

**Ecological Effects of Reservoir Operations
on Blue Mesa Reservoir**

ANNUAL PROGRESS REPORT

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MEMORANDUM

May 5, 1995

To: Folks interested in Blue Mesa Reservoir
From: Brett Johnson, Assistant Professor
Re: Annual progress report

Attached is the annual progress report of research that I and my students conducted at Blue Mesa Reservoir in 1994. As you probably know, this project was funded by the Bureau of Reclamation to study the potential impacts of water reoperation on reservoir productivity and the fishery the reservoir supports. Colorado Division of Wildlife, National Park Service, and National Biological Service have also been instrumental cooperators on this intensive ecosystem study.

Our approach has been to quantify and understand dynamics of each trophic level (phytoplankton, zooplankton, and fish) in response to climatic and anthropogenic factors. We will then use a variety of computer modeling approaches to translate physical changes (e.g., thermal stratification) predicted to result from reoperation into ecological effects at each trophic level. Our hope is that this "ecosystem perspective" will not only provide guidance for the management of Blue Mesa Reservoir, but will also provide broadly applicable insights for reservoir management in mountain reservoirs throughout Colorado and the west.

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SUMMARY

- Reservoir discharge was below the longterm average and reservoir surface elevation was above average during 1994.
- Mean reservoir surface temperature in summer 1994 was below the longterm average.
- Stratification in 1994 was already well underway by the third week in May.
- Temperature profiles along a transect moving away from the dam did not show any detectable effects of reservoir discharge on small-scale patterns in temperature profiles at Sapinero basin.
- Metalimnetic oxygen minima occurred in Cebolla throughout the sampling season, and during July-September in Sapinero.
- Water clarity was generally better in 1994 than all previous years sampled.
- Epilimnetic chlorophyll a concentration peaked at 5-10 $\mu\text{g/l}$, depending on basin, in early June and declined throughout the summer.
- Chlorophyll-a concentration ^{not} differed between 0-5 m and 0-10 m integrated water column samples.
- Based on intensive diel sampling in July, zooplankton in Blue Mesa appear to undergo a diel vertical migration, but that migration is confined to the epilimnion.
- *Daphnia* density was highest in the top 10 m of the water column on all dates in all basins.
- Overall, 88% of total *Daphnia* density in the top 30 m occurred in the top 10 m.

- *Daphnia* were nearly twice as abundant in the 0-5 m stratum as in the 5-10 m stratum.
- *Daphnia pulex* was more abundant than *D. galeata mendotae* through most of the season.
- Zooplankton species composition from Sapinero and in the dam outflow suggest that the vast majority of the water withdrawn through the dam originates at reservoir depths greater than 30 m.
- Projections of total *Daphnia* biomass entrained relative to reservoir standing stock suggest that *Daphnia* entrainment in dam discharge during months studied is probably not a significant mortality factor.
- Kokanee feed almost exclusively on large *Daphnia pulex* in Blue Mesa. Their high diet selectivity suggests an abundant food supply for planktivores.
- Based on experimental vertical gill netting, the pelagic fish community during June-October is dominated by kokanee salmon.
- In June over 70% of kokanee were distributed in the upper 15 m of the water column. In August 79% of kokanee were caught in water 16-30 m deep, and in October 73% were found in the top 20 m.
- Rainbow trout occupied shallower water than kokanee in all months. Rainbow were found in the top 5 m in June and October, and in 6-15 m during August.

INTRODUCTION

With the increasing demand for water in the West to serve an expanding range of purposes, it is reasonable to expect reservoir operations to be altered. Retention time, volume, morphometrics, and other reservoir characteristics will likely change. These physical changes could have important ecological consequences that could alter reservoir productivity, biotic communities, and ultimately the quality of the sport fisheries that can be sustained (Figure 1, 2).

Reservoir operations can have direct and indirect effects on reservoir productivity through a variety of mechanisms (Figure 3). Direct effects of water level management on reservoir productivity include reduced nutrient loading and internal recycling, retention times, and altered angler access to the fishery (boat access and distribution/catchability of fish). Indirect effects can alter food web interactions in two basic ways. 1) Water level influences interactions by changing epilimnetic, metalimnetic, and hypolimnetic volumes, and hence altering the density of organisms in each limnetic stratum. 2) Water level also influences epilimnetic warming which has implications for species interactions, altering zooplankton community composition, plankton production, consumption rates of planktivores, competition among planktivores, and predation rates of piscivores. This effect on reservoir thermal structure can be expected to have important consequences for productivity and sport fish yields.

