FISHERY RESEARCH

PROJECT 5—LAKE AND RESERVOIR RESEARCH

Grant F-73-R-24

July 1, 2001 to June 30, 2002

Arthur E. Butts
Fishery Research Biologist

David Teuscher
Regional Fishery Biologist

Annual Performance Report

July 1, 2001 to June 30, 2002

Grant F-73-R-24

Project 5—Lake and Reservoir Research

By

Arthur E. Butts
Fishery Research Biologist

David Teuscher
Regional Fishery Biologist

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Figures, Continued

LIST OF APPENDICES

JOB PERFORMANCE REPORT

State of: Idaho   Grant No.: F-73-R-24, Fishery Research

Project No.: 5   Title: Lake and Reservoir Research

Contract Period: July 1, 2001 to June 30, 2002

ABSTRACT

        Idaho Fish and Game has recently begun using hydroacoustics as a means to estimate fish densities, abundance, and behavior and to develop bathymetric maps of water bodies. In 2001, hydroacoustic surveys for population estimates were conducted at American Falls Reservoir, Anderson Ranch Reservoir, and twice at Cascade Reservoir, with variable success. Although abundance estimates were not obtained at all reservoirs, the four surveys provided additional information on how environmental, seasonal, diel, and fish behavioral effects may influence the success of a survey. A better understanding of the applicability of hydroacoustics in situations where fish densities are extremely high or where the fish assemblage is composed of overlapping species was also attained.

Authors:

Arthur E. Butts
Fishery Research Biologist

David Teuscher
Regional Fishery Biologist

INTRODUCTION

Sonar applications in fisheries science are diverse. Estimating the abundance of juvenile salmon in lakes is one of the most common uses (Beauchamp et al. 1997; Burczynski and Johnson 1986; Thorne 1979; Thorne and Dawson 1974; Thorne 1971). Other applications include describing the initial survival and spatial distribution of introduced species (Teuscher 1997), locating lake trout spawning beds (Edsall et al. 1992), estimating forage fish abundance (Burczynski et al. 1987), monitoring adult fish movement in rivers (Banneheka et al. 1995), and estimating entrainment loss at hydroelectric facilities (Maiolie and Elam 1996).

In addition to estimating fish abundance, scientific sonar can be used to monitor fish behavior. Examples include describing fish distribution and schooling behavior under varying moon phases (Luecke and Wurtsbaugh 1993), observing avoidance behavior of kokanee to strobe lights (Maiolie et al. 2001), and monitoring fish response to hypolimnetic oxygenation (Aku et al. 1997). Hydroacoustic technology is also used to map benthic habitat (Edsall et al. 1992), estimate lake volume, and generate bathymetric or depth contour maps.

The application with the greatest potential to benefit fisheries management in Idaho is the recent development of horizontal or sidelooking sonar. Sidelooking methods were developed to monitor fish in shallow waters. To date, sidelooking sonar has been used to assess brown trout (Kubecka et al. 1994; Kubecka et al. 1992), cutthroat trout (McClain and Thorne 1991), and rainbow trout populations (Yule 2000; Johnston 1981). Johnston (1981) used sidelooking sonar to estimate rainbow trout abundance in five shallow lakes in Washington. The effort was unique in that the lakes were rotenoned and stocked with rainbow trout prior to completing the survey. In three of the five lakes, survey estimates were within 7% of the stocked number, whereas in the remaining two lakes, estimates were within 25% and 48% of the known populations. In Wyoming, sidelooking sonar was compared to purse seine estimate of fish abundance. Yule (2000) reported a significant correlation (r^2 = 0.89, df = 11, P <0.001, slope = 0.987) between seine and hydroacoustics abundance of rainbow trout in 11 Wyoming waters. Additionally, hydroacoustic estimates of trout size were within 50 mm of the mean sizes of fish caught in purse seines (Yule 2000). Development of techniques similar to those may be used to substantially increase our understanding of population dynamics of rainbow trout, cutthroat trout, and other game species in Idaho.

MANAGEMENT OBJECTIVE

1. Improve flatwater fisheries management by completing quantitative estimates of fish abundance and habitat selection using hydroacoustic technology.

OBJECTIVES

1. To assess whether fish population estimates at American Falls Reservoir and Anderson Ranch Reservoir had declined from estimates obtained in 2000 (Teuscher 2001) as a result of fish losses due to entrainment.

2. To estimate adult northern pikeminnow abundance at Cascade Reservoir and determine if the success of removal efforts can be monitored with hydroacoustics.

STUDY SITES

American Falls Reservoir is a large, shallow, eutrophic impoundment located on the upper Snake River in southeastern Idaho. The reservoir has a mean depth of 9.3 m, a storage capacity of 1,700,000 acre-feet, and is primarily managed for irrigation and power generation. The surrounding area is composed of mainly agricultural land with the town of American Falls located to the southwest. Resident species include rainbow trout *Oncorhynchus mykiss*, cutthroat trout *O. clarki*, brown trout *Salmo trutta*, yellow perch *Perca flavescens*, black bullheads *Ictalurus melas*, and sucker species *Catastomus* sp. Fishery management efforts have focused on providing a rainbow trout fishery through artificial propagation.

Anderson Ranch Reservoir is a deep mesotrophic impoundment located on the South Fork of the Boise River and provides irrigation water, power, and flood and sediment control. The reservoir has a mean depth of 32.3 m, a total storage capacity of 423,200 acre feet, and is located 20 miles northeast of Mountain Home, Idaho. Resident species include kokanee *O. nerka*, bull trout *Salvelinus confluentus*, rainbow trout, smallmouth bass *Micropterus dolomieu*, yellow perch, and northern pikeminnow *Ptychocheilus oregonensis*. Fishery management efforts emphasize providing a kokanee fishery.

Cascade Reservoir is a large, shallow, upper mesotrophic impoundment located on the North Fork of the Payette River. The reservoir is utilized for power generation and irrigation storage, and has a mean depth of 7.5 m and a total storage capacity of 653,200 acre feet. The surrounding watershed is used for agricultural and recreational purposes and is intensively grazed. Resident species include coho salmon *O. kisutch*, kokanee, rainbow trout, whitefish *Prosopium williamsoni*, yellow perch, northern pikeminnow, smallmouth bass, channel catfish *Ictalurus punctatus*, and largescale sucker *Catostomus macrocheilus*. Cascade Reservoir provided a high quality perch fishery in the late 1980s and early 1990s but had collapsed by 1997. The recent decline in abundance of yellow perch has been attributed to predation from an expanding population of northern pikeminnow. Efforts to reduce the northern pikeminnow population by trapping fish as they enter spawning tributaries have recently begun (Paul Janssen, IDFG, personal communication).

METHODS

Hydroacoustics

Hydroacoustic estimates of fish densities, lengths, and vertical depth distributions were obtained with a Hydroacoustic Technology, Inc. (HTI) Model 241-2 split-beam digital echo sounder. The 200 kHz sounder was equipped with two transducers: a 15° vertically aimed transducer (downlooking) and a 6° horizontally aimed transducer (sidelooking), which was set at a 6° angle below the surface. Transducers were suspended at a 1 m depth using a retractable pole mount. Boat speed during data collection ranged from 1 to 1.5 m/s. Sampling transects were determined prior to surveys and were followed using Global Positioning System (GPS) coordinates (Appendices A-C).

Data were collected by fast multiplexing equally between both transducers at a sampling rate of 3.0-6.7 pings/s, which allowed for near-simultaneous data collection at 1.5-3.35 ping/s per transducer. A transmit pulse width of 0.2 ms was used for both transducers.

Yule (2000) determined that the effective detection angle of the 15° transducer approached nominal beam width at 8 m of range and the 6° effective detection angle approached nominal beam width at 10 m of range. Therefore, the sidelooking transducer (6°) collected data in the top 8 m of the water column at a range of 10-50 m, which was manually adjusted *in-situ* using an oscilloscope as a reference. The downlooking transducer (15°) collected data in the remaining water column. Downlooking ranges (depth), sidelooking ranges, and GPS coordinates were automatically recorded to data files at 10 s intervals during surveys.

Thresholds were generally established so that targets larger than –60 dB and –44 dB along the acoustic axis were accepted for the downlooking and sidelooking transducers, respectively. Thresholds corresponded to a minimum size acceptance of 19 mm fish targets for the downlooking transducer and 132 mm for the sidelooking transducer. The bottom threshold was set at 2.0 V, and echoes within 2.0 m of the bottom were excluded from analysis (bottom window).

Target tracking was used to classify returning echoes as fish and thus obtain fish density estimates. This method combines individual echo returns that meet specific criteria and records them as individual fish. Following methods described by Teuscher (2001), fish tracking criteria included: 1) a minimum of three echoes spaced less than 0.2 m apart in three-dimensional space, 2) a maximum difference in returning echo strength of 10 dB, 3) maximum swimming velocity of 3 m/sec, and 4) mean target strength for a tracked fish between a size range of –20 and –60 dB. During the survey, data were collected and processed, and fish were tracked and recorded using the HTI software, Digital Echo Processor (DEP). However, because the default tracking parameters may allow bottom or complex substrate or gas bubbles to be counted as fish, we individually examined tracked fish using HTI's EchoScape software. The software allows the user to further examine individual echoes within a fish trace and thereby reduce errors associated with using the automatic tracking procedures, i.e., overestimating fish density.

Estimates of downlooking fish densities (>8 m) for each transect were obtained using a range weighting technique as described by Yule (2000). This method standardizes fish density estimates by accounting for expanding sampling volume with increasing range. Tracked fish are weighted back to a 1 m swath at the surface using the following formula:

$$F_w = \frac{1}{(2 * R * \tan(7.5°))}$$

where F_w is weighted fish,

R is range, and

7.5° equals half the nominal transducer beam width.

Fish densities (fish/m^2) for each transect were calculated by summing weighted fish and dividing that value by transect length (m). Fish detected by the downlooking transducer that were in the top 8 m of the water column were excluded from analysis to avoid double counting.

Sidelooking fish densities (<8 m) for each transect were estimated by dividing the number of fish detected by the volume of water sampled. The volume of water sampled (m^3) was estimated by multiplying transect length (m) by the average range sampled by the sidelooking transducer (m) by the average height of the cone (m). The first 10 m of range (near field) was not included in the sample volume estimate because of the effective detection angle of the sidelooking transducer (Yule 2000).

When applicable, total fish abundance was estimated by summing sidelooking and downlooking fish densities and multiplying the mean fish density (fish/ha) by the surface area of the reservoir on the survey date. The Bureau of Reclamation (BOR) provided surface area and volume data for all reservoirs sampled during 2001. Ninety percent confidence intervals were calculated for population estimates using the methods described in Brown and Austen (1996). Regardless of transect length, each transect was considered a sample unit.

Vertical depth distributions of tracked fish were calculated for all 2001 surveys. Downlooking depth distributions were calculated by simply summing the number of targets at each depth interval. Sidelooking vertical depths for each tracked fish were calculated using the following equation:

$$F_d = \sin(radians(6°) * R) - Y + T_d$$

where F_d is fish depth (m),

6° is the angle at which the horizontal transducer was aimed,

R is range,

Y is total distance (m) traveled vertically by the fish in the beam, and

T_d is the depth of the physical depth sidelooking transducer (m).

Fish were then summed across each 1 m depth interval to attain vertical depth distributions between 0 and 8 m.

