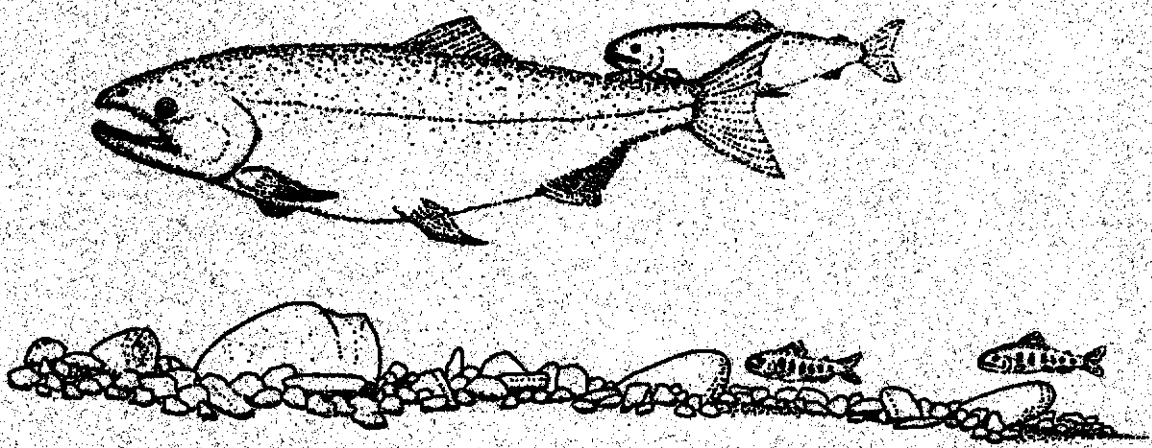
U.S. FISH AND WILDLIFE SERVICE

HORIZONTAL AND VERTICAL DISTRIBUTION OF JUVENILE SALMONIDS IN HOWARD HANSON RESERVOIR



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Horizontal and Vertical Distribution of Juvenile Salmonids in Howard Hanson Reservoir

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ABSTRACT

Horizontal and vertical density distributions of juvenile anadromous salmonids were monitored at the intake end of Howard Hanson Reservoir during the expected normal emigration period (April through July). Our objectives were to 1) characterize the horizontal and vertical distribution of juvenile anadromous salmonids, by day and by night, during the spring migration at the intake end of the reservoir, 2) sample for trends in species and age class composition, by day and night, during the spring migration, and 3) analyze results for implications in the design of a new intake structure. Horizontal and vertical density distributions were obtained from biweekly day and night dual-beam hydroacoustic surveys of six transects. Vertical gill nets were used during this same time period, bimonthly sampling, to obtain specific information on individual species, year class, and day and night behavior.

Horizontal density distributions for both daytime and nighttime showed a strong preference for shore areas. Both daytime and nighttime vertical density distributions showed a strong preference for the upper 15 m, ranging from 80% to 97% of the total fish observed. Nighttime distributions showed this same trend ranging from 80% to 96% for surface preference. Daytime abundance was relatively low throughout the study. In stark contrast, nighttime abundance was over twice that observed during the daytime in April and increased substantially in each succeeding month. Species composition changed over the course of the study. Coho smolts were present in all four months with a peak catch in June. No coho subyearlings were observed, possibly due to their small size relative to the size of gill nets used. Chinook subyearlings were observed in three of the four months (May through July). While the peak catch was observed in June, catches were almost as large in July. Only one chinook yearling and two steelhead smolts were observed during the study. Vertical distribution of gill-net-caught fish showed that coho smolts were generally distributed higher in the water column with chinook subyearlings more evenly distributed vertically. Temperature and dissolved oxygen profiles taken throughout the study showed no barriers to fish movement.

Implications for the design of a fish passage facility were as follows:

1. During spring emigration (April through July) fish preferred shore locations both during the day and night, although less so at night.

2. Densities of fish were substantially higher at night than during the day for the whole study period.

3. While a majority of the fish were in the upper 15 m during the study, a definite shift to a more even distribution through the entire water column was observed in July. This might have been a reflection of species composition change from coho smolts to chinook subyearlings observed in the gill net catches.

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INTRODUCTION

At Howard Hanson Reservoir on the Green River, Washington, the U.S. Army Corps of Engineers (USACOE) and the City of Tacoma have begun feasibility studies of the City's proposal to increase the useable water storage of the reservoir from 29,795.2 cubic dekameters (24,155 acre-feet) to 71885.9 cubic dekameter (58,278 acre-feet) for purposes of municipal water supply and downstream low-flow augmentation for fish. The additional storage would elevate the spring and summer reservoir pool level to a maximum of 358.75 m (1,177 ft) above sea level, 10.97 m (36 ft) above the existing maximum pool level of 347.78 m (1,141 ft). The minimum flood-control pool elevation during winter would remain at approximately 326.14 m (1,070 ft).

During typical spring refill, outflow is shifted from the main outlets (two 3.05-meter-wide (10 ft) radial gates at elevation 315.47 m (1,035 ft) to a 1.22-meter (48 ins) bypass outlet (at elevation 325.83 m (1,069 ft)) as the reservoir is raised to maximum pool elevation of 347.78 m (1,141 ft). In addition, the reservoir may be surcharged to an elevation of 349 m (1,145 ft) for one or two weeks after full pool is achieved for debris-removal, as occurred in 1991, or surcharged to an elevation of 349.3 m (1,146 ft) for additional low flow augmentation in responce to drought conditions, as occurred in 1992. The pool is then gradually drafted through the summer and fall to augment downstream flows. During the refill and drawdown periods the smaller bypass outlet is used because smaller flows can be more effectively passed through this exit than the larger radial gates.

The Muckleshoot Indian Tribe, Washington Departments of Fisheries and Wildlife, City of Tacoma, and Trout Unlimited have made annual releases of steelhead, coho salmon, and chinook salmon in the Green River watershed above the Reservoir. Releases of steelhead fry began in 1982, coho salmon fry in 1983, and chinook salmon fry in 1987, while adult steelhead releases began in 1992. The potential impacts of earlier spring reservoir filling on the successful emigration of anadromous salmonids is a major concern. Fish passage studies conducted by the Washington Department of Fisheries (Seiler and Neuhauser 1985) and U.S. Fish and Wildlife Service (Dilley and Wunderlich 1992, 1993) suggest that as depth increased over the bypass exit during spring refill emigrating anadromous salmonids were less able to find and enter the bypass exit, and were delayed in the reservoir. In addition, during a preliminary effort to obtain information on the vertical distribution of fish in the reservoir near the intake structure, Dilley (1993) found that subyearling chinook were present in the reservoir after what would be considered the normal migration time. Since the proposed increase in water storage would necessitate an even earlier than present refill, the potential for exacerbating existing downstream fish passage problems is likely.

To address this issue, the Corps of Engineers and the City of Tacoma have initiated studies on the horizontal and vertical distribution of migrant fish to design a fish passage facility. The primary study objectives were:

1) Characterize the horizontal and vertical distribution of juvenile salmonids, by day and night, during spring emigration (April through July) at the intake-end of the reservoir.

2) Sample for trends in species and age class composition, by day and night, during spring emigration (April through July) at the intake-end of the reservoir.

3) Analyze results for implications in the design of a new intake structure.

METHODS

The overall experimental approach was to hydroacoustically monitor the vertical and horizontal distribution of juvenile salmonids at the intake end of the reservoir (Figure 1) during the spring migration period (April through July). In addition, we used a combination of gill nets and hydroacoustics to collect specific information on individual species, year class, and day and night horizontal and vertical distribution.

HYDROACOUSTICS

Data Collection

A dual-beam hydroacoustic system (Table 1) was used to obtain horizontal and vertical distribution and size information. A mobile survey design consisting of six transects (Figure 2) was employed to be in close proximity to the intake structure yet far enough away to ensure that fish distribution would not be influenced by any flow patterns (horizontal or vertical) that might be created from subsurface intakes.

Biweekly day and night hydroacoustic sampling started April 5, 1993 and continued until July 29, 1993 for a total of 34 day and 34 night surveys. All day surveys were recorded between 12:00 and 17:00 and all night surveys were recorded approximately two hours after sunset.

Prior to each survey, base system voltages for both hydroacoustic channels were recorded digitally on magnetic tape in beta format to ensure that reference voltages were available for processing and analysis. The transducer, mounted in the tow body, was suspended from a davit and towed alongside the boat at a depth of approximately 1 meter. A boat speed of approximately one meter per second was maintained when possible throughout the survey. During the sampling, all dual-beam data were recorded on magnetic tape for later processing by BioSonics, Inc. At the same time an echogram was produced on a thermal chart recorder. These echograms were later used for comparisons with processed data and served as a back-up in the event the tape recording was unusable.

The dual-beam data were collected by transmitting pulses on the 6-degree transducer element and receiving echoes on both the 6-degree and 15-degree elements with the echo sounder set at 40 logR time varied gain. The echo sounder system parameters were: transmit frequency of 420 kHz; transmit power of -3 dB; receiver gain of 0; band width of 5 kHz; and a pulse width of 0.4 msec. All surveys started with transect 1, in the direction indicated by the arrows in Figure 2, and continued by consecutive number up the reservoir to the end of transect 6.

Data Processing and Analysis

All data stored on magnetic tape was processed by BioSonics, Inc. using a BioSonics ESP281 echo signal processor. The noise threshold was set at 100 millivolts, which corresponds to a -70 dB target on axis. Target tracking was enabled during processing. In target tracking, the target strength was calculated for each echo in the group associated with the target. The results were averaged to produce the best estimate for that fish's target strength. Because of the high ping-to-ping variability of echo strengths received from the same fish, target tracking provided a more accurate target strength estimate for individual fish and since fish target strength is directly proportional to fish size, accurate estimates of individual fish size was possible. Target tracking also provided the opportunity to define the maximum beam width for target acceptance and to collect only the echoes returning from fish within the specified sample volume.

Processed data were converted, with the BioSonics program ESP_VIEW, to database files. Tracked fish were listed with their transect position in time and space, the number of echoes returned from each fish, and their average target strength.

Each transect was divided into four sections, left shore, left middle, right middle and right shore (looking downstream). These sections provided horizontal distribution information across the reservoir in addition to upstream/downstream fish distribution information provided by the individual transects. The echo counting method was employed to obtain fish density estimates (Thorne 1983) for each section of each transect. Sampling volumes were calculated by limiting the acceptance angle of the acoustic beam during processing. The sums of accepted echoes from the tracked fish were divided by the volume of water sampled for each depth interval of each section of every transect. To obtain the vertical distribution of fish densities (fish/m^3) by depth interval and transect section, a correction factor was applied to account for the reduced length of transect at increased depth due to basin shape. Densities (fish/m^3) and target strength distribution were determined for each section of each transect in three-meter depth intervals beginning at one meter and extending to the bottom. In addition, the upper 15 m (49.2 ft) of the water column will be referred to as the "upper" water column. This designation is used at the request of USACOE engineer (Jim Lencioni, Seattle District) as an aid in the future design of a fish passage facility.

Target strength analysis based on a distribution of average target strengths from tracked fish, which has more precision than the distribution of individual echoes comprising the tracked fish (McClain 1985), was used in an effort to separate target strength modes in the population of mixed size species. However, during the analysis, it was determined that the species present at the time of sampling were too similar in size to separate accurately. Target strength information was used to eliminate fish larger than anticipated smolt size (greater than -45 dB) from density estimates.

Within-month comparisons for horizontal and vertical distributions were made by summing fish densities by depth, location, transect and by day and night components (Appendix A). Between-month comparisons of day and night fish densities were made by averaging the total density over surveys.

Analysis of variance was used to test horizontal distributions, by day and by night, for significant effects of month, transect, location relative to shore, and all interactions (P=0.95).

VERTICAL GILL NETTING

Vertical gill nets were used to assist in the identification of species-specific vertical distribution and age class information.

Day and night vertical gill netting took place bimonthly during the same period as hydroacoustic sampling and corresponded to the same day and night sampling day as the hydroacoustic survey (8 day and 8 night samples).

We used three monofilament vertical nets, each having different mesh size, for each sampling. Since the fish of interest were small, (salmonid subyearlings and yearlings), the three mesh sizes were 1.59 cm (5/8 inch), 2.54 cm (1 inch), and 3.81 cm (1 1/2 inch). Three different locations (Figure 2), based on fish presence observed hydroacoustically, were used during the study. Site A was used on April 12th for both day and night sets. Site B was used on April 26th for the daytime set only. All other sets were at site C. After the site was determined, and as soon as possible after the corresponding hydroacoustic survey, anchors were set and the nets unrolled to within 1 m of the bottom. Nets were fished 4 hours during the day and 2 hours during the night. The difference in length of time between day and night sampling was because of lower density of fish (fewer fish available for capture) during daylight hours compared to night.

As fish were recovered from the nets they were placed into plastic bags labeled by mesh size and 3-meter depth interval. These fish were later identified by species and age class with a notation of mesh size, water depth, fork length, and presence of an adipose clip (Appendix B). All data were then combined by month and into day and night components by species.

TEMPERATURE and DISSOLVED OXYGEN

Temperature and dissolved oxygen were recorded at net sample sites, after the daytime gill nets were set, to a depth of 15.24 m (50 ft), in 1.52 m (5 ft) intervals, when operating equipment was available. The change between day and night dissolved oxygen and temperature did not justify night sampling. Additional temperature and dissolved oxygen information was provided by the USACOE from another sample site (Figure 2) for extrapolation past the 15.24 m depth or to fill in data gaps.

RESERVOIR ELEVATION

Reservoir surface elevations, provided by the USACOE, were recorded before each daytime survey.

RESULTS AND DISCUSSION

All data have been organized by month so that observed densities during the study could be viewed over time, as well as compared spatially (with consideration given to species composition and year class, diel movement, or temperature/dissolved oxygen barriers).

HORIZONTAL DISTRIBUTION

Daytime distributions by month, April through July, are shown in Figures 3, 4, 5, and 6. Overall, significantly more fish were observed near shore than toward mid-lake. However, the effect of month was not significant. In April (Figure 3), the largest congregation of fish was observed along the left shore and left middle of transects 5 and 6. Congregations of fish in May were also found along the left shore and left middle but in transects 1, 2 and 3 (Figure 4). Daytime density distributions for June (Figure 5) showed the same trend observed in April and May with a larger concentration of fish along the left shore. While a majority of observations occurred along the left shore, transect 6, fish were also observed in fair numbers along the right shore of transects 5 and 6 and the left middle of transect 1. July distributions showed the largest concentration of fish along the right shore, especially in transect 6 (Figure 6). A smaller concentration of fish were also observed along the left shore.

Nighttime distributions showed the same trend observed during the day with a majority of fish along the shore areas for all four months (Figures 3, 4, 5, and 6). Analysis of variance showed that fish preference for shore was highly significant. Density distributions in April (Figure 3) show the largest congregation of fish along the right shore in transects 1, 2, and 3. While the nighttime preference for shore areas was evident in May (Figure 4), June (Figure 5), and July (Figure 6), fish were generally spread over all six transects.

The preference for shore regions observed during this study was not unlike that observed in other studies. Rees (1957) also found a definite preference to shore regions for coho during periods of clear weather (greater light intensity) in Baker Reservoir. While he did not separate his finding by day and night, his observations show the same trend of daytime, light intensity, preference to shore. Korn et. al. (1967) found the same trend of shore preference for both day and night, for coho, chinook, and steelhead juveniles in North Fork, Pelton, and Round Butte reservoirs in central Oregon.