Reservoir retention time, volume, basin morphometry, and climate interact to determine the thermal structure of reservoirs. Thermal structure is a critically important ecological factor in aquatic systems because it determines physiological rates of poikilothermal (cold-blooded) inhabitants. Thus, temperature drives production of food organisms as well as the consumption rates of predators. In addition, thermal structure controls internal nutrient cycling, and can isolate

or concentrate predators and prey. Both have profound implications for reservoir productivity. While creel survey information is critical to assessing how a particular reservoir operation scheme affects yield of sport fish, it provides little insight into how the observed changes were brought about, nor does it suggest strategies that can optimize water management and reservoir productivity.

This study seeks to provide a better understanding of the mechanisms and pathways by which reservoir operations can impact reservoir productivity and the quality of the fishery the reservoir supports. This knowledge will be valuable for assessing ecological and fishery implications of alternative reservoir operation strategies in the future. The approach is fivefold: 1) Assemble historic datasets on hydrographics and limnology of Blue Mesa Reservoir (BMR) and determine relationships among surface elevation, storage, mean water column temperature, and thermocline depth. 2) Conduct a standardized limnological assessment program at sites throughout the reservoir, sampling temperature-dissolved oxygen profiles, chlorophyll, and zooplankton, and estimate zooplankton production rates. 3) Determine seasonal diet, depth distributions and growth of kokanee and rainbow trout using hydroacoustics and vertical gillnetting. 4) Incorporate sport fish diet, distribution, growth rate information into bioenergetics models to estimate consumption demand and population production. 5) Assess potential entrainment of young-of-year kokanee using hydroacoustics to determine distribution during high discharges in late May, and by assisting with drift net sampling below the dam during the same period.

This report documents the second year of progress on the research project investigating the influence of reservoir water operations on ecosystem structure and function in Blue Mesa

Reservoir, Gunnison County, Colorado. The primary goal of the work in 1993 was to characterize the physicochemical and biological limnology of the reservoir. In 1994, the objectives were to 1) continue monitoring seasonal changes in physicochemical and biological limnology of the reservoir, 2) investigate potential effects of dam operations on stratification patterns in the upper and lower basins of the reservoir, 3) quantify spatial and temporal patterns of zooplankton distribution and abundance, 4) obtain abundance estimates of pelagic fish stocks, 5) determine diet composition of kokanee salmon and rainbow trout, and 6) estimate growth, condition, and depth distribution of sport fishes.

STUDY SITE

Blue Mesa Reservoir is a mesotrophic, 3,700 ha (9,180 ac), 32 km (20 mi) long impoundment in southwestern Colorado. The earthen dam forming Blue Mesa was constructed in 1965 to store and control heavy spring flows of the Gunnison River, and rises 104 m (342 ft) above the streambed of the River. Two 40,000 kilowatt generating units operate at the base of the dam. The lake is one of three reservoirs in the Curecanti Unit of the Colorado River Storage Project, providing water for irrigation, power generation, and recreation. With a storage capacity of $1.16 \times 10^9 \text{ m}^3$ (940,700 ac-ft), Blue Mesa is the largest reservoir in Colorado. Most of the reservoir is within the National Park Service's Curecanti National Recreation Area.

The fish community in BMR consists primarily of kokanee salmon (*Oncorhynchus nerka*), rainbow trout (*O. mykiss*), lake trout (*Salvelinus namaycush*), brown trout (*Salmo trutta*), cutthroat trout (*Oncorhynchus clarki*), and longnose sucker (*Catostomus catostomus*). The lake supports an extremely popular and productive kokanee salmon and rainbow trout fishery. For

example, in 1993, the lake received over 612,000 angler-hours of fishing effort (ice and openwater angling; S. Hebein, CDOW, Gunnison, pers. comm.). About 340,000 fish were harvested, of which 75.3% (255,772 fish) were kokanee salmon, and 18.5% (83,898 fish) were rainbow trout. Angler caught kokanee were among the largest in the state with a mean size of 320 mm.