Target Verification

Gillnets were set for target verification and species partitioning by regional fishery personnel at Anderson Ranch Reservoir and Cascade Reservoir. On August 6, 2001, six 30 m long vertical gillnets were set at Anderson Ranch Reservoir. Three nets consisting of 38, 51, and 76 mm stretch mesh were set above the Falls Creek inlet, while three nets consisting of 19, 25, and 64 mm were set below the Falls Creek inlet. At Cascade Reservoir, 12 sinking experimental gillnets (38, 51, 64, 76, 102, 127 mm stretch mesh) were set at 2 m depth intervals between 0 and 7 m on May 1-3, 2001. Ten experimental gillnets of the same dimensions were again set at 2 m depth intervals between 0 and 6 m on September 25-27, 2001. Fish were identified, and total lengths (TL; nearest mm) were measured and recorded. For kokanee at Anderson Ranch Reservoir and rainbow trout at American Falls Reservoirs, lengths were converted to and from standard and total lengths using relationships for the species reported by Carlander (1969). When possible, species proportions were calculated using the cluster sampling formulas described by Scheaffer et al. (1996):

$$\hat{p} = \frac{\sum_{i=1}^{n} a_i}{\sum_{i=1}^{n} m_i}$$

where $\hat{p}$ is an estimator of the population proportion p,

a_i is the total number of elements in cluster i that possess the characteristic of interest, and

m_i is the number of elements in the ith cluster, $i = 1, 2, \ldots, n$.

The variance around the proportion estimates were calculated using the following equations (Scheaffer et al. 1996):

$$\hat{V}(\hat{p}) = \left(\frac{N - n}{Nn\bar{M}^2} \right) s_p^2$$

where N is the number of clusters in the population,
n is the number of clusters selected in a simple random sample,
$\bar{M}$ is the average cluster size for the population, and
s_p^2 is calculated as follows:

$$s_p^2 = \frac{\sum_{i=1}^{n}(a_i - \hat{p}m_i)^2}{n - 1}$$

Relative abundance estimates for individual species were estimated by multiplying the species proportions obtained from gillnets by the total fish abundance obtained from hydroacoustics. Because abundance estimates for individual species were the products of two random variables, the error around these estimates were calculated using the following equation for the variance around the product of two independent variables (Goodman 1960):

$$v(\bar{x}\,\bar{y}) = \bar{x}^2 \frac{s^2(y)}{n(y)} + \bar{y}^2 \frac{s^2(x)}{n(x)} - \frac{s^2(x)s^2(y)}{n(x)n(y)}$$

where $v(\bar{x}\,\bar{y})$ is the variance of the product $\bar{x}\,\bar{y}$,
$s^2(y)$ is the variance of $\bar{y}$,
$s^2(x)$ is the variance of $\bar{x}$, and
$n(x)$ and $n(y)$ are the sample sizes for each estimate.

Water-Specific Approaches

At Anderson Ranch Reservoir, we attempted to use a length-frequency distribution from converted target strengths (Love 1977) to partition kokanee density estimates into three size classes to approximate the relative abundance of age-0, age-1, and age-2 and older cohorts. However, partitioning age classes based on length frequency distributions from gillnetting and hydroacoustic data was problematic, because modes were difficult to distinguish (Figure 1). Therefore, age classes were largely estimated from size data obtained in a previous year and from other kokanee populations. Fish less than 80 mm (SL) were considered age-0 kokanee, while fish between 80 and 150 mm were designated as age-1 kokanee, and fish larger than 150 mm were considered age-2 and older kokanee.

Population estimates for the kokanee in the lower portion of Anderson Ranch Reservoir were estimated using surface area and reservoir elevation estimates obtained from All Topo Maps software and BOR, respectively.

During transects 26 and 28 at Anderson Ranch Reservoir, densities of kokanee were high enough that return signals from fish overlapped extensively. Unfortunately, the survey was not recorded to digital audiotape (DAT), and we were not able to rerun the survey using echo integration techniques that are ideal for such instances. Because large portions of each transect contained usable data, we excluded data collected during pings 1000-1700 in transect 26 and 1130-1500 in transect 28, where individual fish could not be resolved. Transect length calculations were subsequently corrected for these exclusions.

During analysis of the October survey at Cascade Reservoir, two problems became apparent: 1) Gas bubbles from decaying aquatic vegetation compromised the ability to track fish on the downlooking transducer, and 2) The sidelooking beam often penetrated the substrate during the course of the survey and caused the echogram to be significantly cluttered with return echoes, which also confounded our ability to track fish. To rectify these problems, the survey was rerun from DAT after the threshold for the downlooking transducer was reduced so that targets <-50 dB were not accepted. In addition, the range of the sidelooking beam was manually reduced to exclude return echoes from the substrate.

RESULTS

Hydroacoustic surveys were conducted at American Falls Reservoir on November 19, 2001, Anderson Ranch Reservoir on July 24, 2001, and Cascade Reservoir on May 3 and October 17, 2001. The ability to compute fish density and abundance estimates from hydroacoustic data varied between reservoirs because of sample size, reservoir conditions, and fish distributions. Estimates of species composition were limited to Anderson Ranch Reservoir and Cascade Reservoir, because gillnets were not deployed for the American Falls Reservoir survey.

American Falls Reservoir

Because of drought conditions, American Falls Reservoir was drawn down to a season low 3% of total capacity on October 1, 2001 but had refilled to 22% by the survey date. Windy conditions caused excessive wave action and affected the quality of data collected in a number of hydroacoustic transects during the day survey. Therefore, only six transects were used to calculate fish density in the lower, near-dam area of the reservoir. Fish densities varied greatly between transects and depth with densities increasing as we sampled towards the dam (Table 1). Densities were higher at depths greater than 8 m, although more fish were tracked in the top 8 m because the sidelooking transducers sampled a much larger volume. Tracked fish displayed a modal depth of 6 m with larger fish occupying the top 8 m. The hydroacoustic estimate for mean pelagic fish density in the lower section of the reservoir was 16 fish/hectare. Estimates of fish abundance were not computed because of the survey's small sample size and lack of gillnetting for target verification.

On November 7, 2001, 23,000 catchable rainbow trout ranging between 250 and 300 mm were stocked into American Falls Reservoir. This translates to a target strength range of –43.8 to –42.3 dB for the sidelooking transducer (Kubecka and Duncan 1998) and –39.6 to -38.1 dB for the downlooking transducer (Love 1977). Therefore, it is possible that the majority of fish that were tracked by the sidelooking transducer were the recently stocked catchables, based on the target strength frequency distribution (Figure 2). Although the mode of target strengths from the horizontal transducer does not fall within the predicted range of the stocked rainbows, they are quite close. It is likely that the mode is comprised of the stocked fish, because target strength measurements from horizontally aimed transducers can vary by as much as 25 dB depending on the body aspect of the ensonified fish (Kubecka 1994; Kubecka and Duncan 1998).

The objective of the hydroacoustic survey at American Falls Reservoir was to assess whether fish density estimates had declined from estimates obtained on November 7, 2000 (Teuscher 2001) as a result of fish losses due to entrainment. Transects in the lower area of the reservoir were similar (Appendix A), but fish density estimates above and below 8 m depth were quite different (Table 2). Density estimates in the top 8 m were much higher in 2000 than in 2001, and conversely, estimates were much lower at >8 m depth in 2000. The total mean density estimate for the lower area of the reservoir was 10.8 fish/hectare in 2000 and 16 fish/hectare in 2001. The increase in density is a result of tracking a number of smaller targets (mean = -47.3 dB; 95 mm) at >8 m depth in transects 14 and 15 (Figure 3). The higher density estimate may also be a result of the extreme drawdown that occurred in 2001, which may have caused fish to migrate downstream in the reservoir. Although fish loss from entrainment likely occurred, the ability to detect potential losses was unsuccessful because of low sampling effort, recent fish stockings, and lack of target verification.

Anderson Ranch Reservoir

Anderson Ranch Reservoir also experienced extreme drawdown in 2001, and only the lower half of the reservoir was sampled. Based on GPS coordinates, the starting transect corresponded to transect 16 as reported by Teuscher (2001). Upstream from this point, reservoir conditions were too shallow to safely sample with the sonar vessel. For comparison with results obtained in 2000, it was assumed that the majority of pelagic fish were downstream from the starting point and were included in the survey (Appendix B). Gillnet and hydroacoustics results were partitioned between two areas: above and below Falls Creek, which allowed us to examine potential differences in fish density and depth distributions along the reservoir gradient.

Over 99 percent of the total vertical gillnet catch was comprised of kokanee, and therefore, all pelagic targets were considered to be kokanee. A modal depth of 21 m was observed in kokanee captured by vertical gillnets above and below Falls Creek (Figure 4a). The vertical distributions of kokanee obtained from the hydroacoustic survey showed that kokanee were concentrated in deeper waters. Above Falls Creek, a bimodal distribution was observed where the greatest number of tracked fish occurred at 21 and 31 m (Figure 4b). Echograms of transects above Falls Creek also displayed a pronounced bimodal distribution where fish appeared to avoid depths between 23 and 30 m (Figure 5). This avoidance may have resulted from an apparent zone of unfavorable temperatures or anoxic water. The bimodal distribution may also be a result of habitat preferences of two different species.

Age classes showed similar depth distributions above and below Falls Creek, but more fish were tracked in the lower section of the reservoir (Figure 6). This is probably a result of

kokanee having greater access to deeper and cooler water closer to the dam. Age-1 fish were the most abundant single cohort, which corresponded to estimates of a very strong age-0 cohort obtained in 2000 (Teuscher 2001).

The hydroacoustic estimate of total kokanee abundance in the lower portion of the reservoir was 1,103,975 fish $\pm$ 25% (Table 3). The relative contribution of the three age groups was 235,530 $\pm$ 16% for age-0, 613,281 $\pm$ 31% for age-1, and 255,164 $\pm$ 27% for age-2 and older fish. Kokanee population estimates understated total abundance in 2001, since large portions of two transects with extremely high kokanee densities were not used in abundance calculations, because individual fish targets could not be resolved. In addition, some kokanee may have been located upstream from the beginning transect. Therefore, comparisons between 2000 and 2001 kokanee population estimates at Anderson Ranch Reservoir were not made.

Cascade Reservoir

Cascade Reservoir presented a more difficult scenario for estimating the abundance of individual species, because it contains a wide array of species that overlap in both habitat use and size. Gillnet catches at Cascade Reservoir were similar between dates and were comprised of mainly coho salmon, kokanee, largescale sucker, rainbow trout, and northern pikeminnow (Figures 7 and 8). Gillnet results suggested that northern pikeminnow were distributed throughout the water column in both May and October, although depth distributions may have been somewhat misleading by not including bottom sets (Figure 9).

Estimates of fish density in Cascade Reservoir varied greatly between May and October hydroacoustic surveys. Hydroacoustic transects also varied between the May and October survey (Appendix C). Total pelagic fish abundance was 21,425 $\pm$ 16,497 in May (Table 4), whereas 390,922 $\pm$ 234,553 was estimated in October (Table 5). Hydroacoustic vertical depth distributions showed that fish were mainly residing in the upper 6 m of the water column in May (Figure 10). In October, fish were bimodally distributed at depths of 4 and 9 m. The distribution of target strengths of tracked fish differed greatly between the two surveys (Figure 11). The number of fish tracked with the downlooking transducer increased markedly and supported the depth distribution data regarding the increase in numbers of fish in October. However, larger fish (>-45 dB) appeared to be more predominant in the May survey. These fish may have been surface oriented when water temperatures were cooler, and when temperatures increased, fish may have moved closer to the bottom where they were not susceptible to acoustic gear.

Using the cluster analysis techniques described by Scheaffer et al. (1996), we estimated the population proportions for northern pikeminnow to be 28% $\pm$ 10% in May and 30% $\pm$ 14% in October (Table 6). The proportion estimates of northern pikeminnow from gillnetting are surprisingly similar given the seasonal differences observed in the hydroacoustic abundance estimates. However, discrepancies are readily apparent in other species such as coho salmon, where in May we estimated the proportion to be 2% $\pm$ 2% and in October 21% $\pm$ 12%. Similar differences were noted in the estimates of kokanee and largescale sucker proportions as well. It should also be noted that the variance formula is a useful estimator when sample sizes are large (n > 20), but were nonetheless included in our analysis to demonstrate their utility in future surveys.

Based on population proportion estimates, we estimated the northern pikeminnow population to be 6,043 ± 4,170 in May and 118,091 ± 72,036 In October. Abundance estimates for other species captured in gillnets are also shown in Table 6.

