Hydroacoustic Analysis of Fish Populations in Copco and Iron Gate Reservoirs, California

Klamath Hydroelectric Project
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ABSTRACT

Hydroacoustic sampling was conducted to better characterize the fish community in the deep-water habitat in Copco and Iron Gate Reservoirs as part of the relicensing activities for the Klamath Hydroelectric Project. The impoundments were sampled in August and October 2003 and April 2004. Each survey path was comprised of transects 150 m apart to provide adequate spatial representation of the fish populations, while also minimizing the incidence of multiple acquisition of targets. For each impoundment, a prescribed path was developed over the areas of the impoundments greater than 5 m deep. Two daytime surveys and one nighttime survey were conducted over each survey path for each of the three seasonal analyses. The hydroacoustic activities were conducted concomitantly with deep-set gill netting conducted in the pelagic zones by PacifiCorp staff. Fish species, length, and position in the net were recorded. The results from the August survey indicate that the vast majority of fish targets were above the thermoclines in both impoundments. This is consistent with anoxia present in the hypolimnia of both impoundments. Fish abundance along the survey paths was similar between day and night runs in Copco Reservoir. In Iron Gate Reservoir, a greater number of fish were present in the eastern portion of the reservoir at night. It is unknown whether this represents a movement of fish eastward in the impoundment or a movement of fish from the littoral areas into the narrow pelagic zone. Fish netting conducted in the pelagic zone concurrently with the hydroacoustic activities showed that most of the targets were yellow perch (*Perca flavescens*). Small numbers of black crappie (*Promoxis nigromaculatus*), pumpkinseed (*Lepomis gibbosus*), golden shiner (*Notemigonus crysoleucas*), and tui chub (*Gila bicolor*) were also sampled.

INTRODUCTION

The assessment of fish populations has always presented challenges, especially in deep lakes where traditional shallow-water netting techniques (e.g. fyke nets, traps nets, seining) cannot be employed to characterize the pelagic fisheries. Previous efforts to characterize the fisheries of Copco and Iron Gate Reservoirs have focused on the near-shore and benthic environments. However, to provide a more complete analysis of the total fisheries in these two deep impoundments, a complementary approach involving deep-water net sets and hydroacoustic surveys was implemented. The study began with a survey conducted in August 2003 and continued with surveys in October 2003 and April 2004. The purpose of this report is to present findings from these surveys.

METHODS

Survey paths were designed for conducting the hydroacoustic runs on both Copco and Iron Gate Reservoirs, California. The paths were set at 150 meter-wide transects in the main portions of the impoundments, with paths that followed the thalwegs in the arms of the impoundments (Figure 1). Areas less than 5 m deep (at full pool) were identified and eliminated from the survey paths, unless they constituted a transition to another transect leg. The hydroacoustic analyses were conducted using a BioSonics DT-X acoustic device equipped with a 200 KHz split-beam 6.6° digital transducer. Positional data was acquired with a Sokkia DGPS and linked with the BioSonics unit. The hydroacoustic acquisition threshold was set at –65 dB and a ping rate of 1 per second. Vessel speed generally ranged from 9 to 10 kph. Hydroacoustic and positional data were integrated into files on a Panasonic CF-28 Toughbook®, backed up on CD, and processed using Visual Analyzer® software. The target strength of the hydroacoustic unit was checked against a standardized calibration sphere. No adjustment in the performance of the hydroacoustic unit was necessary. Because of the presence of bubbles in both reservoirs, which were observed at smaller than -40dB, we censored the fisheries hydroacoustic data to represent fish targets as those targets greater than -40 dB. Fish length was estimated from target strength based on Love’s equation (Love 1971).

Because the hydroacoustic data does not distinguish targets into fish species, vertical gill nets were deployed. Information regarding the position and depth of likely fish targets were used to guide where nets were placed (Figures 2 and 3). The gill nets had mesh sizes of 1.5 X 1.0 inches (or 1.5 X 1.5 inches in some cases) and a dimension of 2 m by 30 m. The net sets were run at multiple times during the day and early evening for approximately two hour per net set. Nets were removed from the water and the species and length of each fish in the nets were recorded with respect to their position on the net (and therefore depth in the water column). A summary of the dates and times of the hydroacoustic surveys and net set is provided in Table 1.

During the surveys *in-situ* profiles of temperature, conductivity, pH, and dissolved oxygen (DO) were measured using a YSI 600 XLM multi-parameter sonde. The sonde was calibrated daily prior to use according to manufacturer’s protocol.

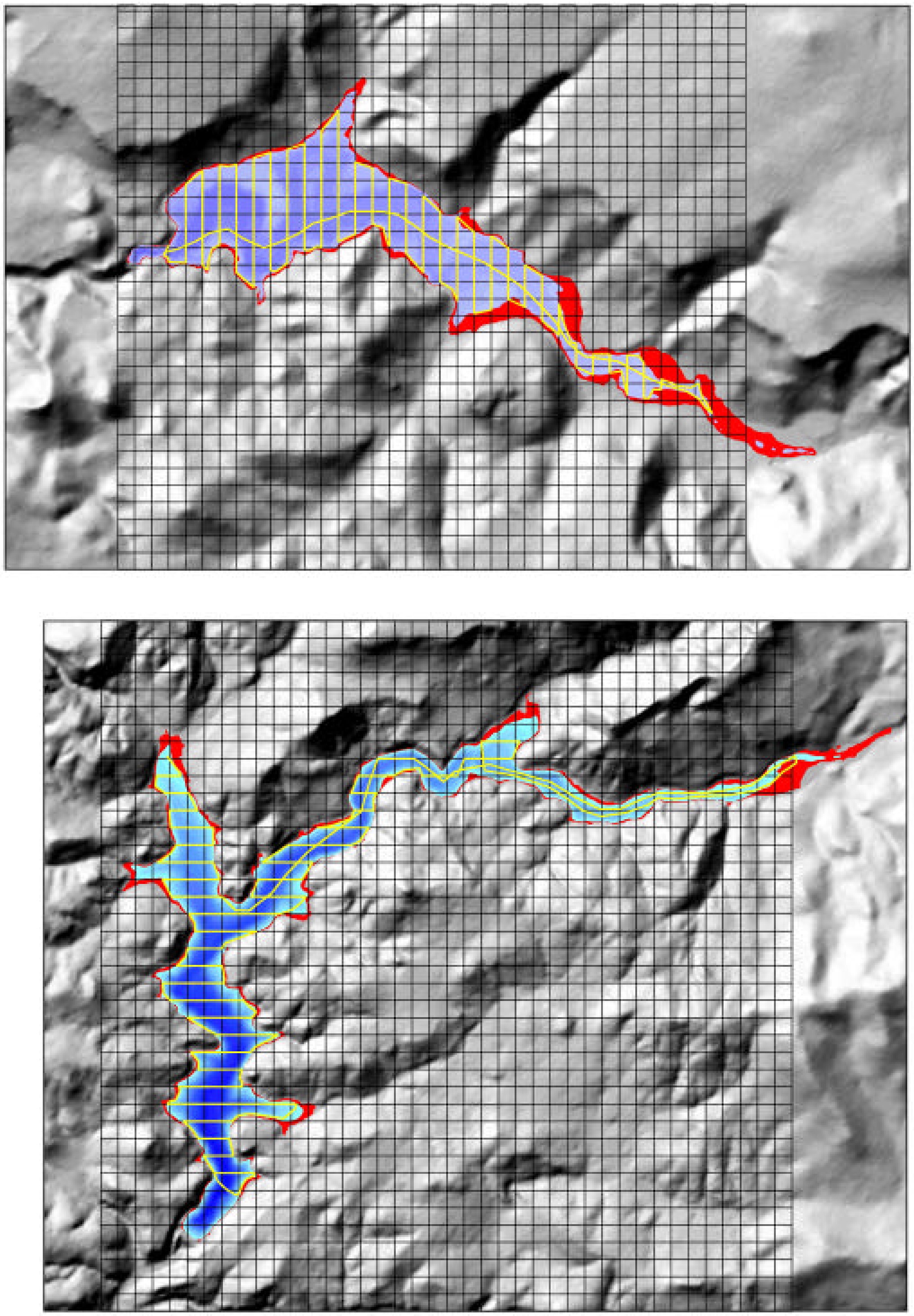


Figure 1. Survey tracks (in yellow) superimposed over the bathymetry for Copco (top) and Iron Gate Reservoirs (bottom). Areas shown in red constitute shallow habitat that was excluded from the survey design.

Table 1. Dates of hydroacoustic (Hydro) and fish netting (Net) activities on Copco And Iron Gate Reservoirs.

Date	Copco		Iron Gate	
	Day	Night*	Day	Night
August 2003				
17			Net	
18			Net	
19	Hydro	Hydro		
20	Hydro, Net		Net	Hydro
21				
October 2003				
29			Hydro, Net	Hydro
30	Hydro (2), Net			
31		Hydro	Hydro, Net	
April 2004				
6	Hydro		Hydro, Net	Hydro
7	Hydro, Net	Hydro		
8			Hydro	Net

* Starting date of night runs; these usually extended past midnight

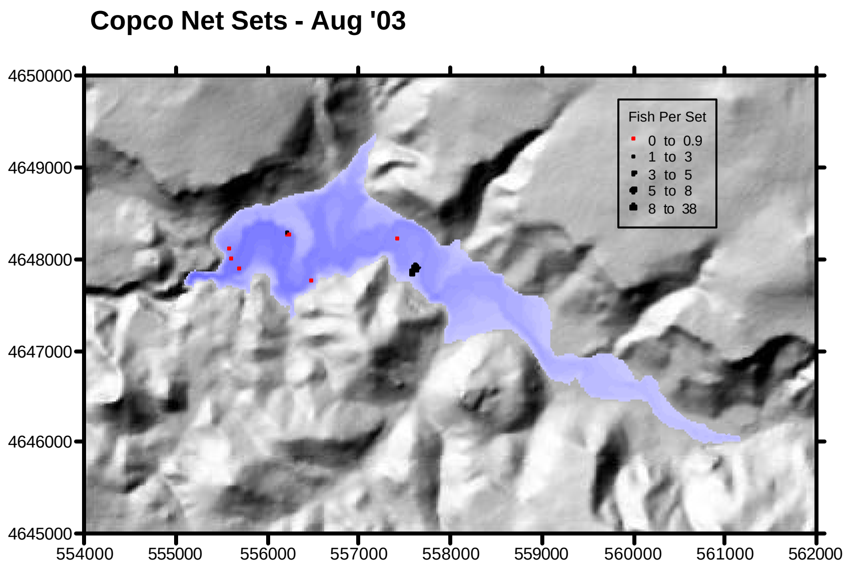


Figure 2. Approximate locations of net sets on Copco Reservoir for the August survey and number of fish caught per net.

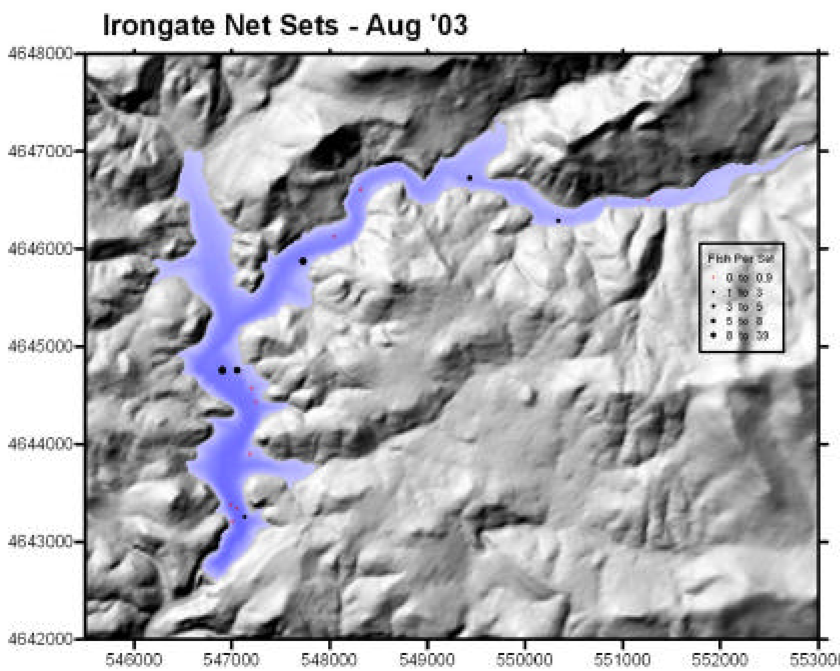


Figure 3. Approximate locations of net sets on Iron Gate Reservoir for the August survey and number of fish caught per net.

RESULTS

1. Water Quality

The water quality results showed that the lakes were strongly stratified in August and weakly stratified in October and April (Figures 4 and 5). Although the October profile on Copco Reservoir was not extended to the deeper areas in the impoundment, it is likely based on the observed pattern in Iron Gate Reservoir, that Copco Reservoir was also weakly stratified. The conductivity profiles in Copco Reservoir were inversely related to the temperature profiles, indicating that unmeasured dissolved minerals and H^+ were present in greater concentrations with depth. This was also the case for Iron Gate Reservoir in August and October, however, the April conductivity profile showed a slight decrease from the surface to the lake bottom. The dissolved oxygen (DO) profile in Copco Reservoir during August showed that the lake was anoxic below 18 m, however, there was also evidence of oxygen depletion from 6 m to 17 m. In Iron Gate Reservoir, the DO profile in August was more complex, with a decrease to 15 m, a slight recovery at 20 m, and a decline to 28 m. The October DO profile in Iron Gate was relatively uniform in the upper water column, but again showed a peak at 20 m before decreasing with depth. DO profiles in both lakes were relatively uniform in April. The pH profiles in both lakes typically followed the temperature and DO patterns distribution. In Copco Reservoir, the pH distribution was very similar to the DO profile, whereas in Iron Gate Reservoir, the pH distribution for August, although similar, did not match the variations in DO concentrations. The pH profiles for both lakes showed only minor changes with depth in October and April.

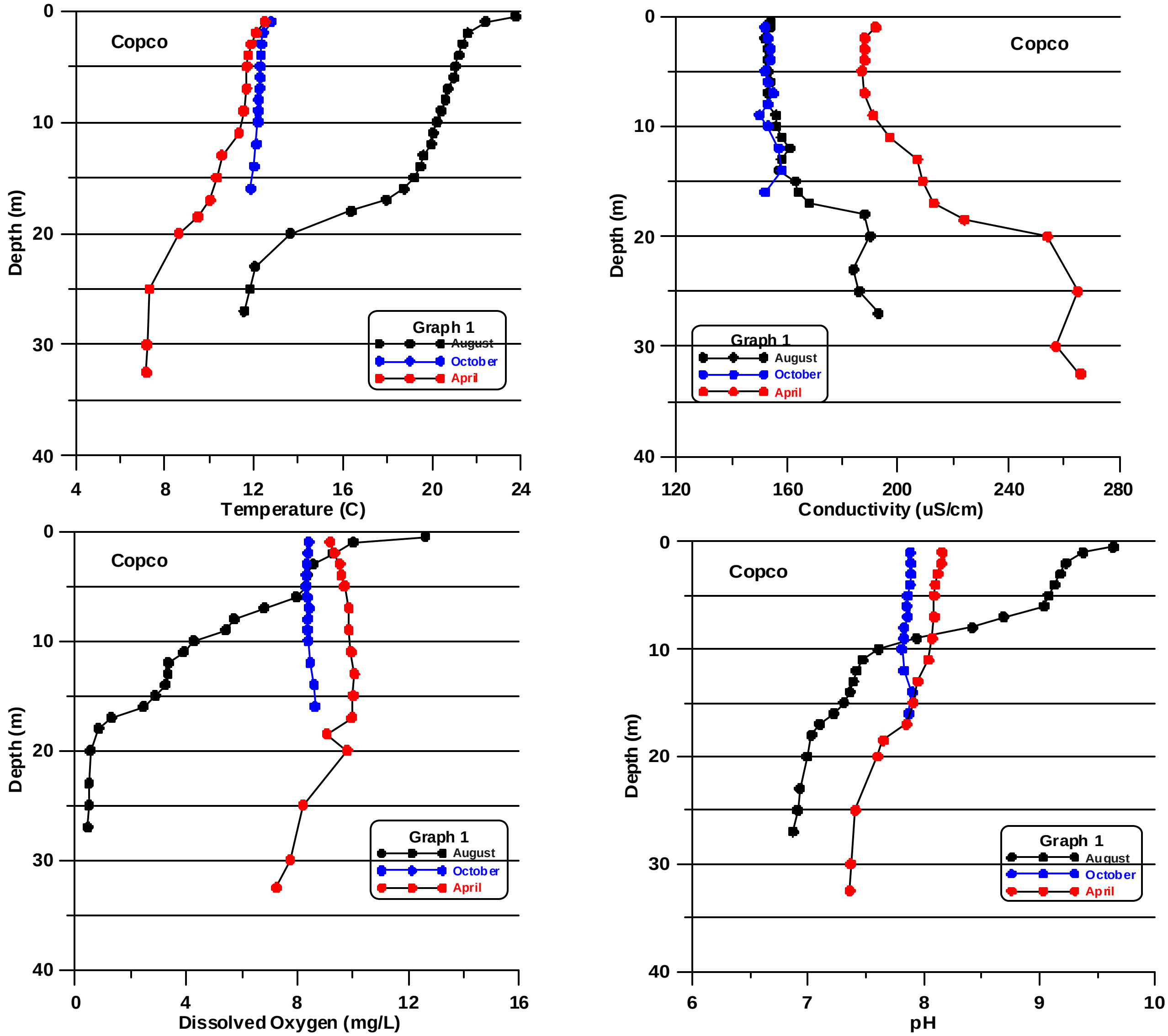


Figure 4. Temperature, conductivity, dissolved oxygen, and pH profiles in Copco Reservoir for each of the three sampling periods. The deepest profile from each sampling period is displayed.

