdrawn from Dworshak Reservoir, Idaho.

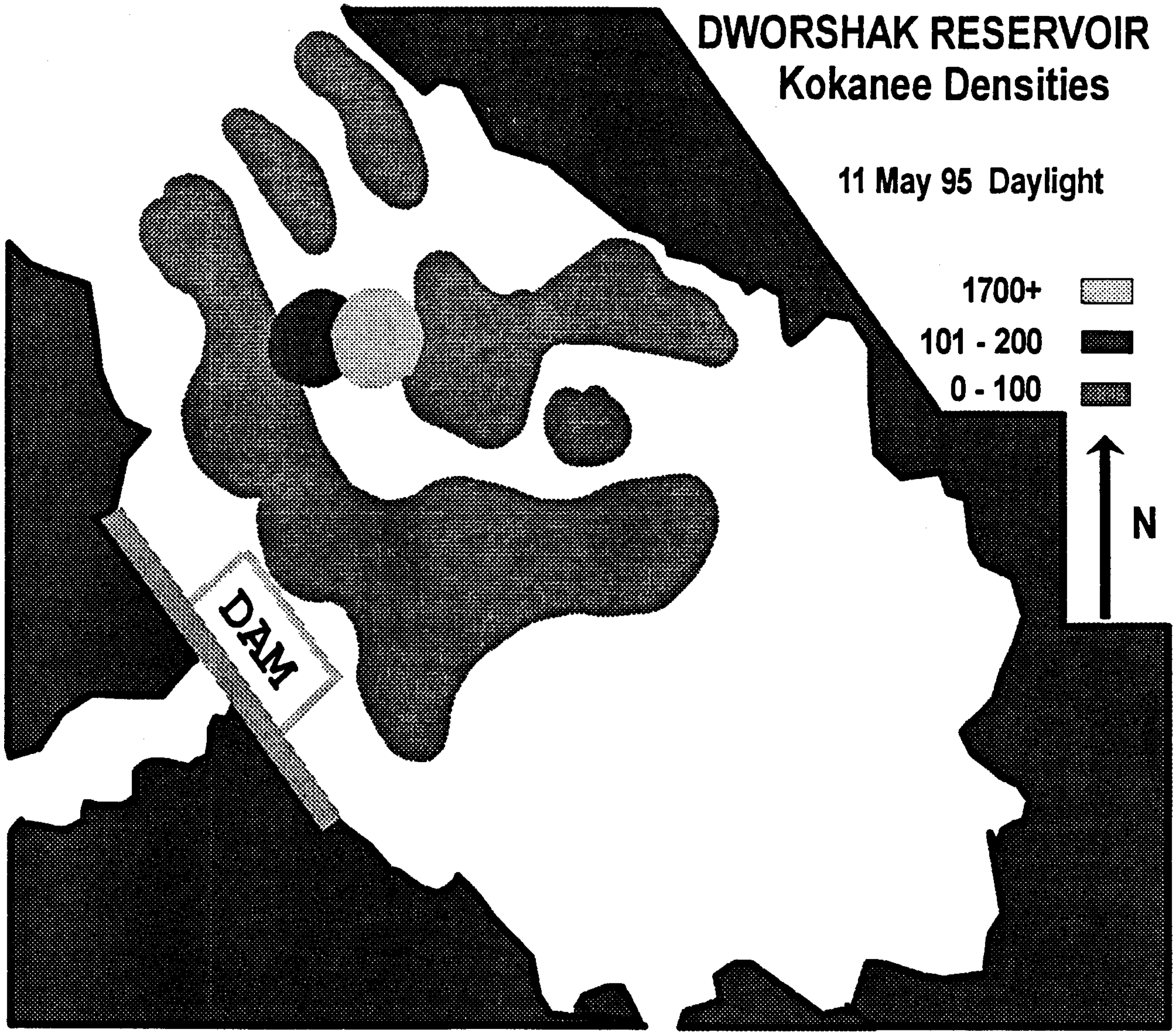

Elevation (meters above mean sea level)
488
477
466
455
444
433
422
411
Elevation (feet above mean sea level)
1600
1550
1500
1450
1400
1350
Turbine 1
Turbine 2
Turbine 3
Spillway gates
Reservoir outlets

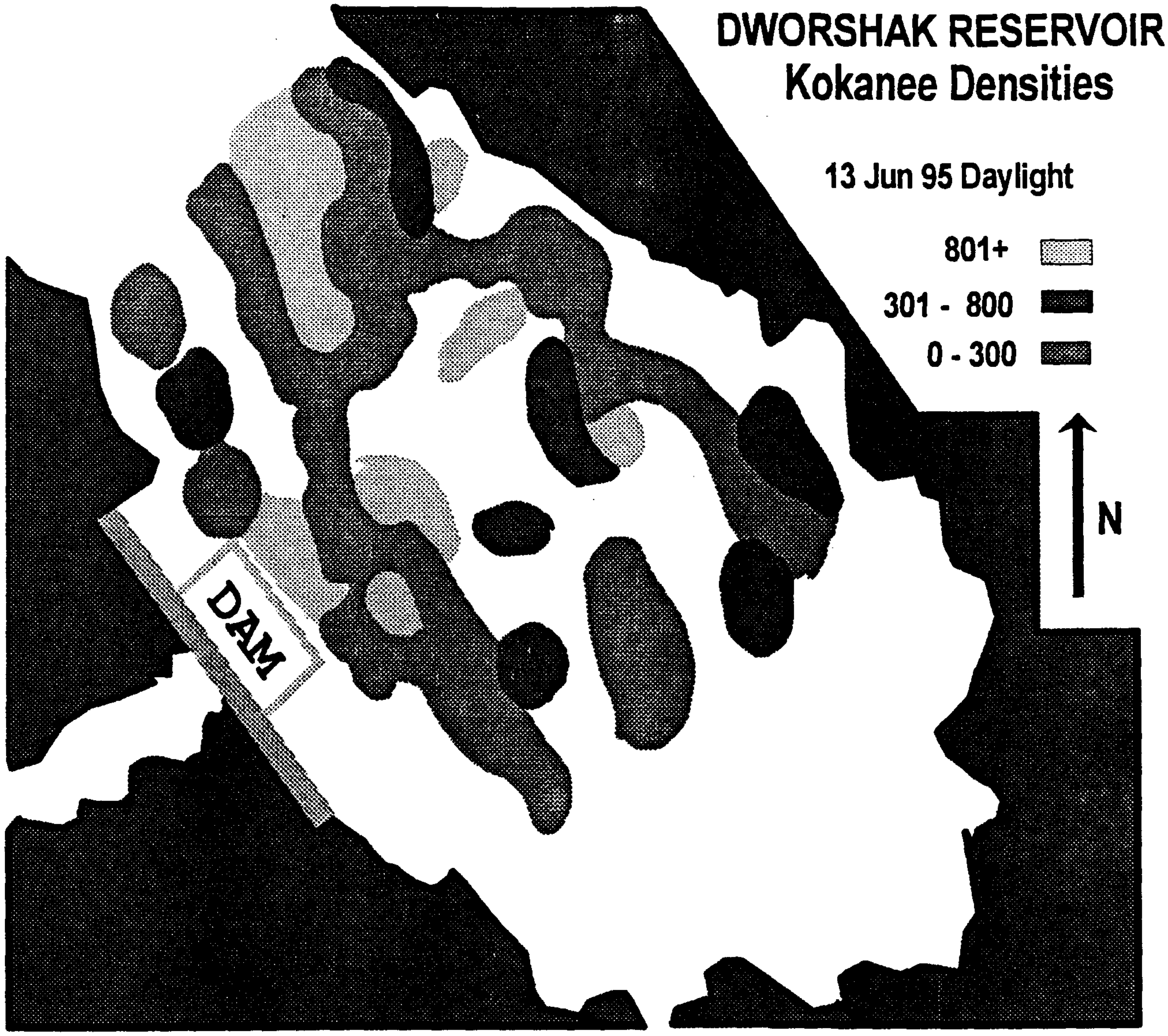
Appendix E.
Distribution of kokanee in the forebay
of Dworshak Reservoir during the day.