A large discrepancy existed between the May and October hydroacoustic fish abundance estimates that was probably a result of environmental conditions and fish behavior during the early spring. Therefore, obtaining an estimate of adult northern pikeminnow by subtracting fish abundance estimates in May from those obtained in October, as described by Teuscher (2001) did not seem to provide a realistic or useful population estimate.

DISCUSSION

The number of hydroacoustic surveys conducted in 2001 was limited, because the biologist position responsible for conducting hydroacoustics was vacant for most of the year. However, the four surveys conducted in 2001 provided further insight into the strengths and limitations of using hydroacoustics to estimate fish abundance.

The American Falls Reservoir survey was largely compromised by heavy wave action that caused air bubbles to become entrained near the surface. Because of this, we were not able to analyze 10 of the 16 transects, particularly for data that were collected with the sidelooking transducer. As the survey approached dusk and the waves subsided, reliable data were collected with both transducers, and we were able to attain some information on fish density and size in the near dam portion of the reservoir. Comparisons between recent stockings of rainbow trout and target strength distributions obtained from the hydroacoustics suggest that there is promise in using hydroacoustics to assess short- and possibly long-term survival of stocked fish in some reservoirs and lakes. The American Falls Reservoir survey also illustrated the importance of collecting fish for size and species verification. Because gillnetting or some other form of collection was not conducted during the survey, we were not able to determine the actual fish species that were detected with hydroacoustic gear.

The Anderson Ranch Reservoir survey also provided information that will be useful for future hydroacoustic surveys conducted by IDFG. First, the survey provided an instance in which fish densities were high enough that return signals overlapped and individual targets could not be resolved in portions of two transects. This situation can generally be remedied by using echo integration instead of target tracking techniques to obtain population estimates. However, because the survey was not backed up to DAT, we were not able to rerun the survey using the different settings and thresholds that are required for echo integration analysis. Therefore, our estimates of kokanee abundance in 2001 likely underestimated actual kokanee abundance.

In addition, the Anderson Ranch Reservoir survey showed promising results for using hydroacoustics to assess the manner in which environmental gradients influence fish distributions. Above the Falls Creek inlet, a zone between 21 and 31 m deep was clearly avoided by fish targets during the survey. This may have been a zone or wedge of anoxic water or possibly other characteristics that were unfavorable to fish, (i.e., extreme temperatures). Shortly after the survey was conducted, a fish kill occurred in the kokanee population (D. Megargle, personal communication). In the future, measuring water temperature and

dissolved oxygen levels in areas of avoidance may help us determine and understand the causes of fish kills such as was observed at Anderson Ranch Reservoir.

The two Cascade Reservoir surveys demonstrated the influence of seasonal differences in fish behavior and environmental conditions such as thermal stratification on hydroacoustic estimates of fish abundance. In May, fish appeared to be surface-oriented and may have also been residing in littoral areas near the shoreline where they would not have detected by hydroacoustics. In October, gas bubbles that were likely the result of decomposing aquatic vegetation limited our ability to resolve smaller targets.

Cascade Reservoir contains a mixed species assemblage of salmonids, catastomids, cyprinids, and percids. This presented a number of difficulties in obtaining a population abundance estimate for a given species using hydroacoustics. Biologists must try and verify the distribution, size, and relative proportion of fish targets by conducting some means of fish collection that represents the actual fish assemblage, such as gillnetting, trap netting, trawling, or purse seining. This is confounded by the fact that both collection gear and hydroacoustics have associated selectivity and efficiency. For example, gillnets can be selective for species, size, and sex of fish captured, causing the over-representation of a parameter (Hubert 1996). Hydroacoustics cannot detect fish that are near bottom substrate or shoreline areas with complex habitat (Brandt 1996). These biases, in combination with complex differences in habitat use (seasonal and diel), behavior (pelagic, benthic, or shoreline dwelling, spawning periods, etc.), and activity that vary between and among species on a diel and seasonal basis, can extensively limit a biologist's ability to estimate a population size for a given species. Therefore, estimates of a particular species that are calculated from a combination of hydroacoustics and fish collection techniques generally understate the actual amount of error around each estimate. If hydroacoustics are to be used to monitor the population of a single species in a multi-species assemblage, efforts must be made to reduce the high level of error that generally occurs with such estimates.

Knowledge of error bounds is extremely important for determining how useful our estimates are for assisting in fishery management actions and decisions. For example, at Cascade Reservoir, hydroacoustics are being used to assess the success of northern pikeminnow removal efforts. Wide confidence bounds around estimates obtained prior to and after removal efforts could limit our ability to detect changes in the northern pikeminnow population.

We estimated the variance around each species population estimate that was computed from species proportions from gillnetting and hydroacoustic abundance estimates using an equation for the variance of a product described by Goodman (1960). We believe that the use of such an equation will give managers some sense of the error around individual species population estimates, particularly in multi-species assemblages such as Cascade Reservoir where species are overlapped, both temporally and spatially.

Confidence limits around our estimates of species-specific abundance in Cascade Reservoir were tighter than anticipated given gillnet variability. However, as noted above, these error bounds only include sampling variability and do not incorporate a great deal of uncertainty regarding what gillnets are actually measuring (species composition, activity, etc.). Regardless, even such optimistic estimates of the error around the population estimates will help biologists determine the amount of effort that will be required to improve the precision around future species population estimates. This, in turn, can determine the feasibility of using hydroacoustics to estimate population parameters such as species abundance and survival. An understanding

of the limitations of hydroacoustics will aid in future research planning and study designs. Population estimates with even moderate confidence interval may not be achievable in some complex systems. However, in some situations, a stable approximation of the relative abundance from hydroacoustics may provide managers with useful information to make sound decisions regarding a fishery (Thorne 1983; Yule 2000).

Teuscher (2001) made several recommendations based on the surveys that were conducted in 2000. These included conducting trout surveys during daylight hours, designing surveys that incorporate enough transects or survey time to sample about 10% of a water body's total volume, and developing standard netting and purse seining procedure for partitioning fish species. This final recommendation continues to be of utmost importance in determining future research possibilities for the IDFG Lake and Reservoir Research program.

The primary limitation of IDFG hydroacoustic assessments is the inability to discern species compositions in a water body. Ideally, fish collection for hydroacoustic target verification will be designed to account for collection gear biases as well as vertical and horizontal environmental gradients in water bodies. This means that more than one type of collection gear should be utilized for capturing fish, and collections should occur at a number of sites and depths along hydroacoustic transects throughout a lake or reservoir.

A 9.1 m deep purse seine with 10 mm square mesh is currently being constructed that will encircle approximately 0.27 ha. Yule (2000) found that a purse seine of similar dimensions and sidelooking hydroacoustic estimates were correlated (r = 0.87, N = 14) across a wide range of densities. In addition, considerable work during this contract year has been done to develop and acquire various gillnetting arrays, including the construction of a gillnet "curtain" designed to reduce bias caused by fish avoidance. A combination of purse seining and gillnetting at various depths and at a wide array of collection sites that correspond to known differences in habitat should provide a reasonable approximation of lake-wide species proportions. A standard purse seining and gillnetting program should be developed that coincides with hydroacoustic surveys and takes the aforementioned factors into account. This will significantly reduce the number of water bodies that can be sampled during a season but should greatly enhance the quality of the estimates. The purse seining and netting data should be analyzed using cluster analysis techniques with vertical and horizontal stratification (Scheaffer et al. 1996).

Measurements of gradients in temperature, dissolved oxygen, pH, conductivity, and secondary production (i.e. zooplankton) should accompany hydroacoustic and netting surveys to assist in the explanation of fish distributions. This should greatly enhance efforts to explain hydroacoustic fish distributions and may also help in determining appropriate times to sample on a seasonal and perhaps diel basis. A Hydrolab MiniSonde 4a multiparameter water quality meter was purchased by IDFG in 2002 for this purpose.

Finally, it is crucial that all surveys be recorded to DAT during each survey as shown by our ability to rerun the October 2001 Cascade Reservoir survey and our inability to reanalyze the Anderson Ranch Reservoir survey using different analysis techniques. Because it is difficult to detect all problems with hydroacoustic thresholds or configurations during actual data collection, the ability to rerun a survey from DAT has the potential to enhance the quality of the analysis of data obtained from the surveys.

Overall, hydroacoustics can be an effective tool for providing fish density and population estimates in many of Idaho's flatwater fisheries. Acoustic assessments have shown to be an excellent means for obtaining estimates in a rapid and cost effective manner. IDFG has gained

a great deal of valuable information about fish behavior, habitat use, and population estimates since the HTI model 241-2 sonar system was purchased in 2000. The limitations described above do not preclude hydroacoustics from being one of the most effective tools available for the management of Idaho's lake and reservoir fisheries. As these limitations are better understood, creative solutions can be incorporated into both survey designs and question development.

RECOMMENDATIONS

1. Develop a standardized gillnetting and purse seining program to accompany hydroacoustic surveys that will be based on the size of the water body and horizontal and vertical gradients in fish distributions, and where n $\geq$ 20 in accordance to cluster sampling assumptions for variance estimates.

2. Measure the horizontal and vertical environmental gradients (i.e., temperature, dissolved oxygen, pH, conductivity, and secondary production) to assist in the explanation of fish distributions.

3. Record all surveys to DAT so that data can be reanalyzed with different thresholds or techniques if needed.

ACKNOWLEDGEMENTS

Table 1.   Fish densities (fish/ha) in five transects at American Falls Reservoir on November 19, 2001.

Transect	Transect Length (m)	Fish Density (number/ha)		
		Downlooking	Sidelooking	Total
11	2,495	3.8	0.10	3.9
12	2,050	0.0	0.01	0.0
13	2,067	4.9	0.01	4.9
14	1,676	40.9	0.04	40.9
15	1,302	46.2	0.01	46.2
16	999	0.0	0.01	0.0
Mean		**16.0**	**0.03**	**16.0**
90% CI		**±17.8**	**±0.03**	**±17.8**

Table 2.   Hydroacoustic estimates of fish densities (fish/ha) above and below 8 m depth in the near-dam area of American Falls Reservoir in November 2000 and 2001.

Transect	<8 m	>8 m	Total
	2000		
10	4.8	0	4.8
11	5.5	0	5.5
12	6	2.7	8.7
13	19.3	4.6	24
Mean	**8.9**	**1.8**	**10.8**
90% CI	**7.4**	**2.4**	**9.6**
	2001		
11	0.1	3.8	3.9
12	0.01	0	0
13	0.01	4.9	4.9
14	0.04	40.9	40.9
15	0.01	46.2	46.2
16	0.01	0	0
Mean	**0.03**	**16.0**	**16.0**
90% CI	**0.03**	**17.7**	**17.7**

Table 3. Kokanee densities (fish/ha) by transect and age class in Anderson Ranch Reservoir on July 23, 2001. Transects 1-16 were too shallow to safely sample using the hydroacoustic boat.

Transect	Transect Length (m)	Kokanee Densities (number / ha)			
		Age-0	Age-1	Age-2+	Total
16	936	246.9	52.1	67.6	366.6
17	932	140.5	262.5	100.0	502.9
18	702	270.0	435.2	145.0	850.3
19	718	416.3	1,153.8	414.9	1,985.0
20	600	606.4	1,892.6	642.7	3,141.7
21	841	647.0	1,750.2	604.0	3,001.2
22	998	661.0	1,294.4	504.6	2,460.1
23	684	590.0	1,756.4	514.7	2,861.1
24	1102	483.4	2,347.3	814.4	3,645.0
25	590	527.5	2,726.6	945.2	4,199.3
26	833	392.6	554.2	309.3	1,256.1
28	626	506.7	1,723.2	937.5	3,167.3
29	845	527.3	494.0	392.1	1,413.4
30	460	639.2	885.2	817.5	2,341.9
	Mean	**475.3**	**1237.7**	**515.0**	**2,228.0**
	90% CI	**76**	**383.7**	**139.1**	**567.4**
	Abundance	**235,530 ±37,685**	**613,281 ±190,117**	**255,164 ±68,894**	**1,103,975 ±281,155**

Table 4. Fish densities (fish/ha) per transect and total fish abundance estimates at Cascade Reservoir on May 3, 2001.