VERTICAL DISTRIBUTION

The relative abundance of fish between different depth levels showed a definite preference for the upper water column for all four months during the day (Figures 7, 8, and 9). Due to low reservoir elevations, for the month of April, the maximum hydroacoustic survey depths were less than 15 m until the last week of that month. This fact renders the term "upper" water column rather meaningless for the month of April. The percent of fish observed in the upper water column during the day were 97% in April, 80% in May, 96% in June, and 96% during July.

Nighttime observations for the study period showed the same trend (Figures 7, 8, and 9) for a preference for the upper water column. The percent of fish observed in the upper water column during the night were 96% in April, 94% in May, 90% June, and 80% during July. Vertical distributions in July (Figure 9) were more evenly distributed over the whole range in depth than in April, May and June.

Cropp (undated) reported the same trend for surface orientation with 96% of his observations occurring in the upper 13.72 m (45 ft). In addition, both Rees (1957) and Korn et al. (1962) found these same trends at Baker Dam and North Fork, Pelton, and Round Butte reservoirs respectively. While Korn et al. (1962) stated that distributions of coho were comparatively deep during the day and shallow at night, it should be noted that a portion of what they classified as relatively deep (9.14 m (30 ft) to 13.72 m (45 ft)) I classified to be in the upper water column in Howard Hanson Reservoir.

DAY VERSUS NIGHT RELATIVE ABUNDANCE

Relative abundance during the daytime was consistently low for all four months (Figure 10). In stark contrast, nighttime densities steadily increased and were consistently greater than during the daytime (Figure 10). Vertical gill net catches verify this trend. Korn and Gunsolus (1962) and Korn et. al. (1967) also observed low densities during daytime sampling, and suggested that low densities may involve dispersion throughout the reservoir.

The question of where the fish were during the day may be explained by Figure 11. During the day, large schools of fish were visually observed feeding on the surface around the intake area (Figure 2). Echogram A (Figure 11) was recorded in the intake area during the day and shows a large school of fish, while Echogram B, recorded in the same area at night, shows few fish. Echograms of this same area were recorded irregularly throughout the four months. The results showed the same trend on each occasion. I concluded from this rather informal information that fish seemed to school in the intake area during the day and disperse into the reservoir at night. One suggestion was that migrant fish were actively passing through the study area and out the intake structure at night and holding in the intake area during the day, and waiting again till nightfall before exiting the reservoir. However, I do not believe this to be the case because, over the course of the study, fish seen feeding at the surface, appeared to move from the intake area and into the reservoir late in the day rather than move from the upper reservoir area toward the intake. Previous studies by Cropp (undated), Dilley and Wunderlich (1992, 1993), and Dilley (1993) tend to confirm the conclusion that fish are delayed in the reservoir and congregate in the forebay area during the day.

HYDROACOUSTICS

While a hydroacoustic assessment was probably the best way to achieve the desired results, it was not without its drawbacks. While collecting data, fish immediately near the surface area were probably frightened by the boat. This was especially true during daytime surveys. Cropp (undated) noted in his hydroacoustic surveys of Howard Hanson Reservoir that few fish were present in the upper 1.5 m (5 ft) of the surface, possibly for the same reason. This would imply that the densities of fish observed in the upper water column could have actually been some what greater than recorded.

Unfortunately fish species lengths were too similar to utilize target strength information for species apportioning into horizontal and vertical distributions. Target strength distribution modes overlapped and were not as apparent as anticipated. However, target strength information was used to separate targets larger than smolts (greater than -45 dB) from all density estimates. Larger-than-smolt-size targets were few in number and eliminated from the data set.

VERTICAL GILL NETTING

Coho smolts were captured in gill nets each month of the study (Table 2) with a peak catch in June. Depth distributions for gill-net-caught coho smolts can be found in Figure 12. Only four coho smolts were captured with gill nets in April, all within 6 m of the surface at night. In May, all day caught and 77% of night caught coho smolts were from the upper water column. In June, 91% of the day and 75% of the night catch of coho smolts were in the upper water column. The pattern continued in July with two of the three day caught and 82% of the night caught coho smolts in the upper water column.

No coho subyearlings were captured during the study, which probably reflects the limitations of the gill nets for capturing smaller fish (discussed below).

Chinook subyearlings were captured in three of the four months (Table 3) starting in late May with peak catches in June (Figure 13). In May, two of the three subyearling chinook during the day and all captures at night were recorded in the upper water column. In June, one subyearling chinook captured during the day and 70% of the night catch was in the upper water column. No subyearling chinook were captured during the day in July. However, 117 chinook subyearlings were captured at night, 66% from the upper water column.

Only one chinook yearling (140 mm) was captured in May. In addition, two steelhead smolts were captured during the study with one in April (186 mm) and one in May (250 mm).

No resident rainbow or cutthroat trout were recorded through the entire study. This lack of resident rainbow and cutthroat trout in the gill net catches matched favorably with the hydroacoustic target strength findings in that very few targets larger than smolt size were recorded.

While species timing itself cannot be defined by the limited gill netting information presented here, it is of value in that the presence of these species coincide with the timing observed by Seiler and Neuhauser (1985), and Dilley and Wunderlich (1992, 1993).

The vertical distribution densities acquired by the hydroacoustic surveys are more representative of actual vertical distribution than gill net data. The project gill netting was never intended to be used for species apportioning to hydroacoustic data. The large area covered during the hydroacoustic surveys, the limit of one set of nets, and the small sample area covered by each net, precluded any such apportioning. In addition, an inherent bias occurs because gill nets target only a specific size range. This was apparent with smaller fish. Chinook subyearlings did not appear in gill net catches until May 24th (Appendix B) with the smallest fish recorded at 75 mm and a mean length of 84 mm (Table 2). A beach seine catch earlier in the month (May 3rd) at the boat ramp (Figure 2) yielded 62 chinook subyearling with a mean length of 62 mm. This mean was far below the smallest fish observed in the gill nets. The boat ramp area is a flat, relatively shallow area in contrast to the deep water area where the gill nets were used. This may account for the fish not being present in earlier gill net sets (a preference for shallow areas at that size range).

TEMPERATURE and DISSOLVED OXYGEN

Temperature profiles taken during the study period (Figures 14 and 15) showed no temperature barriers (>18.5°C, Bell, 1991) and a weakly defined thermocline. Dissolved oxygen profiles taken during the same time period (Figures 16 and 17) also showed no levels (<5ppm, Piper et.al., 1982) that would present a barrier to fish movement.

RESERVOIR ELEVATION

Reservoir elevations during April changed dramatically ranging from 329.82 m (1,082.1 ft) to 344.42 m (1,130.0 ft). This change was part of the normal springtime reservoir refill procedure. Reservoir elevations for the remaining three months, May through July, changed very little, ranging from 347.32 m (1,139.5 ft) to 348.6 m (1,143.7 ft).

SUMMARY

Daytime horizontal density distributions showed a preference for shore areas in all four months. While nighttime distributions showed this same trend, fish were generally spread over the entire survey area.

Juvenile coho and chinook salmon showed a strong preference for the upper 15 m of the reservoir waters, both day and night. Approximately 80% to 96% of all fish observed hydroacoustically were in the upper 15 m.

Daytime observed abundance was consistently low throughout the study. In stark contrast, nighttime abundance was over twice that observed during the daytime in April and increased substantially in each subsequent month.

Trends in species composition changed over the course of the study. Coho smolts were present in all four months with a peak catch in June. No coho subyearlings were observed, possibly due to their small size relative to the size of gill nets used. Chinook subyearlings were observed in three of the four months (May through July). While the peak catch was observed in June, catches were almost as large in July. Only one chinook yearling and two steelhead smolts were observed during the study.

Vertical distribution of gill-net-caught fish showed that coho smolts were generally distributed higher in the water column with chinook subyearlings distributed more evenly throughout the water column.

Temperature and dissolved oxygen profiles taken throughout the study showed no related barriers to fish movement.

Implications for the design of a fish passage facility are as follows:

1. Fish preferred shore locations during both day and night. However, distributions during the night were more dispersed over the entire study area.

2. Total densities of fish were substantially higher at night then during the day for each month.

3. While a majority of the fish were in the upper 15 m of the water column, a definite shift to a more even distribution through the entire water column was observed in July. This might have been a reflection of the species composition change from coho smolts to chinook subyearlings that was observed in the gill net catches.

ACKNOWLEDGEMENTS

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Appreciation also goes to John Olson and his coworkers of U.S. Army Corps of Engineers for their cooperation at Howard Hanson Reservoir.

Literature Cited

Bell, M. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria. Fish Passage and Development Program. North Pacific Division. U.S. Army Corps of Engineers.

Cropp, T. Undated. Howard Hanson Reservoir fish population study, July-August, 1989. Washington Department of Wildlife.

Dilley, S. 1993. Vertical distribution of juvenile salmonids in the forebay of Howard Hanson Reservoir. U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, Washington.

Dilley, S. and R. Wunderlich. 1992. Juvenile anadromous fish passage at Howard Hanson project, Green River, Washington, 1991. U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, Washington.

Dilley, S. and R. Wunderlich. 1993. Juvenile anadromous fish passage at Howard Hanson Dam and Reservoir, Green River, Washington, 1992. U.S. Fish and Wildlife Service, Western Washington Fishery Resource Office, Olympia, Washington.

Korn, L., L. Herha, R. Montagne, W. Mullarkey, and E. Wagner. 1967. The effects of small impoundments on the behavior of juvenile anadromous salmonids. Fish Commission of Oregon, Research Division, Clackamas, Oregon.

Korn, L. and R. Gunsolus. 1962. The development and testing of techniques for studying the behavior of juvenile salmonids in reservoirs. Fish Commission of Oregon, Clackamas, Oregon.

McClain, C.J. 1991. Cohort separation of juvenile sockeye salmon, Onchorhynchus nerka, in Tustumena Lake using hydroacoustics. M.S. Thesis, University of Washington, Seattle, Washington.

Piper, R., I. McElwain, L. Orme, J. McCraren, L. Fowler, J. Leonard. 1982. Fish Hatchery Management. U.S. Fish and Wildlife Service, Washington, D.C.

Rees, W. 1957, The vertical and horizontal distribution of seaward migrant salmon in the forebay of Baker Dam. Washington Department of Fisheries, Fisheries Research Papers, Volume 2, No. 1.

Seiler, D. and S. Neuhauser. 1985. Evaluation of downstream migrant passage at two dams: Condit Dam, Big White Salmon River, 1983 and 1984; Howard Hanson Dam, Green River, 1984. Progress Report No. 235, Washington Department of Fisheries, Olympia.

Thorne, R.E. 1988. An empirical evaluation of the duration-in-beam technique for hydroacoustic estimation. Can J. Fish. and Aq. Sci. 45:1244-1248.

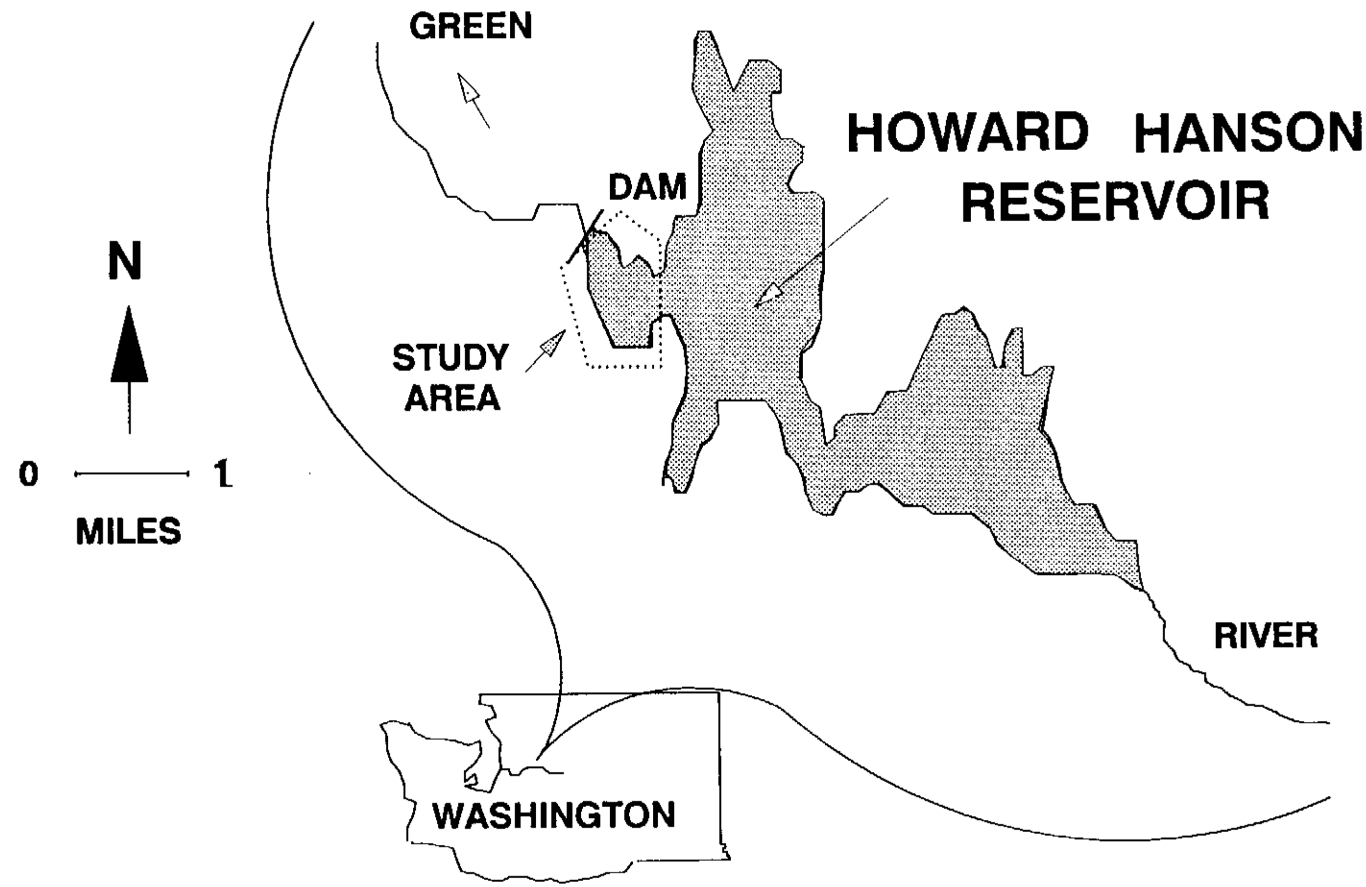


Figure 1. Howard Hanson Reservoir showing study area. Map scale is approximate.