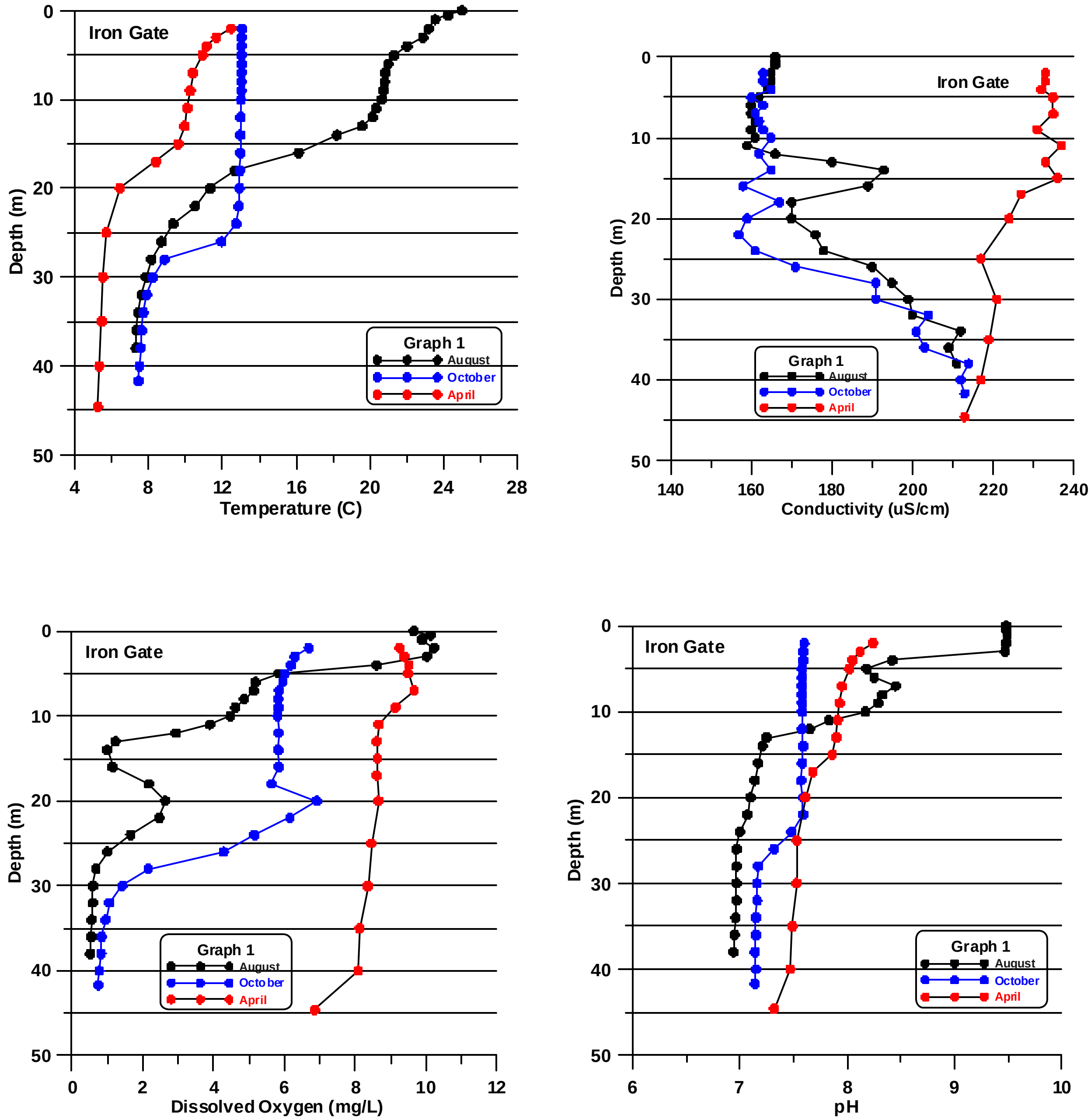


Figure 5. Temperature, conductivity, dissolved oxygen, and pH profiles in Iron Gate Reservoir for each of the three sampling periods. The deepest profile from each sampling period is displayed.

2. Fish Species Composition and Size Distribution Based on Netting

The results for the fish netting show that most of the fish caught were yellow perch (*Perca flavescens*) within the size range of 130 to 285 mm (Figure 6). The median size of fish netted in Copco Reservoir was 193 mm (CV 9.2 mm) and 200 mm (CV 10.3 mm) in Iron Gate Reservoir. The only non-perch fish caught in August were two black crappie (*Promoxis nigromaculatus*) in Copco Reservoir. The variety of fish netted in Copco Reservoir increased in October to include three additional species, pumpkinseed ((*Lepomis gibbosus*), golden shiner (*Notemigonus crysoleucas*), and a tui chub (*Gila bicolor*). Despite the increase in number of species caught, the total number of individuals in the Copco October net set was low. The largest number of species caught in Iron Gate Reservoir was three in April, however as observed in all net sets, the most abundant species was the yellow perch. The smallest fish captured was a 125 mm pumpkinseed in Copco Reservoir and the largest was a 285 mm yellow perch in Iron Gate Reservoir.

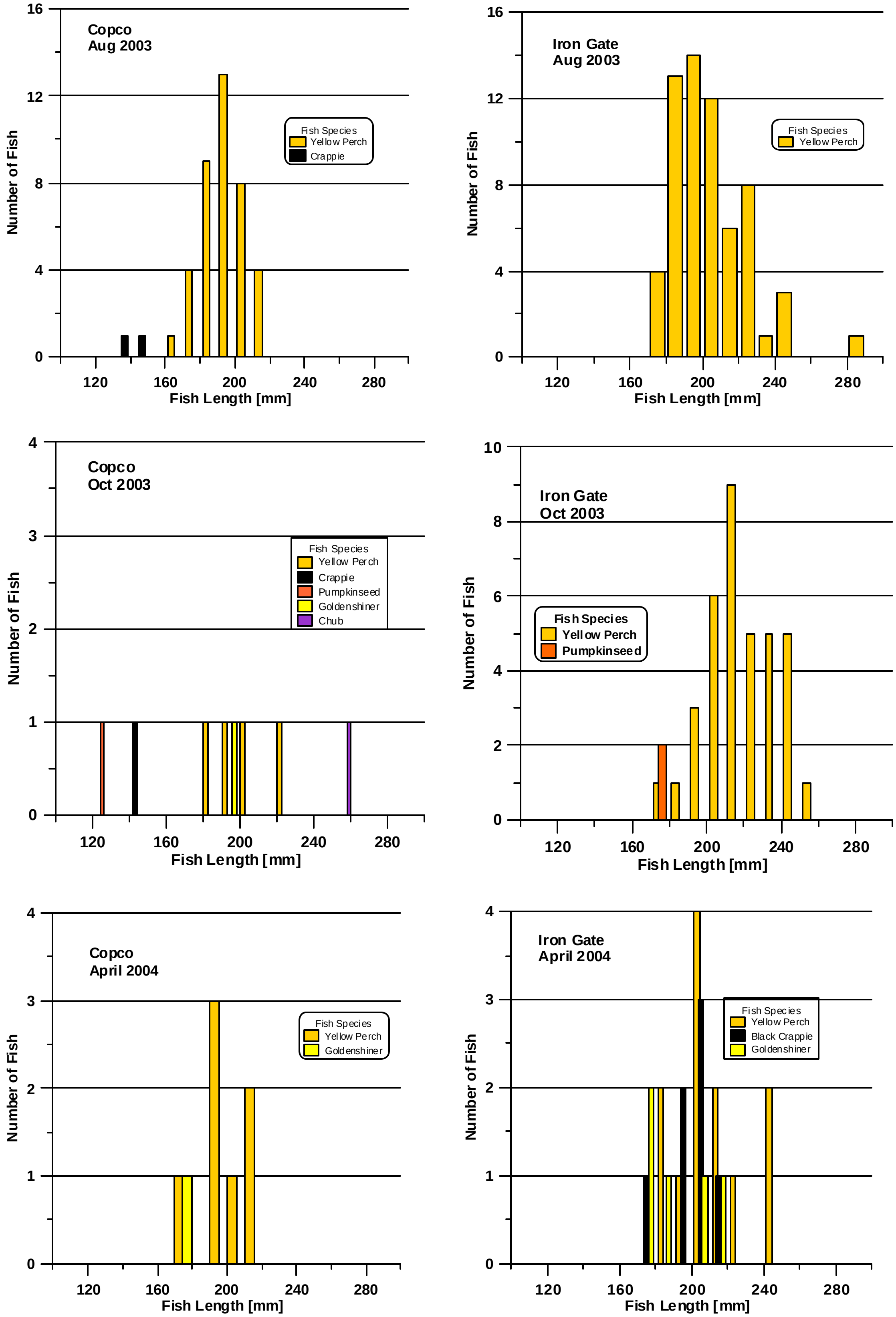


Figure 6. Species composition and size of fish captured in gill net sets in Copco and Iron Gate Reservoirs.

3. Spatial Distribution of Fish Targets

Most of the fish targets observed in Copco Reservoir were generally located towards the middle and eastern end of the lake (Figures 7- 9), where the reservoir begins to constrict. Relatively few targets were present throughout the lake, and very few were present in the pelagic zone. There were relatively minor differences in spatial distribution of the targets in Copco Reservoir between the day runs and night run or among seasons.

The distribution of fish in Iron Gate Reservoir showed few fish present in the open-water area of the main body of the lake oriented north-south (Figures 10- 12). Most fish were observed adjacent to the shorelines, especially the eastern shore, and in the inlet arm. During the night runs, a majority of the fish were congregated in or near the thalweg, 2 km west of the inlet east of the Jenny Creek cove.

The spatial distribution with respect to east-west orientation in the impoundments is illustrated in Figures 13 and 14. For Copco Reservoir, most of the fish remain in the eastern portion of the reservoir, regardless of time of day. In Iron Gate Reservoir, however, we observe an increase in fish targets on the eastern end of the impoundment at night.

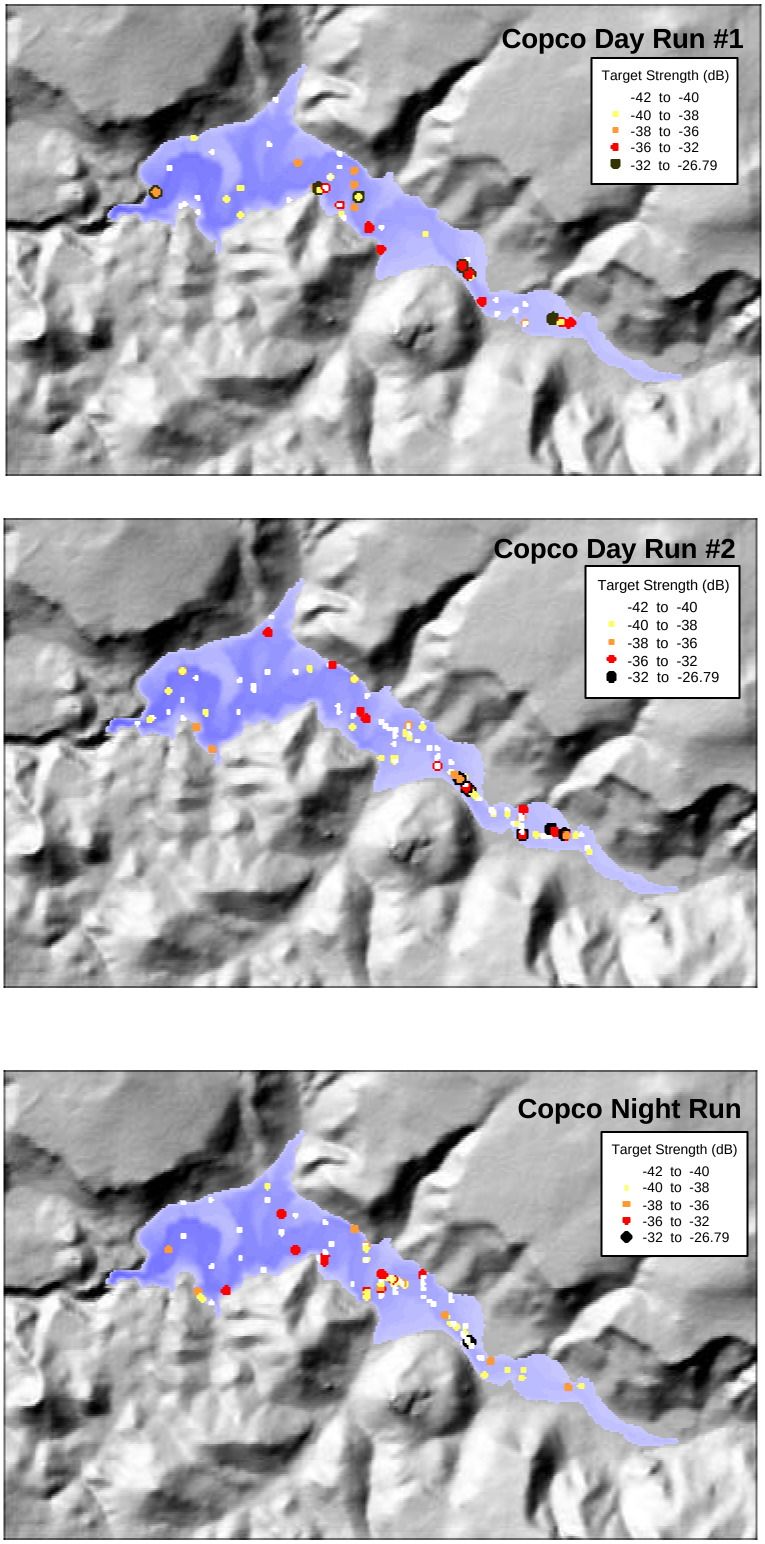
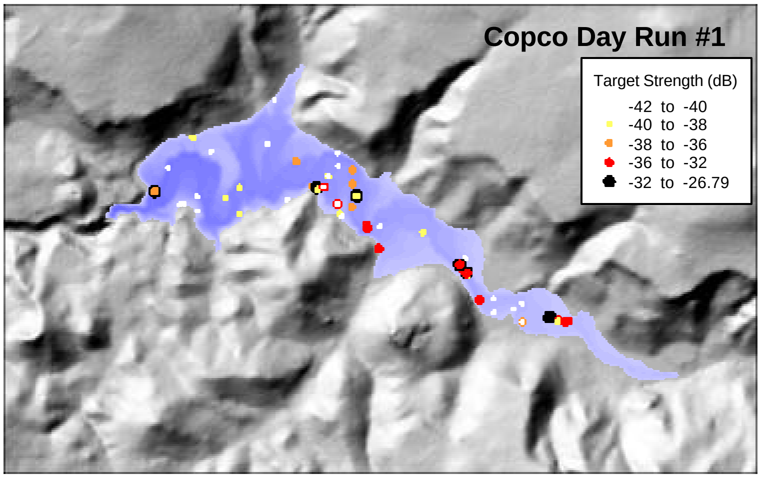
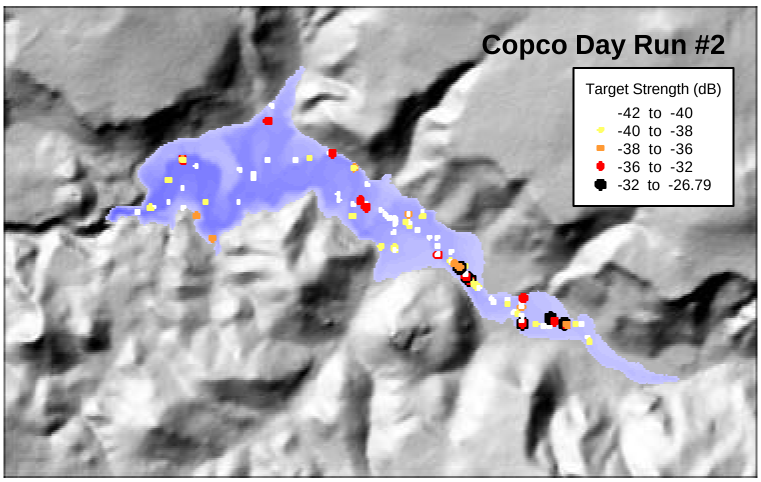


Figure 7.Distribution of fish targets in Copco Reservoir by target strength. August 2003.