Transect	Transect Length (m)	Fish Densities (number/ha)		
		Downlooking	Sidelooking	Total
1	259	0.0	2.5	2.5
2	1687	17.1	0.3	17.3
3	1751	0.0	0.1	0.1
4	1691	0.0	0.3	0.3
5	1876	0.0	0.7	0.7
6	1539	2.8	0.4	3.2
7	509	0.0	0.7	0.7
8	3244	1.6	0.2	1.9
9	1701	0.0	0.0	0.0
10	1621	4.1	0.0	4.1
11	1696	2.3	0.2	2.5
12	742	0.0	2.1	2.1
13	1581	0.0	0.2	0.2
14	1670	2.0	0.1	2.1
	Mean	**2.1**	**0.6**	**2.7**
	90% CI	**± 2.1**	**± 0.4**	**± 2.1**
	Abundance	**16,288 ± 16,288**	**5,137 ± 3,288**	**21,425 ± 16,497**

Table 5.   Fish densities (fish/ha) per transect and total fish abundance estimates at Cascade Reservoir on October 17, 2001. Sidelooking data were not collected in transects 23-24.

Transect	Transect Length (m)	Fish Densities (number/ha)		
		Downlooking	Sidelooking	Total
1	817	0.0	1.8	1.8
2	1193	0.0	0.8	0.8
3	1511	48.6	0.2	48.8
4	1386	59.5	0.2	59.6
5	305	0.0	0.0	0.0
6	497	344.4	0.0	344.4
7	1230	0.0	0.4	0.4
8	995	126.9	0.2	127.1
9	1256	262.7	0.2	262.9
10	1467	0.0	0.1	0.1
11	696	74.2	0.6	74.9
12	1409	195.2	0.2	195.4
13	1820	10.7	0.1	10.8
14	1800	0.0	0.4	0.4
15	614	0.0	4.5	4.5
16	1536	0.0	0.0	0.0
17	815	0.0	0.2	0.2
18	1198	0.0	0.5	0.5
19	740	0.0	0.6	0.6
20	1106	0.0	0.5	0.5
21	579	0.0	2.4	2.4
22	393	0.0	0.5	0.5
23	292	0.0	-	0.0
24	719	173.2	-	173.2
	Mean	**54.0**	**0.7**	**54.6**
	90% CI	**±33.5**	**±0.4**	**±32.8**
	Abundance	**386,632 ± 239,712**	**4,680 ± 2,714**	**390,922 ± 234,553**

Table 6.　Abundance estimates for individual species from data collected during May and October 2001 hydroacoustic surveys at Cascade Reservoir. Abundance was estimated as the product of a species proportion from gillnetting data and the total abundance estimate from hydroacoustics. The 90% CI for species abundance was calculated from the variance of each product.

Species	Proportion ± 90% CI	Abundance	90% CI
May 3, 2001			
Coho Salmon	2% ± 2%	366	± 269
Kokanee	8% ± 7%	1,648	± 1,183
Largescale Sucker	34% ± 15%	7,325	± 5,058
Northern Pikeminnow	28% ± 10%	6,043	± 4,150
Rainbow All	21% ± 16%	4,395	± 3,122
Whitefish	3% ± 3%	549	± 406
Yellow Perch	5% ± 5%	1,099	± 794
October 17, 2001			
Coho Salmon	21% ± 12%	81,442	± 50,210
Kokanee	19% ± 4%	73,298	± 43,617
Largescale Sucker	13% ± 6%	48,865	± 29,777
Northern Pikeminnow	30% ± 14%	118,091	± 71,551
Rainbow All	16% ± 10%	61,082	± 37,953
Tiger Musky	1% ± 2%	4,072	± 3,007
Yellow Perch	1% ± 2%	4,072	± 3,211
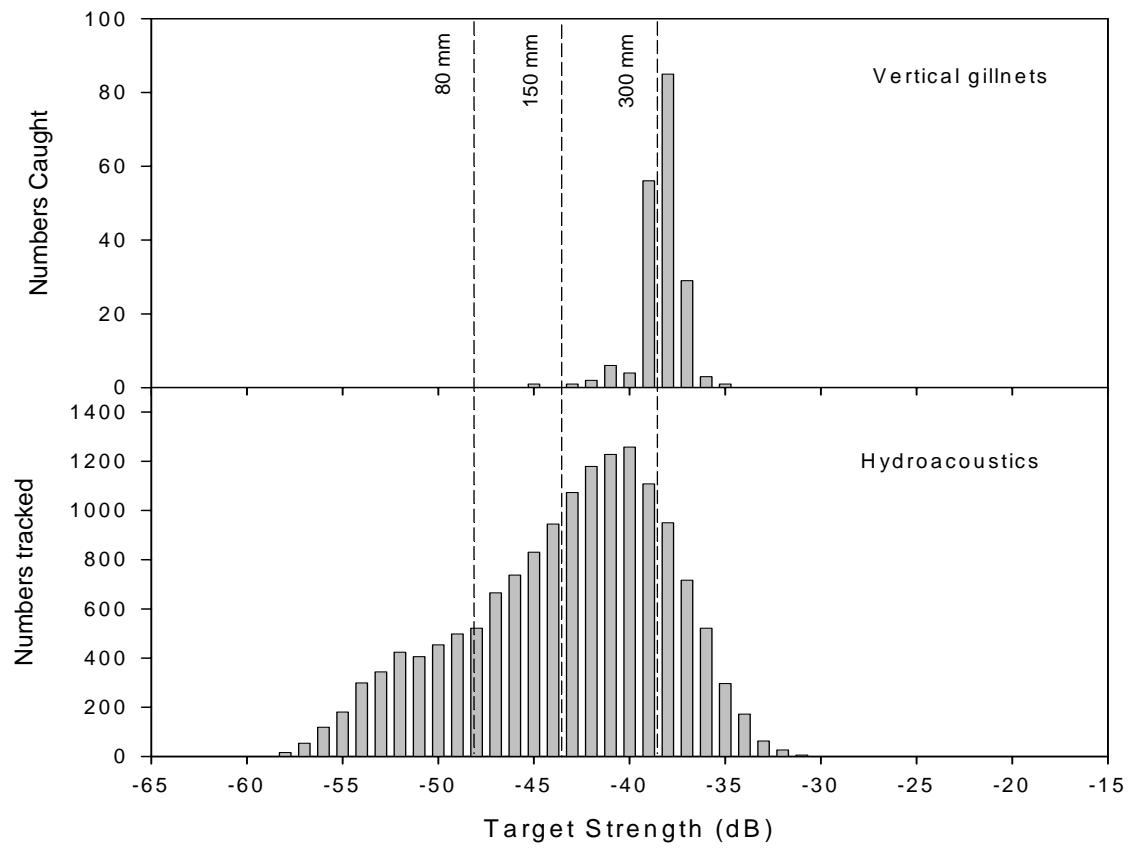
Figure 1.   Size distribution of kokanee caught in vertical gillnets and fish tracked during the hydroacoustic survey. Target strengths for fish captured in gillnets was estimated using Love 1977.
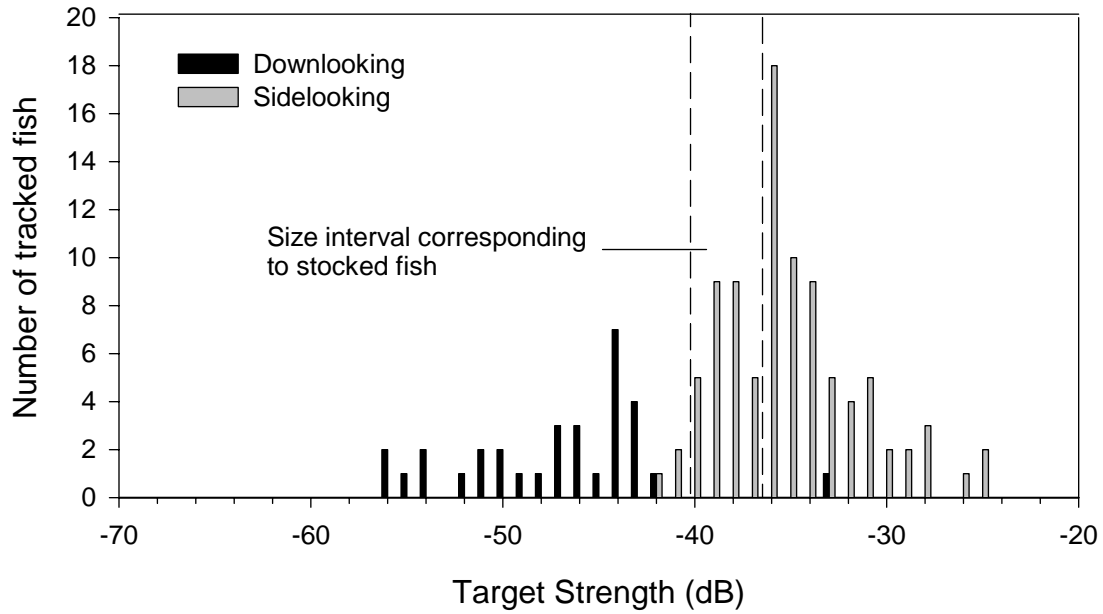
Figure 2.   Distribution of target strengths (dB) of fish tracked during the hydroacoustic survey at American Falls Reservoir on November 19, 2001. The projected size interval of 23,000 rainbow trout that were stocked into the reservoir on November 7, 2001 is also shown.
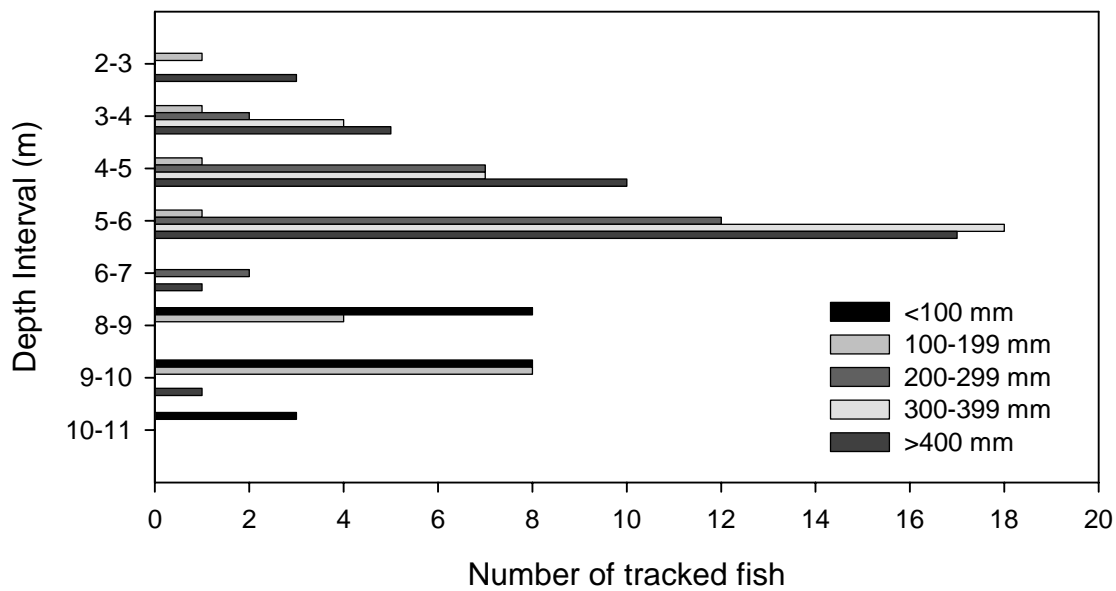