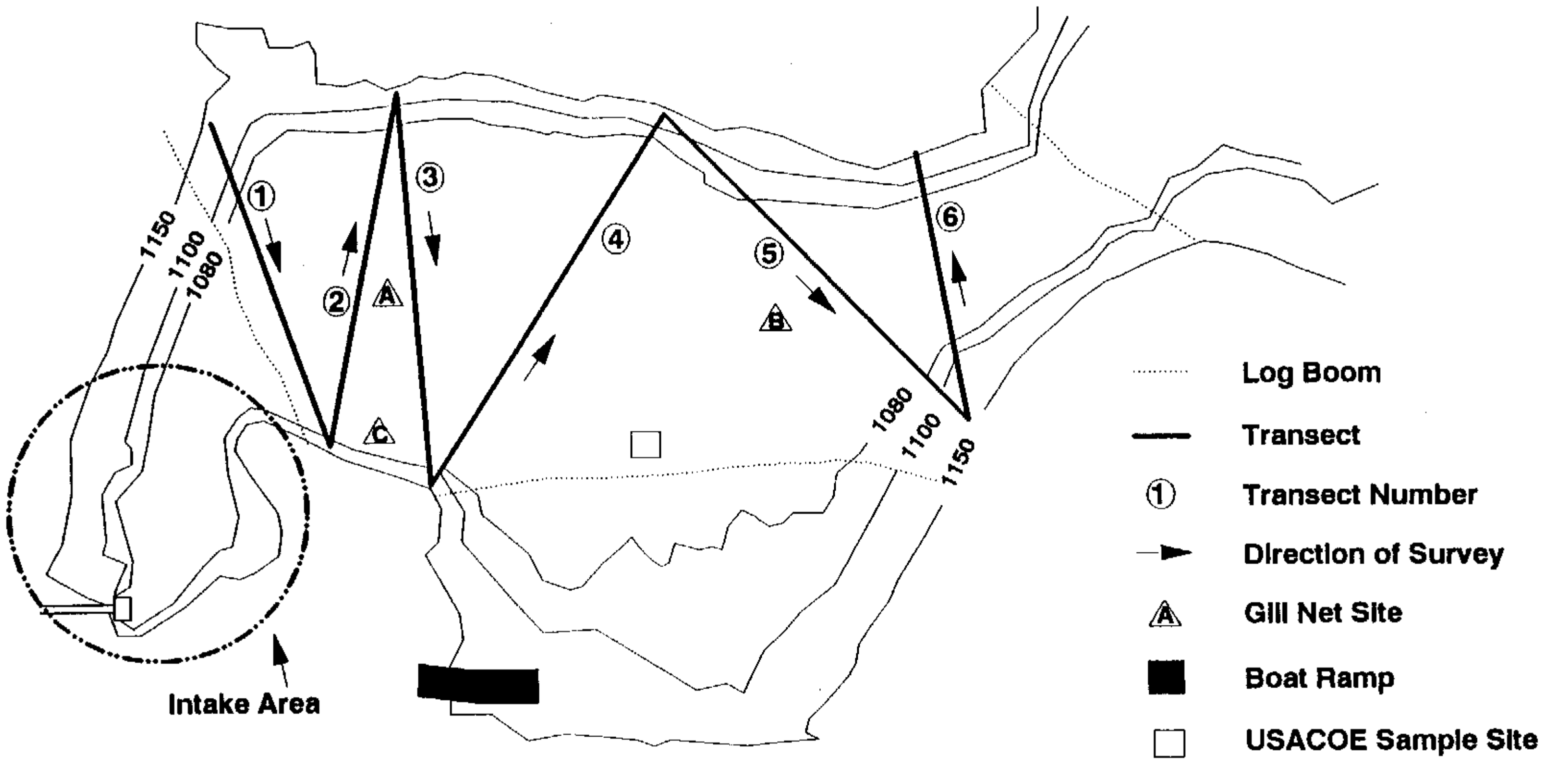
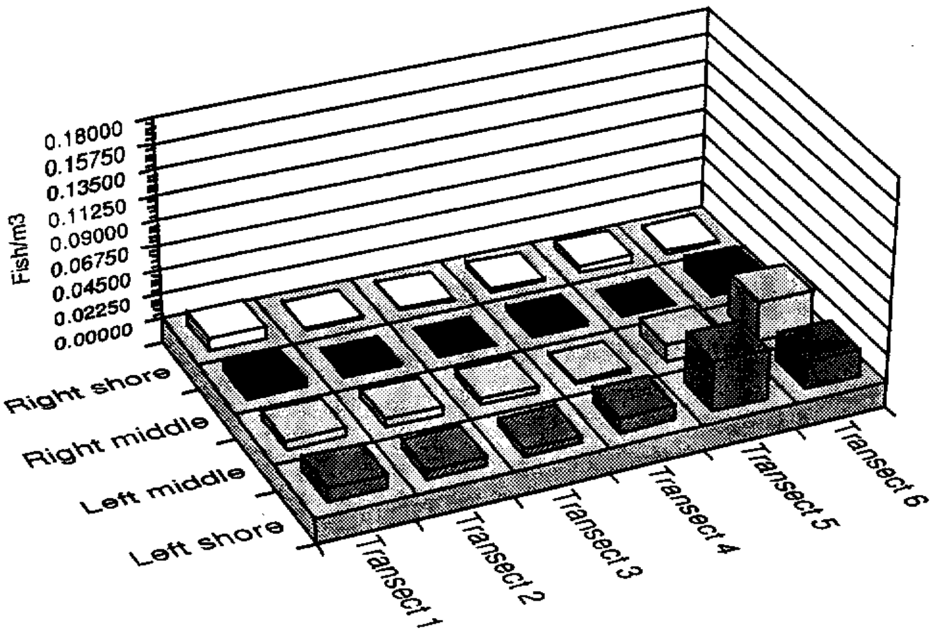


Figure 2. Detailed map of the hydroacoustic transects and gill net sites used during the study at Howard Hanson Reservoir. Map scale is approximate.

DAY



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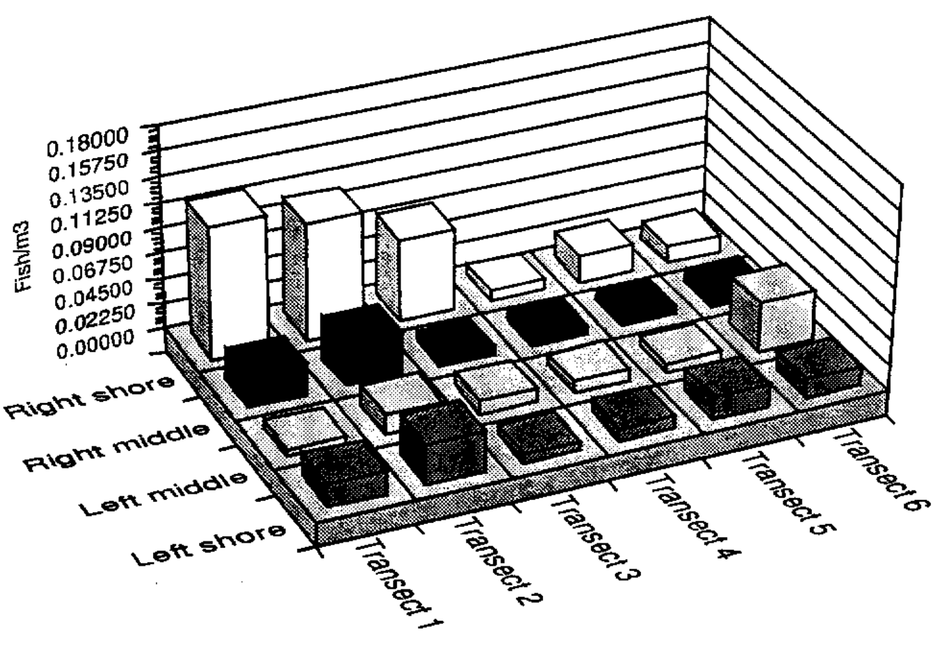
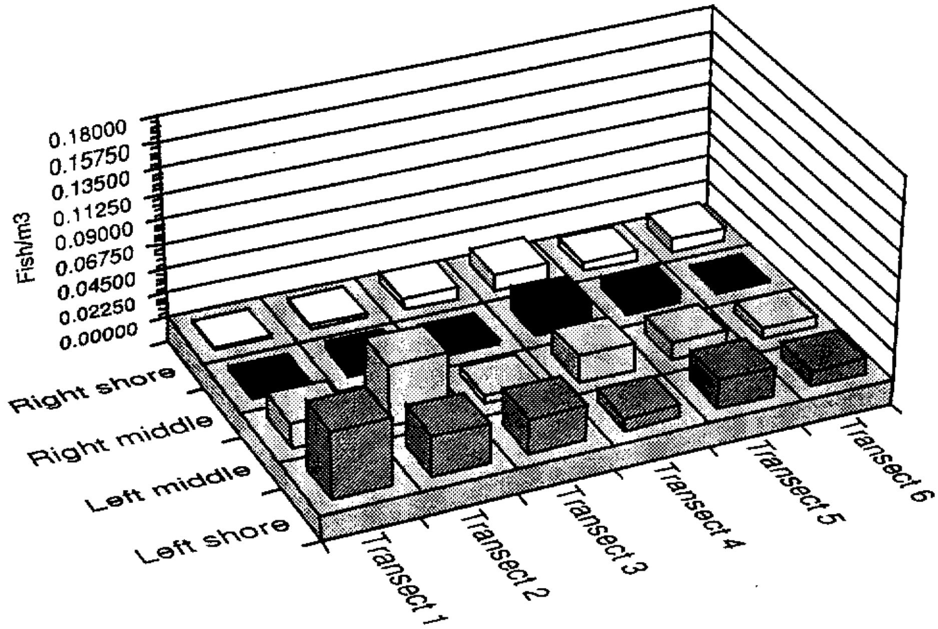


Figure 3. Horizontal density distributions by transect for the month of April.

DAY



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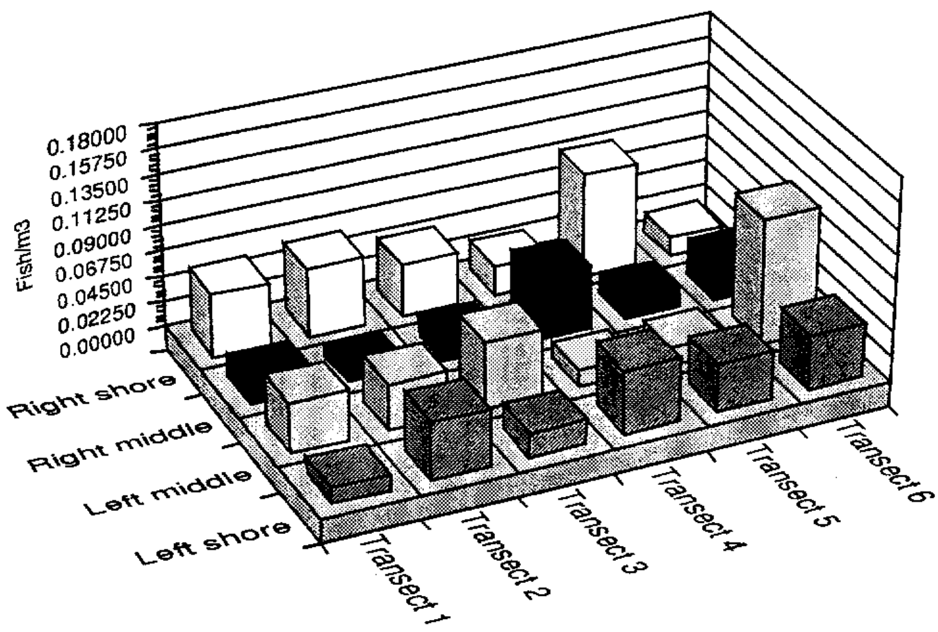

Figure 4. Horizontal density distributions by transect for the month of May.

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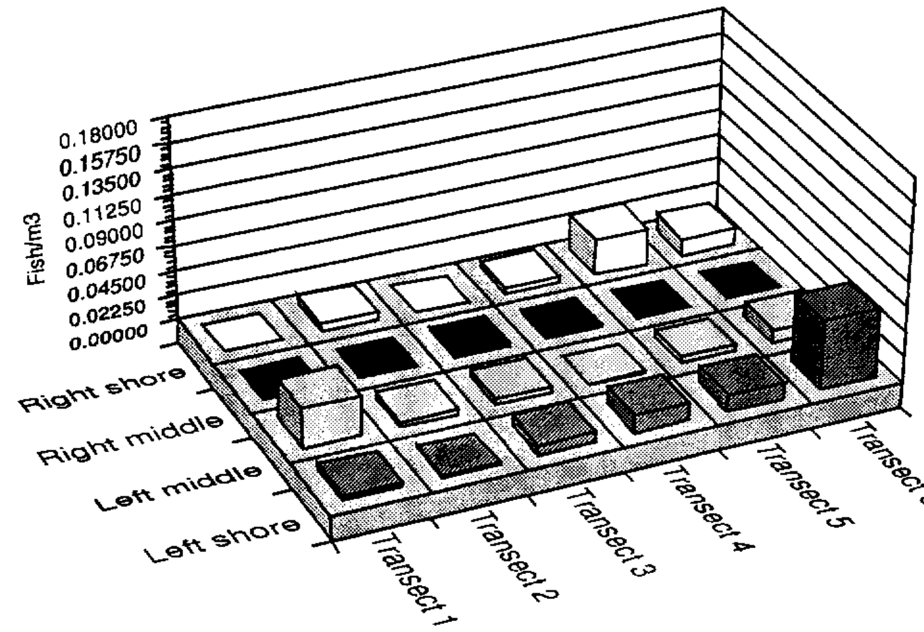

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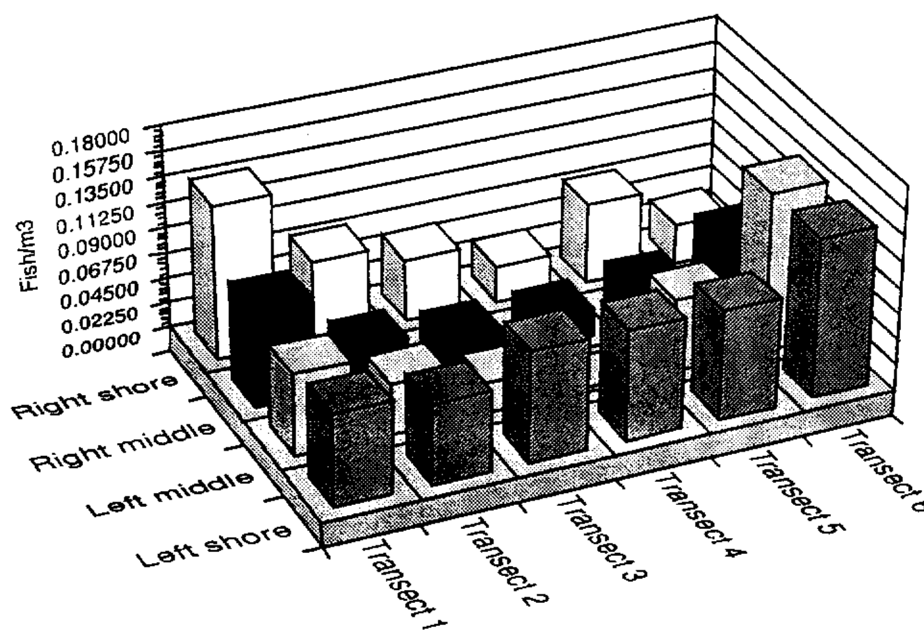

Figure 5. Horizontal density distributions by transect for the month of June.