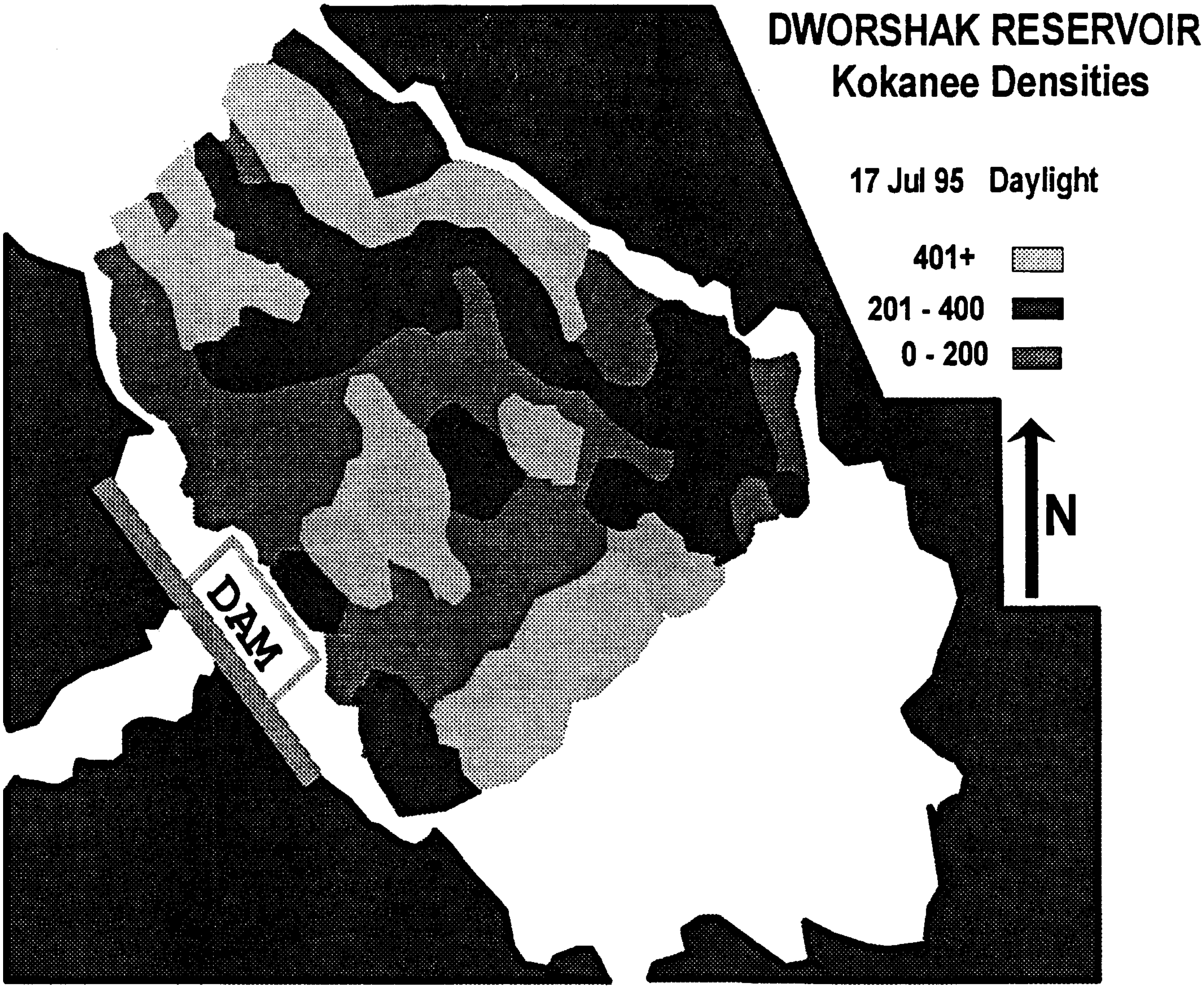

DWORSHAK RESERVOIR
Kokanee Densities
12 Jan 95 Daylight
501+
101 - 500
0 - 100
N
DAM

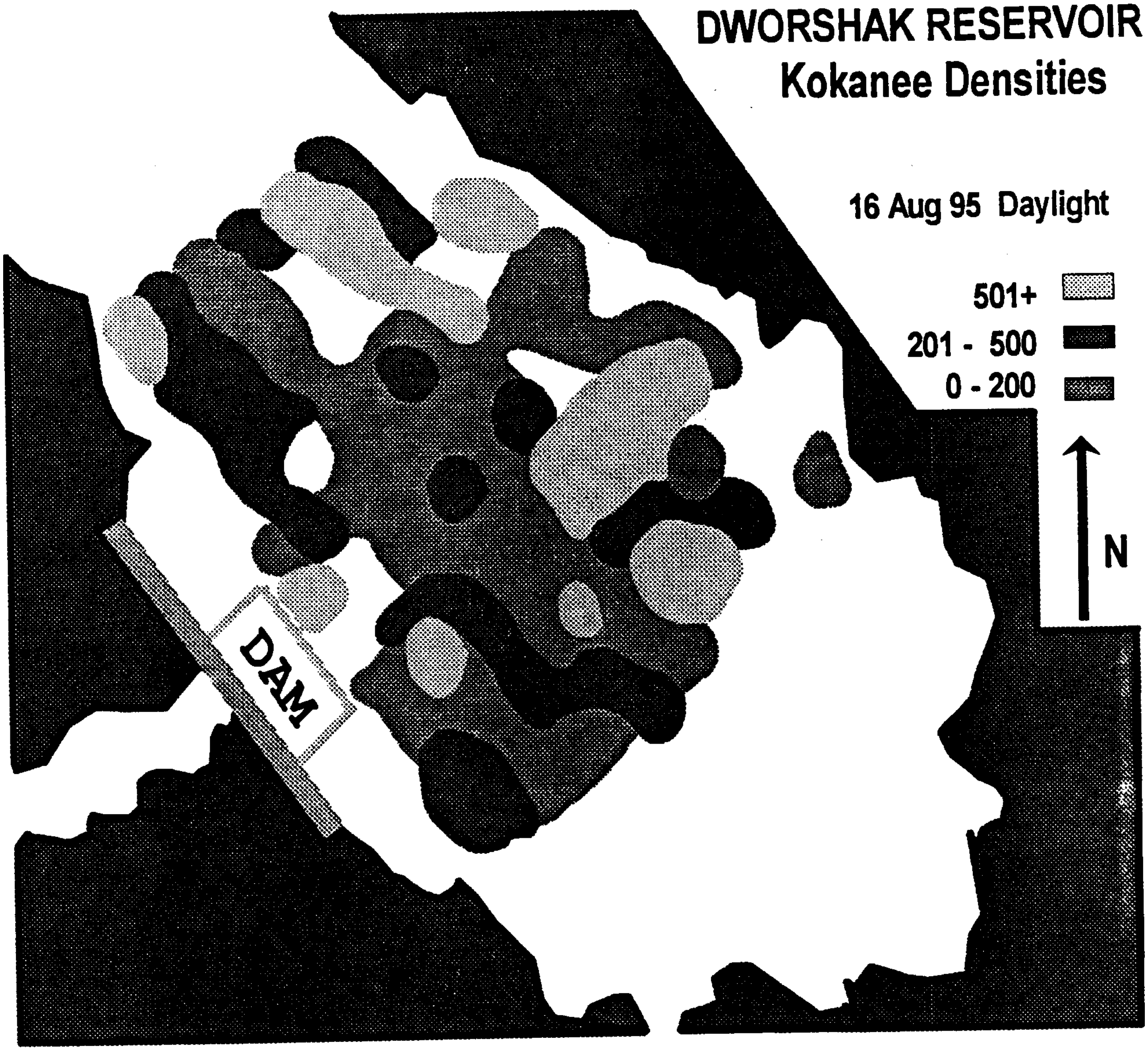

DWORSHAK RESERVOIR
Kokanee Densities
23 Feb 95 Daylight
12001+
201 - 4000
0 - 200
N
DAM