Figure 3.   Depth distribution of pelagic fish by 100 mm size intervals (estimated from target strengths) in American Falls Reservoir on November 19, 2001.
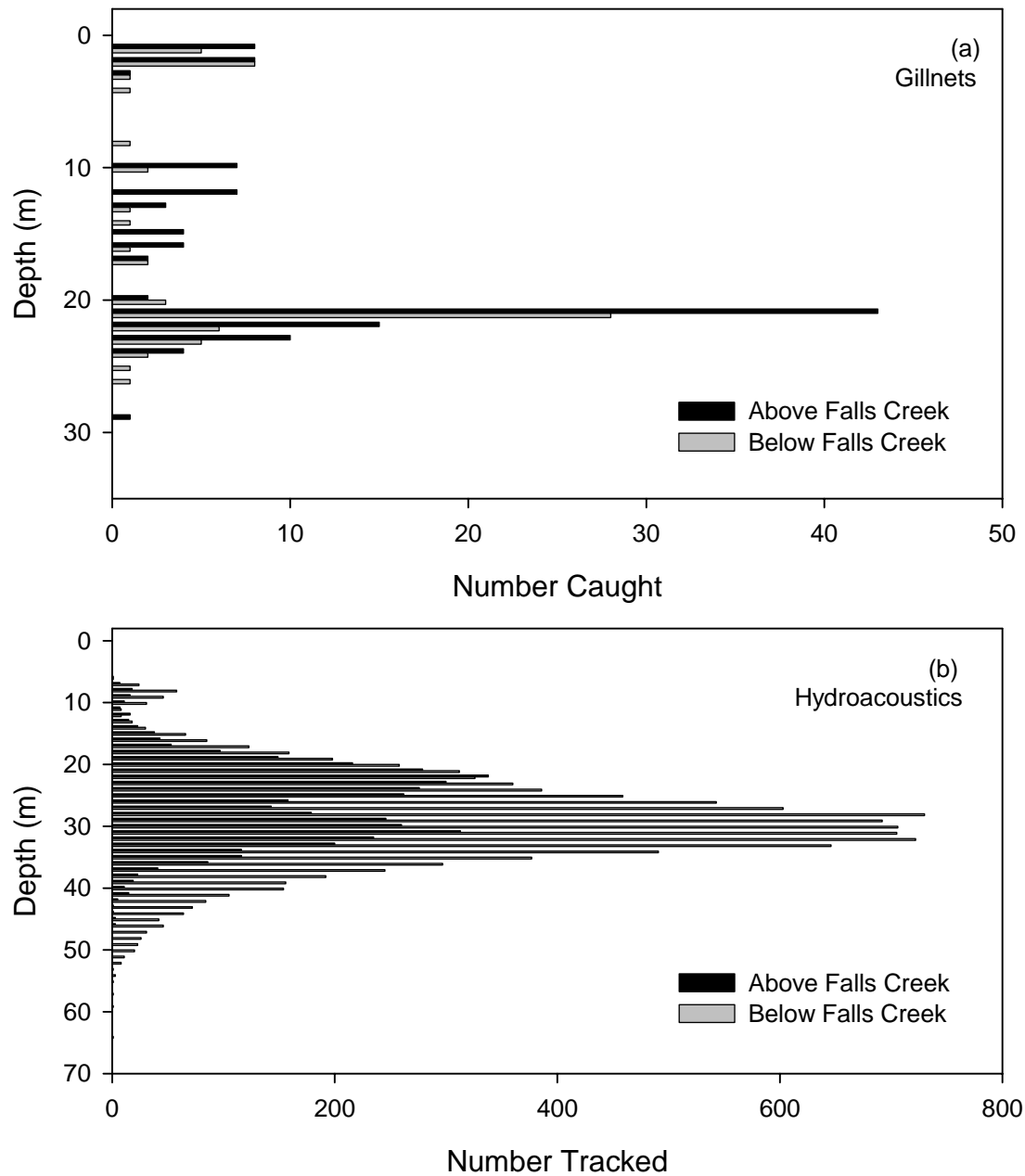
Figure 4. Depth distribution of kokanee captured in vertical gillnets (a) and fish targets tracked by hydroacoustics during the Anderson Ranch Reservoir survey on July 23, 2001 (b). Netting and hydroacoustic distributions are separated into fish that were observed above and below the Falls Creek influence.
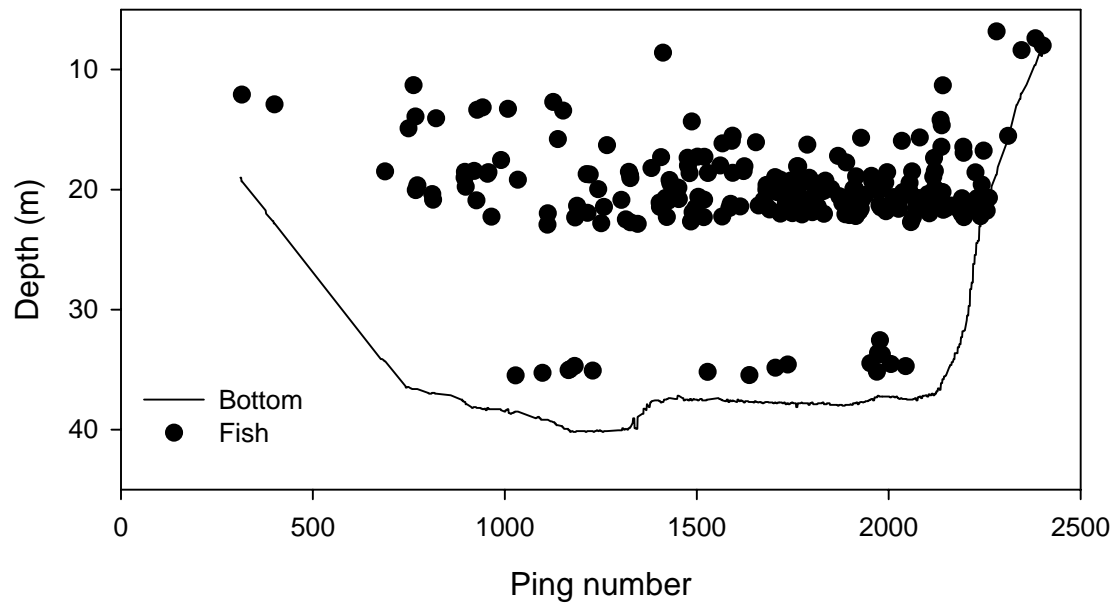
Figure 5.   Echogram of transect 17 at Anderson Ranch Reservoir showing a bimodal depth distribution of fish targets potentially caused by a zone of anoxic water or unfavorable temperatures.
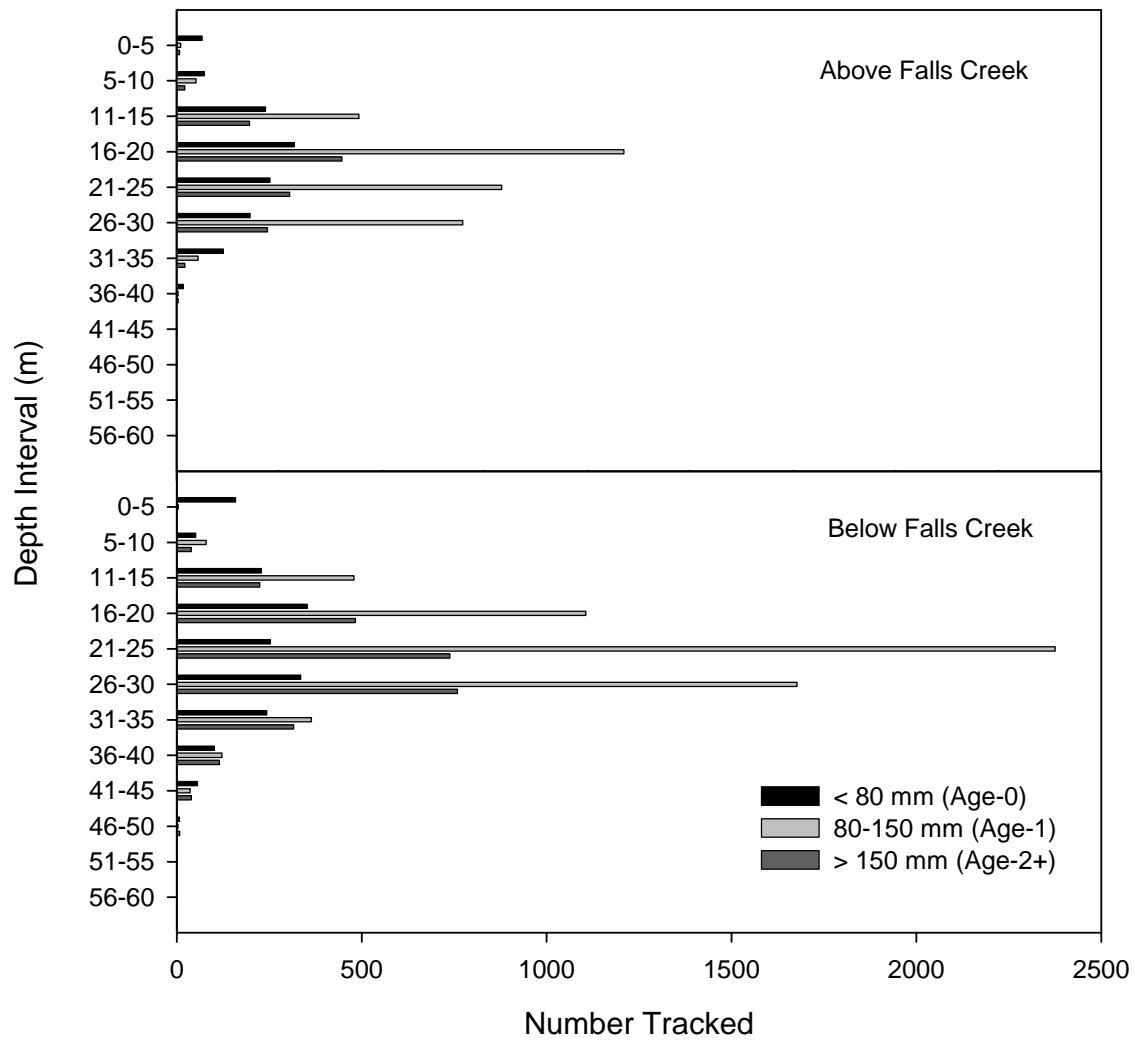
Figure 6. Depth distribution of three size classes of kokanee above and below the Falls Creek inlet.
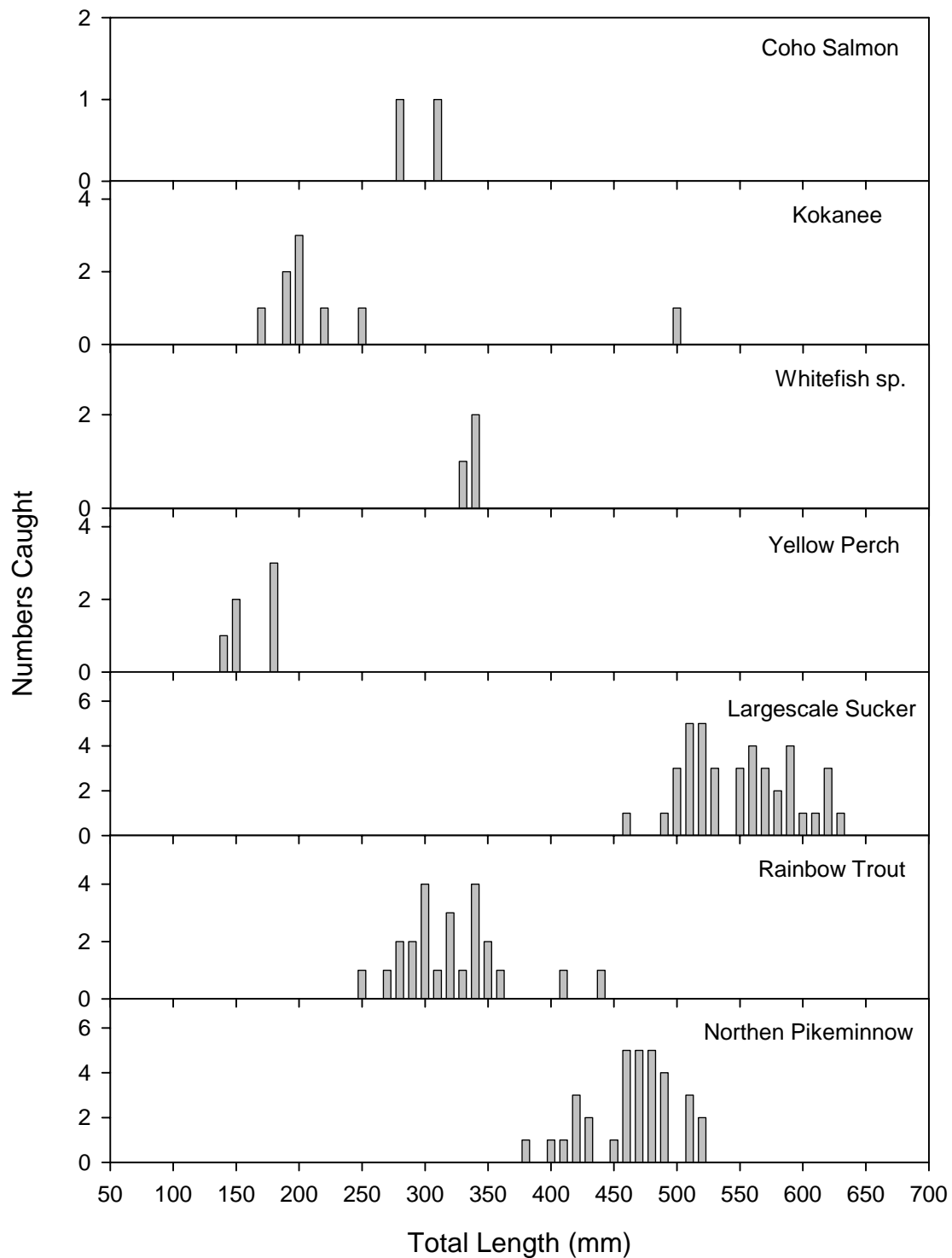