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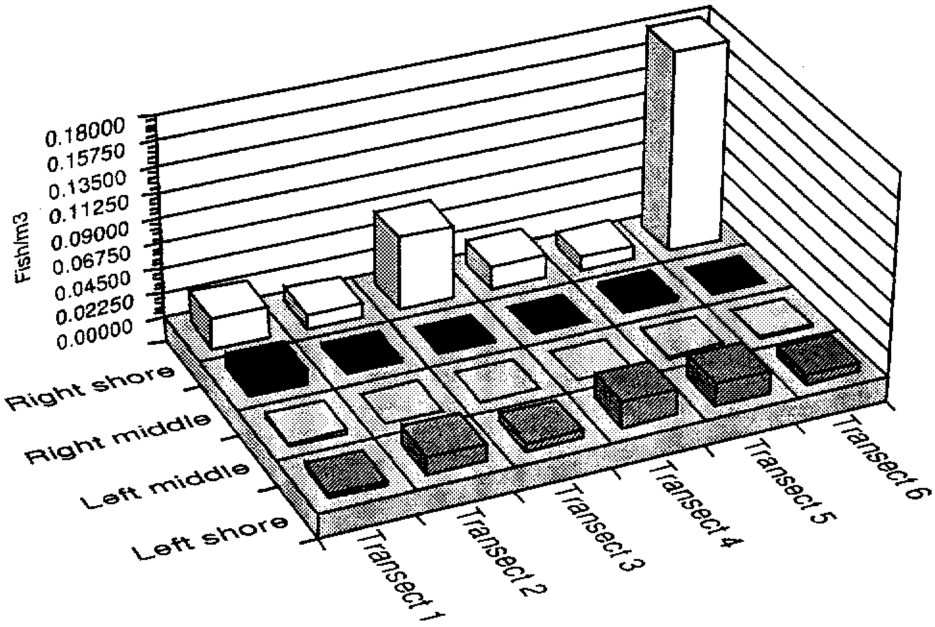

NIGHT

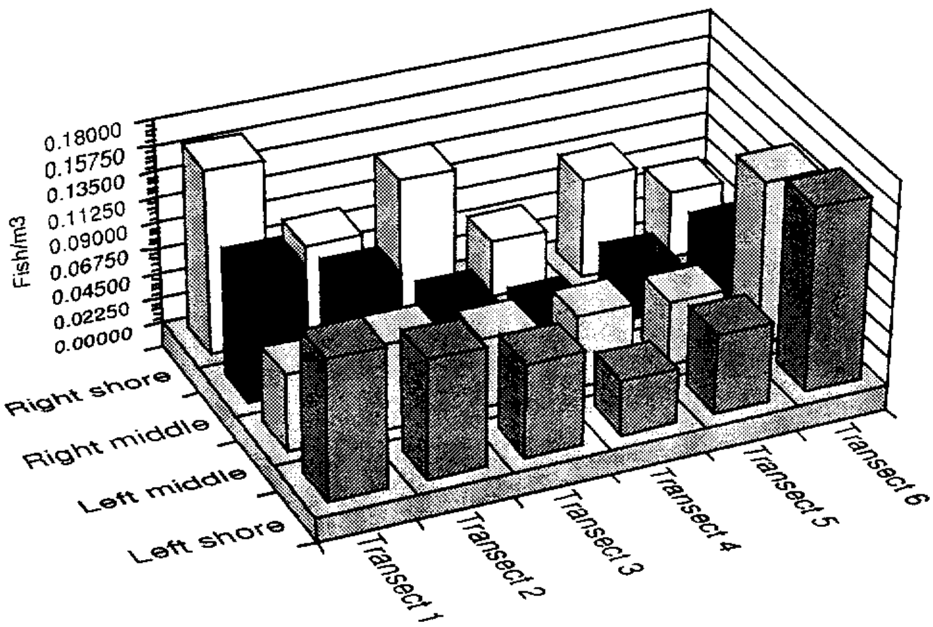

Figure 6. Horizontal density distributions by transect for the month of July.

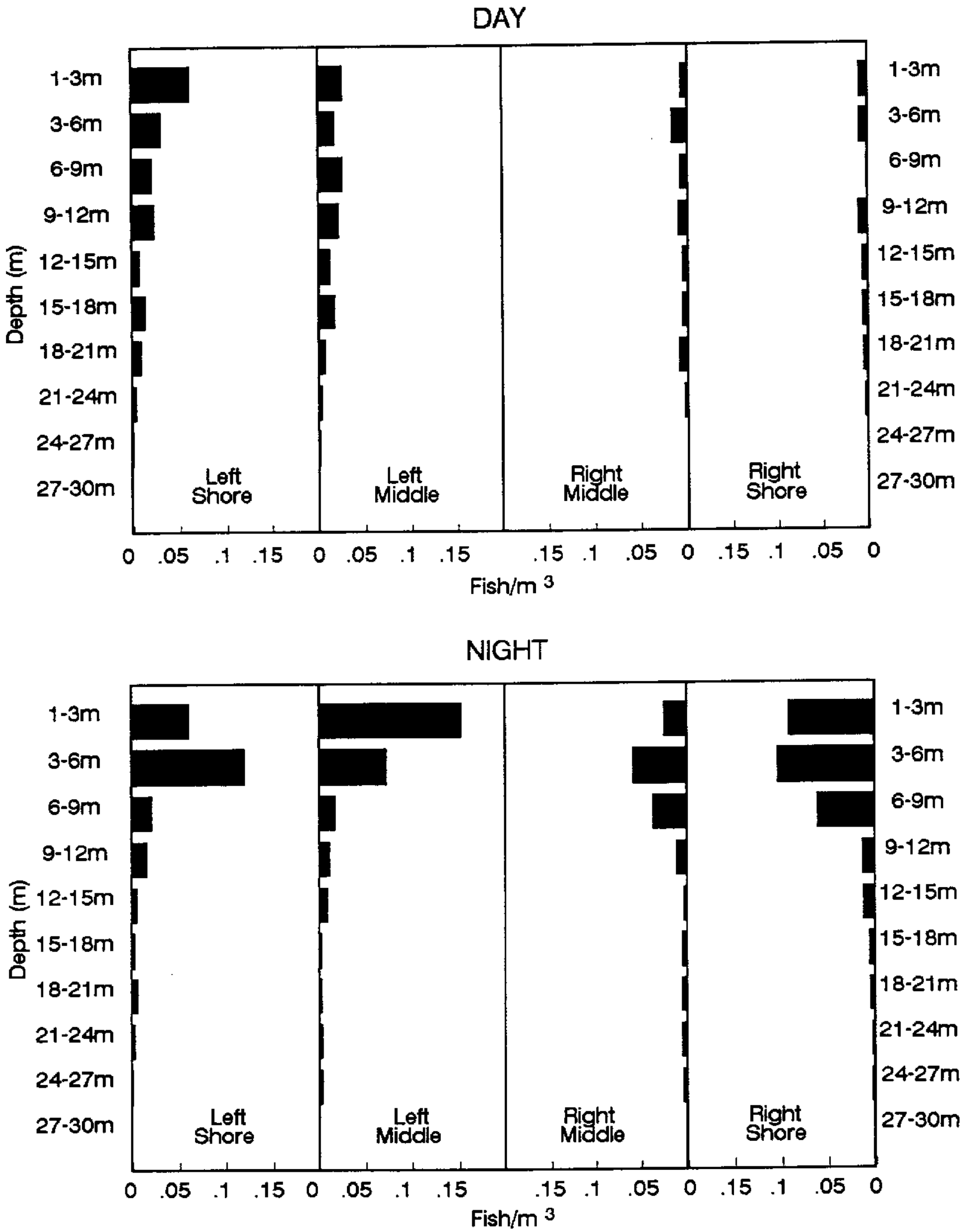

Figure 7. Vertical and horizontal density distributions by day and by night for the month of May.

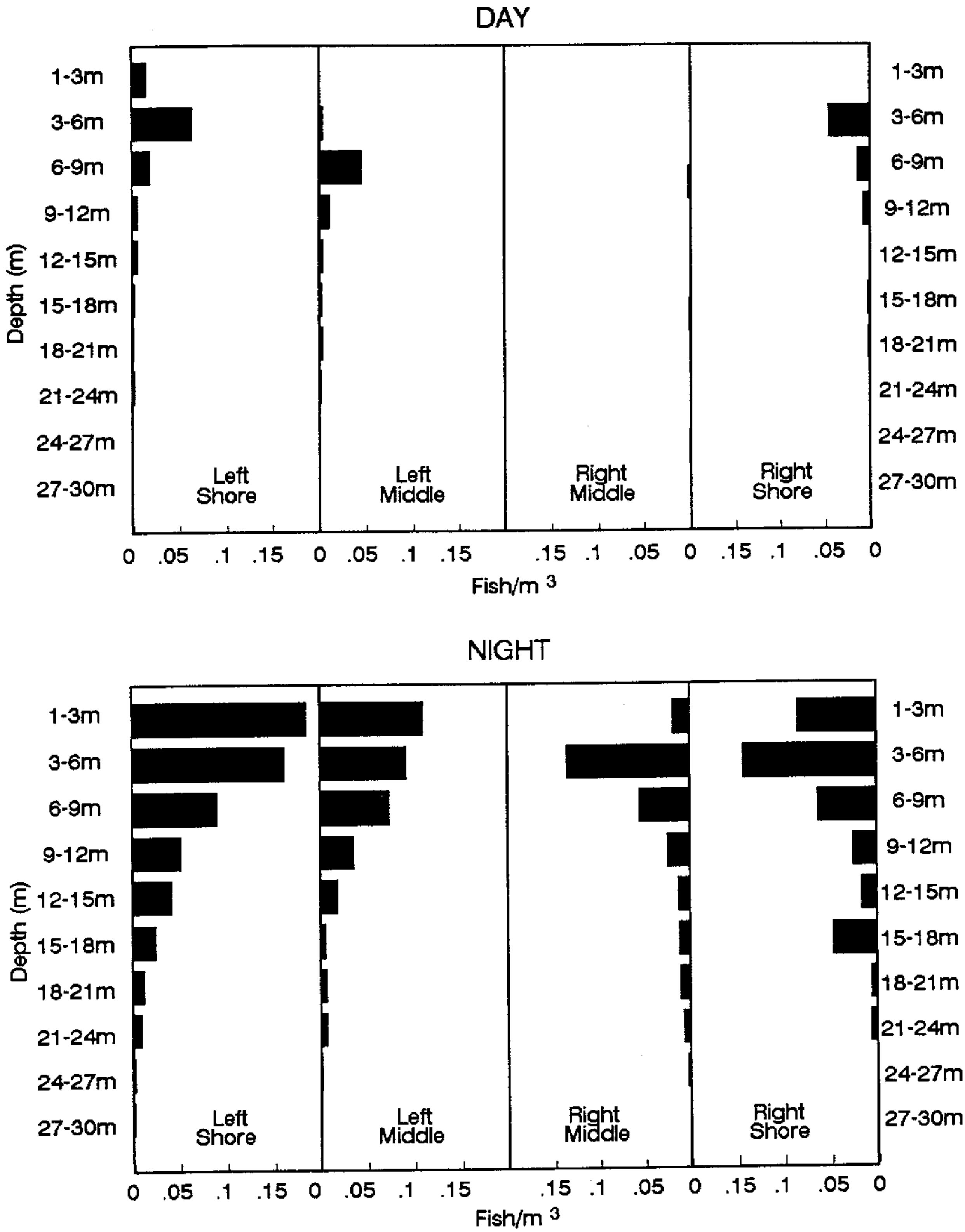

Figure 8. Vertical and horizontal density distributions by day and by night for the month of June.

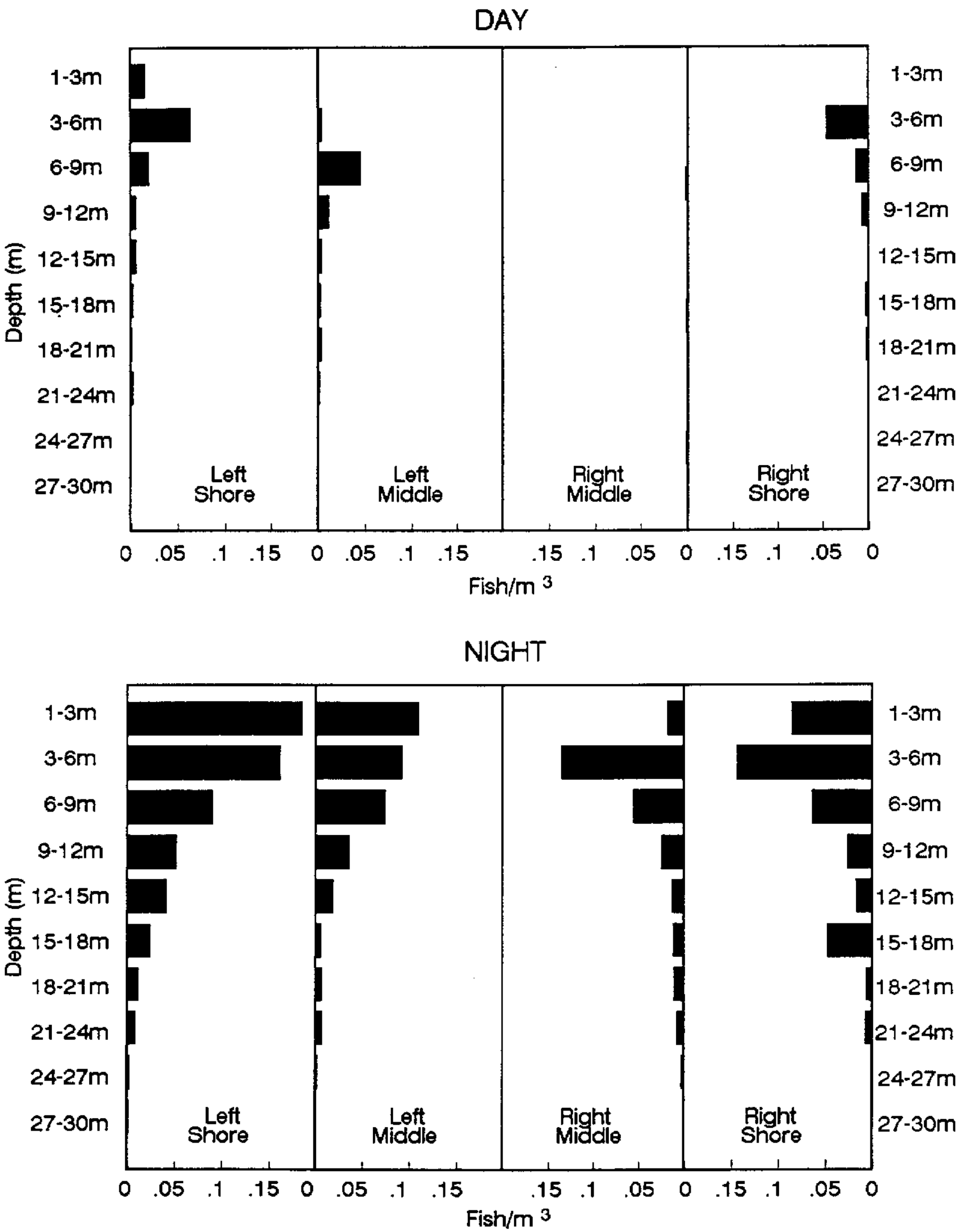

Figure 8. Vertical and horizontal density distributions by day and by night for the month of June.