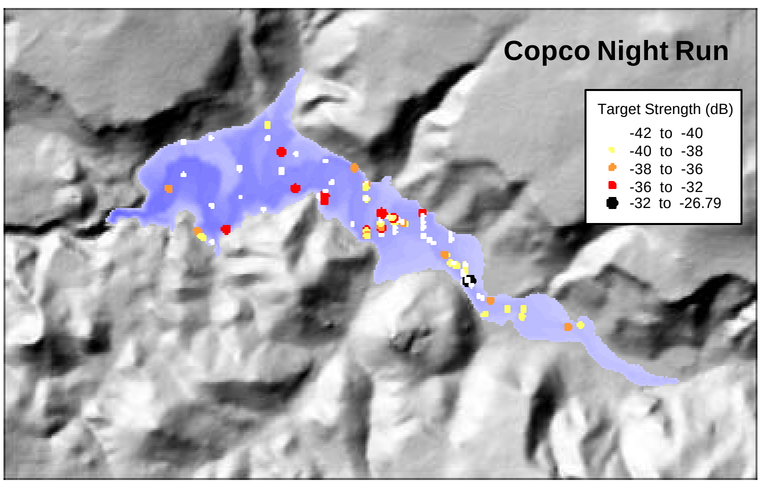
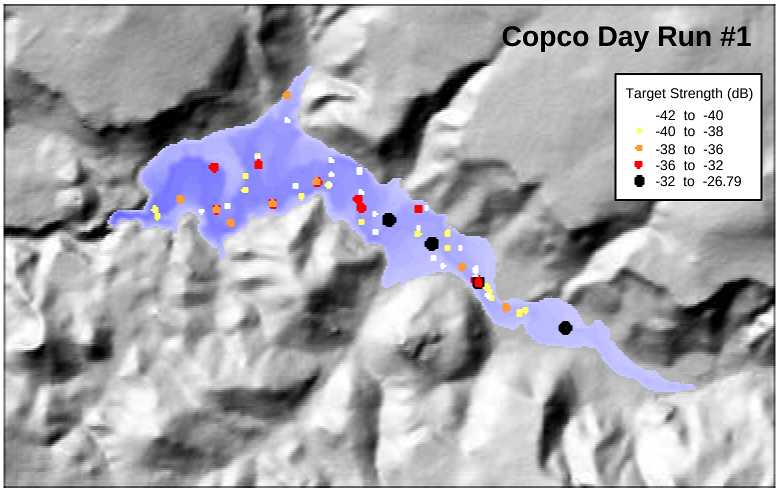
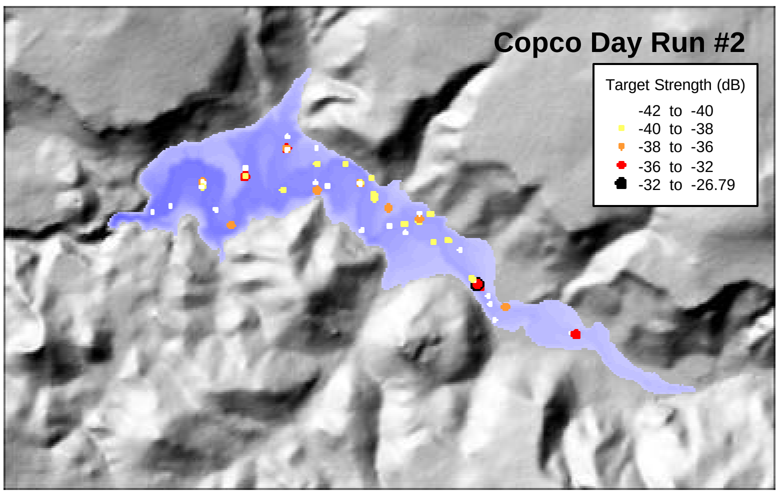


Figure 8.Distribution of fish targets in Copco Reservoir by target strength. October 2003.





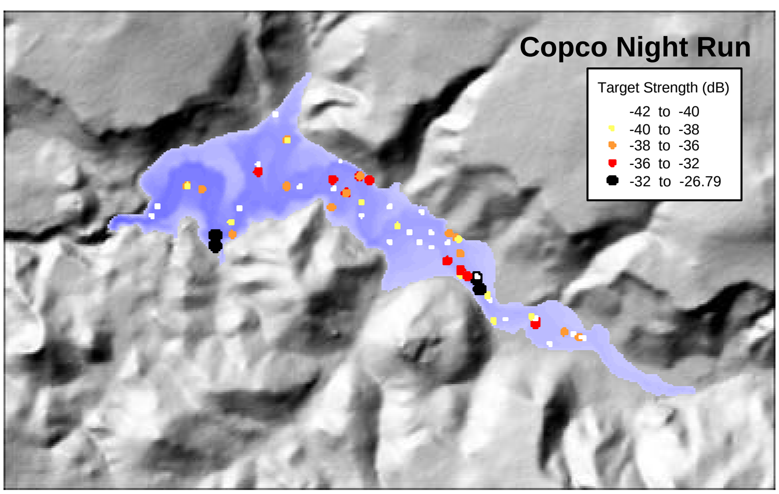
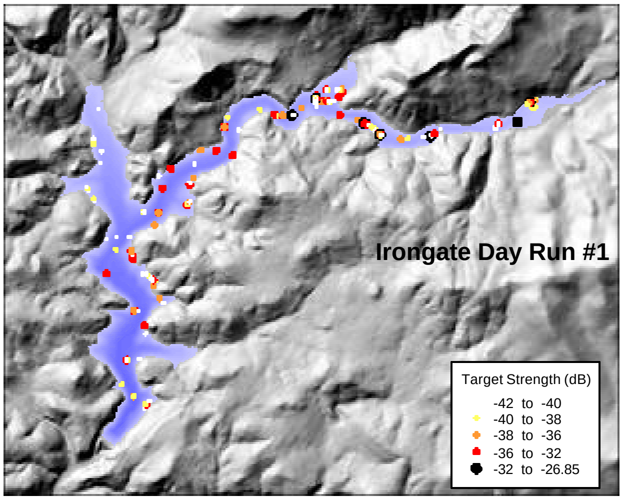
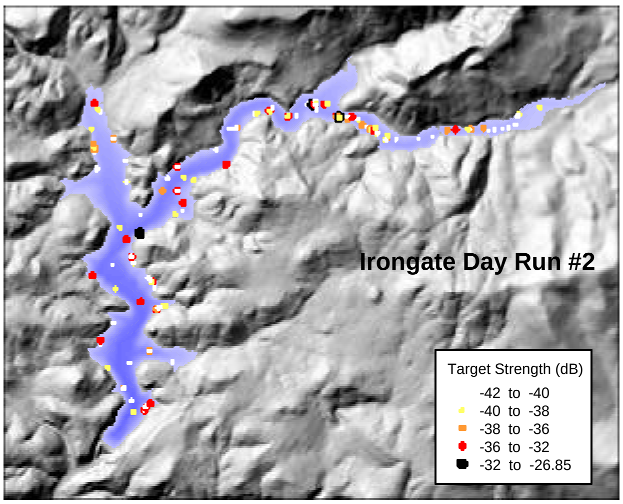


Figure 9. Distribution of fish targets in Copco Reservoir by target strength. April 2004





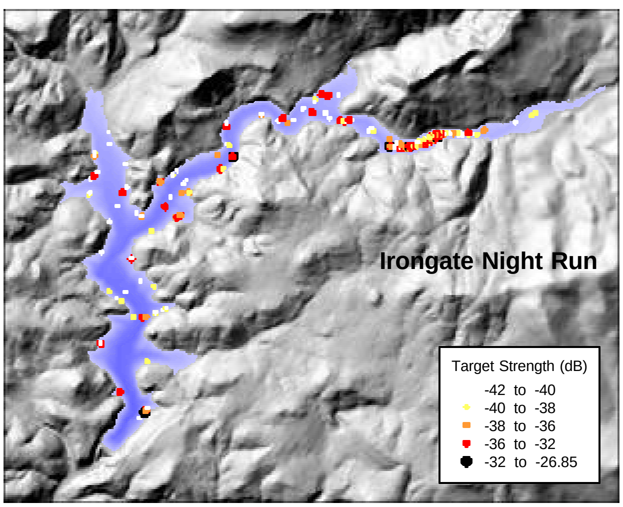
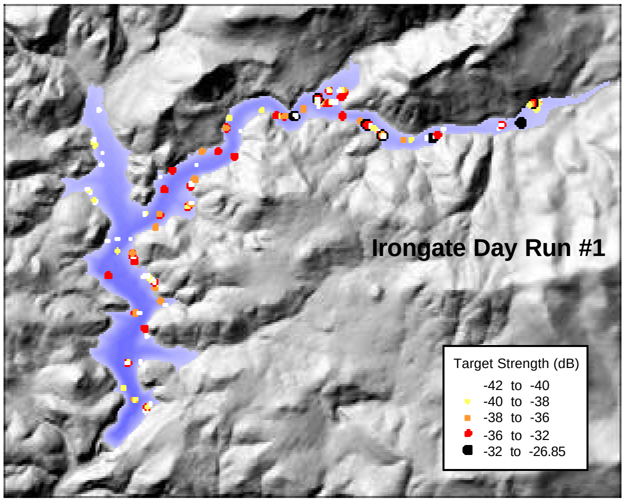
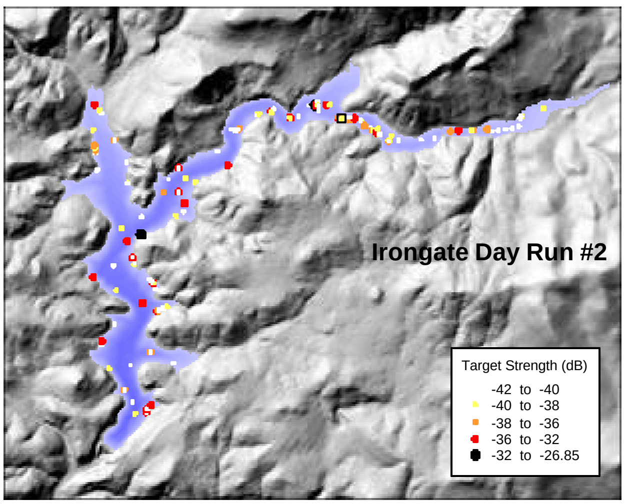


Figure 10. Distribution of fish targets in Iron Gate Reservoir by target strength. August 2003





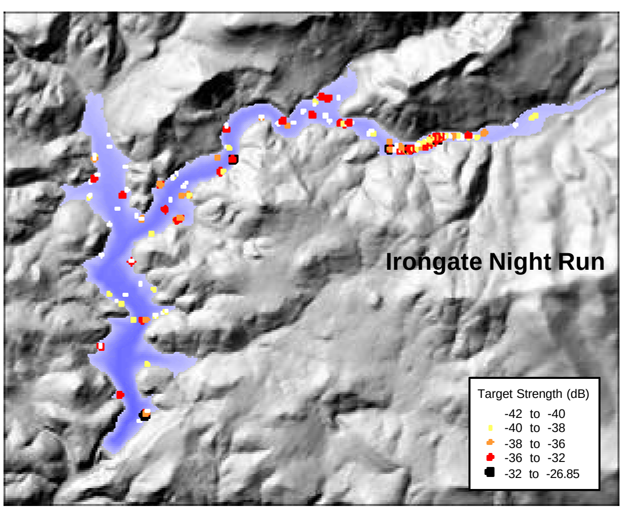


Figure 11. Distribution of fish targets in Iron Gate Reservoir by target strength. October 2003

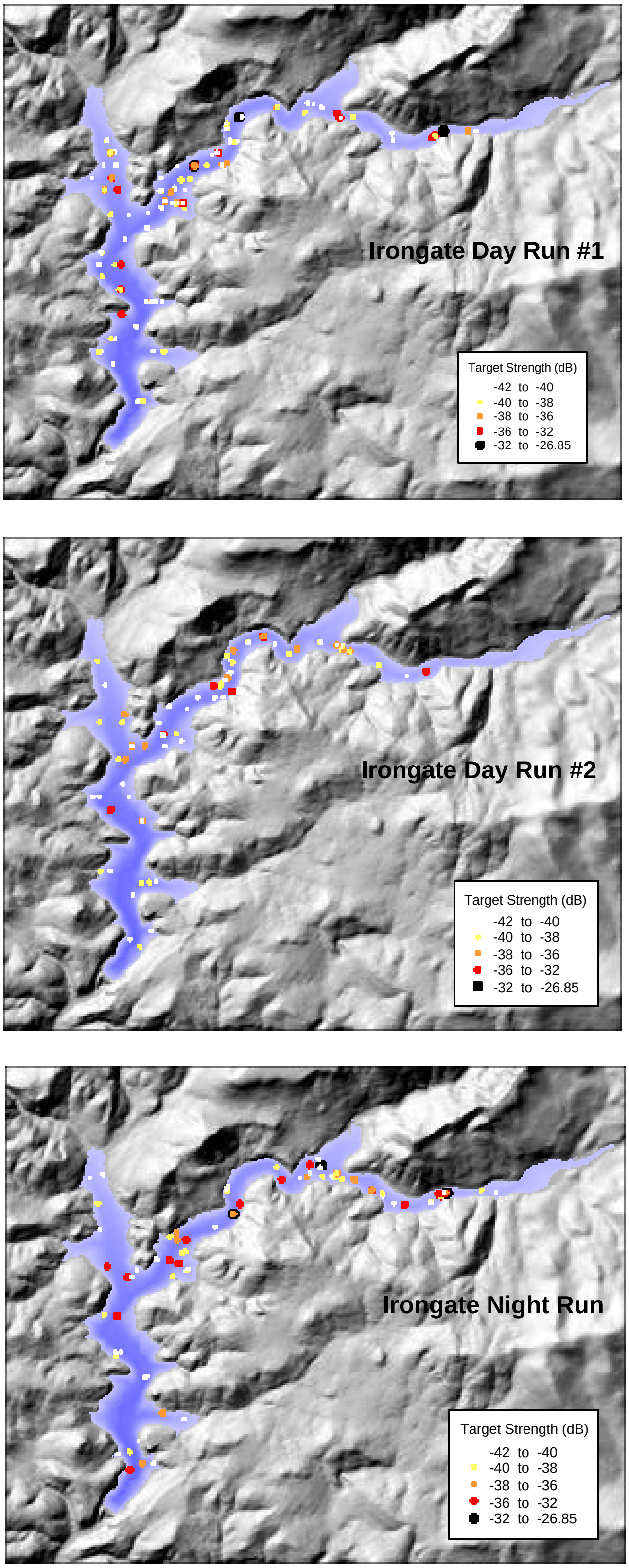


Figure 12. Distribution of fish targets in Iron Gate Reservoir by target strength. April 2004