Figure 7.   Length distribution of various fish species caught in 12 experimental gillnets that were set at 2 m depth intervals on May 1-3, 2001 in Cascade Reservoir. Catches were used to partition the May hydroacoustic abundance estimate into species estimates.
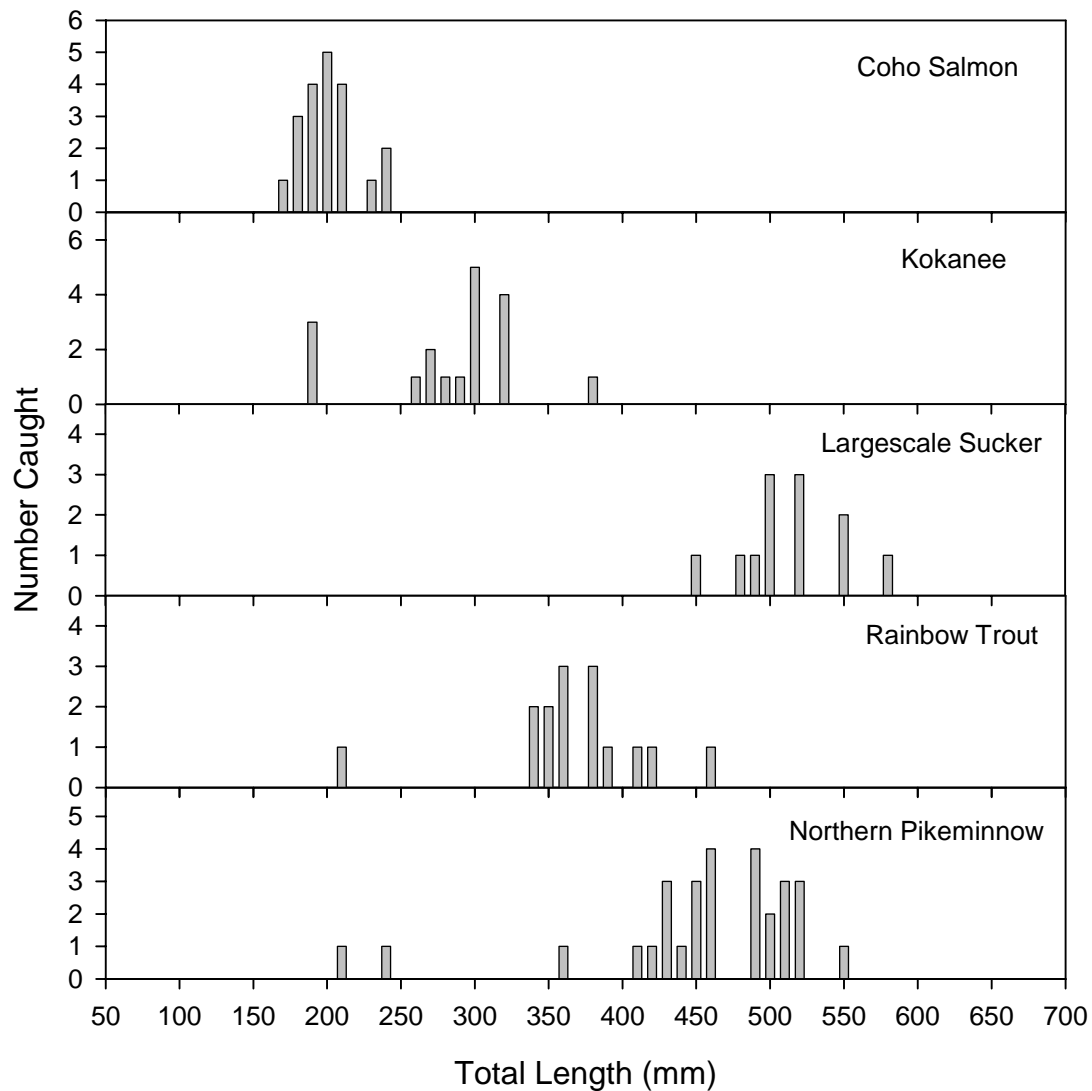
Figure 8.   Length distribution of various fish species caught in 10 experimental gillnets that were set at 2 m depth intervals on September 25-27, 2001 in Cascade Reservoir. Catches were used to partition the May hydroacoustic abundance estimate into species estimates.
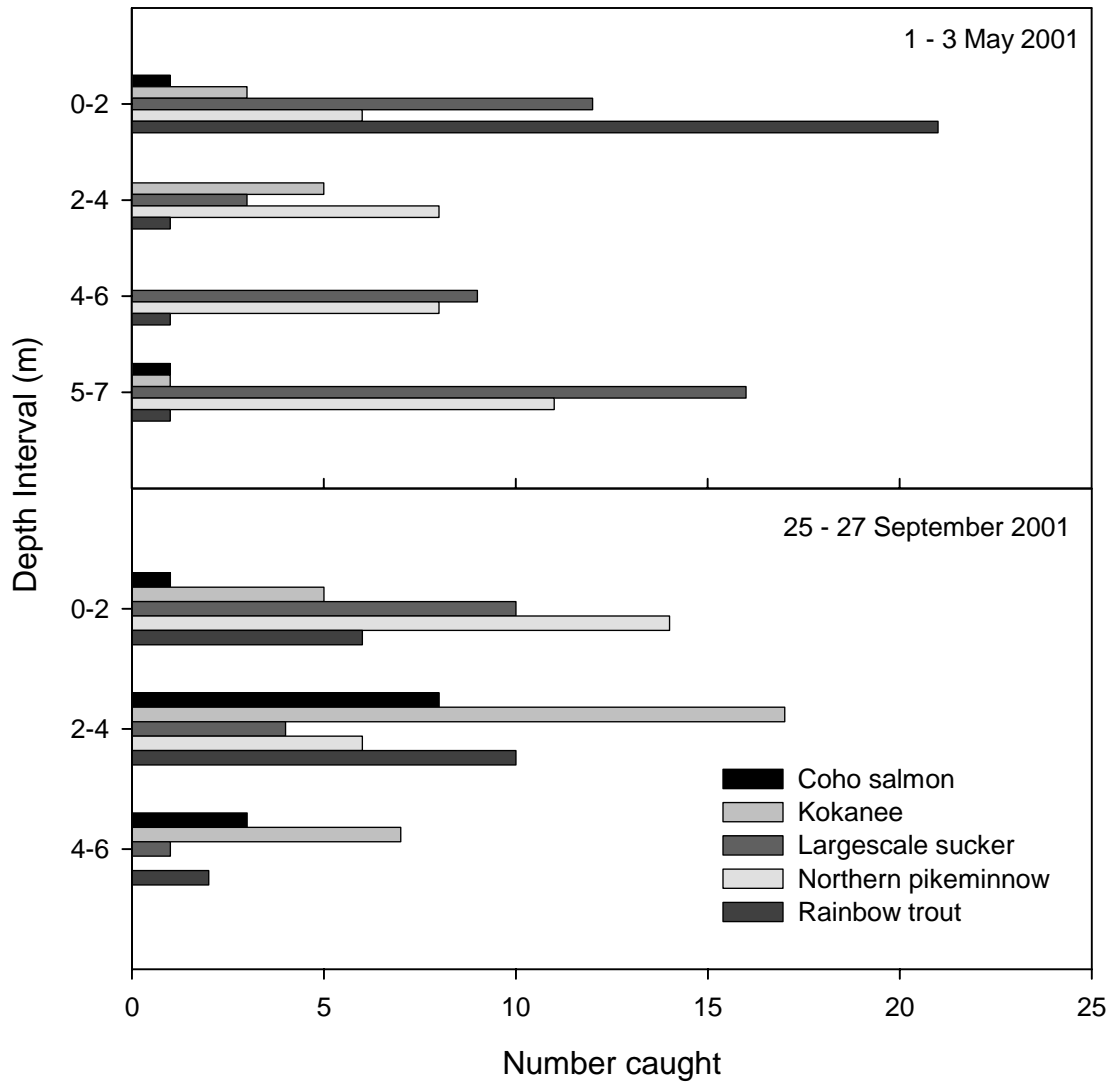
Figure 9. Species composition of gillnet catches by 2 m depth intervals at Cascade Reservoir in May (n = 12) and September (n = 10) dates.
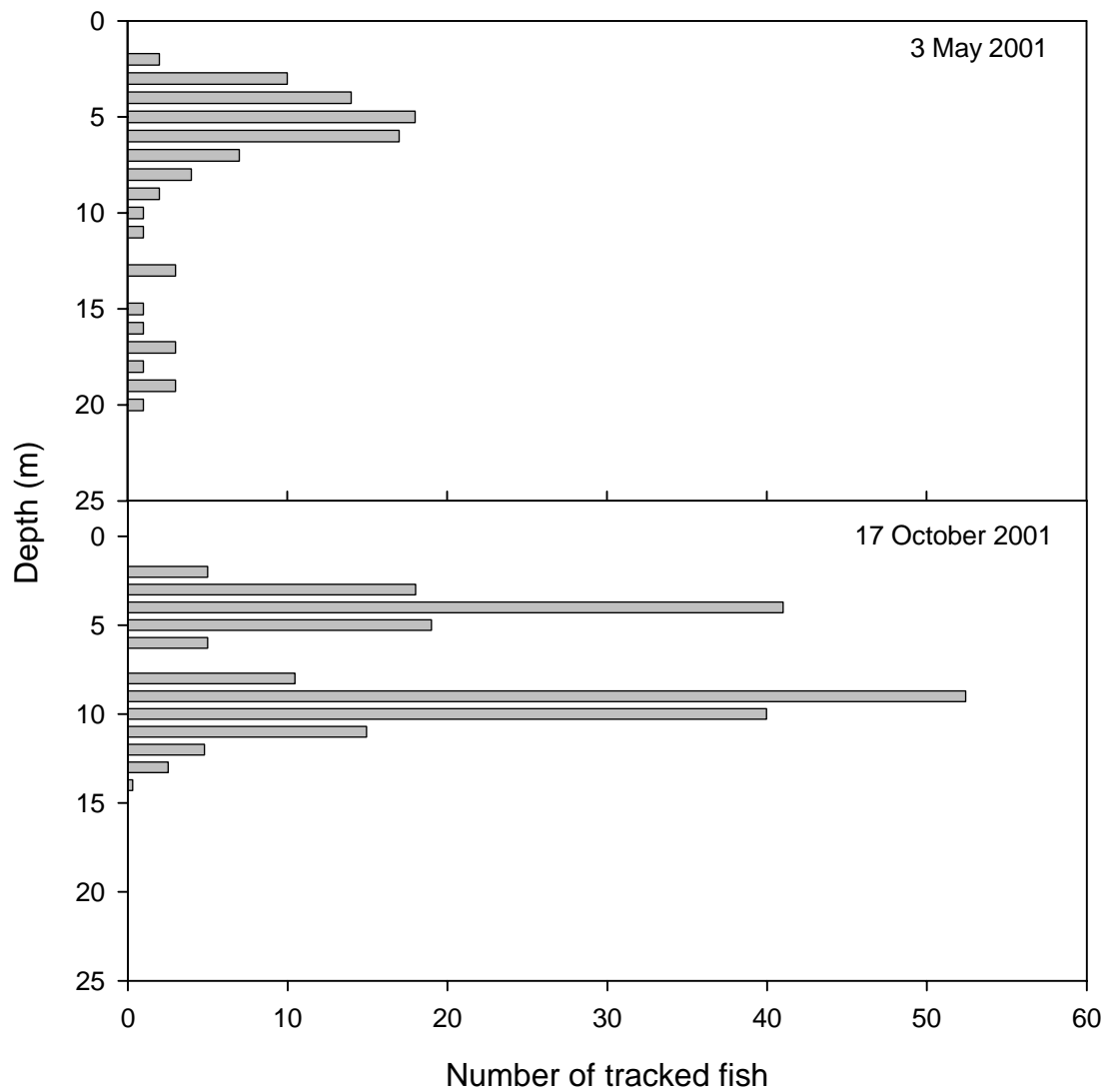
Figure 10. Depth distribution of tracked fish from hydroacoustic surveys conducted on May 3, 2001 and October 17, 2001 at Cascade Reservoir.
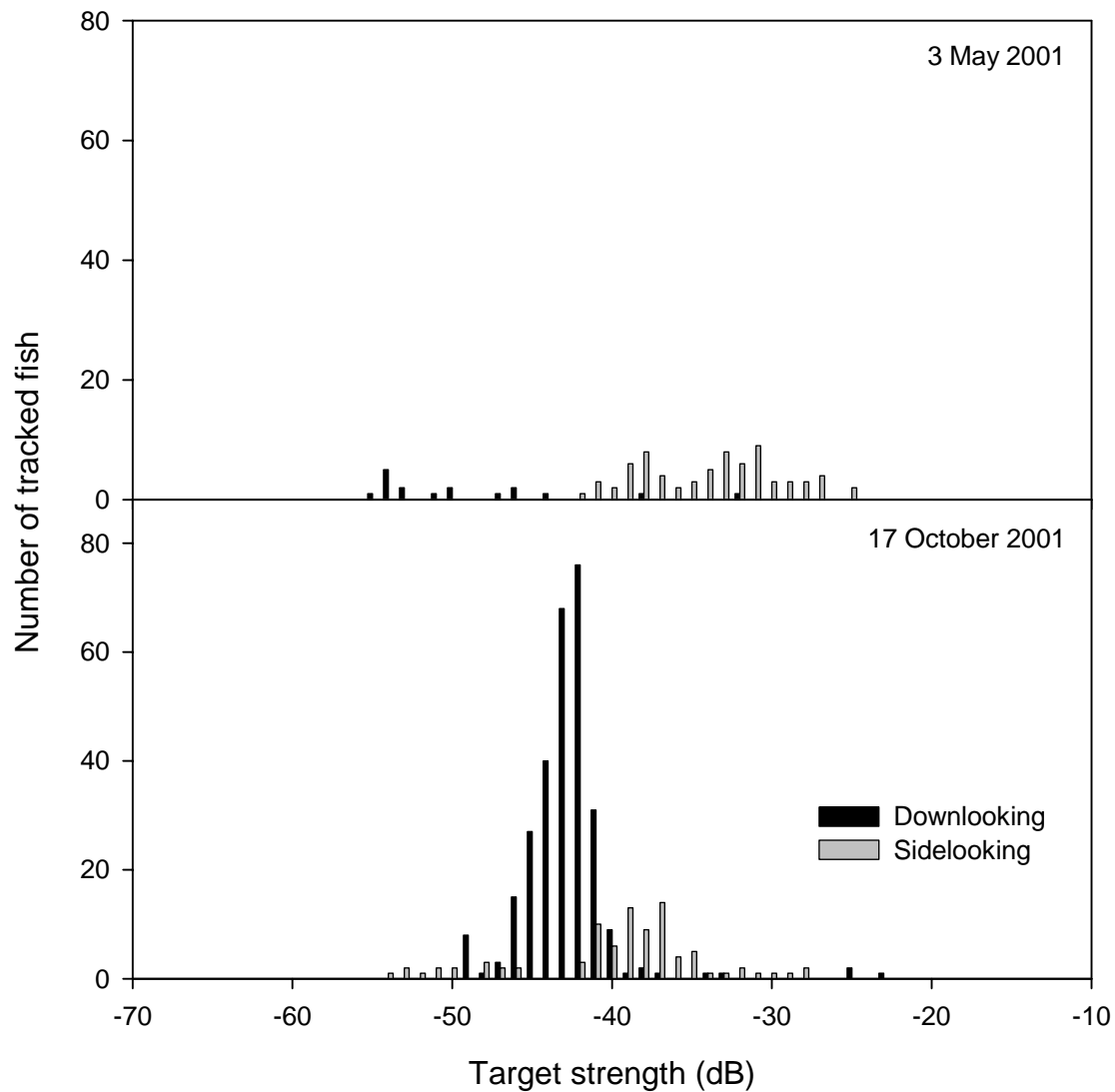
Figure 11. Frequency distribution of target strengths (dB) of fish tracked during the May 3, 2001 and October 17, 2001 hydroacoustic surveys at Cascade Reservoir.