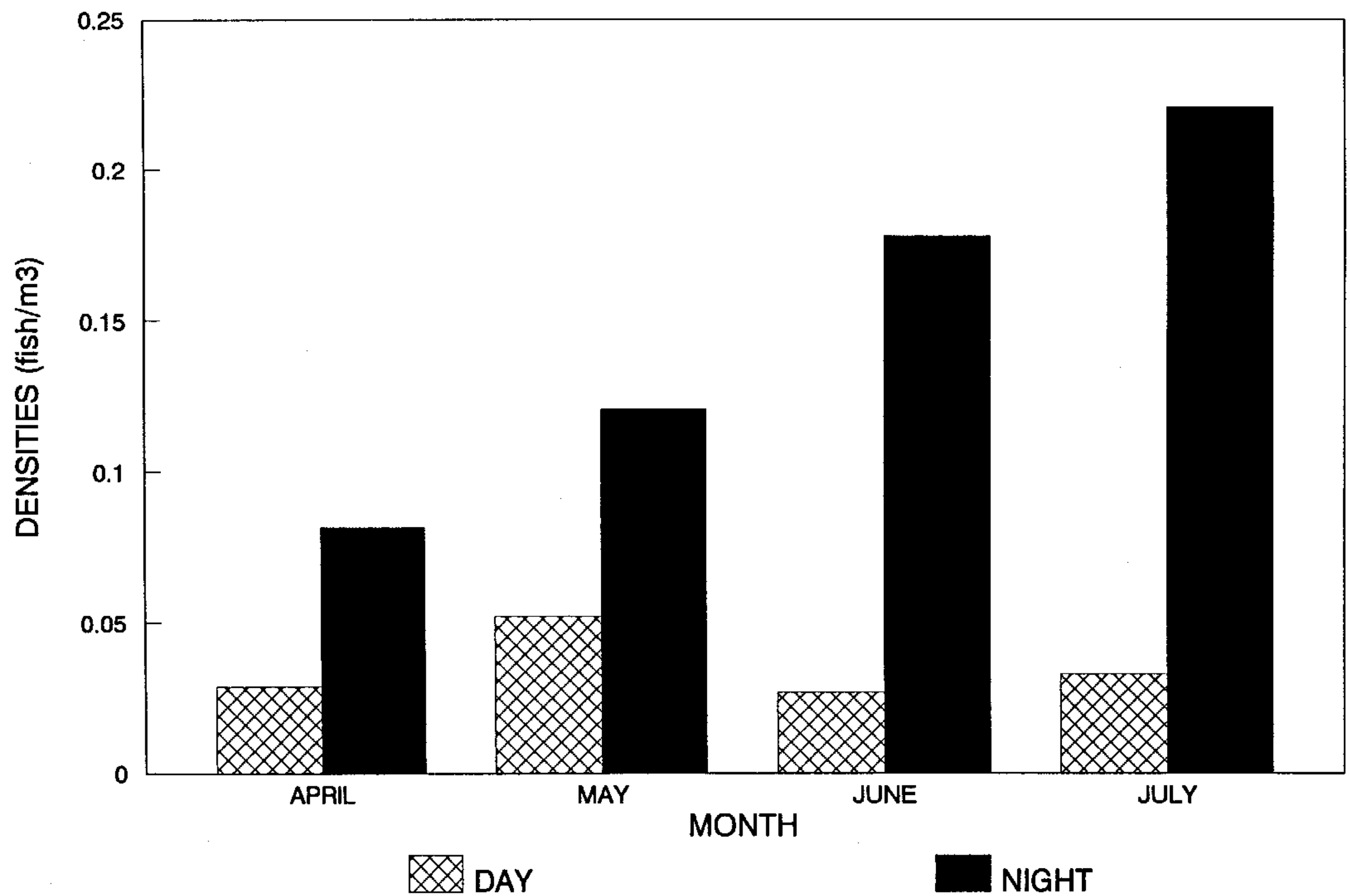

Figure 10. Monthly mean densities of all transects during daytime and nightime.

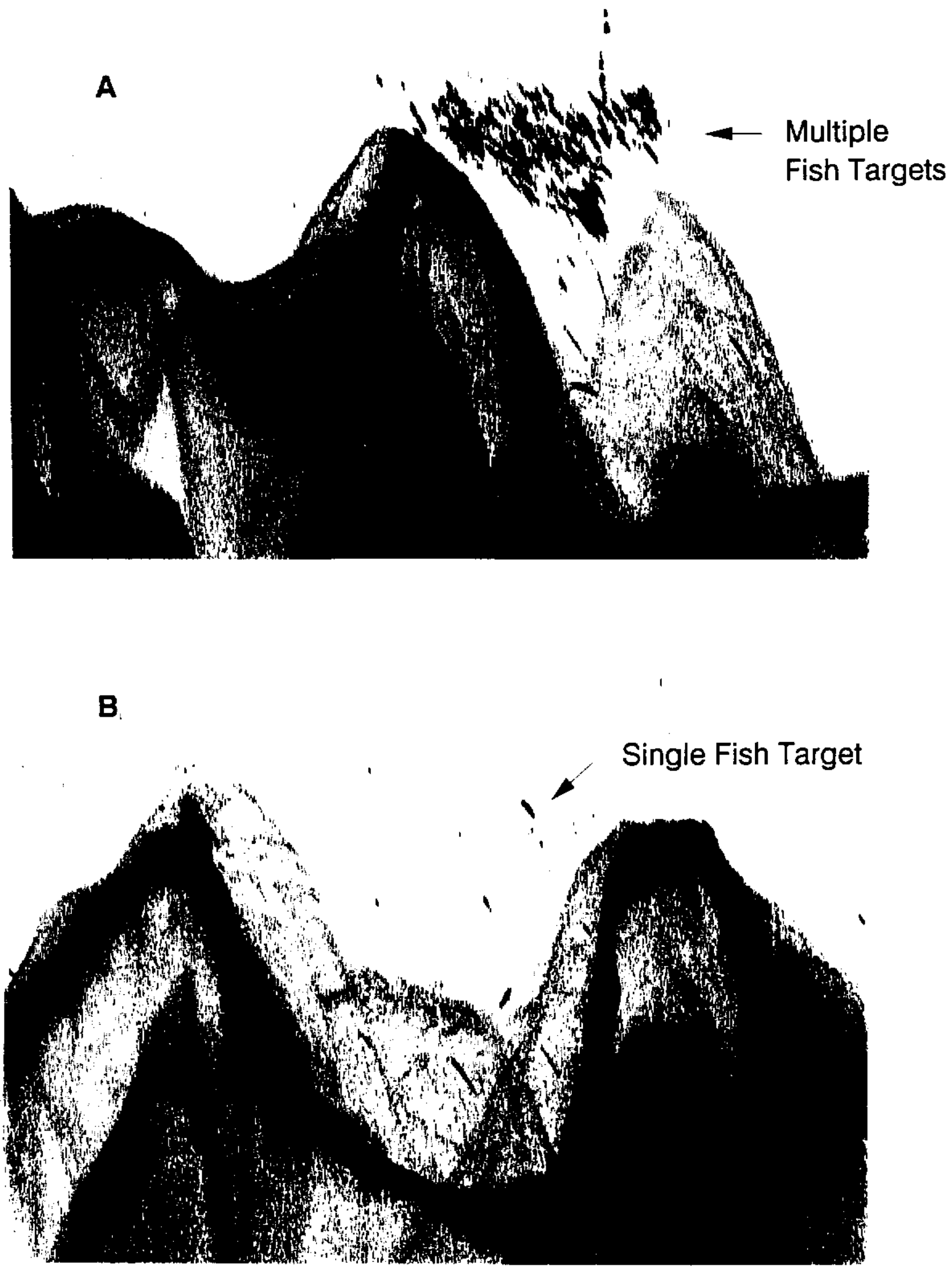

Figure 11. Echograms recorded on June 29th in Howard Hanson Reservoir intake area. Echogram A was recorded at 15:00 (day) and echogram B was recorded at 23:35 (night).

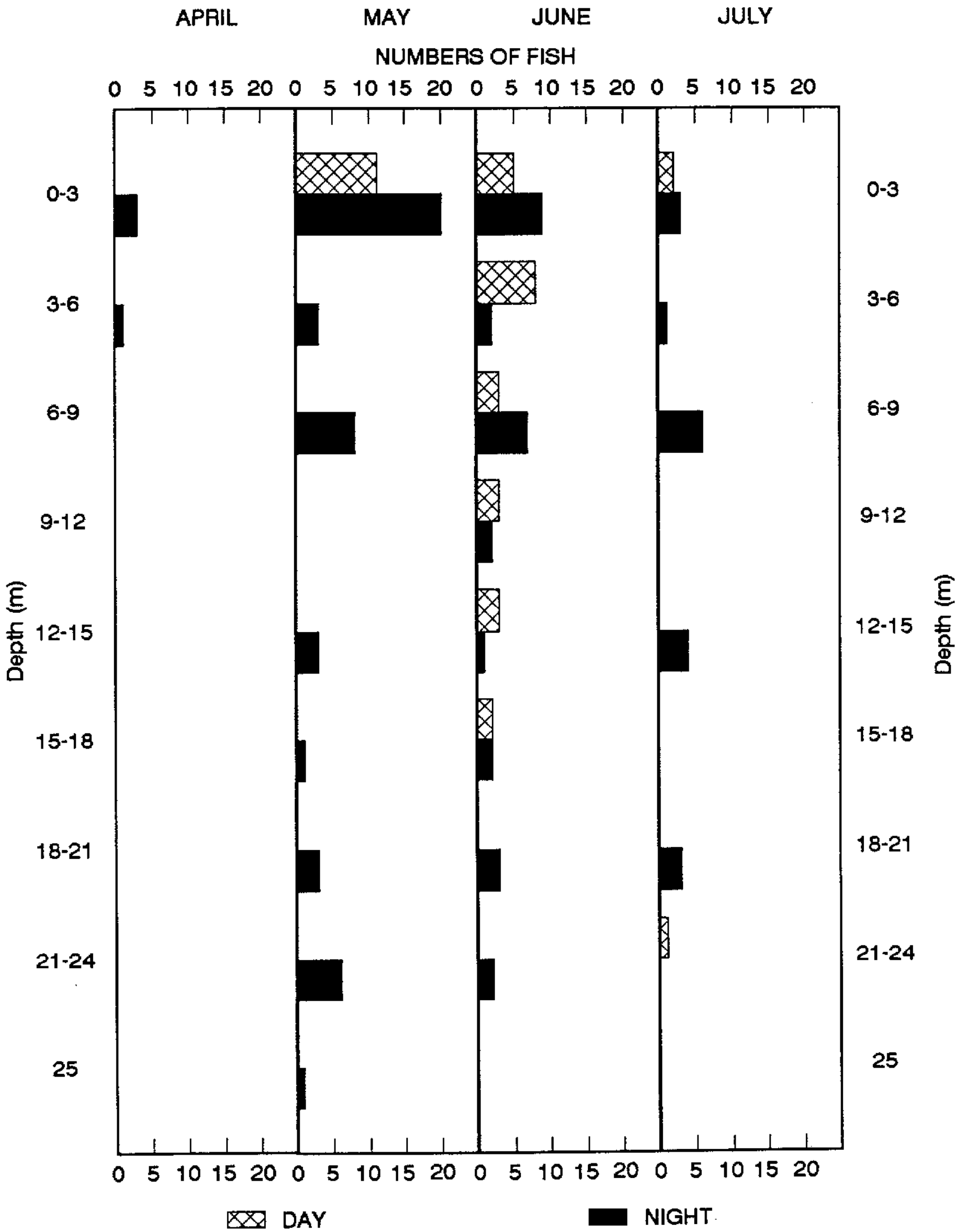

Figure 12. Monthly depth distribution of gill-net-caught coho smolts during the daytime and nighttime.

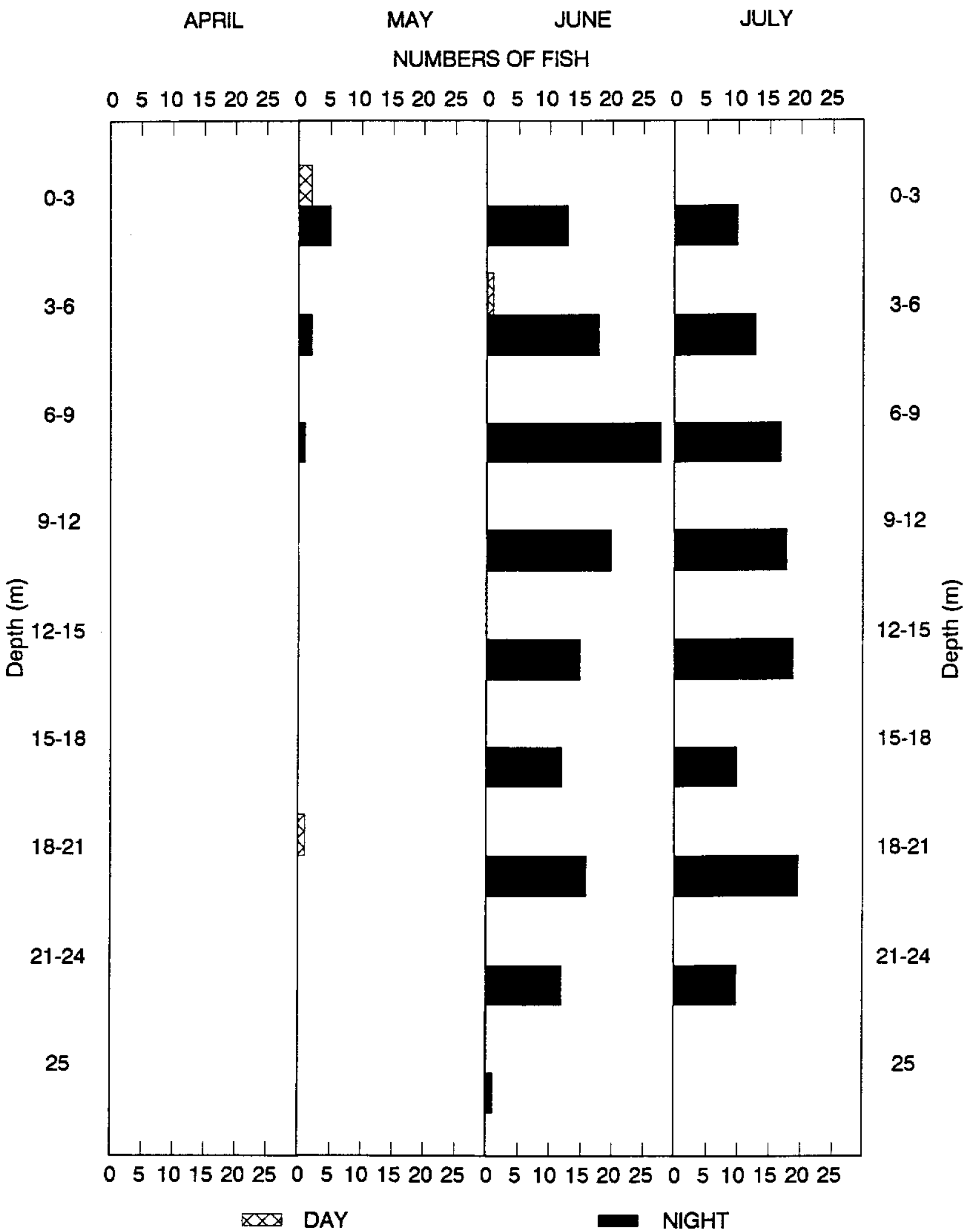

Figure 13. Monthly depth distribution of gill-net-caught chinook subyearlings during the daytime and nighttime.