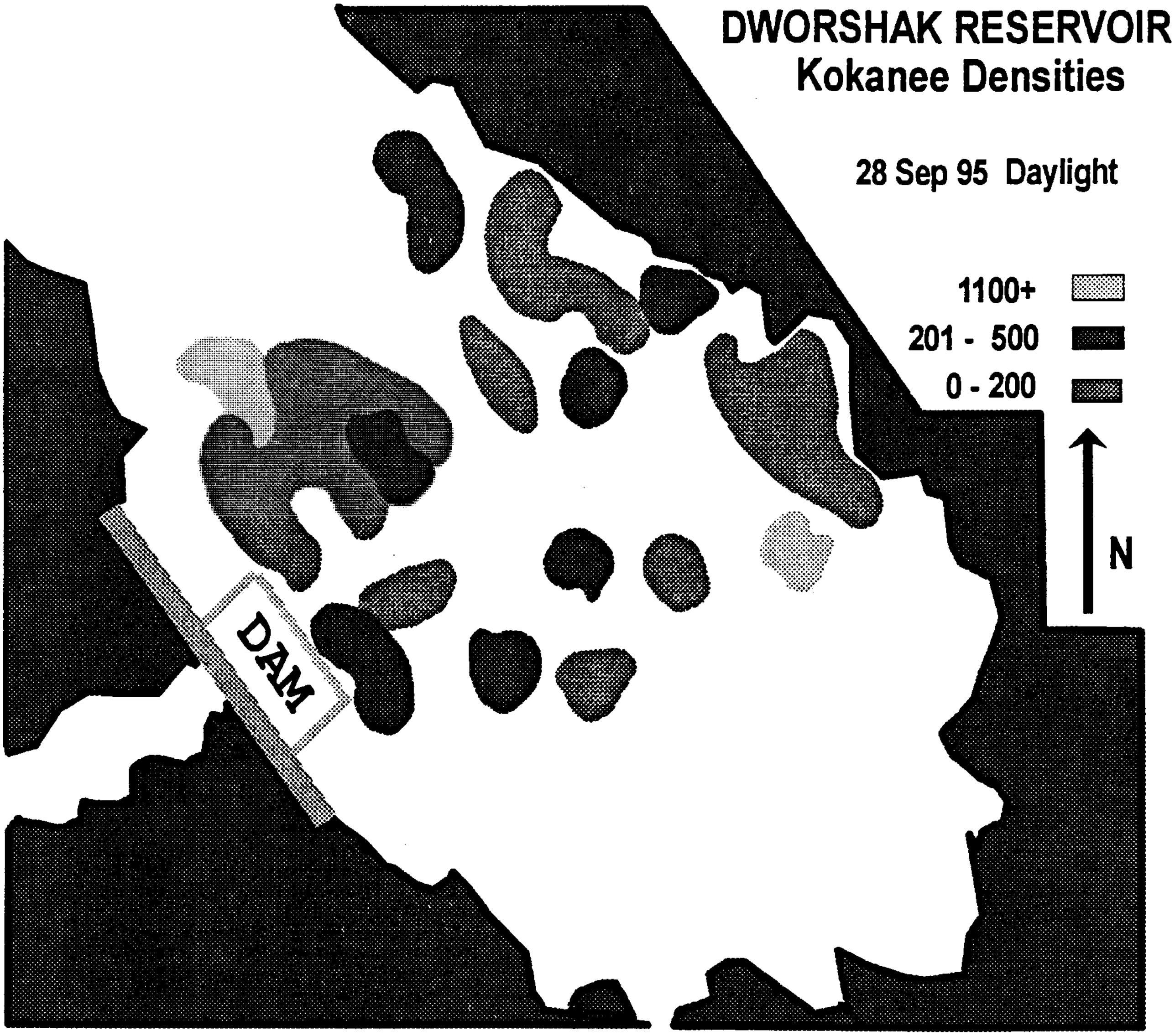

DWORSHAK RESERVOIR
Kokanee Densities
9 Mar 95 Daylight
1001+
101 - 1000
0 - 100
N
DAM

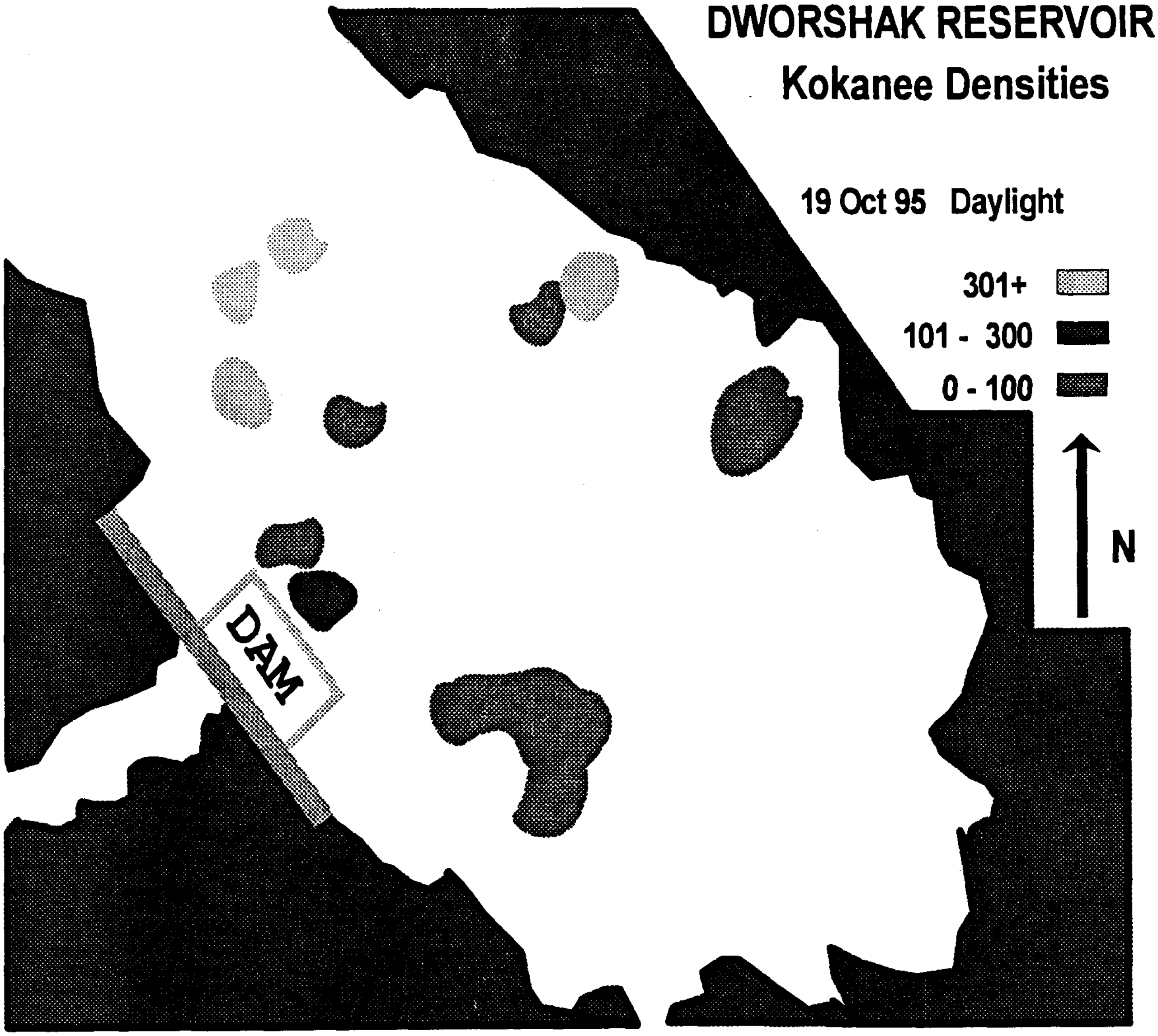

DWORSHAK RESERVOIR
Kokanee Densities
11 May 95 Daylight
1700+
101 - 200
0 - 100
N
DAM


DWORSHAK RESERVOIR
Kokanee Densities
13 Jun 95 Daylight
801+
301 - 800
0 - 300
N
DAM