Job 1-a. Reservoir Limnology

METHODS

Overview

We began the 1994 field season on 23 May 1994 and collected data weekly until 19 August 1994. We returned to CSU on 20 August 1994 but conducted brief sampling trips to BMR during mid-September and the first week of October (Table 1).

During the 1994 field season we monitored the seasonal progression of temperature/dissolved oxygen profiles in the three main basins and checked for possible changes in temperature profiles near the inlet and outlet of the reservoir. We measured secchi depth and collected chlorophyll *a* concentrations to assess primary production throughout the growing season. We also collected data on zooplankton dynamics including: 1) diurnal distributions over the season, 2) one day of sampling to quantify diel vertical migration of zooplankton and 3) a set of depth-stratified samples from Iola basin designed to assess horizontal patchiness in zooplankton distribution both within, and between the upper, middle and lower sections of Iola basin.

In addition, salmonid stomach samples were taken over the summer and vertical gill netting and hydroacoustics data were collected in July, August, and October to gain information on fish

distributions. Thermographs were deployed in July in the five main tributaries to the reservoir.

We collected data at three of the sampling stations used in 1993 (Table 2; Figure 4): station #1 (Sapinero: lower basin), 3 (Cebolla: central basin), and 5 (Iola: upper basin). These stations were selected in mid-basin areas judged to be minimally influenced by inlet streams. The bulk of our 1994 field season sampling time was spent performing two basic daytime activities: routine limnological monitoring and intensive examination of reservoir stratification.

Routine limnological monitoring consisted of secchi-disc readings, temperature/dissolved oxygen profiles, stratified zooplankton net tows, integrated chlorophyll samples, and fish stomach collection from anglers. This suite of measurements was performed at each of the 3 basins during one week periods biweekly throughout the summer.

In alternate weeks we assessed possible changes in temperature and dissolved oxygen profiles (Temp/DO profiles) in a local spatial gradient at the inlet and outlet ends of the reservoir (intensive Temp/DO). We did this sampling at one end of the reservoir per day (morning) usually during consecutive days. It was necessary to complete the intensive Temp/DO data collection before afternoon winds came up and made it impossible to maintain our position at the sampling station.

We ended summer routine monitoring on 18 August 1994 and then returned in mid September for the final 1994 limnology sample. We did not collect fish stomachs in September because of the paucity of anglers on the lake at that time. Our final field sampling trip of the season was during the first week of October to conduct vertical gill netting and a hydroacoustics survey.

Physicochemical Limnology

Reservoir water operations data were obtained from a variety of sources: USGS Water Resources Bulletins, Colorado Division of Wildlife Research Reports (Wiltzius 1974), and U.S. Bureau of Reclamation databases and reports.

Historic data on temperature and dissolved oxygen profiles were obtained from Cudlip et al. (1987), Wiltzius (1971). In 1994, seasonal progression in reservoir temperature and dissolved oxygen structure was recorded biweekly in each basin as part of routine limnological monitoring. Temp/DO profiles were obtained in 1994 using a YSI Model 58 digital meter with 60 m probe cable. Measurements were taken at one meter intervals from 0 to 20 m and at 5 m intervals from 20 to 58 m of depth.

In alternate weeks, Temp/DO profiles were measured at points along transects established in the upper and lower basins. These transects followed the longitudinal axis of the reservoir starting at the dam or at the bridge over the Gunnison River inlet. Our objective was to assess possible changes along a small scale spatial gradient that we hypothesized may be affected by reservoir discharge. Stations on the transect were at 200 meter intervals increasing to 400m as we got near the mid-basin area.

Secchi depth measurements were obtained with a standard 200 mm white and black limnological secchi disc (Wetzel and Likens 1991) by averaging two replicate readings taken on the shaded side of the boat.

Primary Production

Chlorophyll water samples were obtained at using either a 5-m or 10-m integrated water

column sampler. Water samples were filtered through glass microfiber filter paper (Whatman GF/F) using a vacuum pump (Soranno and Knight 1993). The filter papers were frozen on dry ice and stored frozen until they were extracted and processed. Samples were analyzed for chlorophyll-a by the 24-hr methanol extraction (Holm-Hanson and Riemann 1978, Marker et al. 1980, Riemann 1980, Soranno and Knight 1993) and fluorometry method (Lind 1979, Soranno and Knight 1993, Axler and Owen 1994) using a Turner Designs Model 450 fluorometer.