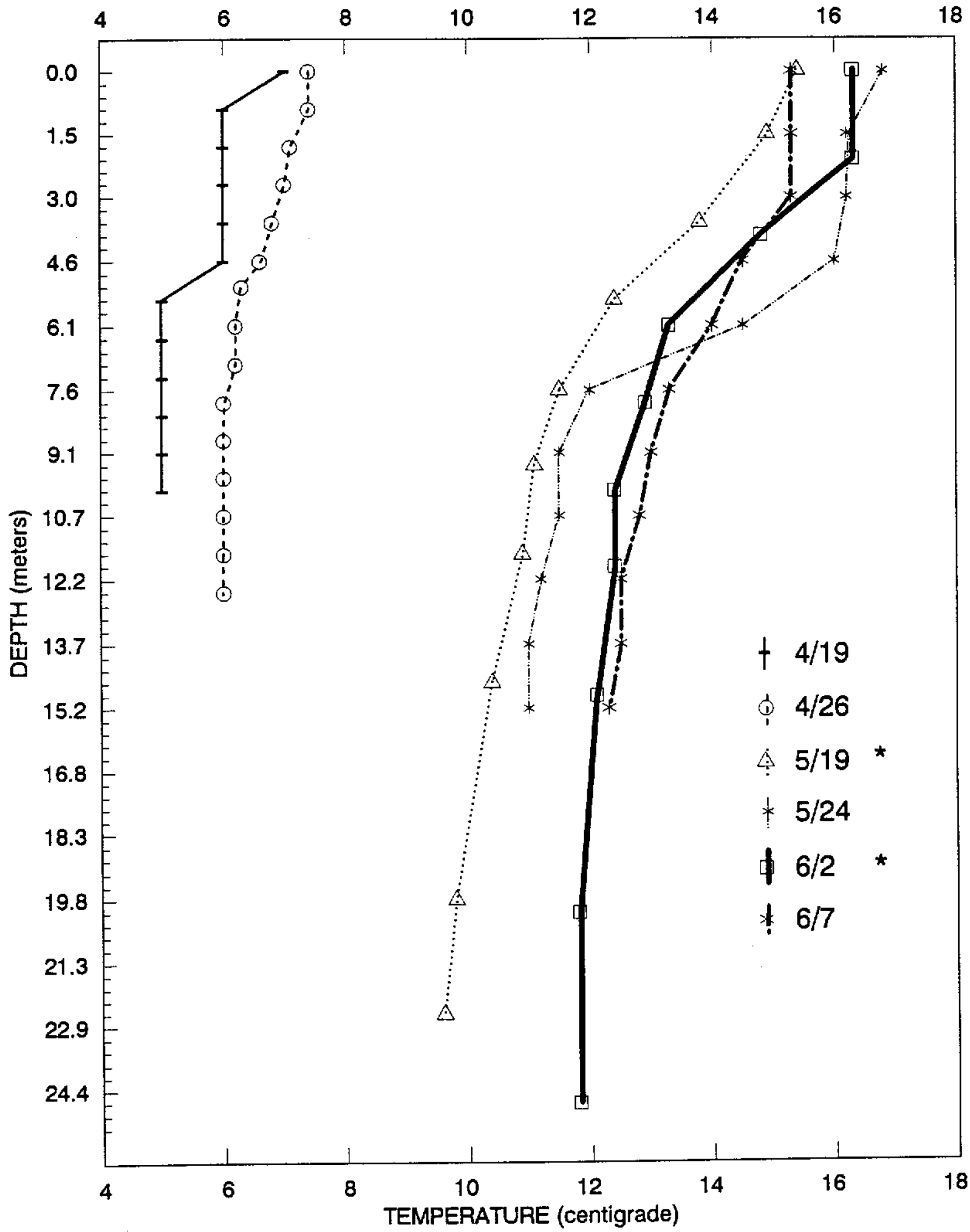

Figure 14. Temperature profiles taken at gill net sites for the period from April 19th to June 7th (* indicates USACOE provided data).

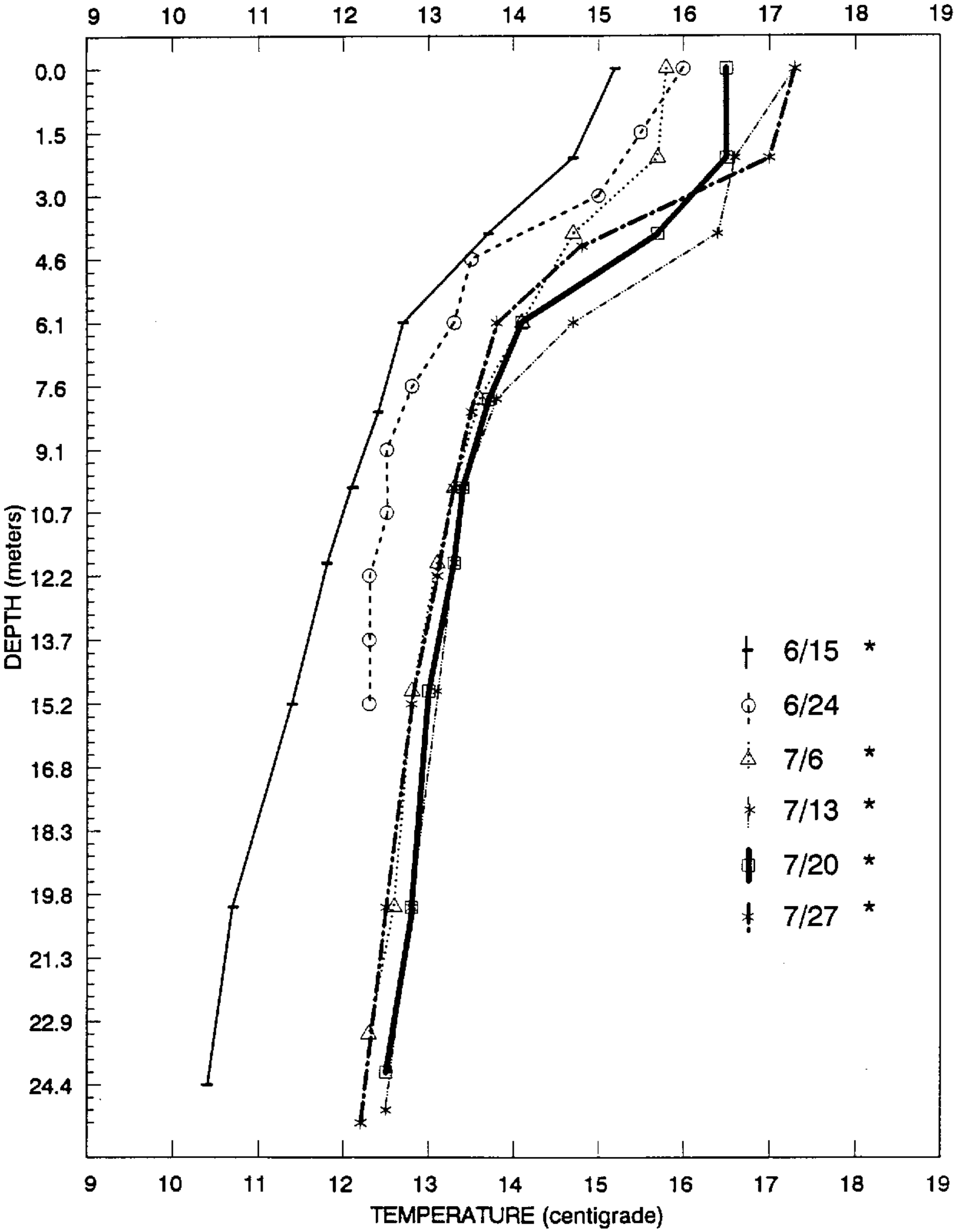

Figure 15. Temperature profiles taken at gill net sites for the period from June 15th to July 27th (* indicates USACOE provided data).

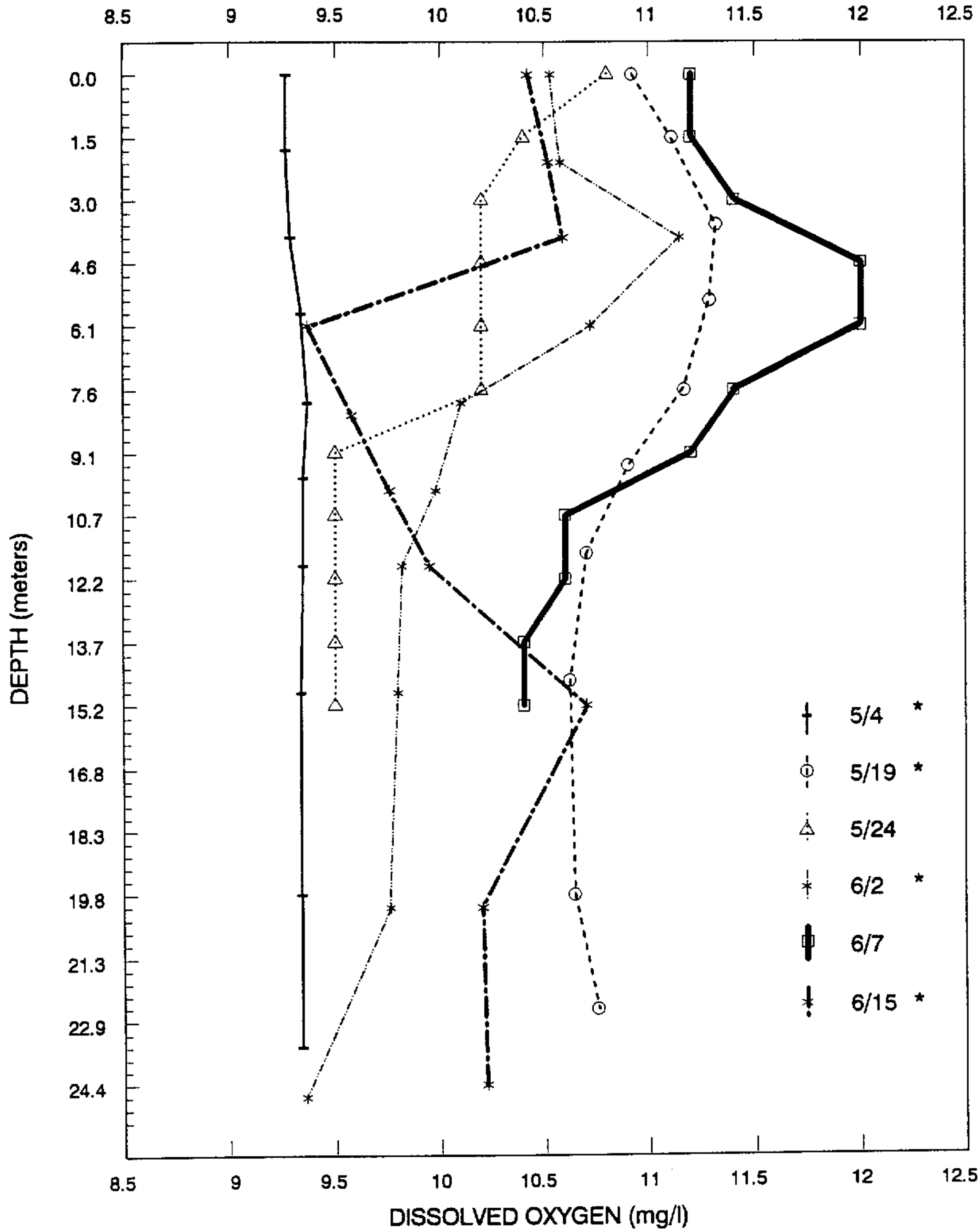

Figure 16. Dissolved oxygen profiles for the period May 4th to June 15th (* indicates USACOE provided data).

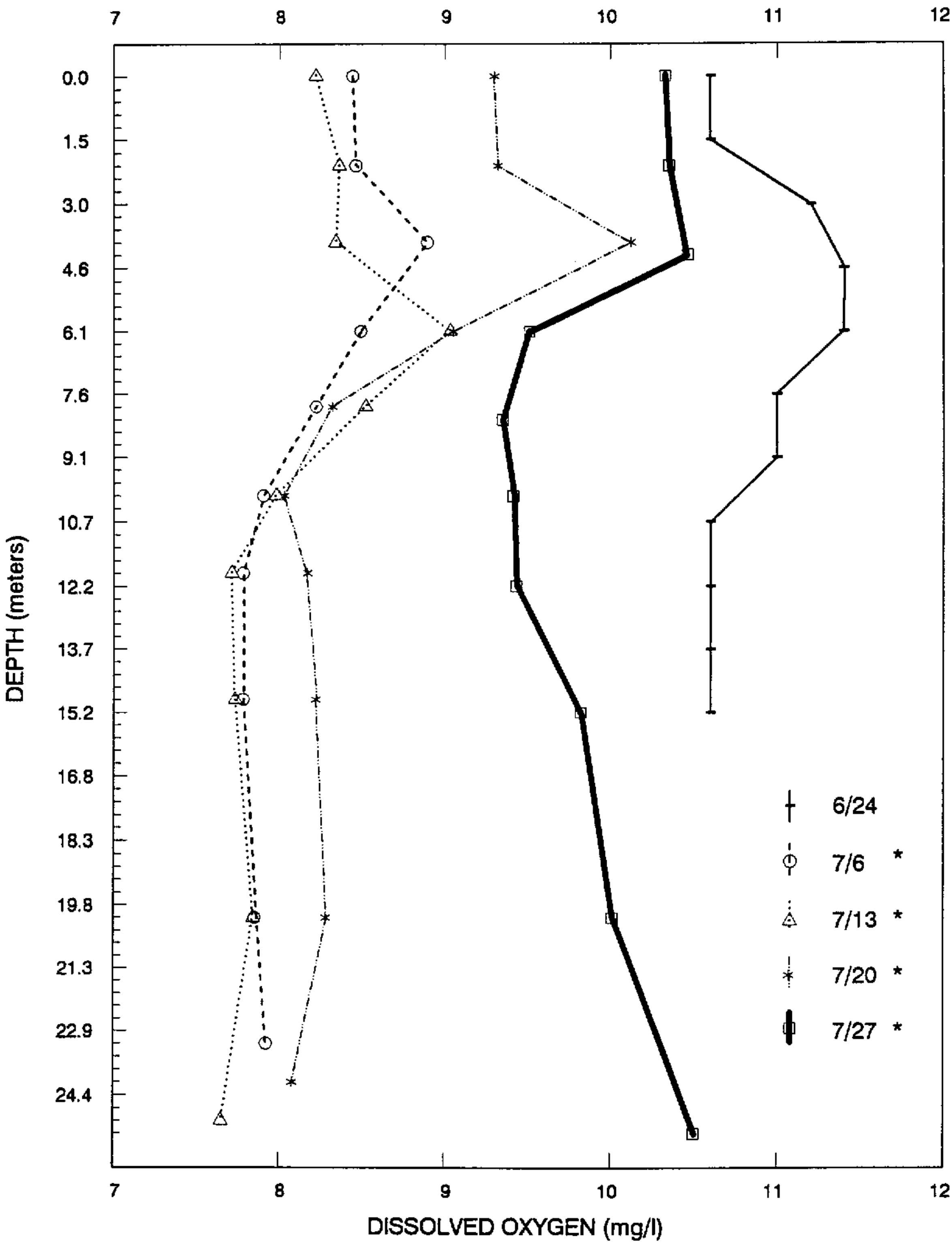

Figure 17. Dissolved oxygen profiles for the period June 24th to July 27th (* indicates USACOE provided data).

Table 1. Hydroacoustic equipment used at Howard Hanson Reservoir.