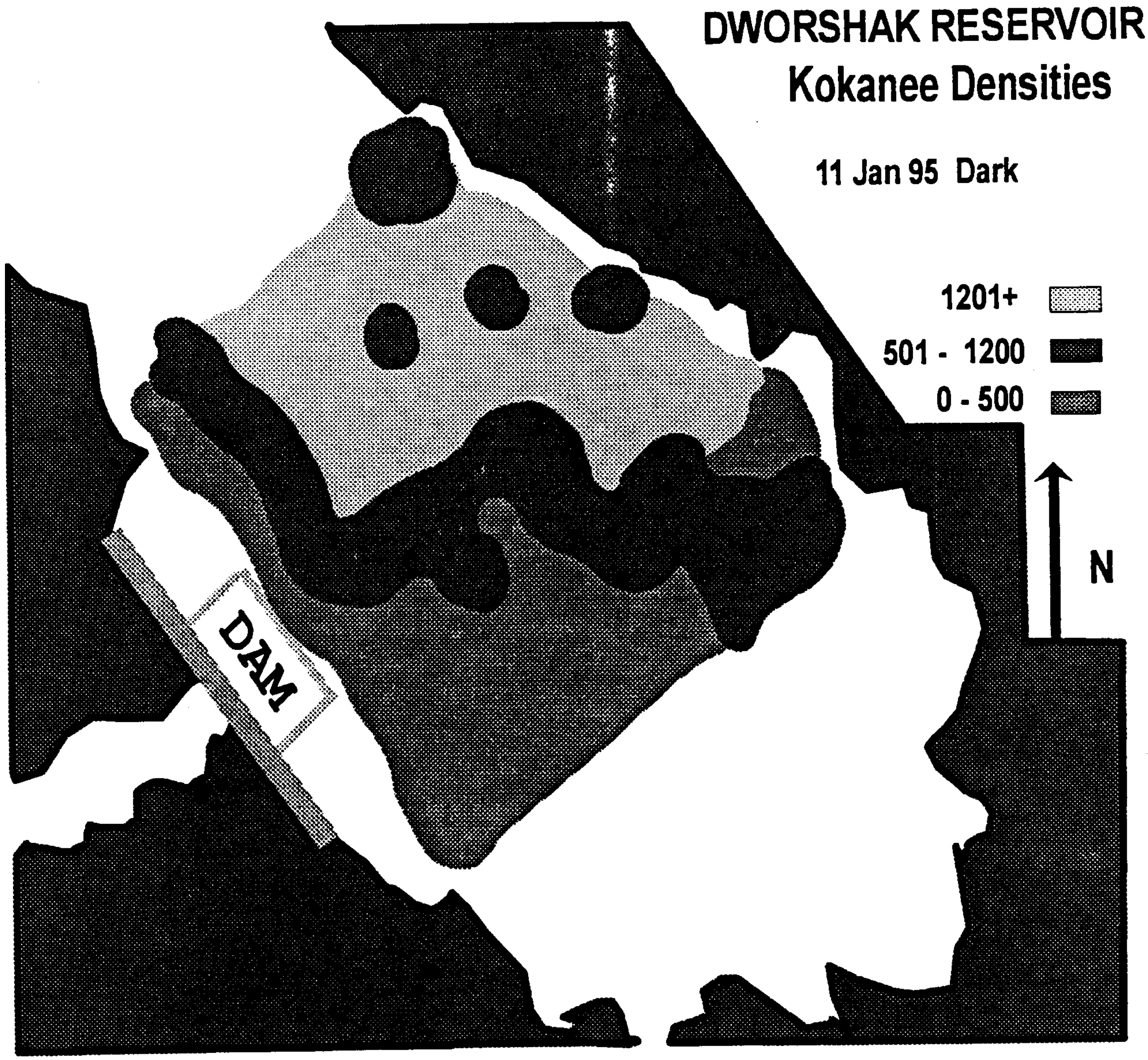

DWORSHAK RESERVOIR
Kokanee Densities
17 Jul 95 Daylight
401+
201 - 400
0 - 200
N
DAM

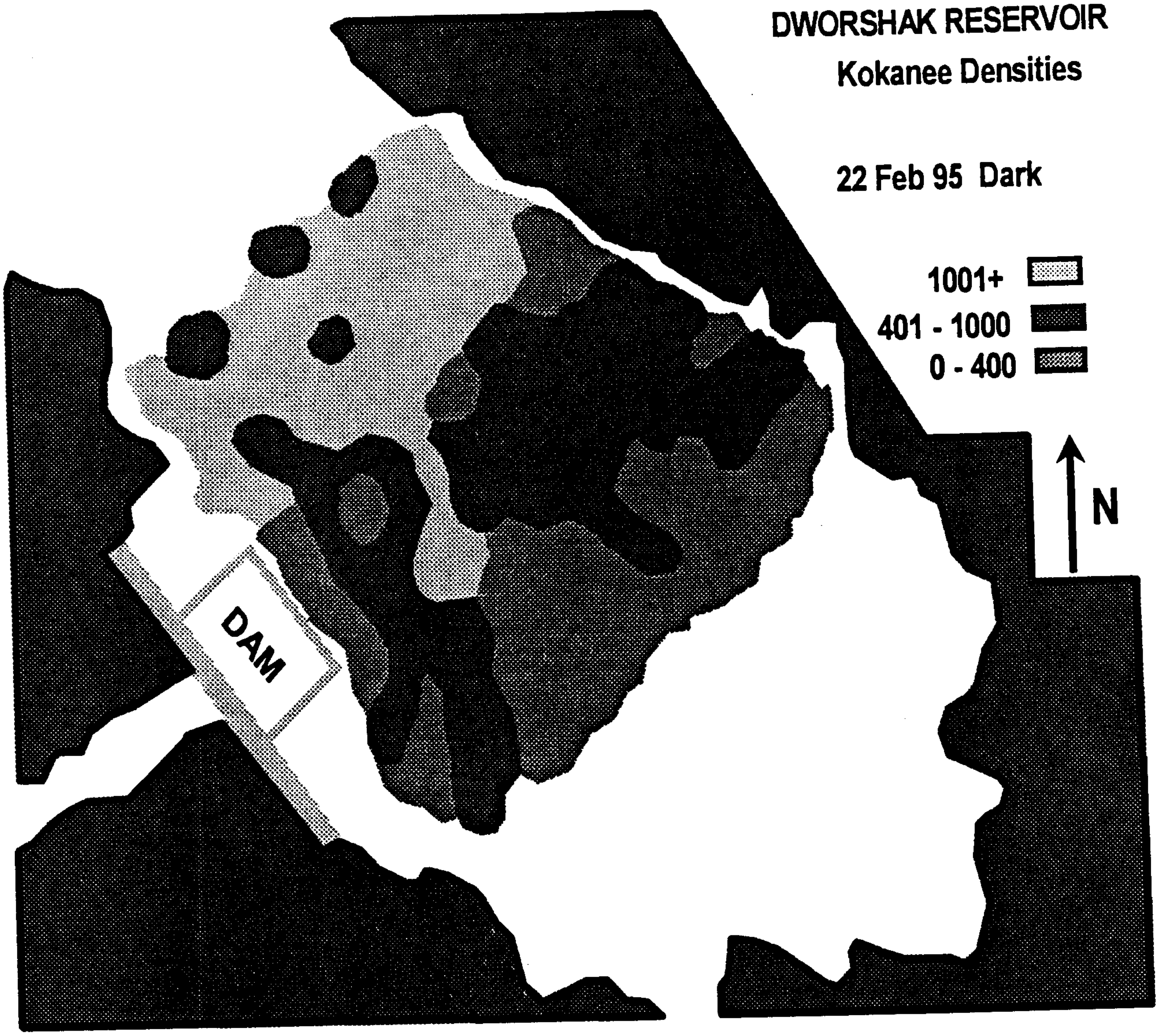

DWORSHAK RESERVOIR
Kokanee Densities
16 Aug 95 Daylight
501+
201 - 500
0 - 200
N
DAM