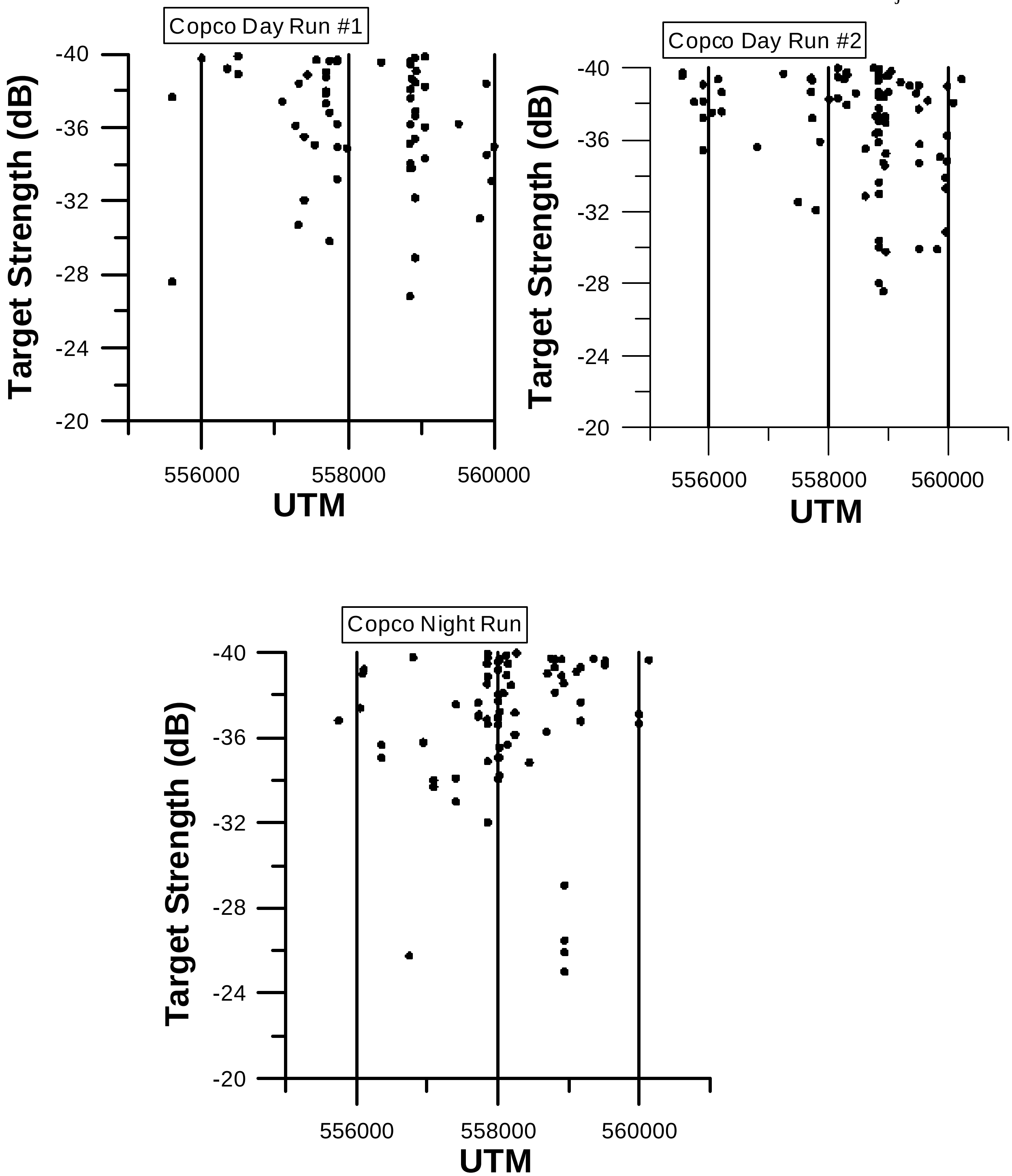


Figure 13. Distribution of fish targets (TS) in Copco Reservoir by longitude (in UTM). August 2003.

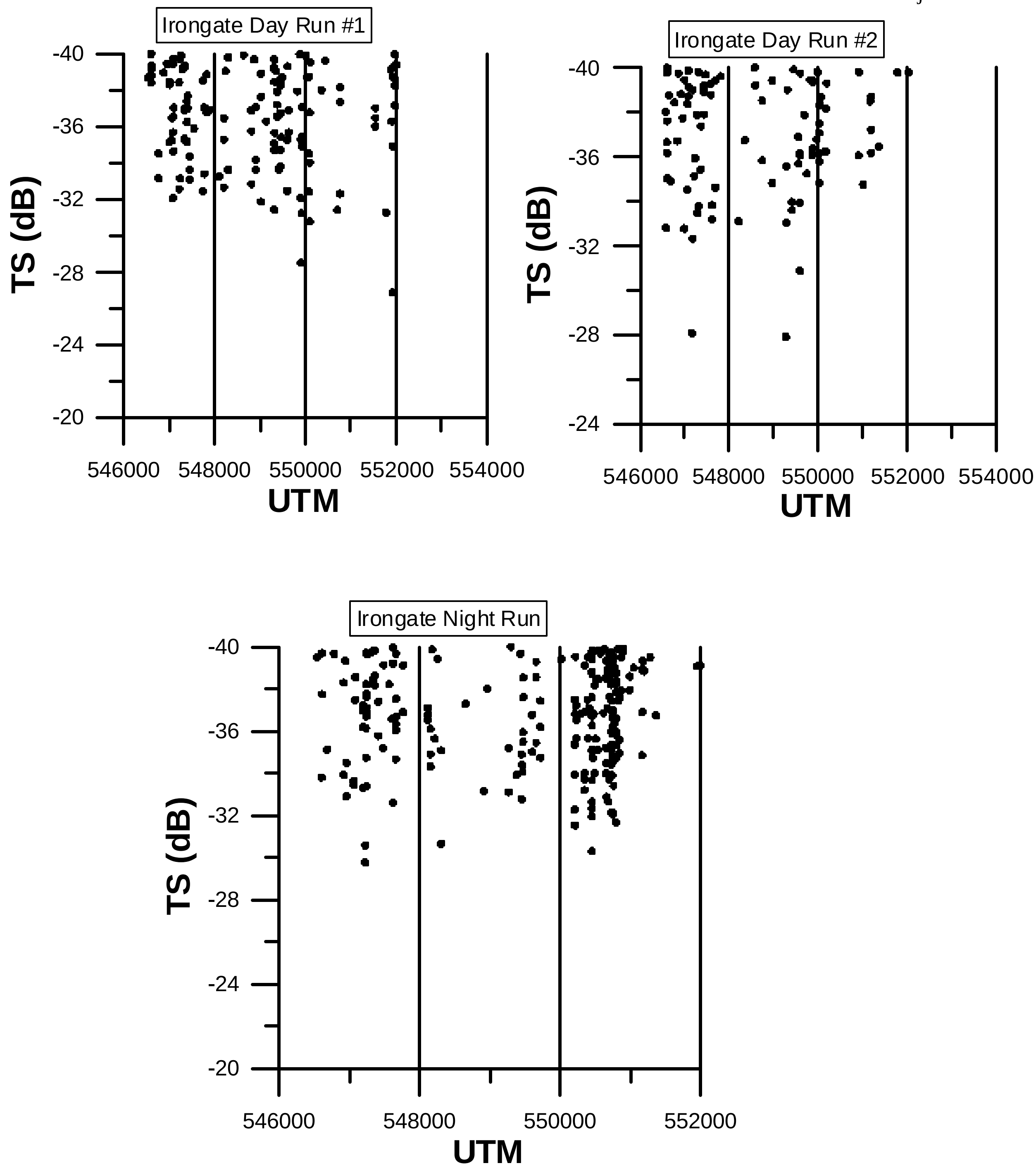


Figure 14. Distribution of fish targets (TS) in Iron Gate Reservoir by longitude (in UTM). August 2003.

4. Vertical Fish Distribution

Most of the fish in Copco Reservoir during August were distributed between 3 and 11 m during the day, but the fish were typically deeper at night, with an average depth of 11 m (Figure 15). A small number of targets were observed at about 25 m during the second day-run on Copco Reservoir. The fish in August tended to show a pronounced aggregation just above 13 m which corresponds to where the dissolved oxygen concentrations drop from near 4 mg/L to near 1 mg/L (Figure 4). In October, we observe most fish in Copco Reservoir are still found at depths less than 15 m, however there were some fish targets observed from 20 m to 25 m (Figure 16). In April, the fish in Copco Reservoir exhibited a more bimodal distribution (Figure 17), although the majority of targets will quite shallow (< 10 m).

In Iron Gate Reservoir, the August depth distributions show a pronounced aggregation of fish targets from 10-13 m (Figure 18). In October, the fish are found much deeper in the lake (~ 25 m), particularly at night (Figure 19). In April the fish targets are generally found from 8 to 20 m, with no strong aggregations at any specific depth within this range (Figure 20).

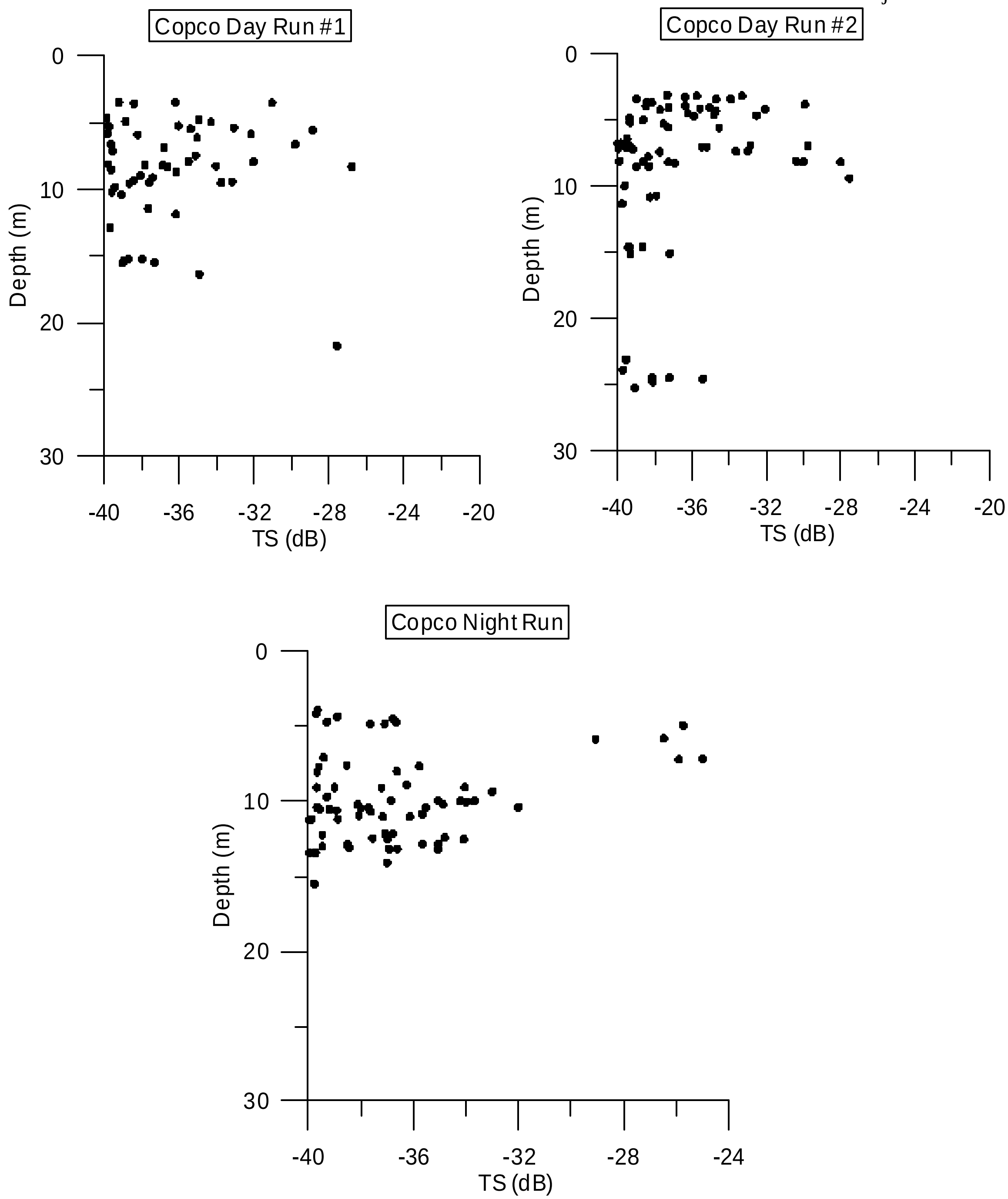


Figure 15. Distribution of fish targets (target strength, TS) by depth in Copco Reservoir, August, 2003.

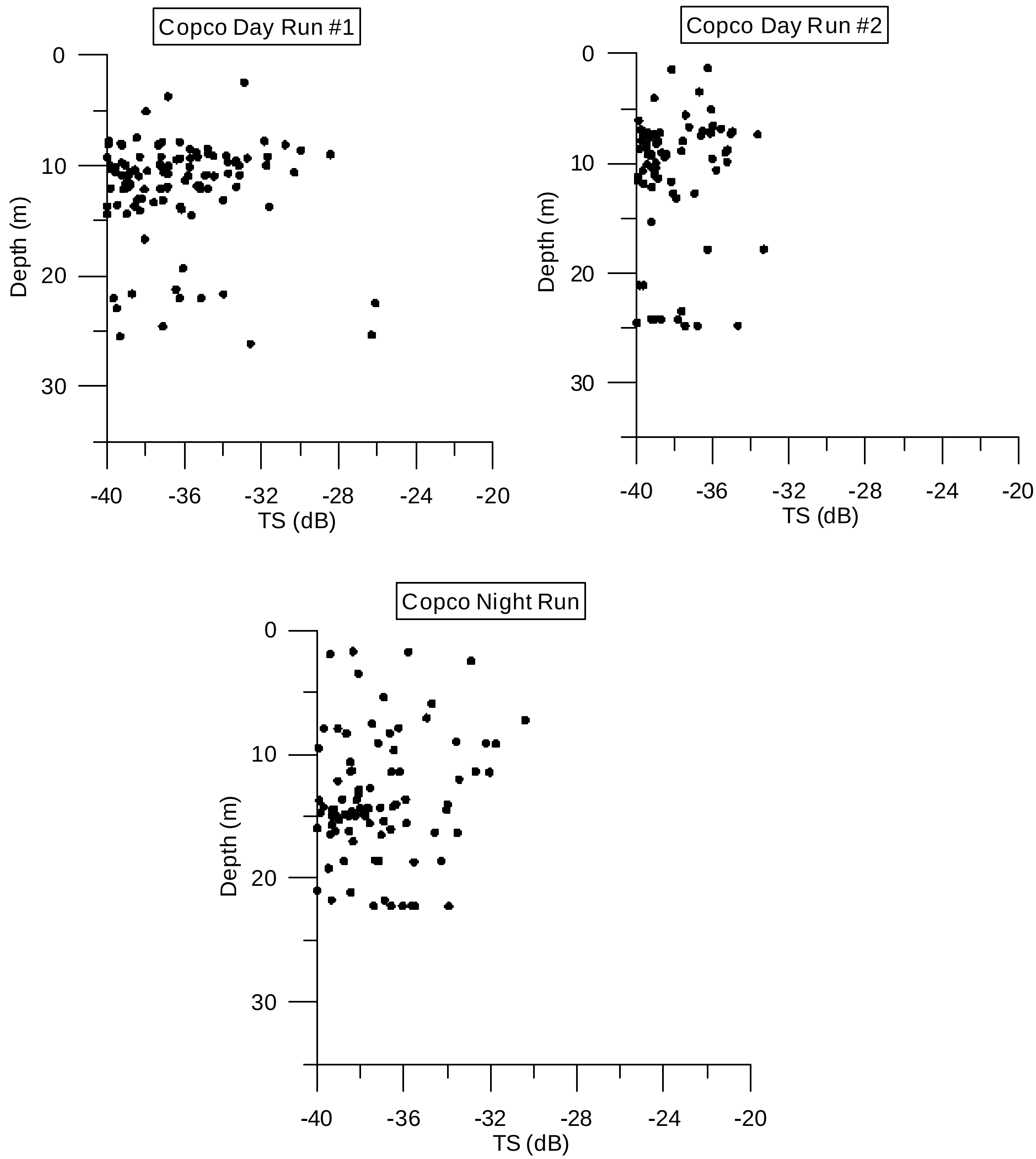


Figure 16. Distribution of fish targets (target strength, TS) by depth in Copco Reservoir, October, 2003.