Item	Manufacturer	Model No.
Dual-beam sounder	Biosonic, Inc.	101
Interface	Biosonic, Inc.	171
Beta tape recorder	Sony	SL-HF 400
Pulse modulator	Sony	PCM-501 ES
Oscilloscope	Hitachi	V-423U
Thermal Chart recorder	Biosonic, Inc.	111
420 kHz 6/15 transducer	Biosonic, Inc.	-
Tow body	Endeco	Type 317 V-FIN

Table 2. Monthly summary by day and by night of coho smolts collected by gill net at Howard Hanson Reservoir.

Month	Time	Sample Size	Adipose Clip	Fork Length(mm)		Mean (mm)
				Min	Max	
April	Day	0	-	-	-	-
April	Night	4	4	121	129	125
May	Day	3	3	124	129	127
May	Night	44	29	108	144	122
June	Day	24	10	123	155	136
June	Night	28	8	115	156	126
July	Day	3	2	111	181	156
July	Night	17	4	144	180	160

Table 3. Monthly summary by day and by night of chinook subyearlings collected by gill net at Howard Hanson Reservoir.

Month	Time	Sample Size	Fork Length(mm)		Mean (mm)
			Min	Max	
April	Day	0	-	-	-
April	Night	0	-	-	-
May	Day	3	82	88	84
May	Night	7	75	90	84
June	Day	0	-	-	-
June	Night	135	89	121	106
July	Day	0	-	-	-
July	Night	117	105	152	127

Appendix A. Combined Transect densities (fish/m^3) by location and depth.

Depth	Right shore	Right middle	Left middle	Left shore
		APRIL DAY		
1-3m	0.00000	0.00000	0.00000	0.00000
3-6m	0.01374	0.00699	0.02633	0.03394
6-9m	0.01362	0.00393	0.01728	0.02388
9-12m	0.00000	0.01094	0.02044	0.02062
12-15m	0.00000	0.00145	0.01022	0.01975
15-18m	0.00000	0.00000	0.00000	0.00556
18-21m	0.00000	0.00000	0.00000	0.00175
21-24m	0.00000	0.00000	0.00000	0.00000
		APRIL NIGHT		
1-3m	0.07501	0.01216	0.02453	0.01080
3-6m	0.06163	0.03021	0.01720	0.04148
6-9m	0.13427	0.03789	0.03306	0.03054
9-12m	0.03212	0.00670	0.00995	0.01903
12-15m	0.03310	0.00394	0.00500	0.00686
15-18m	0.00625	0.00549	0.00570	0.00379
18-21m	0.00074	0.00340	0.00213	0.00165
21-24m	0.00000	0.00038	0.00000	0.00000
		MAY DAY		
1-3m	0.00913	0.00685	0.02613	0.06266
3-6m	0.00938	0.01691	0.01674	0.03057
6-9m	0.00187	0.00829	0.02546	0.02149
9-12m	0.01065	0.00981	0.02184	0.02338
12-15m	0.00654	0.00644	0.01144	0.00661
15-18m	0.00574	0.00544	0.01732	0.01309
18-21m	0.00484	0.00873	0.00645	0.00880
21-24m	0.00288	0.00329	0.00334	0.00270
24-27m	0.00079	0.00068	0.00081	0.00040
27-30m	0.00000	0.00000	0.00000	0.00000
		MAY NIGHT		
1-3m	0.09220	0.02414	0.15741	0.06035
3-6m	0.10326	0.05650	0.07424	0.12049
6-9m	0.06102	0.03615	0.01750	0.02121
9-12m	0.01406	0.01097	0.01178	0.01541
12-15m	0.01259	0.00366	0.00979	0.00513
15-18m	0.00570	0.00503	0.00234	0.00235
18-21m	0.00523	0.00506	0.00298	0.00647
21-24m	0.00274	0.00472	0.00357	0.00267
24-27m	0.00315	0.00438	0.00385	0.00019
27-30m	0.00000	0.00000	0.00000	0.00000

Appendix A. Continued.

Depth	Right shore	Right middle	Left middle	Left shore
		JUNE DAY		
1-3m	0.00000	0.00000	0.00000	0.01344
3-6m	0.04402	0.00000	0.00271	0.06369
6-9m	0.01394	0.00248	0.04515	0.01825
9-12m	0.00662	0.00000	0.01004	0.00448
12-15m	0.00000	0.00000	0.00257	0.00377
15-18m	0.00175	0.00082	0.00152	0.00078
18-21m	0.00058	0.00016	0.00163	0.00013
21-24m	0.00007	0.00000	0.00014	0.00141
24-27m	0.00019	0.00136	0.00000	0.00000
27-30m	0.00000	0.00000	0.00000	0.00000
		JUNE NIGHT		
1-3m	0.08586	0.01681	0.11097	0.18870
3-6m	0.14465	0.13112	0.09258	0.16497
6-9m	0.06423	0.05391	0.07424	0.09082
9-12m	0.02617	0.02371	0.03613	0.05215
12-15m	0.01656	0.01159	0.01894	0.04175
15-18m	0.04766	0.01093	0.00553	0.02435
18-21m	0.00651	0.00906	0.00672	0.01118
21-24m	0.00676	0.00668	0.00704	0.00797
24-27m	0.00114	0.00237	0.00131	0.00132
27-30m	0.00041	0.00000	0.00000	0.00094
		JULY DAY		
1-3m	0.00000	0.00000	0.00000	0.00000
3-6m	0.09750	0.00000	0.00243	0.04661
6-9m	0.04645	0.01392	0.00000	0.01905
9-12m	0.04117	0.00227	0.00109	0.00075
12-15m	0.00476	0.00000	0.00000	0.00642
15-18m	0.00345	0.00274	0.00073	0.00200
18-21m	0.00010	0.00000	0.00158	0.00128
21-24m	0.00010	0.00000	0.00036	0.00019
24-27m	0.00000	0.00037	0.00000	0.00000
		JULY NIGHT		
1-3m	0.01668	0.04850	0.02561	0.10373
3-6m	0.19108	0.06807	0.10405	0.15528
6-9m	0.10345	0.06075	0.09329	0.09881
9-12m	0.09066	0.04871	0.07504	0.08480
12-15m	0.06328	0.04413	0.05861	0.04439
15-18m	0.04662	0.03247	0.04641	0.03711
18-21m	0.04186	0.04035	0.03540	0.03115
21-24m	0.00652	0.02100	0.02430	0.02623
24-27m	0.00065	0.00569	0.00735	0.00733

Appendix B. Gill net catches of salmonids collected during the study.

DATE	TIME	SPECIES	LENGTH (mm)	DEPTH (m)	MESH (cm)	CLIP	WEIGHT (g)
APR 12	day	0					
APR 12	night	0					
APR 26	day	0					
APR 26	night	coho	129	00-03	2.54	ad	19.6
APR 26	night	coho	122	00-03	2.54	ad	17.7
APR 26	night	coho	121	00-03	2.54	ad	16.1
APR 26	night	coho	128	03-06	2.54	ad	19.5
APR 26	night	steelhead	186	00-03	3.81		62.0
MAY 10	day	0					
MAY 10	night	coho	129	00-03	2.54	ad	21.3
MAY 10	night	coho	125	00-03	2.54	ad	18.0
MAY 10	night	coho	129	00-03	2.54	ad	20.2
MAY 10	night	coho	132	00-03	2.54	ad	23.2
MAY 10	night	coho	122	00-03	2.54	ad	16.4
MAY 10	night	coho	120	00-03	2.54	ad	17.7
MAY 10	night	coho	137	00-03	2.54	ad	22.6
MAY 10	night	coho	135	00-03	1.59	ad	21.6
MAY 24	day	coho	129	00-03	2.54	ad	
MAY 24	day	coho	124	00-03	2.54	ad	
MAY 24	day	coho	128	00-03	1.59	ad	
MAY 24	day	chinook	83	00-03	1.59		
MAY 24	day	chinook	88	00-03	1.59		
MAY 24	day	chinook	82	18-21	1.59		
MAY 24	day	steelhead	250	00-03	1.59		
MAY 24	night	coho	140	00-03	1.59	ad	
MAY 24	night	chinook	75	00-03	1.59		
MAY 24	night	chinook	85	00-03	1.59		
MAY 24	night	chinook	84	00-03	1.59		
MAY 24	night	chinook	90	00-03	1.59		
MAY 24	night	chinook	85	03-06	1.59		
MAY 24	night	chinook	87	03-06	1.59		
MAY 24	night	coho	108	06-09	1.59		
MAY 24	night	chinook	83	06-09	1.59		
MAY 24	night	coho	126	00-03	2.54	ad	
MAY 24	night	coho	134	00-03	2.54	ad	
MAY 24	night	coho	134	00-03	2.54	ad	
MAY 24	night	coho	131	00-03	2.54	ad	
MAY 24	night	coho	140	00-03	2.54		
MAY 24	night	coho	137	00-03	2.54	ad	
MAY 24	night	coho	123	00-03	2.54		
MAY 24	night	coho	131	00-03	2.54		
MAY 24	night	coho	110	00-03	2.54	ad	
MAY 24	night	coho	120	00-03	2.54	ad	
MAY 24	night	coho	112	00-03	2.54		
MAY 24	night	coho	118	03-06	2.54		
MAY 24	night	coho	120	03-06	2.54		
MAY 24	night	coho	115	03-06	2.54		

Appendix B. Continued.

DATE	TIME	SPECIES	LENGTH (mm)	DEPTH (m)	MESH (cm)	CLIP	WEIGHT (g)
MAY 24	night	coho	130	06-09	2.54	ad	
MAY 24	night	coho	121	06-09	2.54	ad	
MAY 24	night	coho	115	06-09	2.54		
MAY 24	night	coho	136	06-09	2.54	ad	
MAY 24	night	coho	116	06-09	2.54		
MAY 24	night	coho	112	06-09	2.54		
MAY 24	night	coho	120	06-09	2.54		
MAY 24	night	coho	119	12-15	2.54		
MAY 24	night	coho	144	12-15	2.54	ad	
MAY 24	night	coho	116	12-15	2.54	ad	
MAY 24	night	coho	116	15-18	2.54		
MAY 24	night	coho	112	18-21	2.54		
MAY 24	night	coho	128	18-21	2.54	ad	
MAY 24	night	coho	135	18-21	2.54	ad	
MAY 24	night	coho	110	21-24	2.54		
MAY 24	night	coho	132	21-24	2.54	ad	
MAY 24	night	coho	130	21-24	2.54	ad	
MAY 24	night	coho	128	21-24	2.54	ad	
MAY 24	night	coho	120	21-24	2.54		
MAY 24	night	coho	115	21-24	2.54		
MAY 24	night	chinook	140	00-03	3.81		
JUN 7	day	coho	155	00-03	1.59	ad	
JUN 7	day	coho	123	03-06	1.59		
JUN 7	day	coho	133	03-06	1.59	ad	
JUN 7	day	coho	130	03-06	1.59	ad	
JUN 7	day	coho	145	03-06	1.59	ad	
JUN 7	day	coho	150	03-06	1.59	ad	
JUN 7	day	coho	126	06-09	1.59		
JUN 7	day	coho	130	06-09	1.59		
JUN 7	day	coho	135	06-09	1.59	ad	
JUN 7	day	coho	125	09-12	1.59		
JUN 7	day	coho	140	15-18	1.59		
JUN 7	day	coho	147	15-18	2.54	ad	
JUN 7	night	coho	131	00-03	1.59		
JUN 7	night	coho	142	06-09	1.59	ad	
JUN 7	night	coho	128	06-09	1.59		
JUN 7	night	chinook	92	06-09	1.59		8.5
JUN 7	night	chinook	94	09-12	1.59		8.4
JUN 7	night	chinook	90	21-25	1.59		7.1
JUN 7	night	coho	121	00-03	2.54		
JUN 7	night	coho	121	00-03	2.54		
JUN 7	night	coho	133	00-03	2.54		
JUN 7	night	coho	156	00-03	2.54	ad	
JUN 7	night	coho	132	00-03	2.54		
JUN 7	night	coho	132	00-03	2.54	ad	
JUN 7	night	coho	123	03-06	2.54		
JUN 7	night	coho	120	03-06	2.54		

Appendix B. Continued.

DATE	TIME	SPECIES	LENGTH (mm)	DEPTH (m)	MESH (cm)	CLIP	WEIGHT (g)
JUN 7	night	coho	115	06-09	2.54		
JUN 7	night	coho	108	06-09	2.54		
JUN 7	night	coho	125	06-09	2.54		
JUN 7	night	coho	123	06-09	2.54	ad	
JUN 7	night	coho	128	06-09	2.54		
JUN 7	night	coho	120	09-12	2.54		
JUN 7	night	coho	116	09-12	2.54		
JUN 7	night	coho	122	15-18	2.54		
JUN 7	night	coho	135	15-18	2.54	ad	
JUN 7	night	coho	129	18-21	2.54		
JUN 7	night	coho	135	18-21	2.54	ad	
JUN 7	night	coho	123	18-21	2.54		
JUN 7	night	coho	126	21-24	2.54		
JUN 7	night	coho	129	21-24	2.54		
JUN 7	night	chinook	101	00-03	2.54		11.2
JUN 24	day	coho	136	00-03	1.59		
JUN 24	day	coho	135	03-06	1.59		
JUN 24	day	coho	148	09-12	1.59		
JUN 24	day	coho	133	00-03	2.54	ad	
JUN 24	day	coho	143	00-03	2.54	ad	
JUN 24	day	coho	136	00-03	2.54	ad	
JUN 24	day	coho	137	03-06	2.54		
JUN 24	day	coho	128	03-06	2.54		
JUN 24	day	chinook	111	03-06	2.54		
JUN 24	day	coho	131	09-12	2.54		
JUN 24	day	coho	135	12-15	2.54		
JUN 24	day	coho	128	12-15	2.54		
JUN 24	day	coho	145	12-15	2.54		
JUN 24	night	chinook	121	00-03	1.59		
JUN 24	night	chinook	97	00-03	1.59		
JUN 24	night	chinook	99	00-03	1.59		
JUN 24	night	chinook	105	00-03	1.59		
JUN 24	night	chinook	106	00-03	1.59		
JUN 24	night	chinook	91	03-06	1.59		
JUN 24	night	chinook	97	03-06	1.59		
JUN 24	night	chinook	102	03-06	1.59		
JUN 24	night	chinook	106	03-06	1.59		
JUN 24	night	chinook	95	03-06	1.59		
JUN 24	night	chinook	107	03-06	1.59		
JUN 24	night	chinook	105	06-09	1.59		
JUN 24	night	chinook	103	06-09	1.59		
JUN 24	night	chinook	95	06-09	1.59		
JUN 24	night	chinook	89	09-12	1.59		
JUN 24	night	chinook	111	09-12	1.59		
JUN 24	night	chinook	96	09-12	1.59		
JUN 24	night	chinook	94	12-15	1.59		
JUN 24	night	chinook	108	15-18	1.59		

Appendix B. Continued.