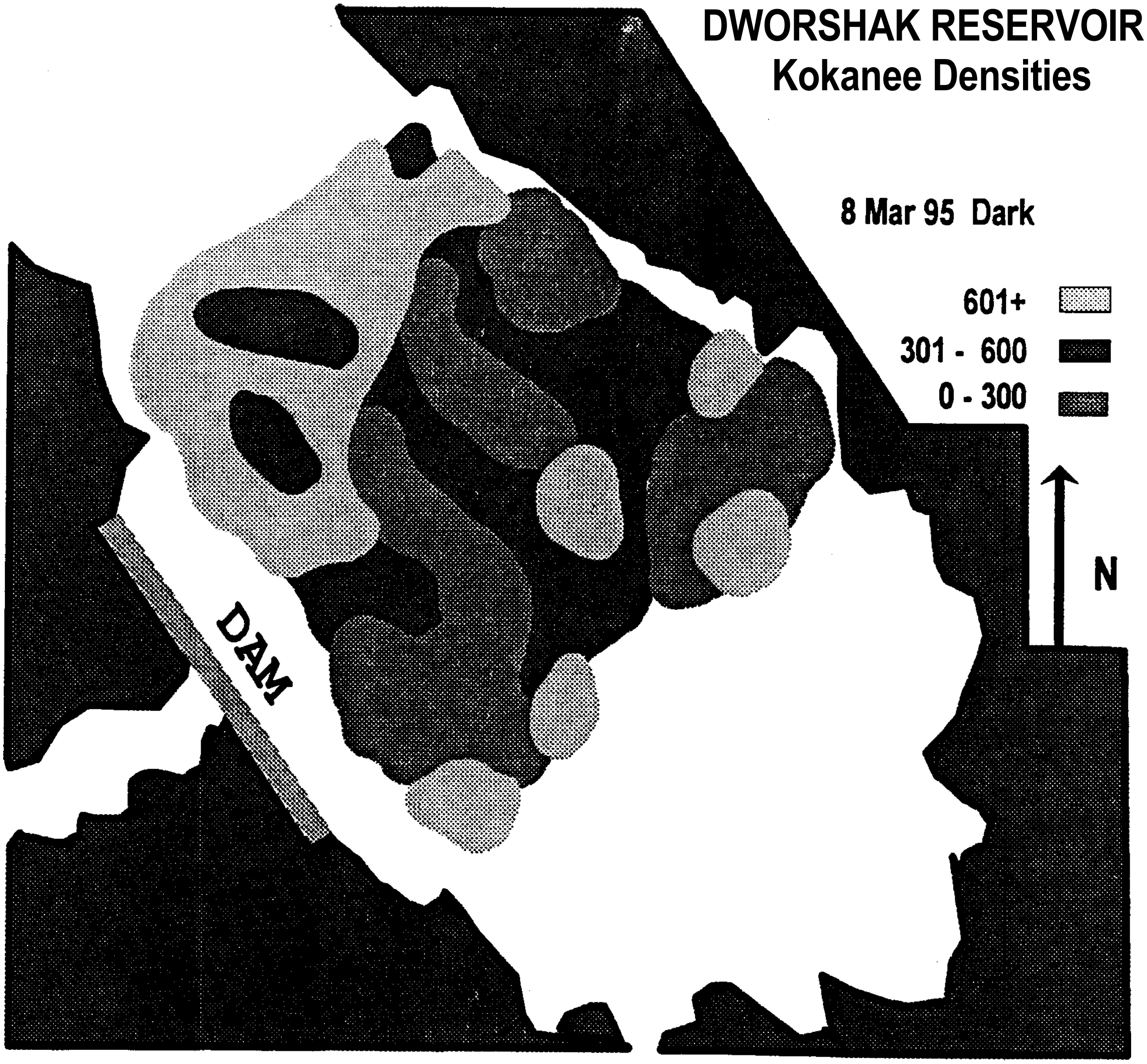

DWORSHAK RESERVOIR
Kokanee Densities
28 Sep 95 Daylight
1100+
201 - 500
0 - 200
N
DAM

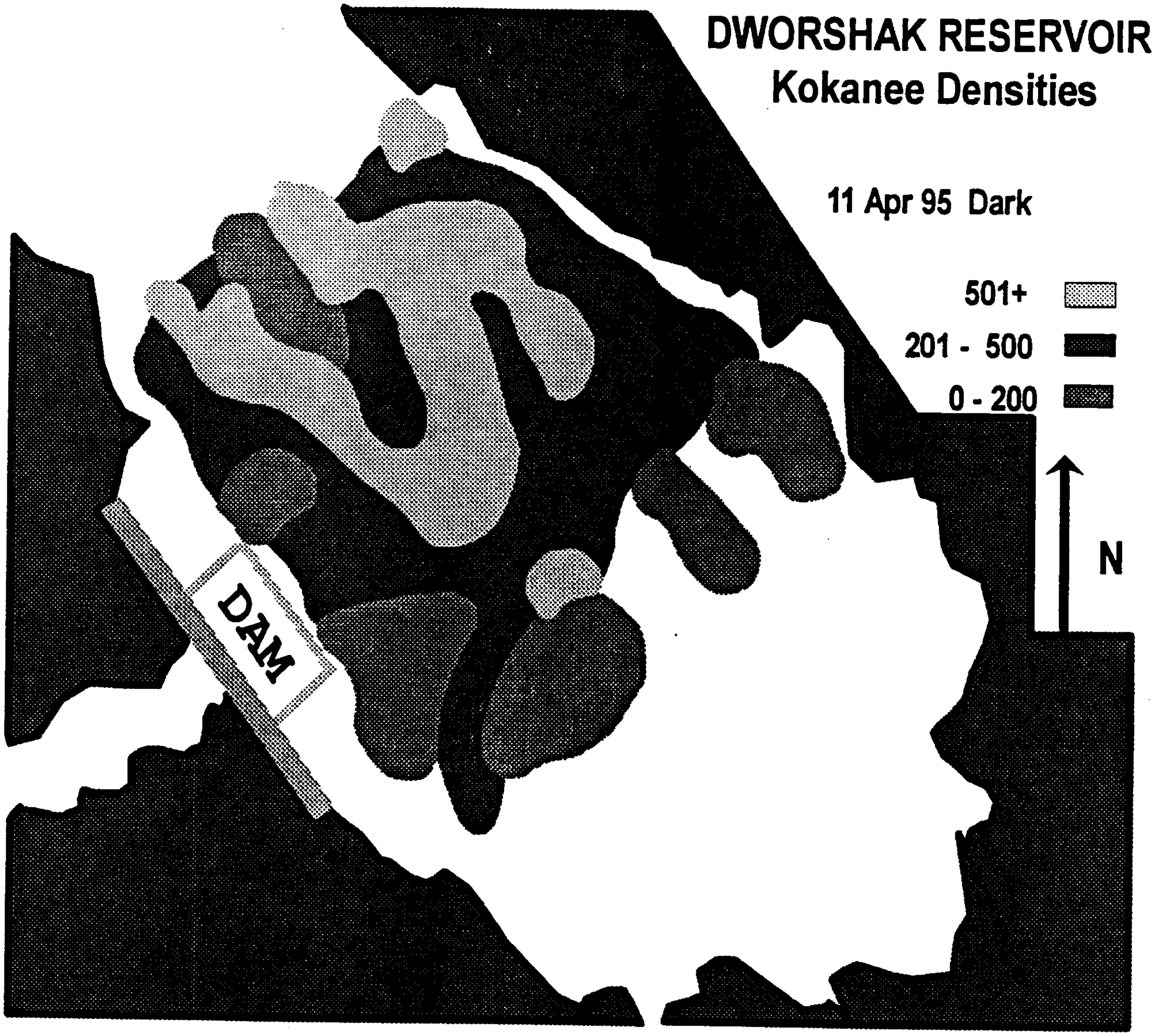

DWORSHAK RESERVOIR
Kokanee Densities
19 Oct 95 Daylight
301+
101 - 300
0 - 100
N
DAM