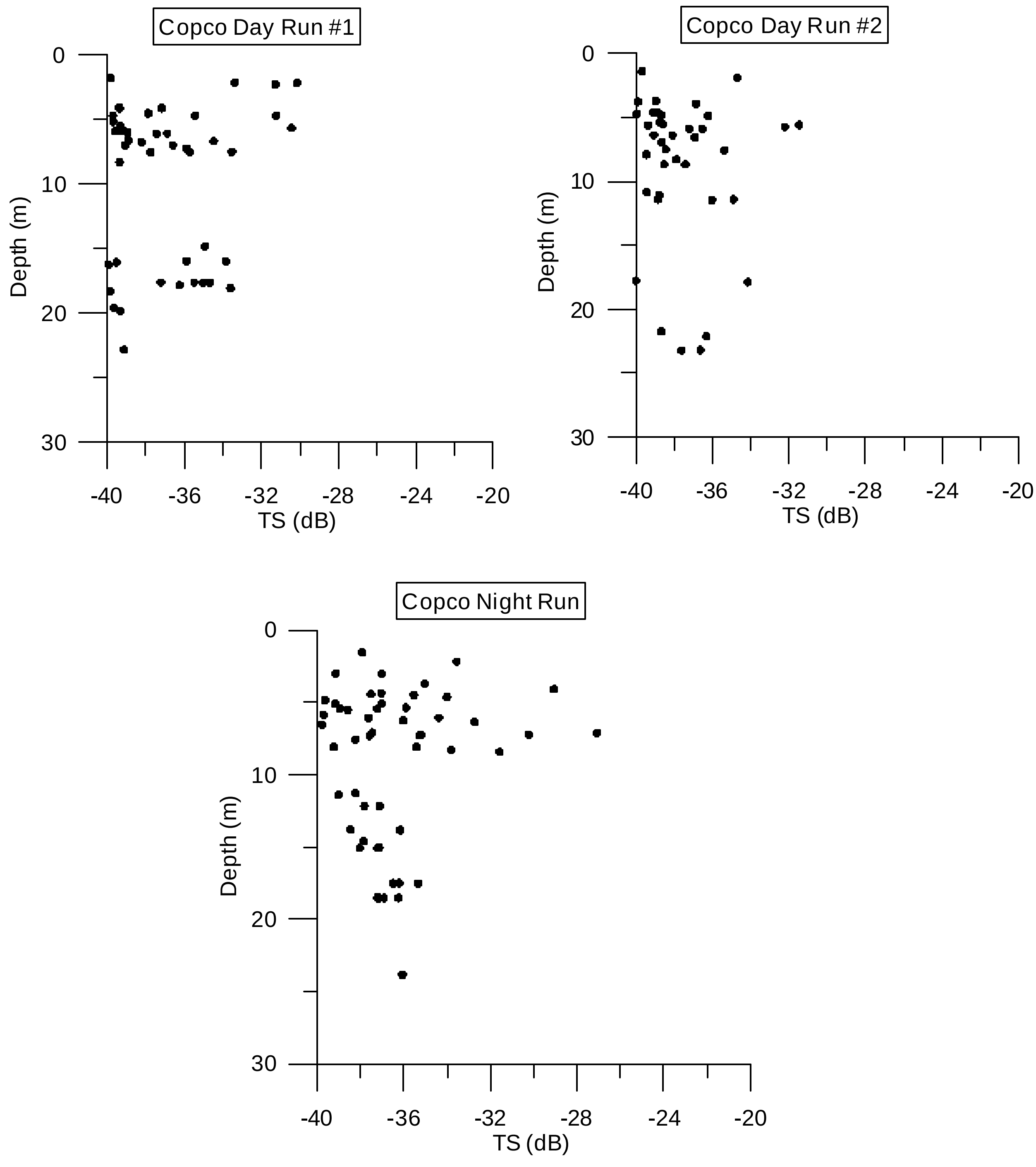


Figure 17. Distribution of fish targets (target strength, TS) by depth in Copco Reservoir, April 2004.

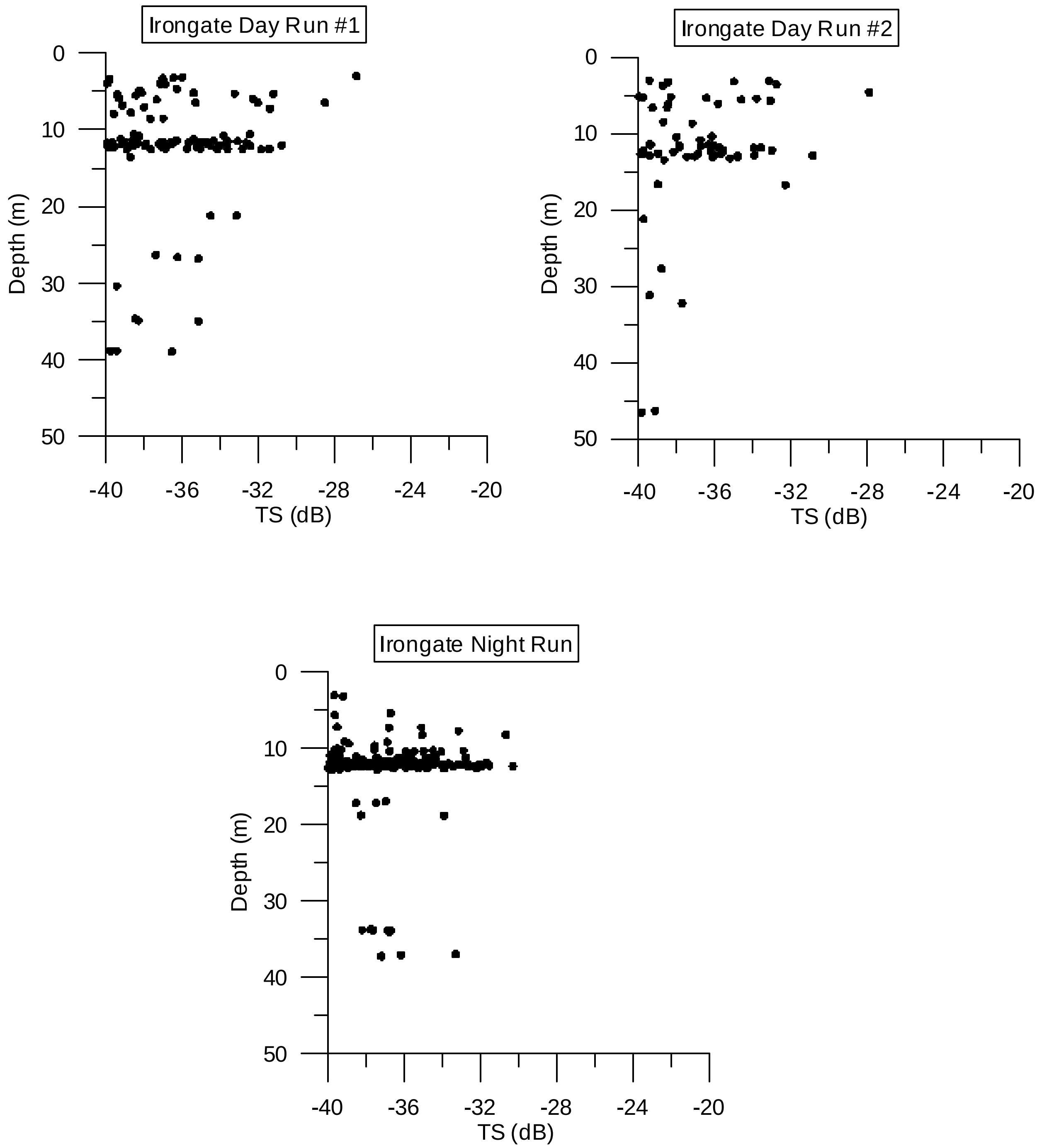


Figure 18. Distribution of fish targets (target strength, TS) by depth in Iron Gate Reservoir, August, 2003.

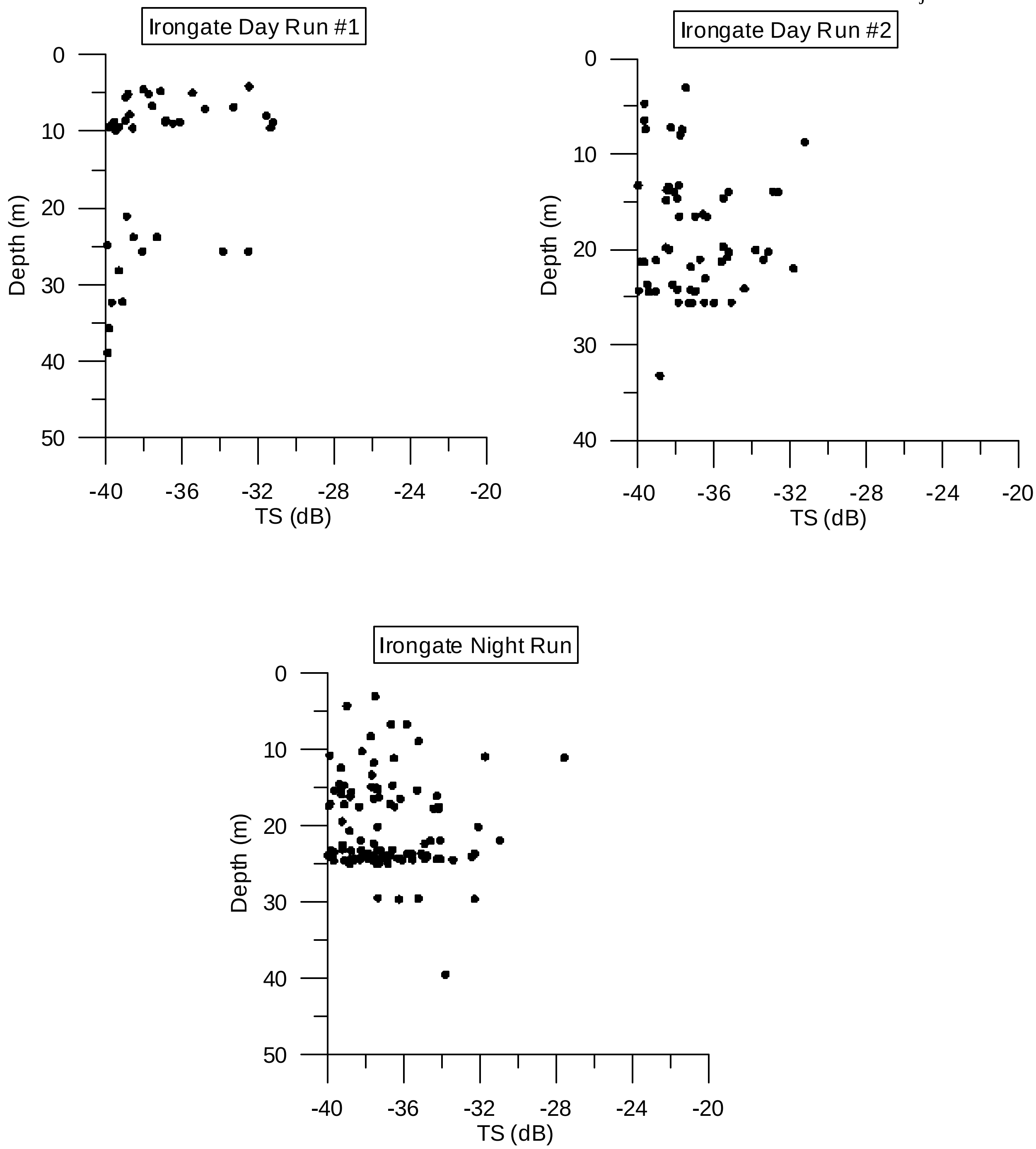


Figure 19. Distribution of fish targets (target strength, TS) by depth in Iron Gate Reservoir, October, 2003.

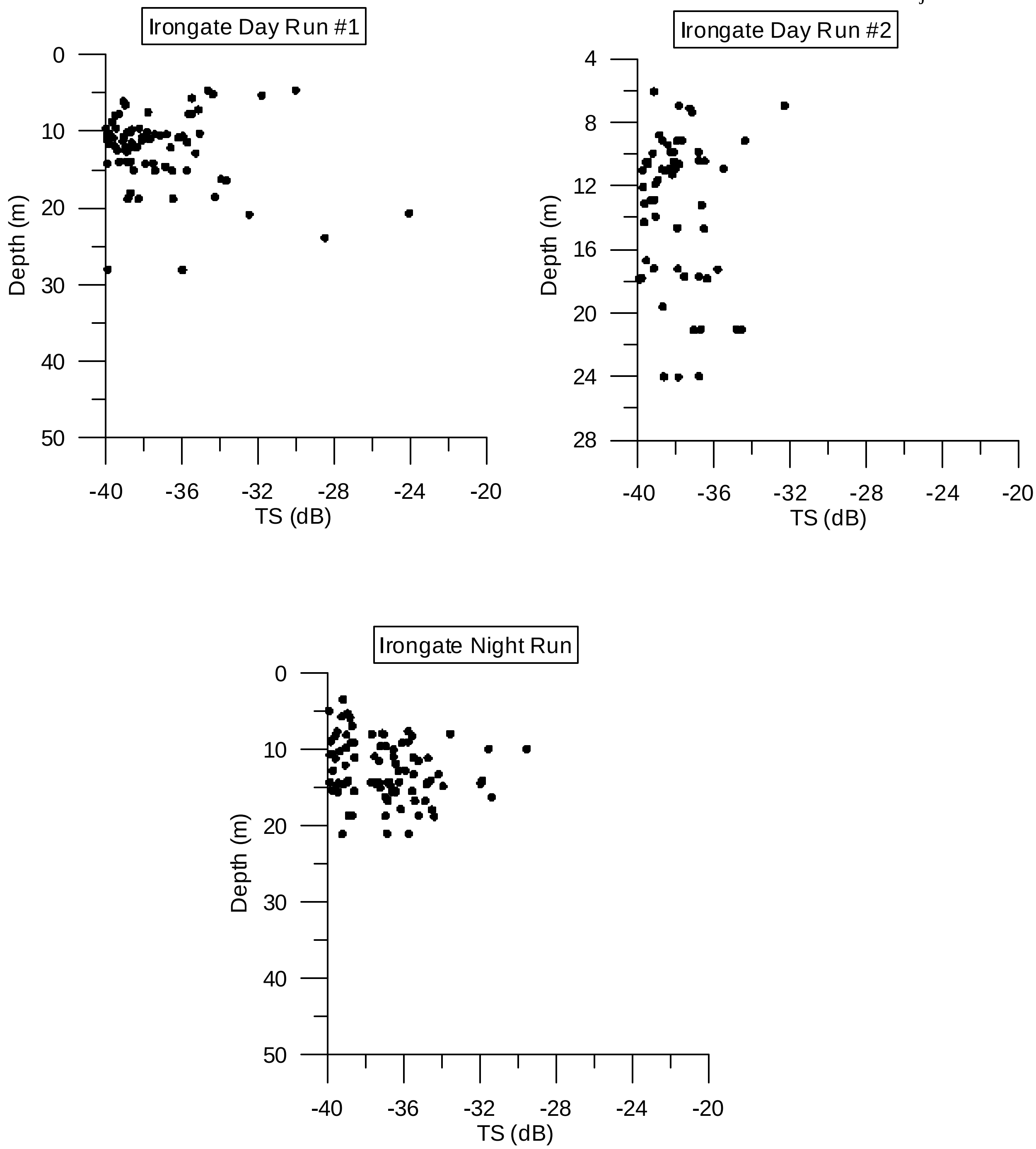


Figure 20. Distribution of fish targets (target strength, TS) by depth in Iron Gate Reservoir, April 2004.

5. Comparison of Fish Based on Netting and Hydroacoustics

The comparisons between fish lengths caught in the nets and fish counts derived from hydroacoustic analyses are presented in Figures 21 - 26. The primary reason for deploying the nets during the fisheries survey was to provide information regarding species composition in the impoundments. The fish netting indicated that most of the fish in the non-littoral area (< 5 m) were yellow perch.

Most of the fish sampled with both methods (hydroacoustic and netting) were in the 100-250 mm size range. The largest yellow perch netted was 280 mm, which would be considered a large perch for the Pacific Northwest (Wydoski and Whitney 2003). In contrast to the netting results, the hydroacoustic data showed a 7.2 percent of fish targets exceeding 400 mm in length in each survey and 1.8 percent of fish targets estimated in the 600- 800 mm size class. It is unknown what species of fish the 400 – 800 mm size class represents, although it is unlikely that they include any of the five taxa captured during the netting.