DATE	TIME	SPECIES	LENGTH (mm)	DEPTH (m)	MESH (cm)	CLIP	WEIGHT (g)
JUN 24	night	chinook	113	18-21	1.59		
JUN 24	night	chinook	103	00-03	2.54		
JUN 24	night	chinook	103	00-03	2.54		
JUN 24	night	chinook	99	00-03	2.54		
JUN 24	night	chinook	99	00-03	2.54		
JUN 24	night	chinook	103	00-03	2.54		
JUN 24	night	chinook	97	00-03	2.54		
JUN 24	night	chinook	98	00-03	2.54		
JUN 24	night	coho	115	00-03	2.54	ad	
JUN 24	night	coho	125	00-03	2.54		
JUN 24	night	chinook	113	03-06	2.54		
JUN 24	night	chinook	116	03-06	2.54		
JUN 24	night	chinook	101	03-06	2.54		
JUN 24	night	chinook	111	03-06	2.54		
JUN 24	night	chinook	119	03-06	2.54		
JUN 24	night	chinook	106	03-06	2.54		
JUN 24	night	chinook	112	03-06	2.54		
JUN 24	night	chinook	112	03-06	2.54		
JUN 24	night	chinook	105	03-06	2.54		
JUN 24	night	chinook	103	03-06	2.54		
JUN 24	night	chinook	105	03-06	2.54		
JUN 24	night	chinook	102	03-06	2.54		
JUN 24	night	chinook	111	06-09	2.54		
JUN 24	night	chinook	100	06-09	2.54		
JUN 24	night	chinook	102	06-09	2.54		
JUN 24	night	chinook	101	06-09	2.54		
JUN 24	night	chinook	108	06-09	2.54		
JUN 24	night	chinook	111	06-09	2.54		
JUN 24	night	chinook	102	06-09	2.54		
JUN 24	night	chinook	108	06-09	2.54		
JUN 24	night	chinook	101	06-09	2.54		
JUN 24	night	chinook	103	06-09	2.54		
JUN 24	night	chinook	112	06-09	2.54		
JUN 24	night	chinook	118	06-09	2.54		
JUN 24	night	chinook	102	06-09	2.54		
JUN 24	night	chinook	101	06-09	2.54		
JUN 24	night	chinook	113	06-09	2.54		
JUN 24	night	chinook	108	06-09	2.54		
JUN 24	night	chinook	103	06-09	2.54		
JUN 24	night	chinook	118	06-09	2.54		
JUN 24	night	chinook	104	06-09	2.54		
JUN 24	night	chinook	117	06-09	2.54		
JUN 24	night	chinook	108	06-09	2.54		
JUN 24	night	chinook	99	06-09	2.54		
JUN 24	night	chinook	94	06-09	2.54		
JUN 24	night	chinook	109	06-09	2.54		
JUN 24	night	chinook	109	09-12	2.54		

Appendix B. Continued.

DATE	TIME	SPECIES	LENGTH (mm)	DEPTH (m)	MESH (cm)	CLIP	WEIGHT (g)
JUN 24	night	chinook	103	09-12	2.54		
JUN 24	night	chinook	118	09-12	2.54		
JUN 24	night	chinook	117	09-12	2.54		
JUN 24	night	chinook	115	09-12	2.54		
JUN 24	night	chinook	104	09-12	2.54		
JUN 24	night	chinook	117	09-12	2.54		
JUN 24	night	chinook	103	09-12	2.54		
JUN 24	night	chinook	104	09-12	2.54		
JUN 24	night	chinook	105	09-12	2.54		
JUN 24	night	chinook	100	09-12	2.54		
JUN 24	night	chinook	103	09-12	2.54		
JUN 24	night	chinook	104	09-12	2.54		
JUN 24	night	chinook	107	09-12	2.54		
JUN 24	night	chinook	100	09-12	2.54		
JUN 24	night	chinook	103	09-12	2.54		
JUN 24	night	chinook	108	12-15	2.54		
JUN 24	night	chinook	103	12-15	2.54		
JUN 24	night	chinook	108	12-15	2.54		
JUN 24	night	chinook	112	12-15	2.54		
JUN 24	night	chinook	108	12-15	2.54		
JUN 24	night	chinook	107	12-15	2.54		
JUN 24	night	chinook	102	12-15	2.54		
JUN 24	night	chinook	107	12-15	2.54		
JUN 24	night	chinook	107	12-15	2.54		
JUN 24	night	chinook	115	12-15	2.54		
JUN 24	night	chinook	97	12-15	2.54		
JUN 24	night	chinook	108	12-15	2.54		
JUN 24	night	chinook	113	12-15	2.54		
JUN 24	night	chinook	107	12-15	2.54		
JUN 24	night	coho	125	12-15	2.54	ad	
JUN 24	night	chinook	105	15-18	2.54		
JUN 24	night	chinook	108	15-18	2.54		
JUN 24	night	chinook	104	15-18	2.54		
JUN 24	night	chinook	116	15-18	2.54		
JUN 24	night	chinook	100	15-18	2.54		
JUN 24	night	chinook	105	15-18	2.54		
JUN 24	night	chinook	104	15-18	2.54		
JUN 24	night	chinook	108	15-18	2.54		
JUN 24	night	chinook	106	15-18	2.54		
JUN 24	night	chinook	111	15-18	2.54		
JUN 24	night	chinook	108	15-18	2.54		
JUN 24	night	chinook	122	18-21	2.54		
JUN 24	night	chinook	112	18-21	2.54		
JUN 24	night	chinook	107	18-21	2.54		
JUN 24	night	chinook	106	18-21	2.54		
JUN 24	night	chinook	118	18-21	2.54		
JUN 24	night	chinook	109	18-21	2.54		

Appendix B. Continued.

DATE	TIME	SPECIES	LENGTH (mm)	DEPTH (m)	MESH (cm)	CLIP	WEIGHT (g)
JUN 24	night	chinook	111	18-21	2.54		
JUN 24	night	chinook	113	18-21	2.54		
JUN 24	night	chinook	105	18-21	2.54		
JUN 24	night	chinook	97	18-21	2.54		
JUN 24	night	chinook	112	18-21	2.54		
JUN 24	night	chinook	101	18-21	2.54		
JUN 24	night	chinook	103	18-21	2.54		
JUN 24	night	chinook	103	18-21	2.54		
JUN 24	night	chinook	106	18-21	2.54		
JUN 24	night	chinook	109	21-24	2.54		
JUN 24	night	chinook	111	21-24	2.54		
JUN 24	night	chinook	107	21-24	2.54		
JUN 24	night	chinook	105	21-24	2.54		
JUN 24	night	chinook	108	21-24	2.54		
JUN 24	night	chinook	94	21-24	2.54		
JUN 24	night	chinook	102	21-24	2.54		
JUN 24	night	chinook	110	21-24	2.54		
JUN 24	night	chinook	108	21-24	2.54		
JUN 24	night	chinook	109	21-24	2.54		
JUN 24	night	chinook	108	21-24	2.54		
JUN 24	night	chinook	108	21-24	2.54		
JUL 12	day	coho	111	21-24	2.54		
JUL 12	night	coho	157	00-03	3.81		
JUL 12	night	coho	151	00-03	3.81		
JUL 12	night	coho	156	06-09	3.81		
JUL 12	night	coho	161	06-09	3.81		
JUL 12	night	coho	155	06-09	3.81		
JUL 12	night	chinook	132	06-09	3.81		28.6
JUL 12	night	coho	145	12-15	3.81		
JUL 12	night	coho	170	12-15	3.81		
JUL 12	night	coho	153	18-21	3.81		
JUL 12	night	coho	165	18-21	3.81		
JUL 12	night	chinook	141	21-24	3.81		33.4
JUL 12	night	chinook	137	00-03	2.54		32.9
JUL 12	night	chinook	125	00-03	2.54		20.0
JUL 12	night	chinook	126	00-03	2.54		23.6
JUL 12	night	coho	162	00-03	2.54		
JUL 12	night	chinook	134	03-06	2.54		26.7
JUL 12	night	chinook	126	03-06	2.54		22.4
JUL 12	night	chinook	125	03-06	2.54		26.6
JUL 12	night	chinook	115	03-06	2.54		18.8
JUL 12	night	chinook	120	03-06	2.54		19.9
JUL 12	night	chinook	123	03-06	2.54		21.3
JUL 12	night	chinook	128	03-06	2.54		26.0
JUL 12	night	chinook	115	03-06	2.54		18.0
JUL 12	night	chinook	137	03-06	2.54		28.1
JUL 12	night	chinook	106	06-09	2.54		13.5

Appendix B. Continued.

DATE	TIME	SPECIES	LENGTH (mm)	DEPTH (m)	MESH (cm)	CLIP	WEIGHT (g)
JUL 12	night	chinook	130	06-09	2.54		27.9
JUL 12	night	chinook	111	06-09	2.54		16.4
JUL 12	night	chinook	121	06-09	2.54		20.7
JUL 12	night	chinook	131	06-09	2.54		26.2
JUL 12	night	chinook	129	06-09	2.54		24.1
JUL 12	night	chinook	128	06-09	2.54		23.4
JUL 12	night	chinook	111	06-09	2.54		16.4
JUL 12	night	chinook	124	06-09	2.54		24.0
JUL 12	night	chinook	129	06-09	2.54		26.8
JUL 12	night	chinook	125	09-12	2.54		25.2
JUL 12	night	chinook	123	09-12	2.54		19.7
JUL 12	night	chinook	127	09-12	2.54		23.3
JUL 12	night	chinook	121	09-12	2.54		19.9
JUL 12	night	chinook	113	09-12	2.54		16.9
JUL 12	night	chinook	128	09-12	2.54		23.9
JUL 12	night	chinook	116	09-12	2.54		17.2
JUL 12	night	chinook	105	09-12	2.54		12.8
JUL 12	night	chinook	113	12-15	2.54		16.9
JUL 12	night	chinook	110	12-15	2.54		16.5
JUL 12	night	chinook	130	12-15	2.54		28.1
JUL 12	night	chinook	113	12-15	2.54		19.2
JUL 12	night	chinook	130	12-15	2.54		25.4
JUL 12	night	chinook	126	12-15	2.54		23.3
JUL 12	night	chinook	120	15-18	2.54		20.6
JUL 12	night	chinook	123	15-18	2.54		21.0
JUL 12	night	chinook	128	15-18	2.54		26.6
JUL 12	night	chinook	114	15-18	2.54		17.4
JUL 12	night	chinook	130	15-18	2.54		22.8
JUL 12	night	chinook	125	15-18	2.54		21.1
JUL 12	night	chinook	131	15-18	2.54		28.9
JUL 12	night	chinook	118	15-18	2.54		18.8
JUL 12	night	chinook	113	15-18	2.54		16.4
JUL 12	night	chinook	136	15-18	2.54		29.5
JUL 12	night	chinook	117	18-21	2.54		20.1
JUL 12	night	chinook	110	18-21	2.54		16.5
JUL 12	night	chinook	135	18-21	2.54		28.4
JUL 12	night	chinook	120	18-21	2.54		19.2
JUL 12	night	chinook	123	18-21	2.54		20.3
JUL 12	night	chinook	127	18-21	2.54		23.2
JUL 12	night	chinook	125	18-21	2.54		27.7
JUL 12	night	chinook	115	18-21	2.54		18.0
JUL 12	night	chinook	114	18-21	2.54		16.9
JUL 12	night	chinook	125	18-21	2.54		24.0
JUL 12	night	chinook	116	21-24	2.54		17.6
JUL 12	night	chinook	123	21-24	2.54		21.0
JUL 12	night	chinook	111	21-24	2.54		15.2
JUL 12	night	chinook	125	21-24	2.54		23.1

Appendix B. Continued.

DATE	TIME	SPECIES	LENGTH (mm)	DEPTH (m)	MESH (cm)	CLIP	WEIGHT (g)
JUL 12	night	chinook	112	21-24	2.54		17.4
JUL 12	night	chinook	117	00-03	1.59		19.2
JUL 12	night	chinook	0	00-03	1.59		
JUL 12	night	chinook	107	00-03	1.59		13.6
JUL 12	night	chinook	126	03-06	1.59		25.9
JUL 12	night	chinook	115	03-06	1.59		16.9
JUL 12	night	chinook	105	12-15	1.59		15.1
JUL 26	day	coho	181	00-03	1.59	ad	
JUL 26	day	coho	181	00-03	1.59	ad	
JUL 26	night	chinook	139	00-03	1.59		28.1
JUL 26	night	chinook	132	09-12	1.59		28.8
JUL 26	night	chinook	152	09-12	1.59		41.8
JUL 26	night	chinook	144	09-12	1.59		32.5
JUL 26	night	chinook	109	00-03	2.54		13.8
JUL 26	night	chinook	119	00-03	2.54		18.6
JUL 26	night	chinook	146	00-03	2.54		35.7
JUL 26	night	chinook	125	03-06	2.54		23.3
JUL 26	night	chinook	122	03-06	2.54		21.6
JUL 26	night	chinook	134	06-09	2.54		28.2
JUL 26	night	coho	160	06-09	2.54	ad	
JUL 26	night	chinook	113	06-09	2.54		15.0
JUL 26	night	chinook	131	06-09	2.54		23.4
JUL 26	night	chinook	140	06-09	2.54		31.7
JUL 26	night	chinook	148	09-12	2.54		38.1
JUL 26	night	chinook	129	09-12	2.54		26.4
JUL 26	night	chinook	134	09-12	2.54		26.9
JUL 26	night	chinook	140	09-12	2.54		36.3
JUL 26	night	chinook	146	09-12	2.54		36.3
JUL 26	night	chinook	123	09-12	2.54		22.7
JUL 26	night	chinook	152	12-15	2.54		41.6
JUL 26	night	chinook	125	12-15	2.54		23.6
JUL 26	night	chinook	130	12-15	2.54		25.0
JUL 26	night	chinook	129	12-15	2.54		22.4
JUL 26	night	chinook	139	12-15	2.54		29.8
JUL 26	night	chinook	120	12-15	2.54		19.4
JUL 26	night	chinook	133	12-15	2.54		27.3
JUL 26	night	chinook	143	12-15	2.54		33.3
JUL 26	night	chinook	125	18-21	2.54		27.8
JUL 26	night	chinook	124	18-21	2.54		26.1
JUL 26	night	chinook	131	18-21	2.54		22.9
JUL 26	night	chinook	149	18-21	2.54		36.4
JUL 26	night	chinook	129	21-24	2.54		23.6
JUL 26	night	chinook	138	21-24	2.54		30.2
JUL 26	night	coho	174	03-06	3.81	ad	
JUL 26	night	coho	167	06-09	3.81	ad	
JUL 26	night	coho	180	06-09	3.81	ad	
JUL 26	night	chinook	141	06-09	3.81		30.3

Appendix B. Continued.

DATE	TIME	SPECIES	LENGTH (mm)	DEPTH (m)	MESH (cm)	CLIP	WEIGHT (g)
JUL 26	night	chinook	149	06-09	3.81		42.8
JUL 26	night	chinook	142	09-12	3.81		34.7
JUL 26	night	coho	162	12-15	3.81		
JUL 26	night	coho	144	12-15	3.81		
JUL 26	night	chinook	147	12-15	3.81		38.5
JUL 26	night	chinook	143	12-15	3.81		35.2
JUL 26	night	chinook	150	12-15	3.81		36.7
JUL 26	night	chinook	143	12-15	3.81		36.3
JUL 26	night	coho	161	18-21	3.81		
JUL 26	night	chinook	151	18-21	3.81		40.3
JUL 26	night	chinook	144	18-21	3.81		37.2
JUL 26	night	chinook	146	18-21	3.81		36.5
JUL 26	night	chinook	150	18-21	3.81		39.3
JUL 26	night	chinook	140	18-21	3.81		33.2
JUL 26	night	chinook	138	18-21	3.81		34.2
JUL 26	night	chinook	148	21-24	3.81		39.2
JUL 26	night	chinook	146	21-24	3.81		38.3