LITERATURE CITED

Aku, P. M. K., L. G. Rudstam, and W. M. Tonn. 1997. Impact of hypolimnetic oxygenation on the vertical distribution of cisco *Coregonus artedi* in Amisk Lake, Alberta. Canadian Journal of Fish and Aquatic Science. 54:2182-2195.

Banneheka, S. G., R. D. Routledge, I. C. Guthrie, and J. C. Woodey. 1995. Estimation of in-river fish passage using a combination of transect and stationary hydroacoustic sampling. Canadian Journal of Fish and Aquatic Science. 52:335-343.

Beauchamp, D. A., C. Luecke, W. A. Wurtsbaugh, H. G. Gross, P. E. Budy, S. Spaulding, R. Dillenger, and C. P. Gubala. 1997. Hydroacoustic assessment of abundance and diel distribution of sockeye salmon and kokanee in the Sawtooth Valley Lakes, Idaho. North American Journal of Fisheries Management 17:253-267.

Brandt, S. B. 1996. Acoustic assessment of fish abundance. Pages 385-419 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Brown, M. J., and D. J. Austen. 1996. Data management and statistical techniques. Pages 17-61 in B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Burczynski, J. J., and R. L. Johnson. 1986. Application of dual-beam acoustic survey techniques to limnetic populations of juvenile sockeye salmon *Oncorhynchus nerka*. Canadian Journal of Fish and Aquatic Science. 43:1776-1788.

Burczynski, J. J., P. H. Michaletz, and G. M. Marrone. 1987. Hydroacoustic assessment of the abundance and distribution of rainbow smelt in Lake Oahe. North American Journal of Fisheries Management 7:106-116.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, volume one. Iowa State University Press, Ames, Iowa.

Edsall, T. A., C. L. Brown, G. W. Kennedy, and T. P. Poe. 1992. Lake Trout spawning habitat in the six fathom bank-Yankee reef lake trout sanctuary, Lake Huron. Journal of Great Lake Research. 18(1):70-90.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55(292):708-713.

Hubert, W. A. 1996. Passive capture techniques. Pages 157-182 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Johnston, J. M. 1981. Inland and marine game fish research: development and evaluation of hydroacoustic techniques for instantaneous fish population estimates in shallow lakes. Washington Department of Game. PROJ. #: WASH F-068-R-04 /JOB I-1/FIN.

Kubecka, J. 1994. Simple model on the relationship between fish acoustical target strength and aspect for high-frequency sonar in shallow waters. Journal of Applied Ichthyology. 10:75-81.

Kubecka J. and A. Duncan. 1998. Acoustic size vs. real size relationships for common species of riverine fish. Fisheries Research. 35:115-125.

Kubecka J., A. Duncan, and A. Butterworth. 1992. Echo counting or echo integration for fish biomass assessment in shallow waters. European Conference on Underwater Acoustics, ed. M. Weydert, pp. 129-132.

Kubecka J., A. Duncan, W. M. Duncan, D. Sinclair, and A. J. Butterworth. 1994. Brown trout populations of three Scottish lochs estimated by horizontal sonar and MultiMesh gillnets. Fisheries Research. 20(1994):29-48.

Love, R. H. 1977. Target strength of an individual fish at any aspect. Journal of Acoustical Society of America. 62:1397-1403.

Luecke, C., and W. A. Wurtsbaugh. 1993. Effects of moonlight and daylight on hydroacoustic estimates of pelagic fish abundance. Transactions of the American Fisheries Society. 122:112-120.

Maiolie, M. A., B. Harryman, B. Ament. 2001. Response of free-ranging kokanee to strobe lights. Pages 27-35 in C. C. Coutant, editor. Behavioral technologies for fish guidance. American Fisheries Society, Symposium 26, Bethesda, Maryland.

Maiolie, M. and S. Elam. 1996. Dworshak Dam impact assessment and fisheries investigation: kokanee depth distribution in Dworshak Reservoir and implications toward minimizing entrainment. Annual Progress Report. Idaho Department of Fish and Game, Boise, Idaho.

McClain, C. J., and R. E. Thorne. 1991. Fish assessment in Yellowstone Lake, Wyoming using a simultaneous down- and sidelooking acoustic system. BioSonic, Inc., Seattle Washington.

Rieman B. E. and D. L. Myers. 1991. Kokanee population dynamics. Job completion report. Project F-73-R-13. Idaho Department of Fish and Game, Boise, Idaho.

Scheaffer, R. L., W. Mendenhall III, R. L. Ott. 1996. Elementary survey sampling, 5th edition. Duxbury Press, Belmont, California.

Teuscher, D. 1997 in Montana Fish Wildlife and Parks regional fisheries annual progress report. Great Falls, Montana.

Teuscher, D. 2001. Lake and reservoir research. Job performance report. Grant F-73-R-23 Project 5. Idaho Department of Fish and Game, Boise, Idaho.

Thorne, R. E. 1971. Investigations into the relation between integrated echo voltage and fish density. Journal of the Fishery Research Board of Canada. 28:1269-1273.

Thorne, R. E. 1979. Hydroacoustic estimates of adult sockeye salmon *Oncorhynchus nerka* in Lake Washington, 1972-75. Journal of the Fishery Research Board of Canada. 36:1145-1149.

Thorne, R. E. 1983. Hydroacoustics. Pages 239-259 *in* L. Nielsen and D. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Thorne, R. E., and J. J. Dawson. 1974. An acoustic estimate of the escapement of sockeye salmon *Oncorhynchus nerka* into Lake Washington in 1971. Journal of the Fishery Research Board of Canada. 31:222-225.