Zooplankton Dynamics

Zooplankton were collected by oblique tows using a Wildco model 37-315 Clark-Bumpus plankton sampler with 130 mm diameter opening and 153 μ net. The flow meter on the Clark-Bumpus sampler was calibrated using a Schwaffer water velocity meter. One revolution of the Clark-Bumpus flow meter equaled 5.29 liters passing through the net. During May two replicate samples were taken at each of the three stations for the routine zooplankton monitoring. During June through September we collected three replicate samples from the 0-5 m, 5-10 m, and 10-15 m strata and two replicates from the 15-30 m stratum at each station. All samples were taken between the hours of 0900 and 1200. Samples were preserved in sugared, buffered formalin to prevent osmotic explosion.

Sampling in 1994 assessed the magnitude of spatial and temporal variation in the distribution and abundance of macrozooplankton. Spatial variation can occur at three scales: local horizontal, vertical, and longitudinal (large scale horizontal).

Variability in Local Horizontal Distribution

We designed a sampling plan to assess the degree of localized horizontal patchiness in distribution of zooplankton. This sampling was conducted in Iola basin on 12 July 1994. We divided the basin into thirds on the map, then we chose a range of appropriate distances that we could select randomly. We collected a complement of depth stratified samples from each of eight randomly selected stations in each section of the basin.

Variation in Vertical Distribution

Vertical distribution was assessed by sampling four discrete depth strata at each mid-basin station biweekly during routine limnological monitoring. In the 1993 field season oblique zooplankton net tows were made at 0-5 m, 5-10 m, 10-20 m, and 20-30 m. The 1993 data showed that the majority of zooplankton were found in the top 20m of the water column. Therefore, the 1994 sampling plan was modified by adding a 10-15 m stratum and changing the lower stratum to 15-30 m. The 1994 design comprised of replicate samples at every site in each of four strata: 0-5 m, 5-10 m, 10-15 m, and 15-30 m. *Daphnia* spp, the most important members of the zooplankton community with respect to fish predation, were scarce in the 15-30 m strata so only two replicates were taken. Beginning in June three replicates were taken at all other strata. As in 1993, we also took two replicate samples from the 0-10 m stratum at every site for Pat Martinez, CDOW, to obtain data comparable to his standardized sampling in other mountain reservoirs.

Longitudinal Variation

Longitudinal variation was assessed by sampling at mid-basin sampling sites in the upper, middle and lower reservoir basins. Possible within-basin longitudinal distribution gradients will be assessed from the horizontal patchiness sampling done in Iola basin (discussed above). We expect that Iola basin would be more likely than the downreservoir basins to show a within-basin longitudinal distribution gradient since it is heavily influenced by inflow from the Gunnison River.

Temporal Variation

Temporal variation may occur at two time scales: diel and seasonal. Variation in diel vertical distribution was assessed by quantifying distributions over transitions from darkness to light and light to darkness. Seasonal variation was assessed by sampling at regular intervals (every two weeks) over the entire growing season.

Data from 1993 suggested that zooplankton in BMR may exhibit a diel vertical migration (DVM). The 1993 DVM sampling was done at the same strata as the daytime samples: 0-5 m, 5-10 m, 10-20 m, and 20-30 m. In 1994 we obtained a finer resolution of zooplankton vertical distribution by sampling during the light transition periods of morning and evening and at discrete depth strata (1 m, 3 m, 6 m, 9 m, 12 m, and 15 m). DVM sampling was done on July 7, 1994 during the new moon, at sampling station #3, Cebolla basin.

Time constraints made it impossible to take replicate samples. Instead, we made long net tow runs (3X as long as what we were doing for our routine day samples) in an effort to minimize sampling error due to possible local horizontal variability. One sample was taken from each stratum during a single sampling pass. The six samples taken in each pass constituted a "set of samples". In the first pass a set of samples was taken in total darkness spanning a time period

from 0415 to 0500. The second pass consisted of another set of six samples taken from 0508 to 0550 during what was judged to be the time period of greatest change in light intensity. The third set was collected in full sunlight from 0645 to 0728. Three evening sampling passes using the same protocol were done on the same day and sampling site as the morning sampling passes. By comparing densities between samples taken from the same depth but at different light intensities it was possible to quantify changes in depth distribution over time.