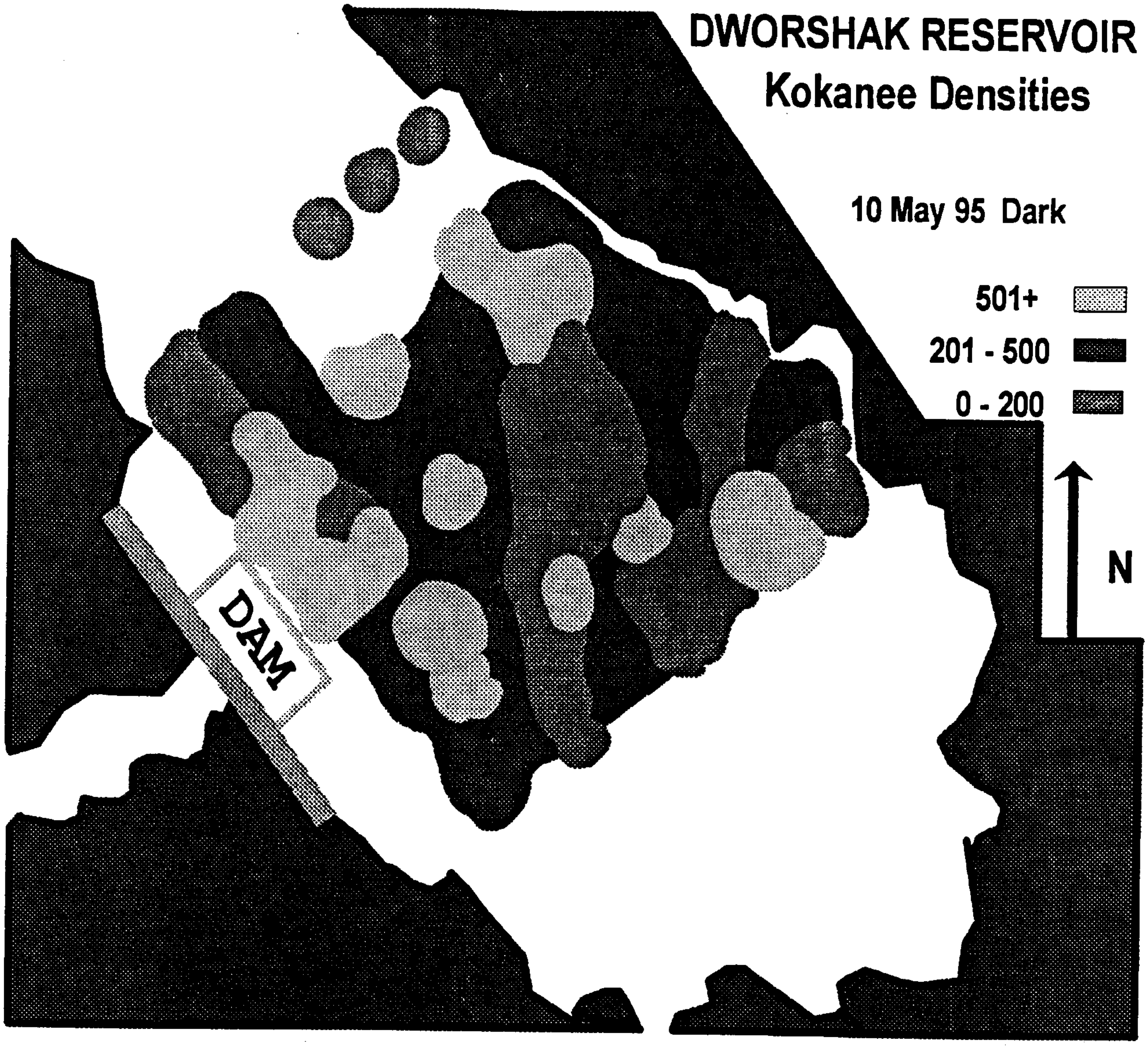
Appendix F.
Distribution of kokanee in the forebay
of Dworshak Reservoir at night.

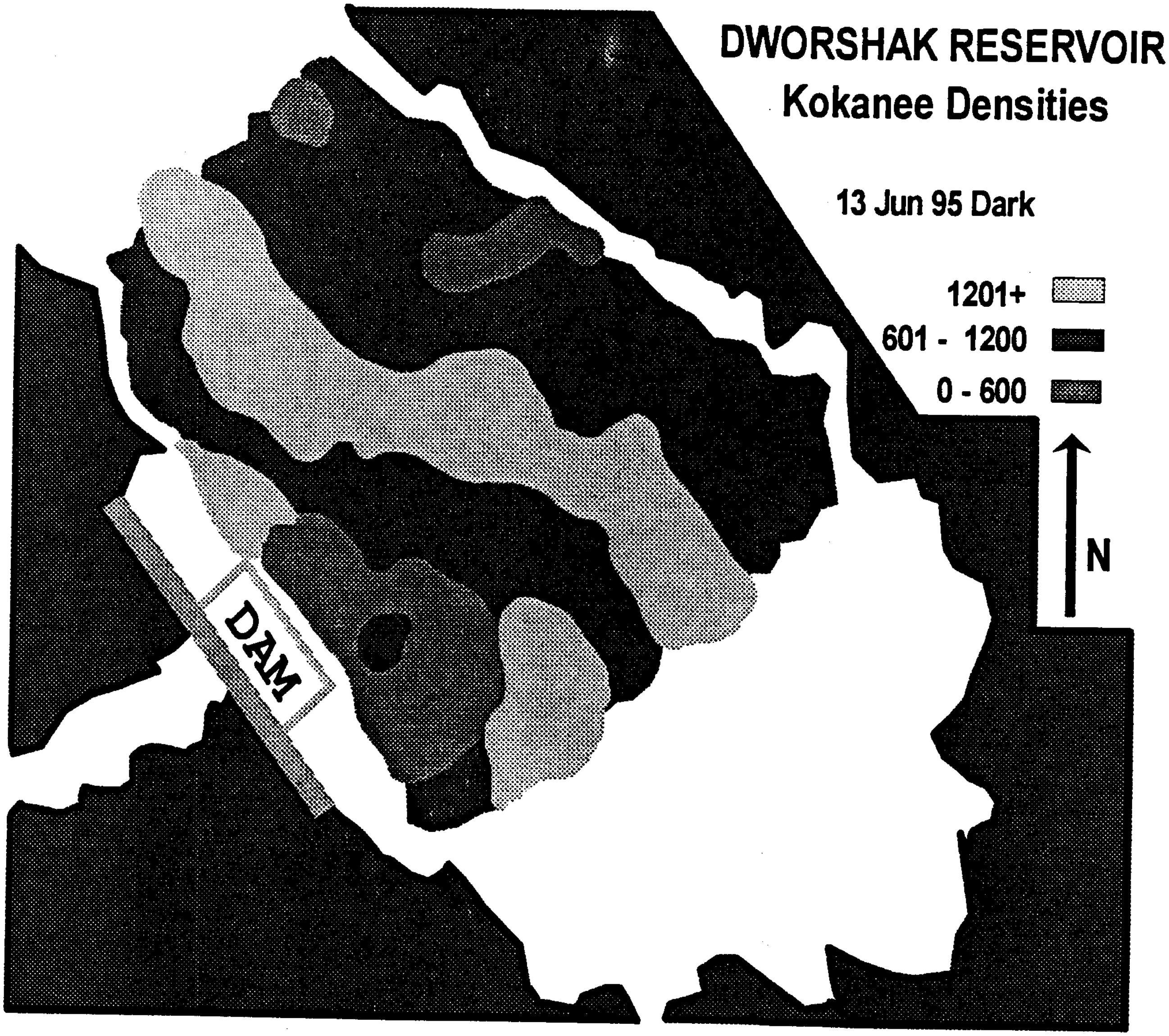

DWORSHAK RESERVOIR
Kokanee Densities
11 Jan 95 Dark
1201+
501 - 1200
0 - 500
N
DAM


DWORSHAK RESERVOIR
Kokanee Densities
22 Feb 95 Dark
1001+
401 - 1000
0 - 400
N
DAM