In most cases, the hydroacoustic results showed the presence of fish smaller than were sampled using netting. Fish less than 100 mm and greater than 250 mm were not accurately sampled with gill nets. Nevertheless, several small fish were captured in the nets in Copco Reservoir that were less than the minimum size of fish estimated based on the hydroacoustics. This is an artifact of censoring the hydroacoustic data to targets greater than -40 dB. The rationale for censoring the hydroacoustic signals is presented in the following section.

In general, the overall fish abundance was similar between hydroacoustic and netting data. The hydroacoustic results indicated that overall abundance of fish in Copco Reservoir (in the open-water area) was lower in October (especially at night) and April, which may partly explain the low counts in the net sets. In August (night), the netting yielded more fish in the 180 – 220 mm range than were counted using hydroacoustics. This anomaly could be explained by (1) very patchy distribution of the yellow perch, or (2) uncertainty in the converting the target strength data into estimates of fish length. Iron Gate Reservoir was similar to Copco Reservoir in that overall fish abundance was greatest in August.

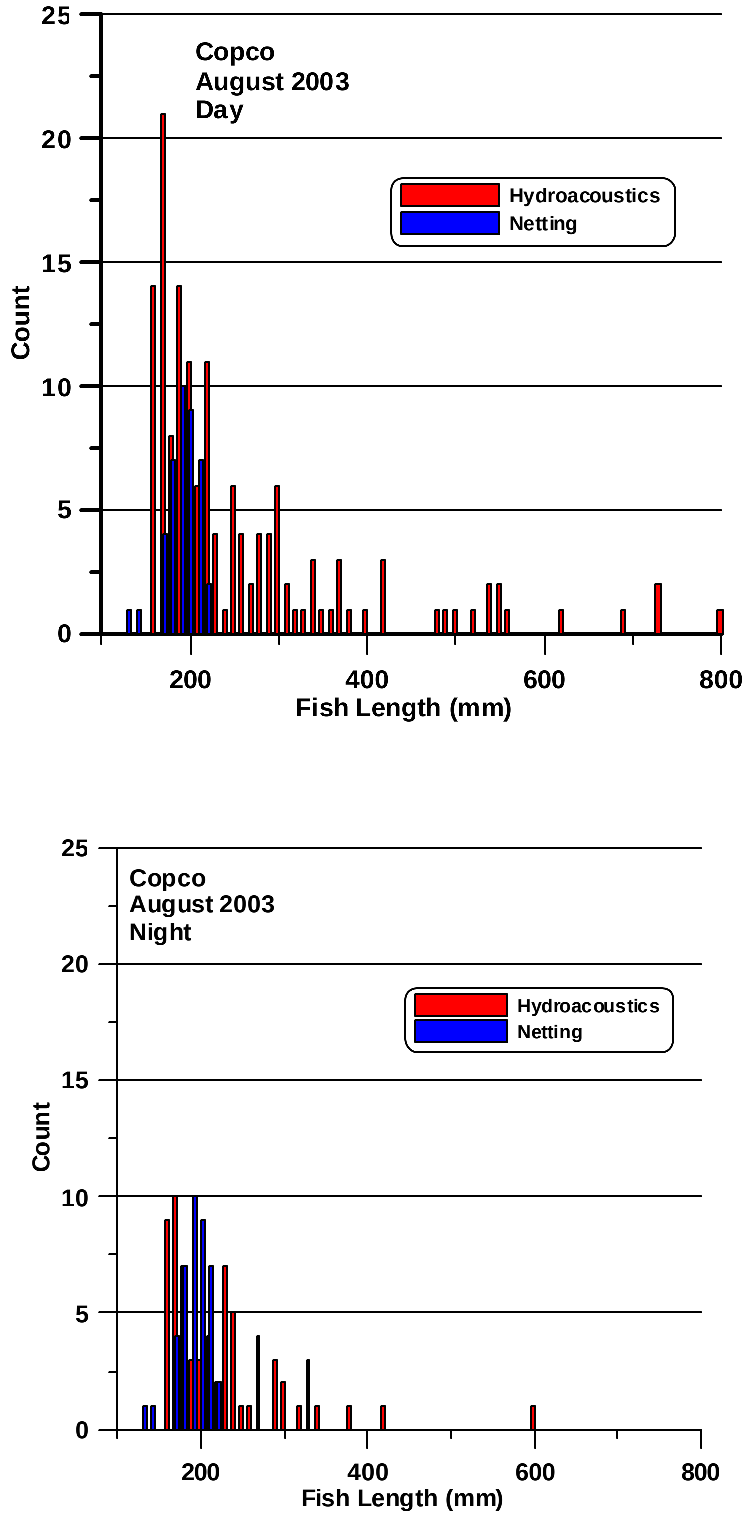


Figure 21. Comparison of fish caught in gill nets and identified with hydroacoustics for Copco Reservoir, August 2003. The hydroacoustics results from both day runs have been added together.

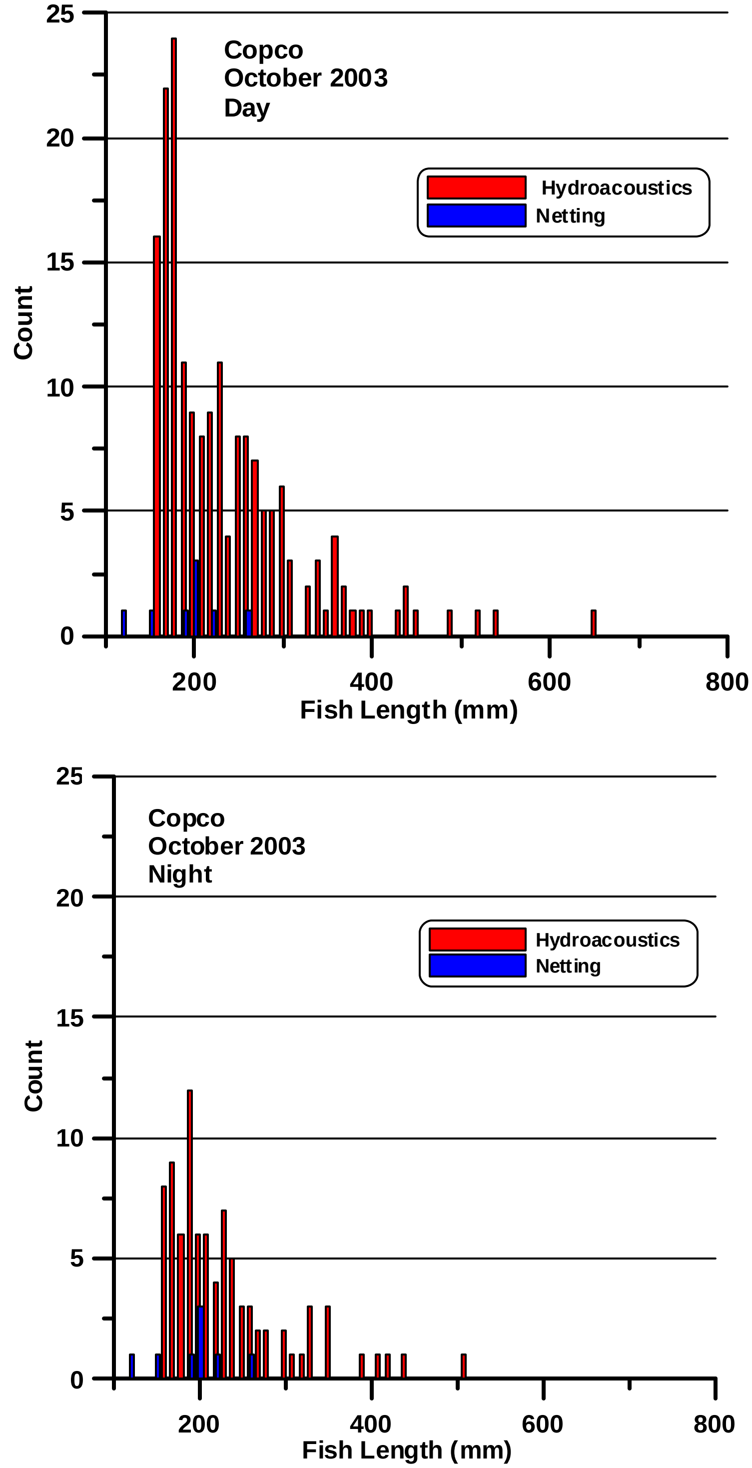
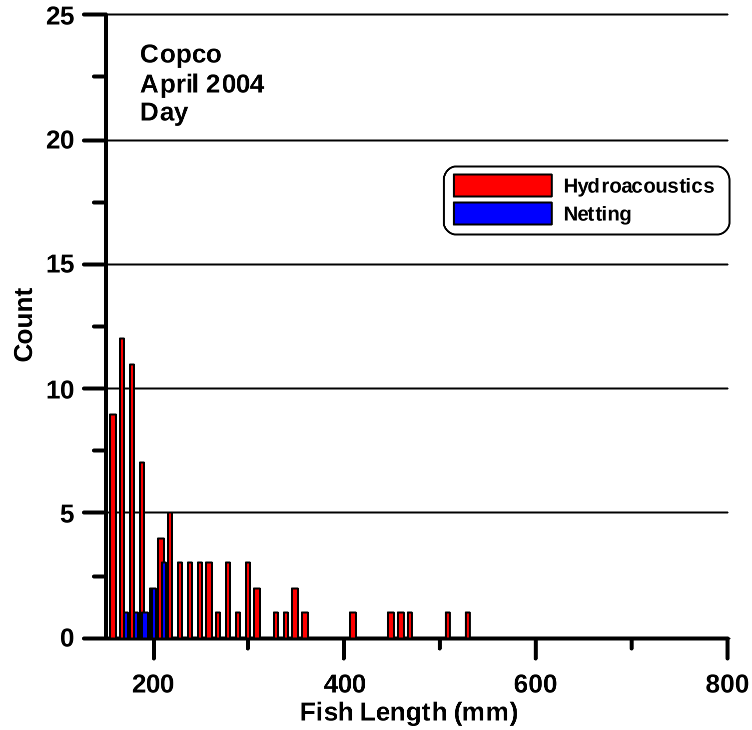


Figure 22. Comparison of fish caught in gill nets and identified with hydroacoustics for Copco Reservoir, October 2003. The hydroacoustics results from both day runs have been added together.



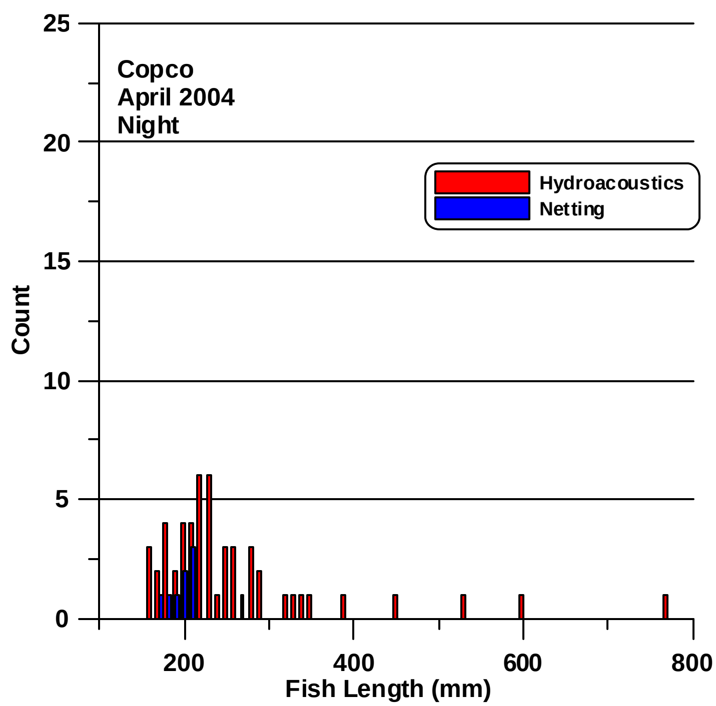


Figure 23. Comparison of fish caught in gill nets and identified with hydroacoustics for Copco Reservoir, April 2004. The hydroacoustics results from both day runs have been added together.

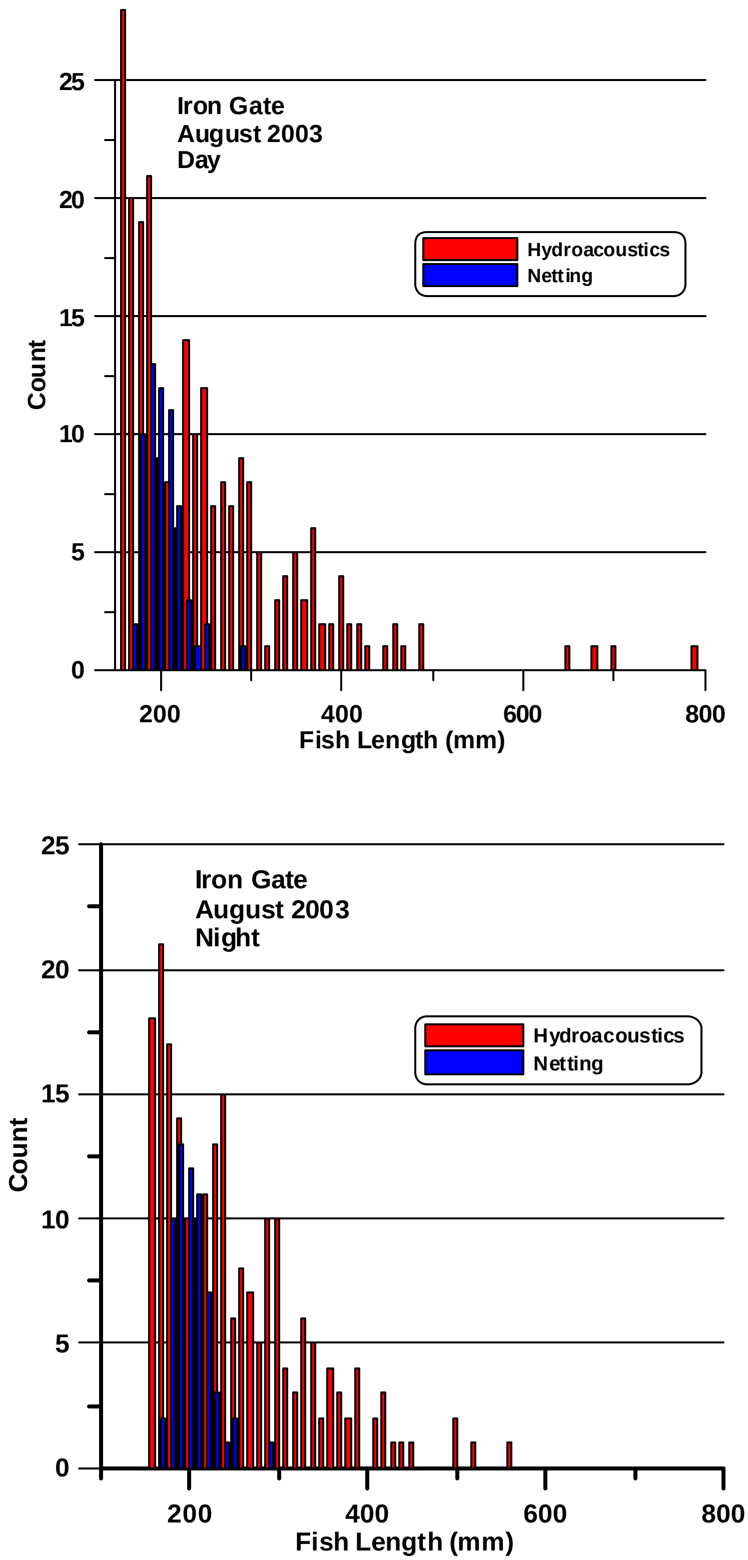


Figure 24. Comparison of fish caught in gill nets and identified with hydroacoustics for Iron Gate Reservoir, August 2003. The hydroacoustics results from both day runs have been added together.