Zooplankton Sample Processing

Each sample was diluted to a density that would provide 20-30 zooplankters in a single 1 ml aliquot taken with a Hensen-Stemple pipette. Aliquots were placed in a Sedgwick-Rafter cell where all species were identified and enumerated (Lind 1979, Soranno and Knight 1993) under a compound microscope. We processed three aliquots from each of the two-replicate samples (May sampling dates only), and two aliquots from three-replicate samples (June-September).

Copepods (*Diacyclops* spp. and *Leptodiaptomus* spp.), and the cladocerans *Bosmina* spp., *Ceriodaphnia* spp., and the rare *Diaphanosoma* spp., and *Alona* spp. were all identified to genus. Two *Daphnia* species (*Daphnia pulex* and *Daphnia galeata mendotae*) are present in BMR. Both were identified to species and the first 24 individuals encountered in every sample were measured and their eggs counted. Neither egg counts nor measurements were taken on any other organisms. Zooplankton abundance data were computed as number per liter of lake water (density).

RESULTS AND DISCUSSION

Physicochemical Limnology

Reservoir Operations

Mean daily discharge (cubic feet per second; CFS) from BMR was below average in water year (WY) 1994. Discharge was lower in January-September of water year (WY) 1994 than the average discharge observed during water years 1976-1992 (Figure 5). Discharge was near the average during June-September of WY 1994. Data are missing for March, May and August. Mean daily discharge peaked at about 1,700 CFS during July 1993. February 1994 differed most from the long-term mean. During the pre-reoperation period of 1976-1992 peak discharge occurred on average during July; however, a spring to early summer peak in discharge is less distinct during this period (Figure 6).

Mean surface elevation of the reservoir was higher in all months of WY 1994 than the long-term mean (Figure 7). The divergence from the mean was greatest in April, followed by March and May. Surface elevation was greater than WY 1993 in spring, and lower throughout the summer. Monthly inflow (ac-ft) peaked during May-June 1994 at about 190 ac-ft (Figure 8). Inflow mimicked the temporal pattern observed in WY 1993, but the magnitude of inflow was generally lower during WY 1994.

Temperature-Dissolved Oxygen

The reservoir was already stratified when we began measuring temperature-dissolved oxygen (Temp-DO) profiles on 23 May (Figures 9, 10, 11); surface temperature at this time was approximately 12°C. July surface temperature was generally lower in 1994 than the mean July

temperature for eight years during 1967-1994 for which data were available (Figure 12). In 1994 the reservoir was warmest during August 14-18 (Figures 9, 10, 11). The mixed layer on the surface extended to about 10 m during late June through the third week in August when sampling ceased until mid September. Blue Mesa was still stratified in mid September but the mixed depth extended to about 17 m and average temperature of the mixed surface layer had fallen to about 17.4°C.

Intensive temperature profiles in Sapinero basin did not show any indication that stratification was being altered by dam discharge- temperature profiles among stations were basically indistinguishable on all six sampling dates (Figure 13). During June it appeared that stratification in the top 10 m became weaker with increasing distance from the dam, which could be a result of wind effects that increase as the basin widens away from the dam. Because discharge was below average in 1994 we can not fully assess the potential for reoperation of the dam to alter small scale stratification at Sapinero. In Iola basin there was considerably more variability in temperature profiles along a transect from the reservoir inlet to mid-basin (Figure 14). Cooler temperatures were usually found shallower at stations closest to the inlet. It is difficult to say the degree to which dam operations influenced stratification in Iola basin because of the apparent strong effect of the incoming Gunnison River.