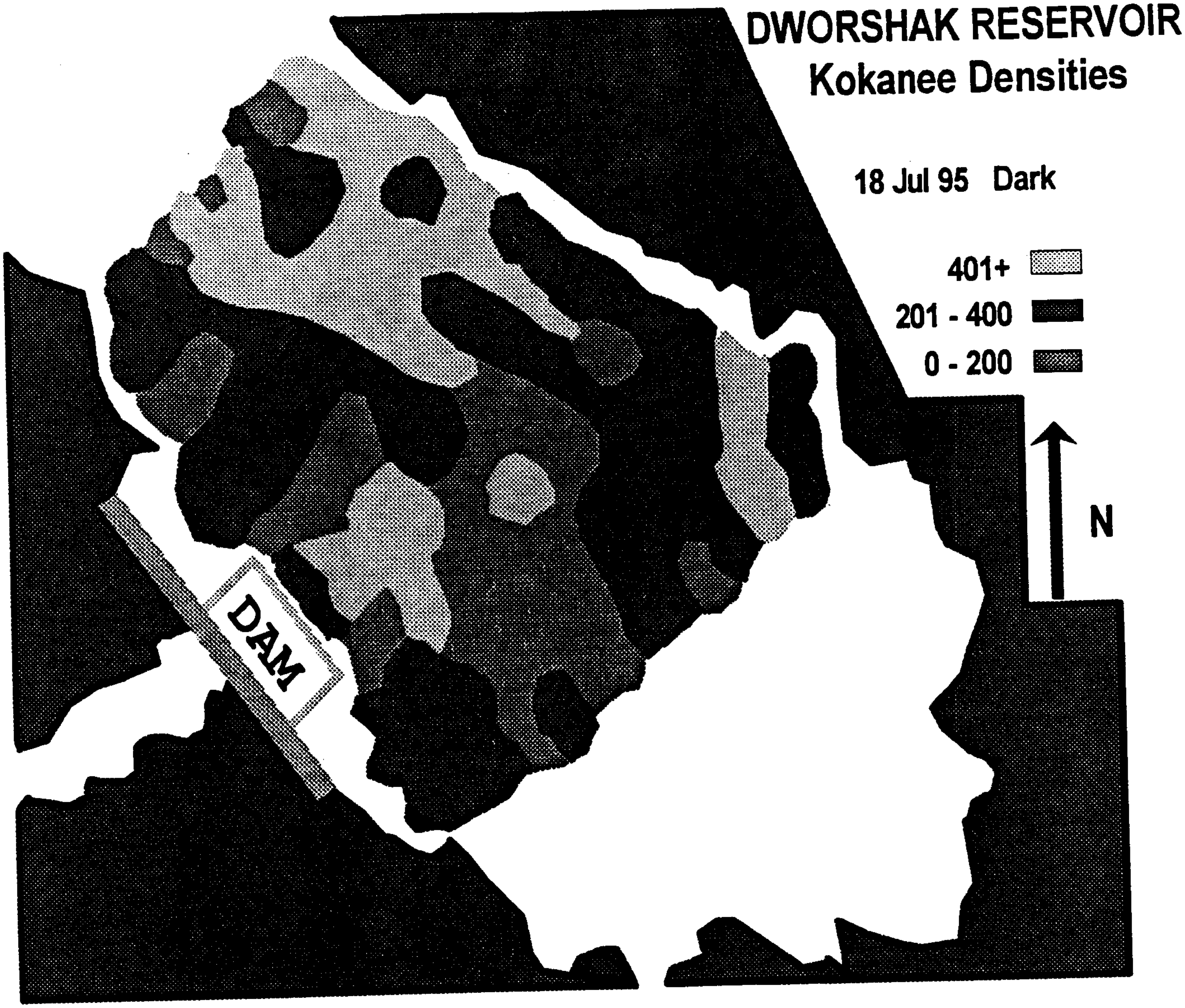

DWORSHAK RESERVOIR
Kokanee Densities
8 Mar 95 Dark
601+
301 - 600
0 - 300
N
DAM

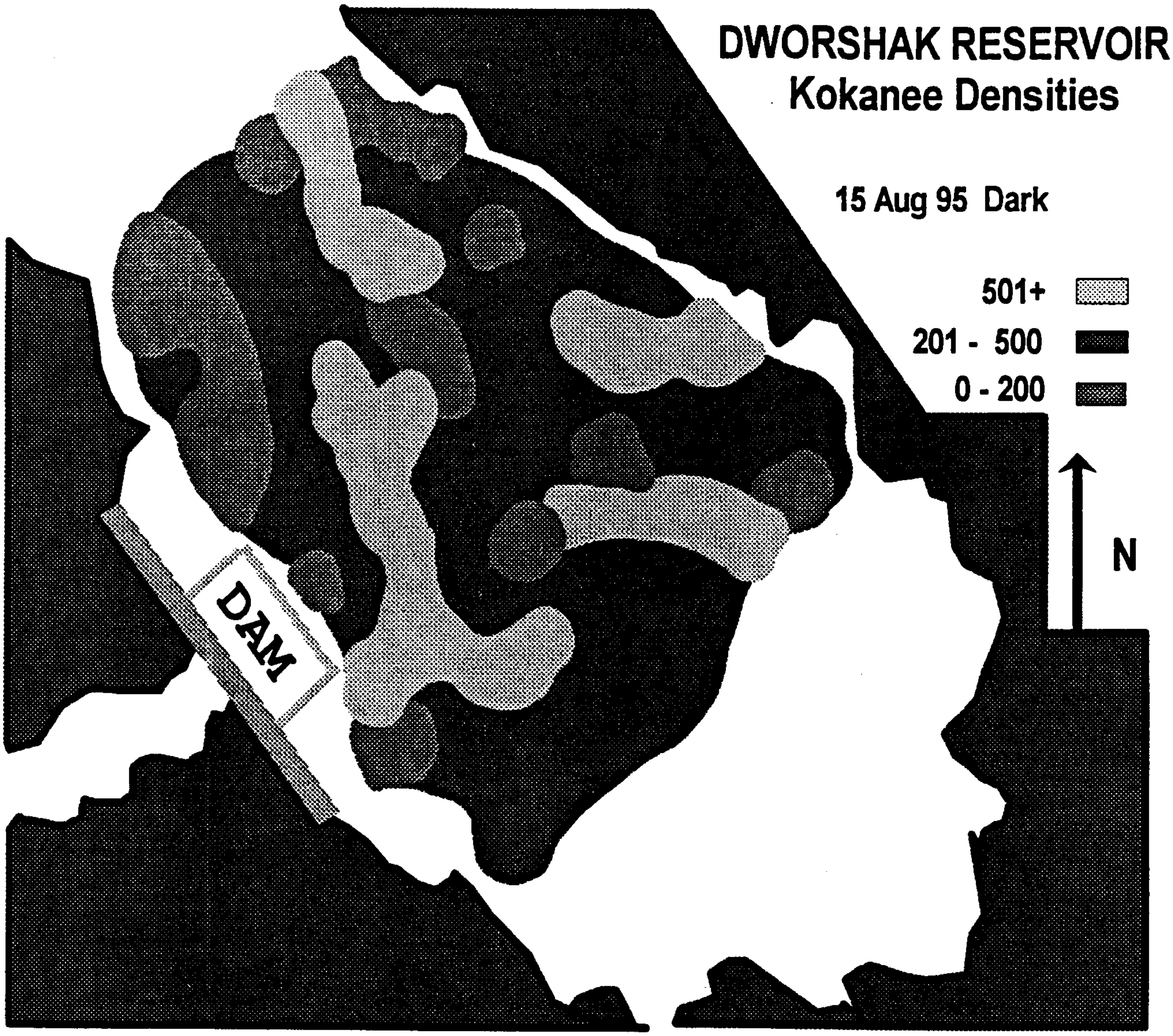

DWORSHAK RESERVOIR
Kokanee Densities
11 Apr 95 Dark
501+
201 - 500
0 - 200
N
DAM

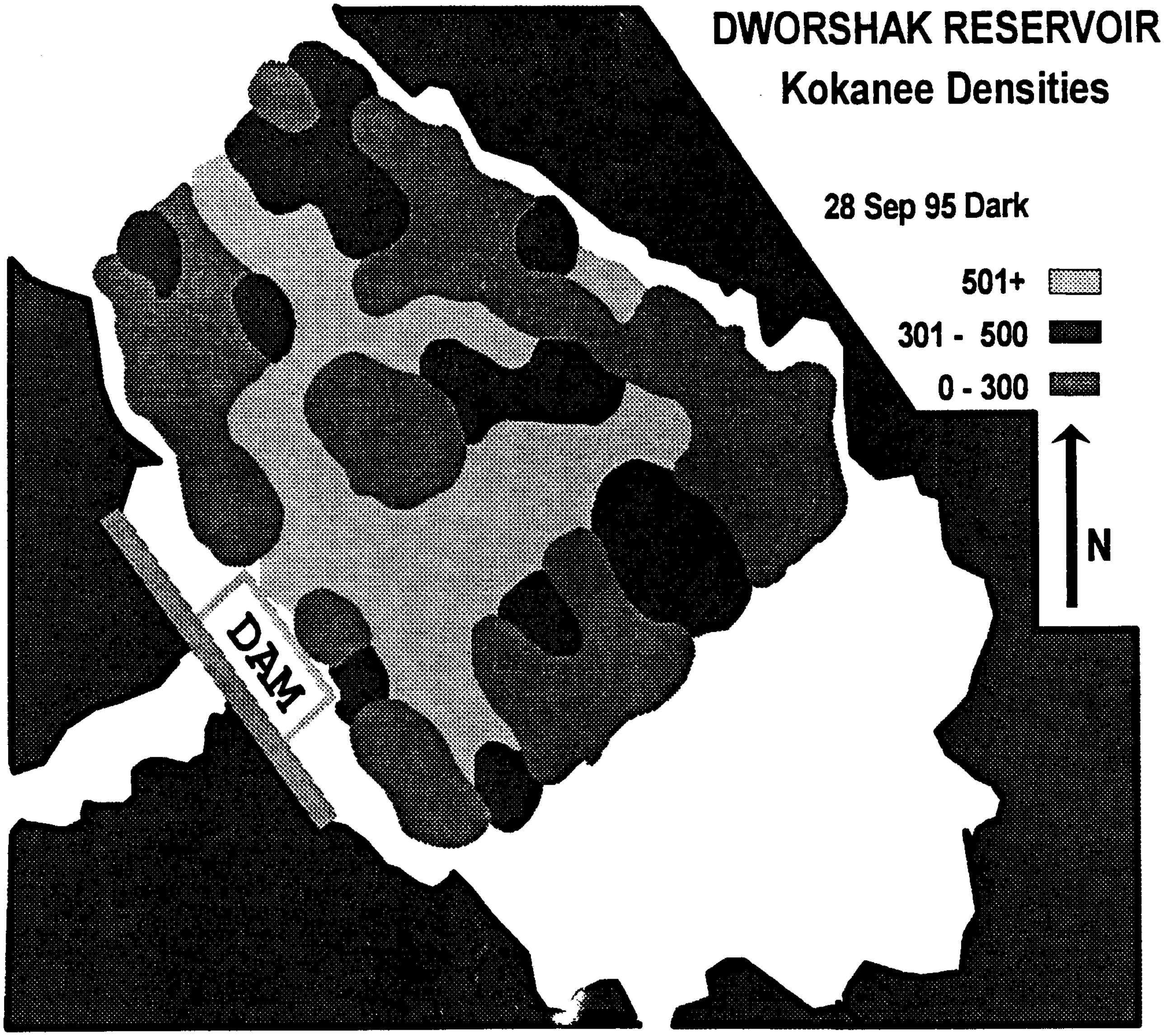

DWORSHAK RESERVOIR
Kokanee Densities
10 May 95 Dark
501+
201 - 500
0 - 200
N
DAM

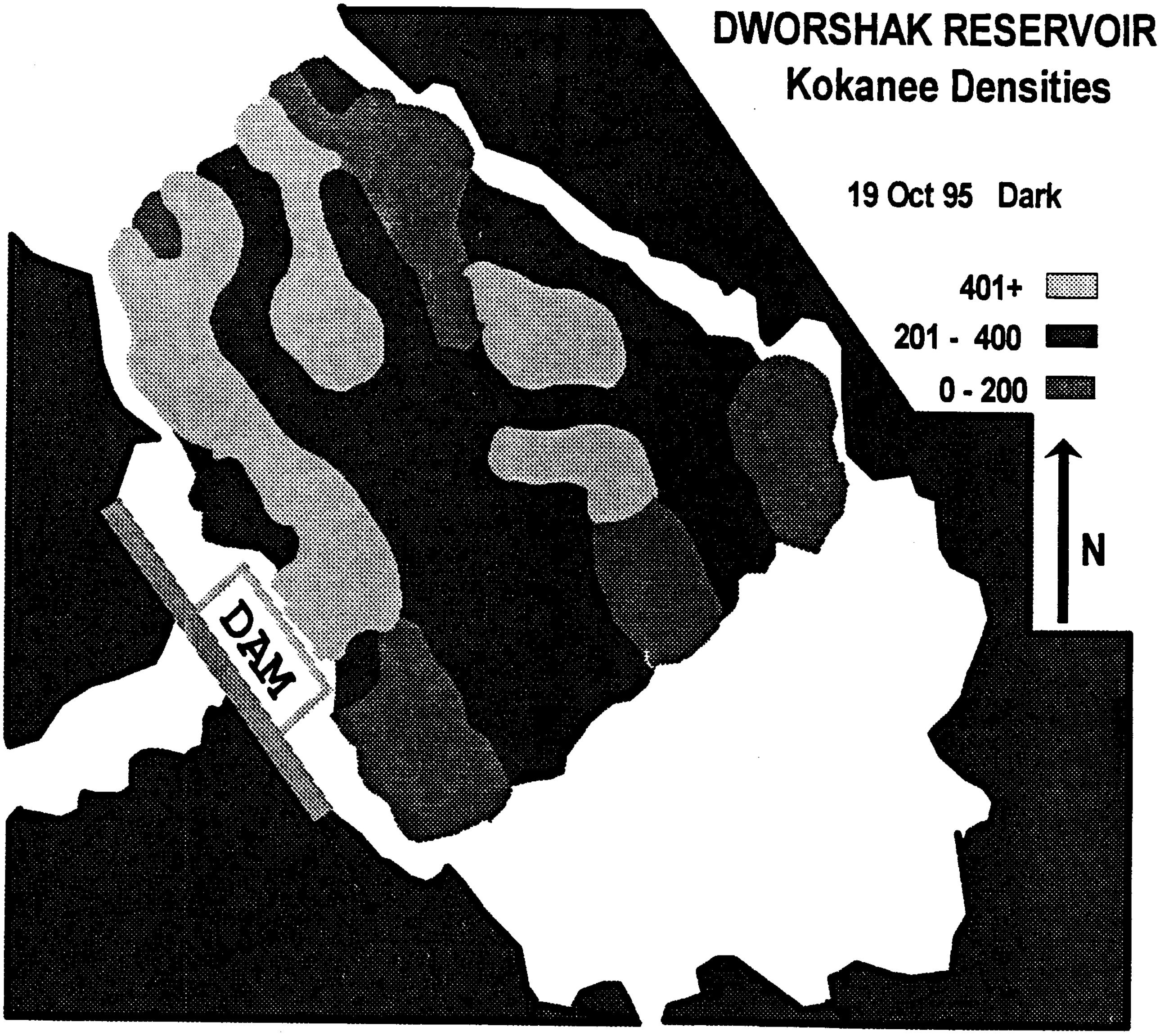


DWORSHAK RESERVOIR
Kokanee Densities
13 Jun 95 Dark
1201+
601 - 1200
0 - 600
N
DAM


DWORSHAK RESERVOIR
Kokanee Densities
18 Jul 95 Dark
401+
201 - 400
0 - 200
N
DAM


DWORSHAK RESERVOIR
Kokanee Densities
15 Aug 95 Dark
501+
201 - 500
0 - 200
N
DAM


DWORSHAK RESERVOIR
Kokanee Densities
28 Sep 95 Dark
501+
301 - 500
0 - 300
N
DAM



DWORSHAK RESERVOIR
Kokanee Densities
19 Oct 95 Dark
401+
201 - 400
0 - 200
N
DAM

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