Yule D. L. 2000. Comparison of purse seine and horizontal acoustic estimates of trout densities and sizes in eleven Wyoming waters. North American Journal of Fisheries Management 20:759-775.
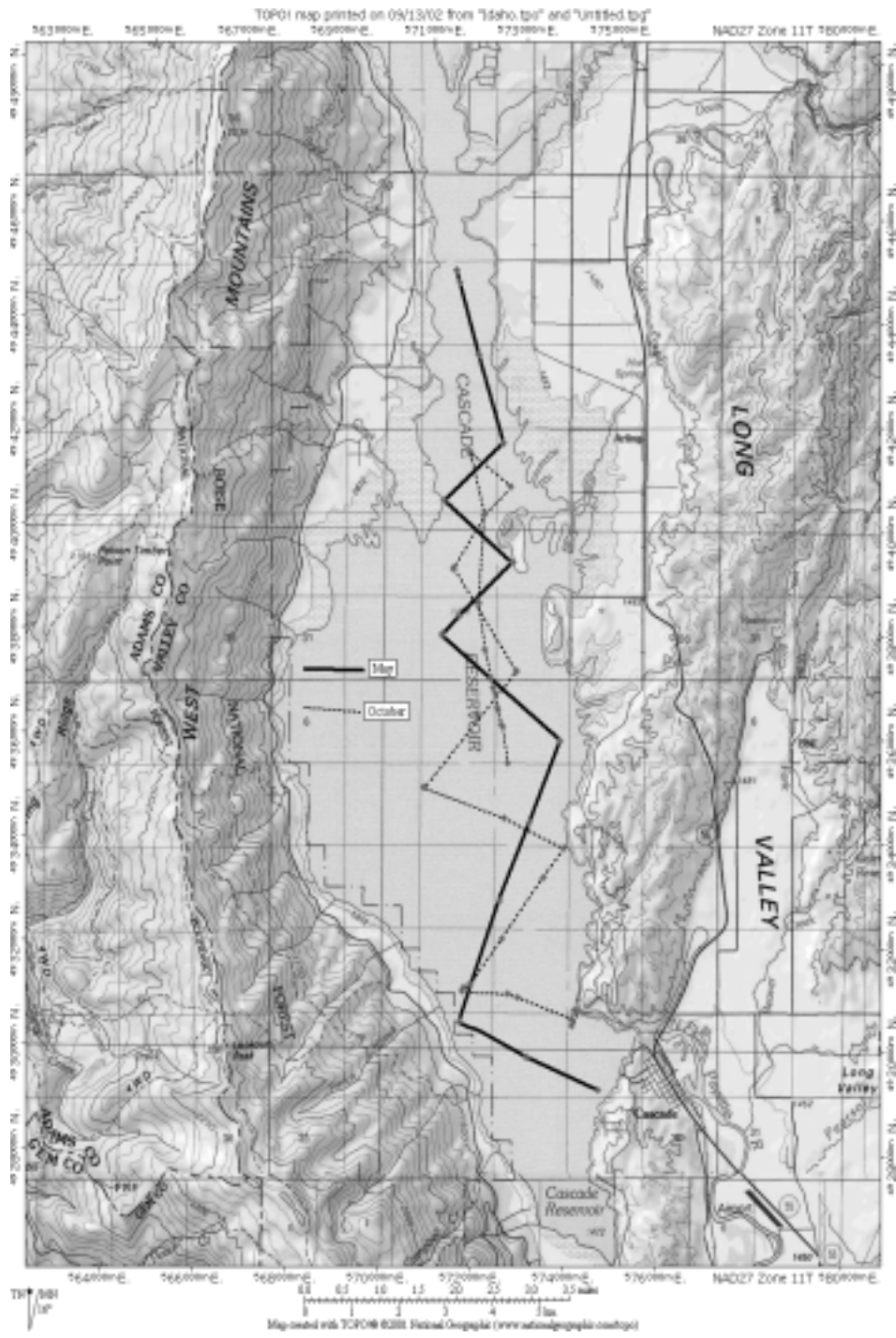
APPENDICES

Appendix A. Near-dam hydroacoustic transects at American Falls Reservoir for November 2000 and 2001 fish density comparisons.
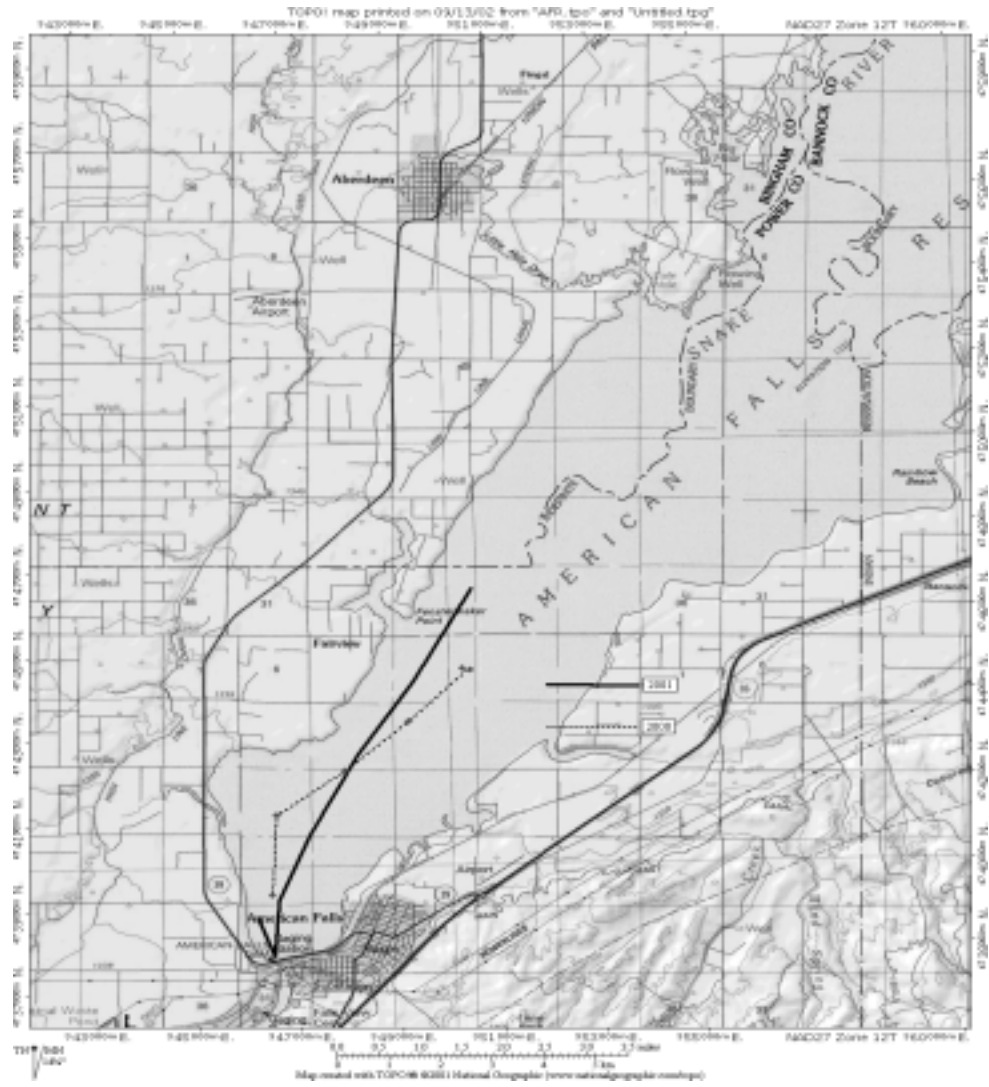
Appendix B.   Hydroacoustic transects for Anderson Ranch Reservoir on July 24, 2001.
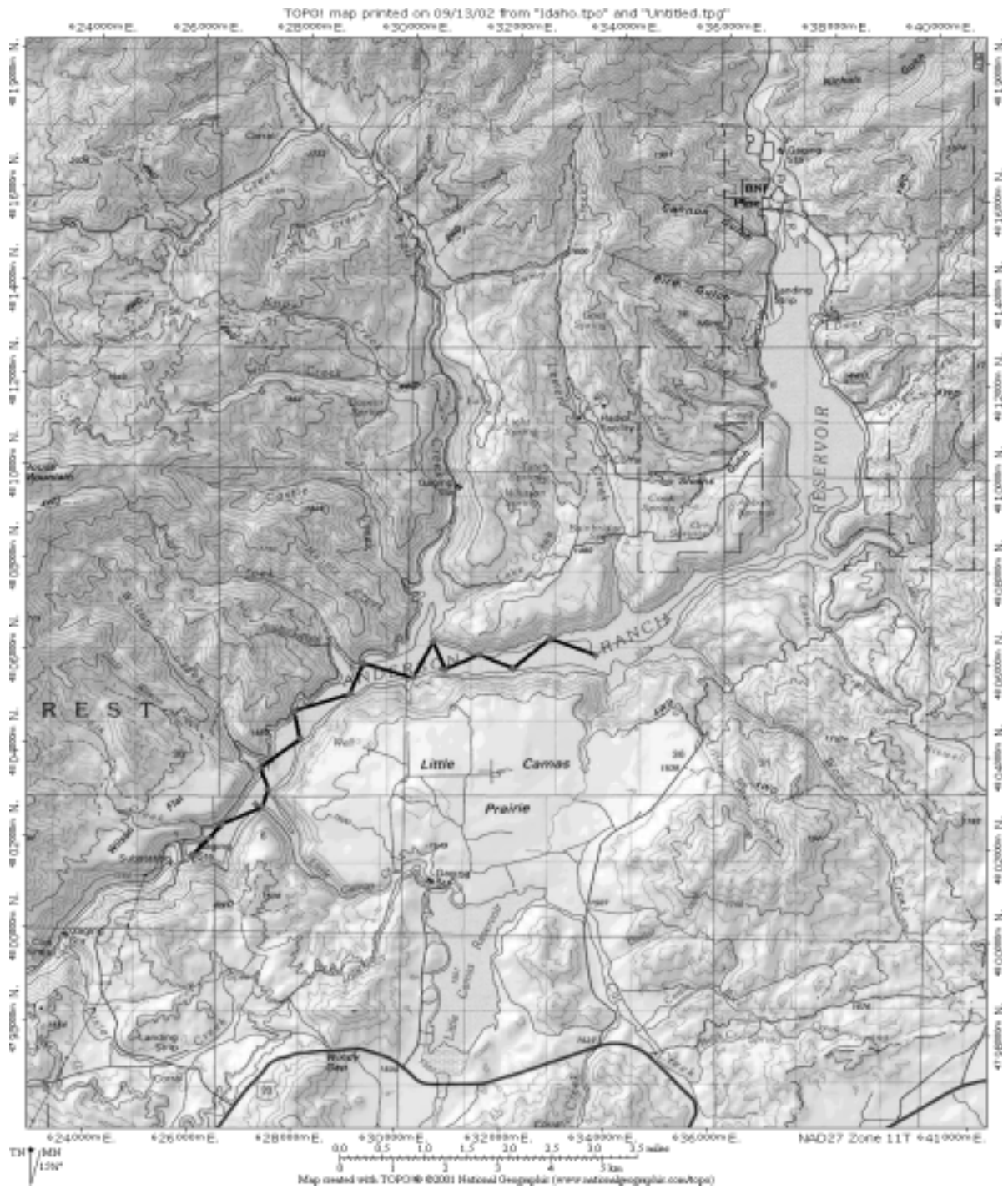
Appendix C. Hydroacoustic transects for Cascade Reservoir on May 3, 2001 and October 17, 2001.

Prepared by:

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Arthur E. Butts
Fishery Research Biologist

Virgil K. Moore, Chief
Bureau of Fisheries

David Teuscher
Regional Fishery Biologist

Steve Yundt
Fishery Research Manager