Dissolved oxygen levels were generally high (> 6 mg/l) throughout the reservoir during May-July but the lower half of the water column in Iola dropped below 6 mg/l DO beginning in July (Table 3). Dissolved oxygen was sufficient for fish habitation (> 4 mg/l) from top to bottom throughout the May-September sampling period except at 18-20 m in Iola during August (Table 3). An unusual pattern in which DO measurements were lowest in mid-depths of the water

column (approximately 12-20 m) occurred in Cebolla basin beginning in May and in Sapinero in July (Table 3). The midwater DO slump persisted through September at Sapinero and Cebolla. The pattern was not evident in Iola basin, which showed a nearly continuous decline in DO with depth on all sampling dates (Table 3).

Secchi Depth

As in 1993 water transparency increased through the season in 1994 at all stations (Figure 15). Transparency was lowest at Iola in June and highest at Sapinero in September. There were no consistent interbasin trends in water transparency. Transparency was more variable in 1994 than the average observed by Cudlip et al. (1987) during 1983-1985 (Figure 16). In general water transparency was greater in 1994 than in 1993 or during 1983-85. The grand mean of all months and sites was higher in 1994 (4.9 m) than in 1993 (3.5 m) or in the 1983-85 period (3.0 m).

There is considerable variability inherent in secchi depth readings between observers and the method is sensitive to sampling conditions; however, there is a trend towards increasing water clarity in the available data. Whether this trend is real or artefactual is unknown at present. If the pattern is real then it could indicate either an increase in grazing pressure by the zooplankton community, lower input or mixing of inorganic material that causes turbidity, or reduced nutrient availability for primary production. The chlorophyll and zooplankton sampling we have undertaken should prove very helpful in determining an explanation for changes in the secchi depth data.

Primary Production

Chlorophyll a

Methods for collection of water samples obtaining integrated water column samples for chlorophyll analysis, sample filtration and preservation in the field, and pigment extraction were refined in 1994. Calibrations of the fluorometer using a spectrophotometer and known dilution concentrations of a chlorophyll standard produced the required linear relationship between true chlorophyll concentration and the F_t-F_s fluorometer readings with R^2 values > 0.99 . Further, the strong relationship held for all fluorometer gain settings we tested, which encompassed the entire range of gains we anticipate needing for sample processing.

Variability in fluorometer measurements taken on replicate samples was very low. As a result, our measurements of chlorophyll concentration ($\mu\text{g/l}$) were quite precise (Figure 17). There was no detectable difference in chlorophyll concentration between 0-5 m and 0-10 m integrated water samples suggesting that the top 10 m of the reservoir are well mixed throughout the growing season. Chlorophyll concentration ($\mu\text{g/l}$) peaked on 22 June in Sapinero basin, and on about 8 June in Cebolla and Iola basins (Figure 17). Chlorophyll concentration declined steadily after the June peak in Sapinero and Cebolla, but was more variable in Iola. Chlorophyll concentration was generally lowest at Sapinero, highest at Iola, and intermediate at Cebolla.

Secchi depth is sometimes used as a convenient and inexpensive surrogate for chlorophyll measurements (Cole 1983). At BMR there was only a weak negative relationship evident between secchi depth and chlorophyll concentration (Figure 18). Variation in inorganic turbidity and in the size composition of the phytoplankton community may be responsible for the lack of correspondence between secchi depth and chlorophyll (Edmondson 1980).

Zooplankton Dynamics

The Zooplankton Community

We collected 270 zooplankton samples during 1994 including 235 samples from our routine zooplankton monitoring and 35 samples from DVM assessment. Six species of crustacean macrozooplankton were sampled in 1994, two species of copepods, and four cladoceran species. The zooplankton community was dominated by the copepod *Diacyclops*. When averaged across all basins, sampling dates, and strata, *Diacyclops* was 2.6 times more abundant than any other species. The second most abundant species were *Daphnia pulex*, and a *Bosmina* spp., which were equally common in 1994. These were followed by *Daphnia galeata mendotae*, a *Ceriodaphnia* spp. and a *Leptodiaptomus* spp. (Figure 19). Cudlip et al. (1987) found a similar composition of the community in 1984-1985. In their samples *Cyclops* (we assume *Diacyclops*) was ranked number 1, *Daphnia* spp. number 2, and *Diaptomus* (we assume *Leptodiaptomus*) and *Bosmina* were third.