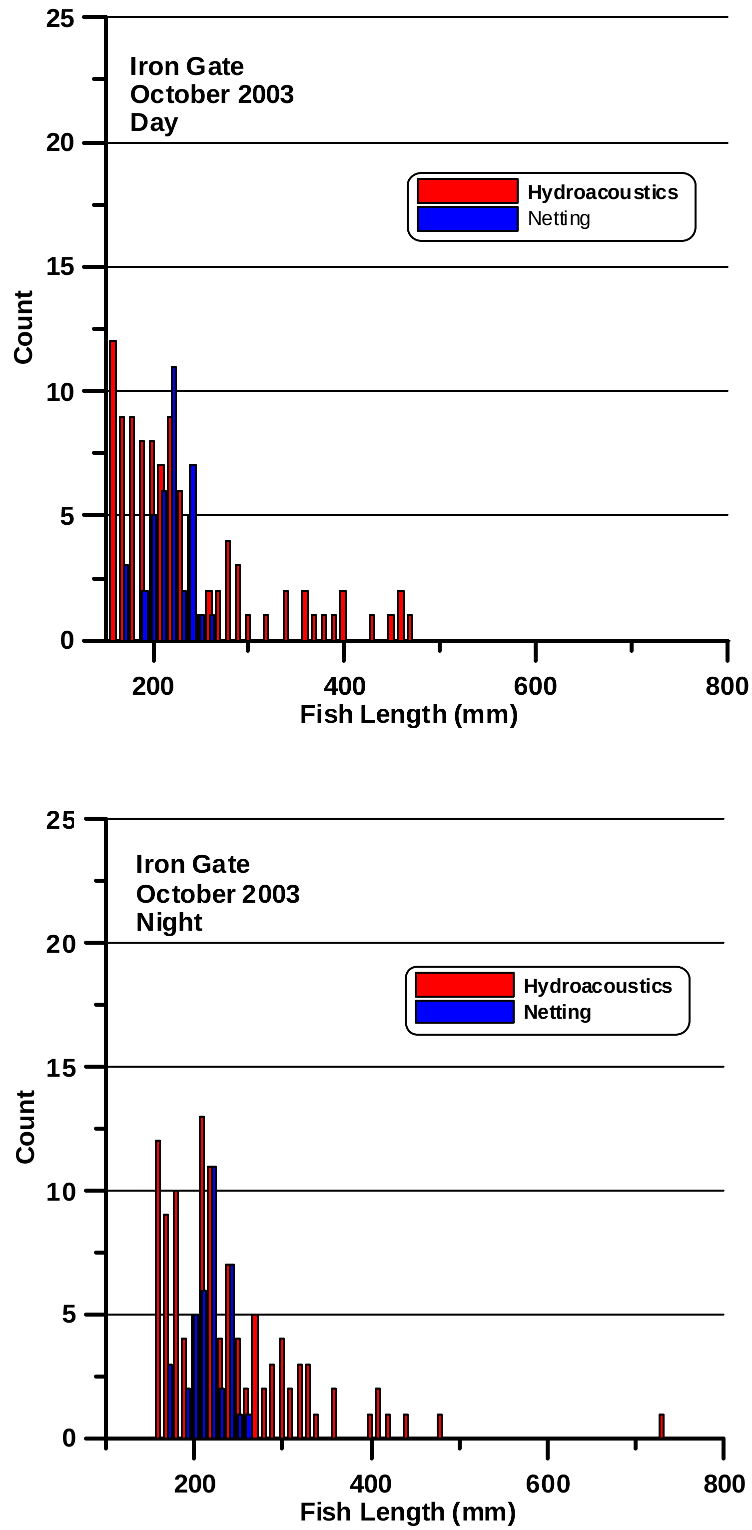
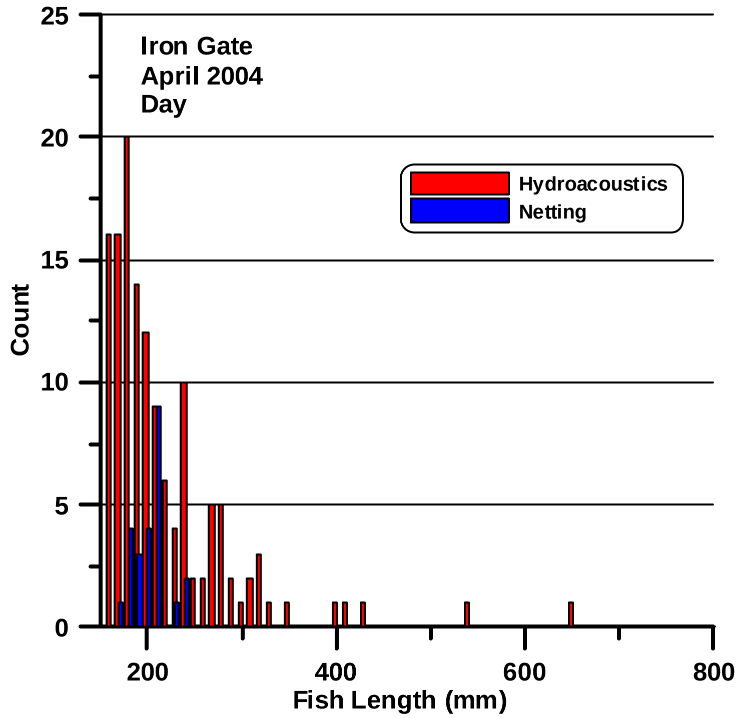


Figure 25. Comparison of fish caught in gill nets and identified with hydroacoustics for Iron Gate Reservoir, August 2003. The hydroacoustics results from both day runs have been added together.



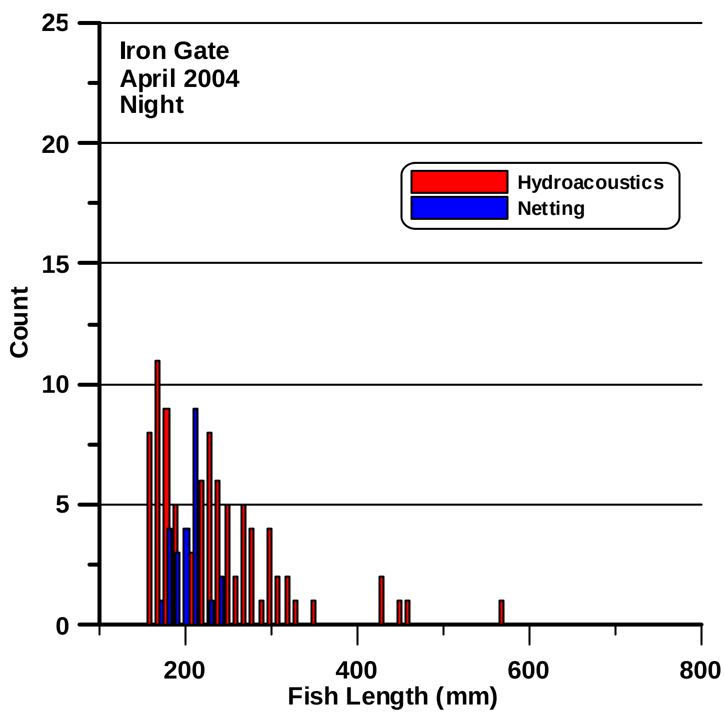


Figure 26. Comparison of fish caught in gill nets and identified with hydroacoustics for Iron Gate Reservoir, August 2003. The hydroacoustics results from both day runs have been added together.

6. Gas Bubbles in Copco and Iron Gate Reservoirs

The hydroacoustic data indicated the presence of gas evolution from the bottom waters of the impoundments, particularly in the thalwegs of the upper reaches of the lakes. The bubbles in the two impoundments occurred as both repeated observations in deeper portions of the lakes and as single event observed in Copco Reservoir. Examples of the bubbles that were identified in Iron Gate Reservoir with a re-occurring pattern are shown in Figures 27- 29. These echograms show the presence of the bubbles in virtually the same position on a repeating transect during the August survey. These targets were present at about 30 m, and because of this repetition in both time and space, it is extremely unlikely that these targets were biological in nature. Furthermore, this zone of Iron Gate Reservoir was anoxic in August (Figure 5), which would eliminate most fish from consideration. The targets did not continue up through the water column, indicating that the bubbles were likely re-adsorbed higher in the water column. This could have been the case if gases, such as CO_2 or CH_4 generated under anoxic conditions, were transformed in the epilimnion. Confirmation that the small targets were gas bubbles was determined by maintaining a stationary position over some of the most target-rich areas and observing the targets move in a constant vertical manner (Figure 30). The maximum gas bubble size was determined to be about –40 dB. Thus, targets equal to or less than –40 dB were censored from the data set.

A special event was observed in Copco Reservoir during the night run on October 31, 2003. During a run that began under nominal conditions, the echograms became completely filled with targets throughout the water column (Figure 31). Continued operation showed that this pattern extended over much of the deeper survey tracks and made continued tracking for fish targets impossible to conduct. The lake surface appearance during this event displayed extensive bubble formation that was far in excess of what might have been generated by the wind conditions at the time. Although we have no previous experience with this type of event, the rapid release of bubbles could have been triggered by high CO_2 concentrations in the lake bottom (associated with high rates of decomposition in these productive lakes) combined with favorable weather conditions preceding the release of gas. Examination of weather data from an airport in the area illustrated the rapid decrease in temperature during the October survey, a reduction in barometric pressure, and the onset of more rapid winds (Figure 32). Although we do not have water quality data from the entire water column in Copco Reservoir for October, the data from Iron Gate Reservoir shows that this reservoir was isothermal to 25 m, indicating that Copco Reservoir was probably approaching isothermal conditions as well.

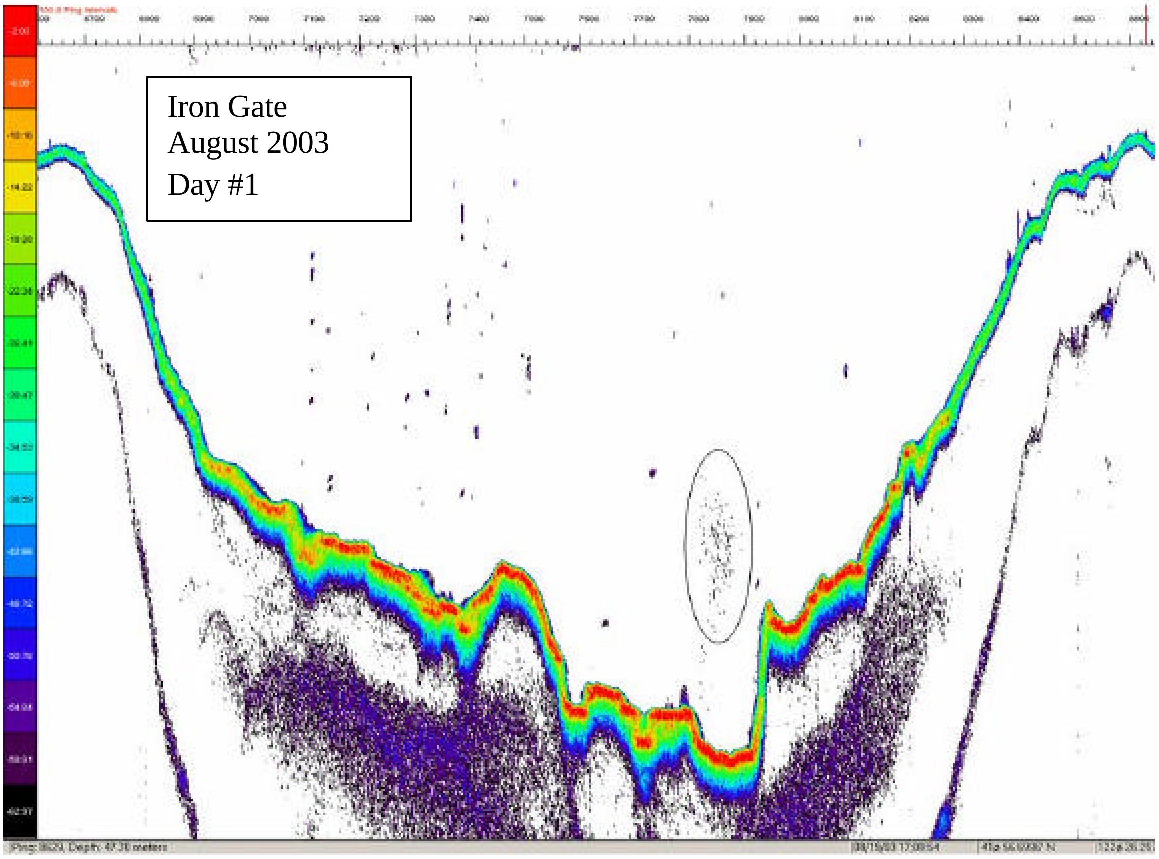


Figure 27. Repeating transect for Iron Gate, August 2003, day #1 run. Small targets (< -40 dB) are circumscribed.

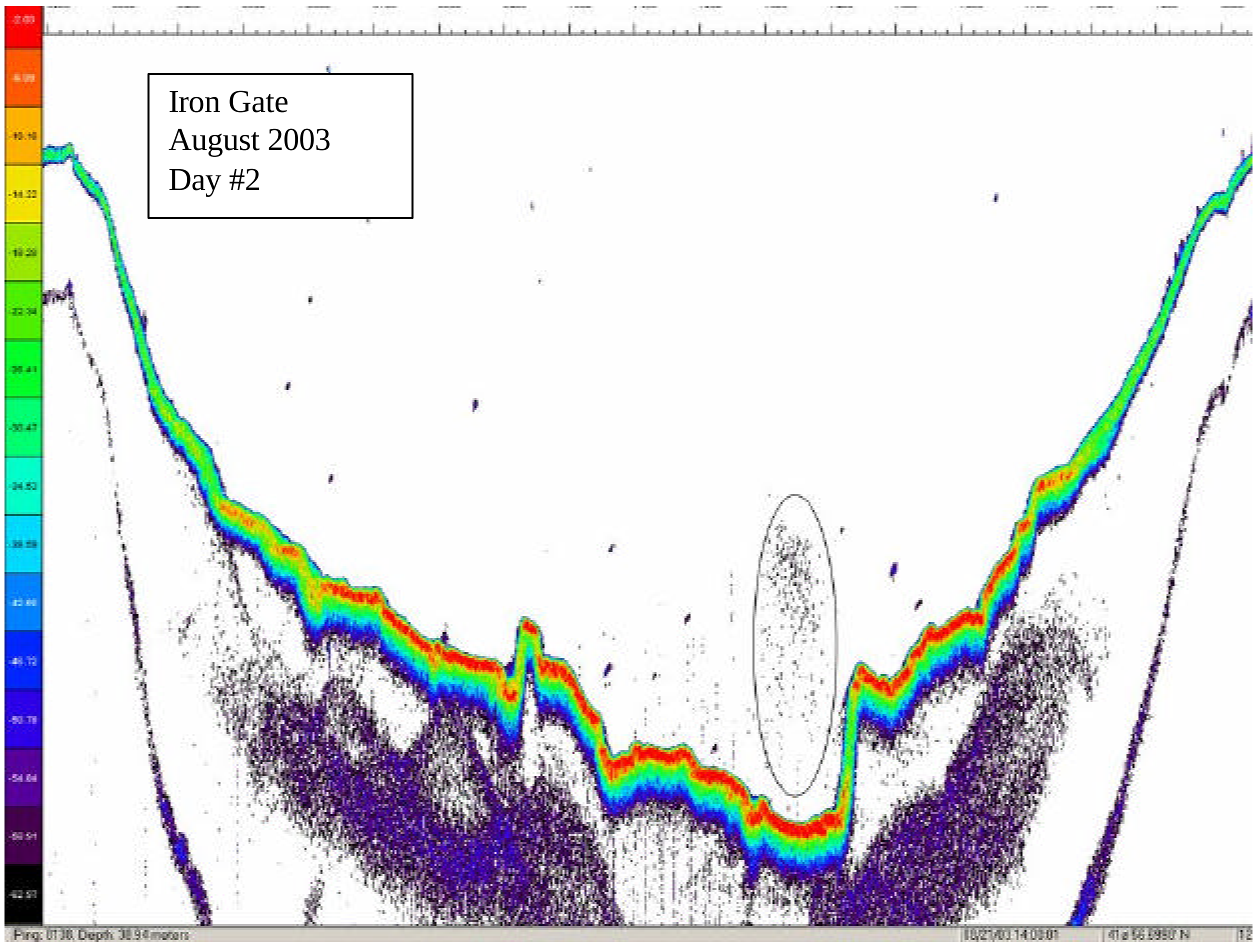


Figure 28. Repeating transect for Iron Gate, August 2003, day #2 run. Small targets (< -40 dB) are circumscribed.