There are some differences in relative abundance of zooplankton in 1994 compared to 1993. In 1993, *Diacyclops* was four times more abundant than any other species and *Daphnia pulex* was more common than *Bosmina*. In our 1993 report we noted that *Bosmina* may have increased or *Leptodiaptomus* had decreased in relative abundance somewhat since 1984-85. This trend may be continuing because in 1994 *Bosmina* was second in abundance along with *Daphnia pulex*, and *Leptodiaptomus* was ranked fourth in abundance.

Mean size of *Daphnia pulex*, averaged across all stations, dates, and depths, was about 0.24 mm greater than the average of *Daphnia galeata mendotae*. *Daphnia pulex* size ranged from 0.42 to 2.22 mm (0.52 to 2.51 mm in 1993) and *Daphnia galeata mendotae* ranged from 0.45 to

1.89 mm (0.52 to 1.79 mm in 1993). To our knowledge, no historic data on zooplankton population size structure are available.

Spatial Distribution- Vertical

When all stations, sample times, and dates are combined all species of zooplankton were most abundant in the top ten meters of the reservoir (Figure 20). *Daphnia* spp. were nearly twice as abundant in the 0-5 m stratum as in the 5-10 m stratum. This was not true for any other species. All non-*Daphnia* zooplankton had nearly equivalent densities in the 0-5 m and 5-10 m strata in 1994. In 1993, most non-*Daphnia* species were at least 50% more numerous (per unit volume) in the 0-5 m stratum than in any other depth stratum. *Diacyclops* showed the same depth distribution in both years: it was almost equally numerous in the 0-5 and 5-10 m strata. The 1994 data showed that 65% of all non-*Daphnia* sampled in the 0-30 m strata occurred in the top 10 m of the water column, whereas 88% of total *Daphnia* density was in the top 10 m and 98% in the top 15 m. All species were least numerous in the 15-30 m stratum (Figure 20).

Spatial Distribution- Horizontal

Mean *Daphnia pulex* egg counts in 1994 were about the same in all three basins, and mean *Daphnia galeata mendotae* egg count was highest at Iola (Table 4); however, count variance was very high because only a small portion of the larger *Daphnia* were carrying eggs. *Daphnia* density was very close to the same in all three basins from mid-July to mid-August (Figure 21). Peak *Daphnia* density was highest in Cebolla, followed by Iola, and Sapinero (Figure 21). Overall density of *Ceriodaphnia* spp. was only slightly higher in Iola and Cebolla than in

Sapinero. Overall *Bosmina* density in each of the two upper basins was twice that of Sapinero. Overall *Diacyclops* densities were roughly equivalent in all three basins in 1994 (Figure 22).

Our results are similar to those of 1993 except that in 1993 there was a moderate increase in *Diacyclops* density upreservoir. Also, the upreservoir increase in *Daphnia* density was much more pronounced in 1993. In 1993 the overall mean density of *Daphnia pulex* in Iola basin was three times higher than in Sapinero basin; overall mean density of *Daphnia galeata mendotae* was two times higher in Iola than in Sapinero.

Over the entire season, with all depth strata combined, total zooplankton density was greatest at the Iola station; however, Cebolla was only slightly lower (Figure 22). Sapinero Basin had the lowest mean zooplankton density. When *Daphnia* densities in the top 15 m of the reservoir are averaged across all dates in each of the three basins, these means are remarkably similar among basins: Sapinero 12.7/L, Cebolla 12.5/L and Iola 11.9/L. This suggests that the differences among basins in *Daphnia* production are mainly seasonal.

The most outstanding temporal differential in *Daphnia* density among basins was the time lag in peak abundance. Sapinero and Cebolla peaked at the same time and Iola had its peak *Daphnia* about 18 days later. This time lag may be a result of apparent increased suspended sediments in Iola early in the season. Suspended particulate matter supplies abundant nutrients to the upper basin but also creates turbidity, especially during spring runoff. High turbidity restricts light penetration thereby limiting autochthonous phytoplankton production (Goldman 1966). Suspended sediments also interfere with *Daphnia* filter feeding- Haney (1971) found that ingestion rates varied along the longitudinal axis of the reservoir in direct proportion to concentrations of suspended sediments. Suspended sediments may even reduce food availability

of *Daphnia* to starvation levels (Lampert 1977). Sedimentation of particulate matter creates a down-reservoir gradient of increasing light penetration which allows higher early season algal productivity (Thornton et al.1990). Secchi depths in BMR on May 21-23 were: Iola 1.5 m , Cebolla 3.7 m, and Sapinero 4.5 m (Figure 15).