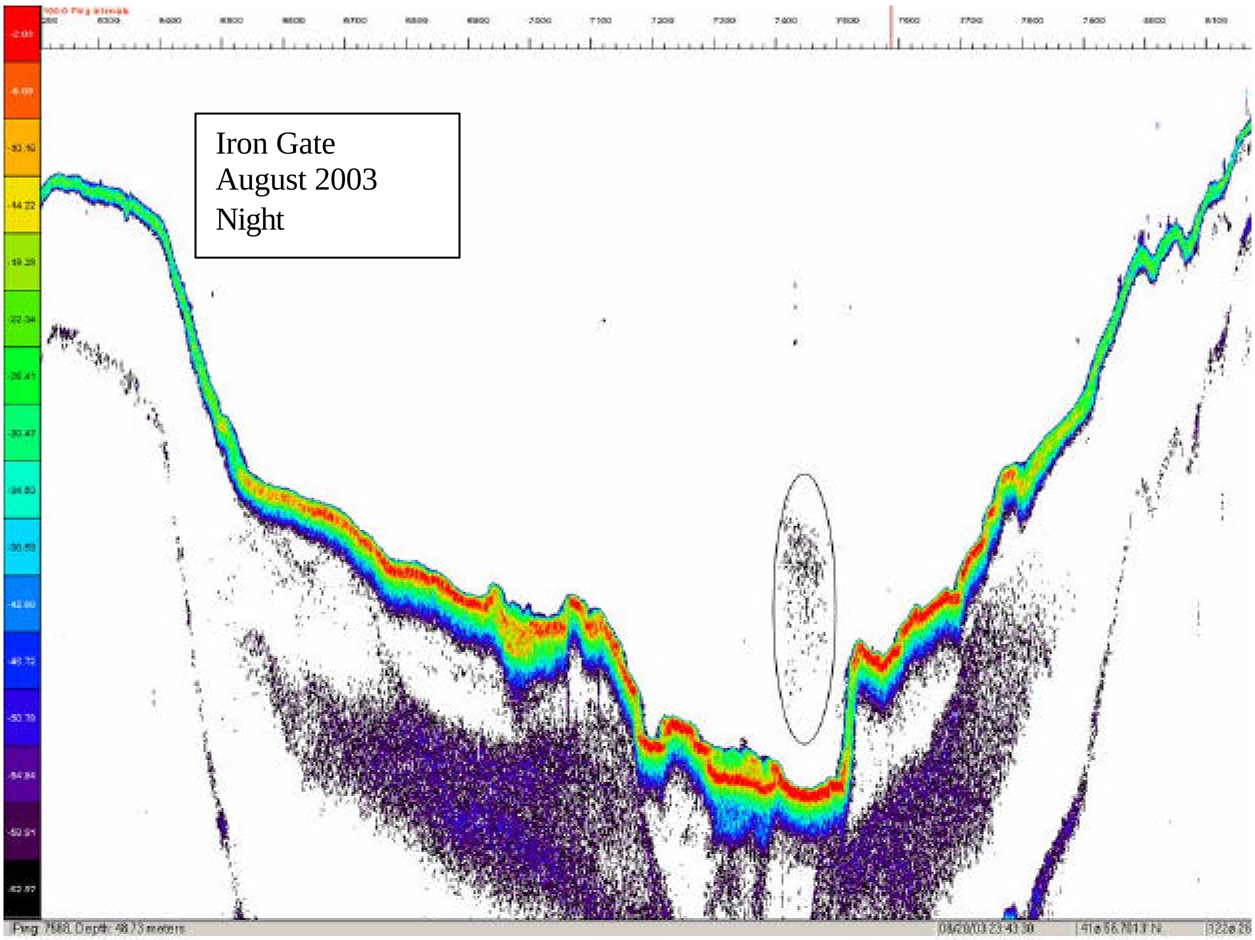


Figure 29. Repeating transect for Iron Gate, August 2003, night run. Small targets (< -40 dB) are circumscribed.

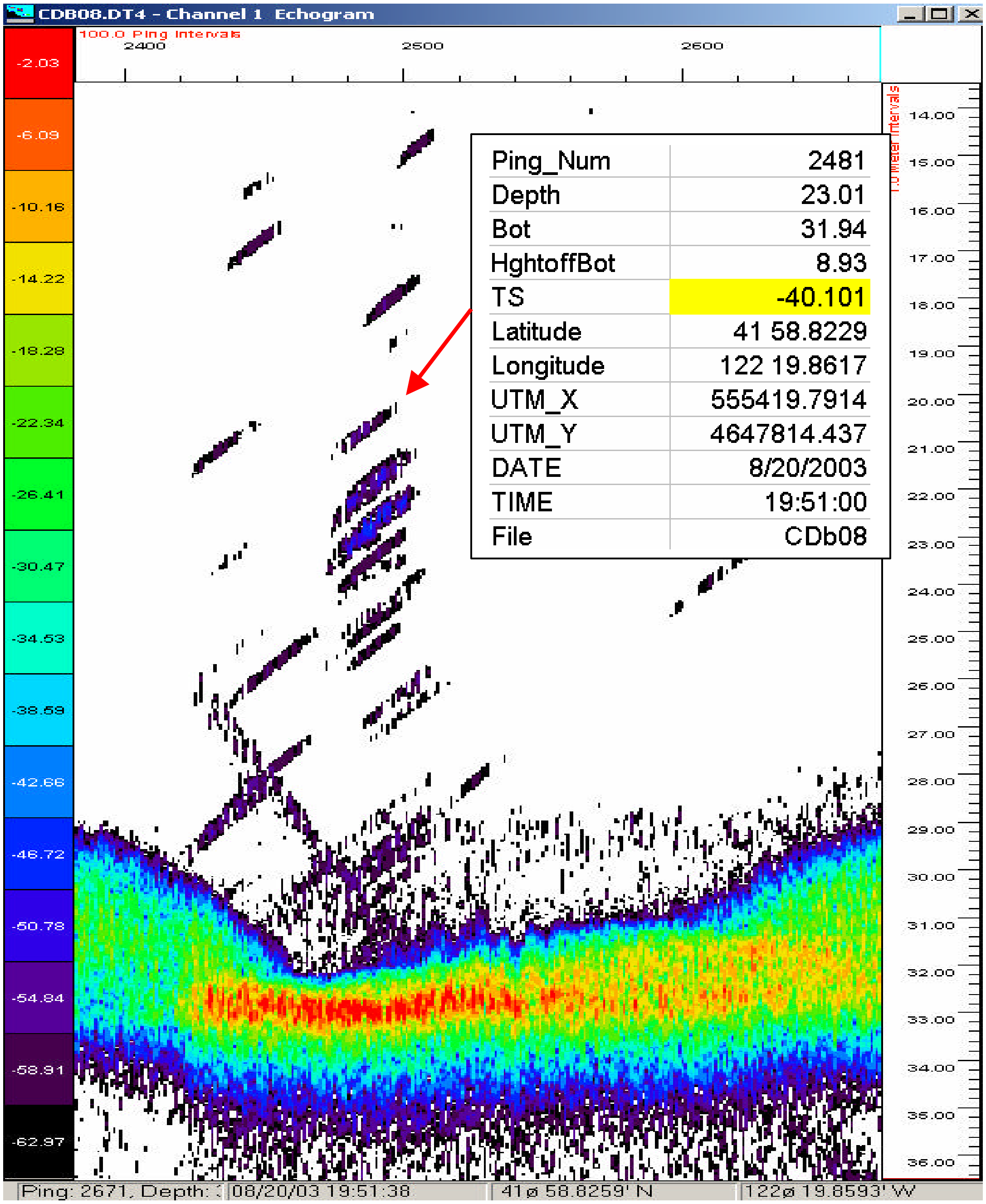


Figure 30. Enlargement of echogram from a stationary position over suspected bubble targets indicating the size and characteristics of the images.

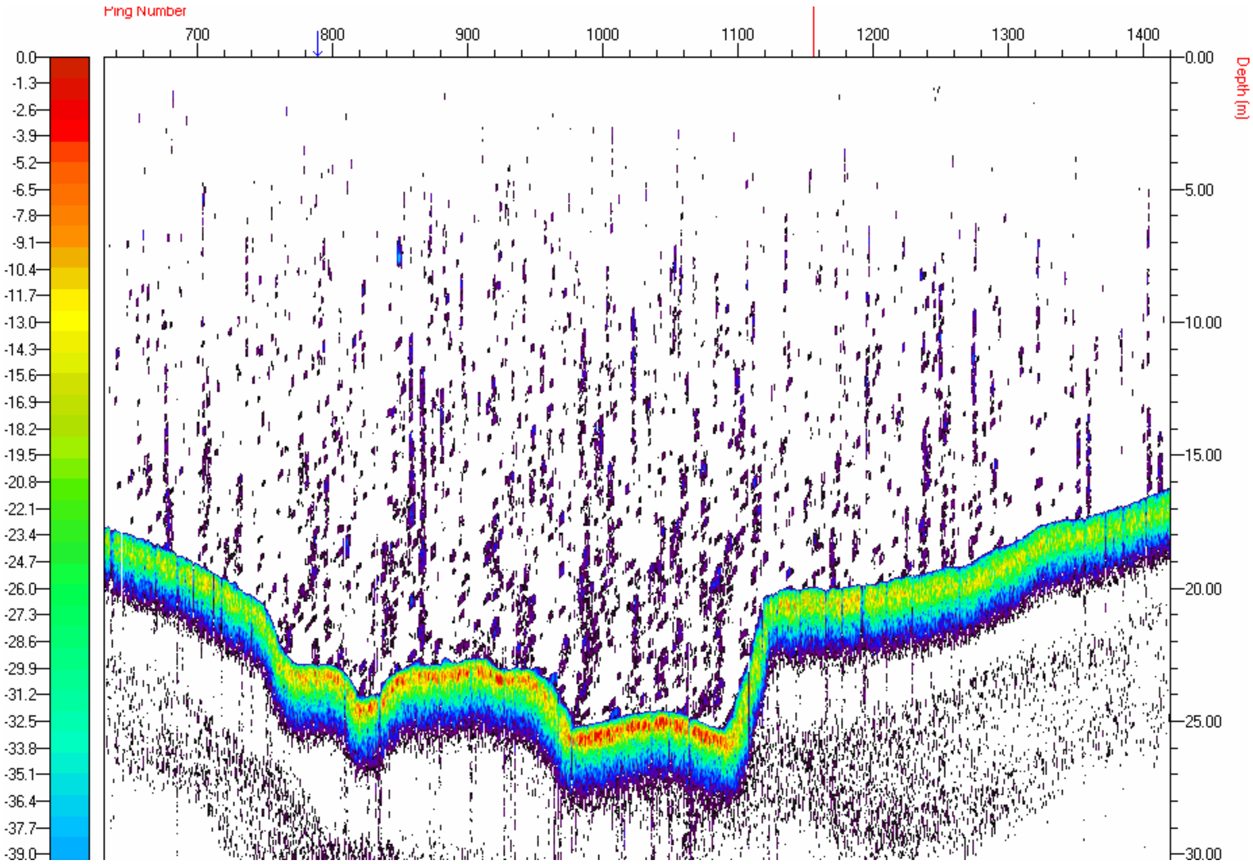


Figure 31. Echogram of Copco Reservoir, October 31, 2003, night run, showing the release of bubbles from the lake bottom.

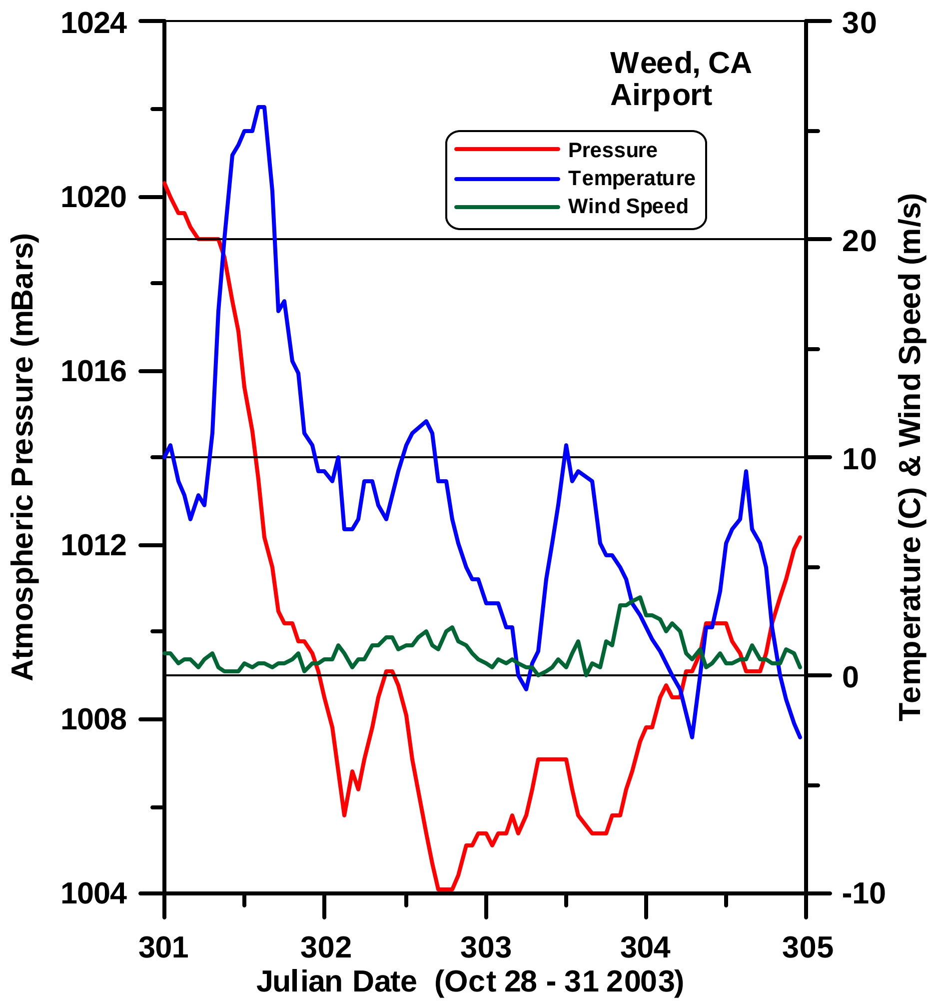


Figure 32. Climate data recorded at Weed Airport (approx 40 km south of Copco Reservoir) illustrating the changes in weather conditions observed during the course of the hydroacoustic survey in October 2003.

DISCUSSION AND CONCLUSIONS

The hydroacoustic and netting data from 2003-2004 show that fish distribution in the pelagic areas of Copco and Iron Gate Reservoirs is low in both systems. The paucity of fish in the pelagic areas is consistent with the dominant fish species present, which were taxa that favored shallow, weedy habitats. The dominant species represented in both impoundments based on the net data is yellow perch. Other taxa included small number of black crappie, pumpkinseed, golden shiner, and chub. However, a small number of larger fish targets in both lakes indicate the likely presence of species capable of greater growth than that of yellow perch or the other taxa represented in the net samples.

Most fish targets were present at depths less than 15 m, although some fish targets were present up to 25 m depths during the October and April surveys. The vertical distribution of fish in Copco and Iron Gate Reservoirs in August was strongly influenced by the dissolved oxygen concentrations (Figures 11 and 12). This is particularly evident in Iron Gate Reservoir where a sharp decline in dissolved oxygen occurred at 12 m. The lake temperature declines as well, but the dissolved oxygen depletion occurs more abruptly and slightly precedes the most rapid decline in water temperature. The hydroacoustic signals show that some fish are present in the hypolimnion, but these may be brief excursions into this zone of low dissolved oxygen. Net sets in Copco and Iron Gate Reservoirs confirmed the presence of fish at these depths (Figures 13 and 14) despite the limited concentration of dissolved oxygen at depth.

Fish populations were more abundant in the shallower, eastern portions of both impoundments. The position of the fish populations appeared to remain relatively stable in Copco Reservoir. However, a shift in fish abundance was noted in Iron Gate Reservoir between the day and night surveys. This could have been caused by a movement of fish to the eastern portion of the impoundment at night or it may have just reflected a greater movement of fish from the littoral zone into the pelagic zone in this region of the lake. The movement of these littoral species would be favored where the distances between preferred habitats are relatively short.

Bubbles were identifiable in both reservoirs during most surveys, however, they were most pronounced in the deep areas of Iron Gate Reservoir. There was some overlap in target strength between the smallest of fish captured in the nets and the larger bubbles. However, most of the bubbles were less than -40 dB and could reasonably be censored from the dataset without affecting the interpretations from the hydroacoustic surveys. The one exception occurred in Copco Reservoir during the October survey where the massive release of gas from the lake bottom obscured all fish targets, forcing a delay in the survey. This anomaly was short-lived and appeared to be related to the arrival of a cold front at the moment the lake was approaching isothermic conditions.

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