One could expect higher abundance of autochthonous algae and lower suspended sediment concentrations down-reservoir to result in higher *Daphnia* density at the lower end of the reservoir during the early part of the season. Thornton et al.(1990) note that zooplankton populations increase near the source of food. Higher down-reservoir *Daphnia* density was observed in BMR in 1994 where, on May 21 *Daphnia* density in the top 15 m of Iola was only 1/L, while Cebolla was 10/L, and Sapinero was 15/L. These density differences can't be explained by temperature differences since there was only a 0.4°C differential in mean temperature of the top five meters among basins at this time.

Temporal Dynamics- Overall

Overall abundance of zooplankters declined continuously from June to August (Figure 23). There was a general trend of increasing abundance of zooplankton from mid-August to mid-September. Changes in relative abundance were very similar in all three basins over the 1994 field season. Relative abundance of *Daphnia pulex* remained fairly constant in Sapinero, and in Iola from early July through September, but decreased notably in Cebolla toward the end of the season (Figures 24, 25). *Leptodiaptomus* and *Ceriodaphnia* were the only taxa to show an increasing seasonal trend in abundance. *Leptodiaptomus* and *Ceriodaphnia* were rare in May and June (< 1/L). In September, *Leptodiaptomus* increased to 16/L and *Ceriodaphnia* to 25/L (Figure

23). This pattern held true in all three basins (Figures 24, 25).

The ratio of *Daphnia pulex* to *Daphnia galeata mendotae* followed a general seasonal pattern throughout the reservoir (Figures 24, 25). The two *Daphnia* species were at nearly equal densities at the start of the growing season. As the season progressed *D. pulex* became from two to four times more abundant than *D. galeata mendotae*. In September, *D. galeata mendotae* and *D. pulex* returned to nearly equivalent abundance in Sapinero and Cebolla but in Iola *Daphnia pulex* remained dominant. When averaged over the entire season and across all basins and strata, *Daphnia pulex* was 65% of total abundance of the two species and *Daphnia galeata mendotae* averaged 35%. Range of differences in *Daphnia* abundance ratios was about the same in Sapinero and Cebolla. *Daphnia pulex* ranged from 47-72% of total *Daphnia* abundance in Sapinero and 46-82% in Cebolla. Iola had the greatest changes in *Daphnia* ratio with *D. pulex* extremes at 37-89%.

Daphnia egg counts were variable through the season (Table 4). *Daphnia pulex* egg counts were fairly consistent in May through July, peaked in August, and then decreased in September. *Daphnia galeata mendotae* egg counts were also consistent in May through July but then declined sharply in August and September (Table 4). These data have not yet been tested for statistical significant differences.

Temporal Dynamics- Seasonal/Vertical

Daphnia species remained consistently more abundant in the upper strata throughout the season in all basins. *Daphnia* density in all strata varied synchronously but in Sapinero and Cebolla the variation was dampened with increasing depth (Figure 26). In Iola, contrary to the

lower two basins, the deep stratum varied temporally in equal proportion to the upper two strata. Seasonal patterns of change in relative abundance showed no apparent differences between the 0-5 m and 5-10 m strata in all three basins (Figures 27, 28, 29).

Daphnia density in the three upper strata of both Sapinero and Iola reaches a minimum some time in August and then increases to mid-September. Cebolla differs slightly in this regard as only the 5-10 and 10-15 m strata follow this pattern while the 0-5 m stratum decreases sharply from August 17 to September 17 (Figure 26). Relative density of *Daphnia* among depth strata retains about the same general pattern over the season (Figures 30, 31, 32). *Daphnia* density was always highest in the 0-5 m stratum, except on 5 July in Cebolla basin when *Daphnia* density was slightly higher in the 5-10 m stratum.

The data suggest that in spring *Daphnia* undergo a rapid increase first in the 0-5 m stratum, followed by an elevated rate of increase in the 5-10 m stratum which narrows the density difference between these two strata in subsequent days. During the initial spring-time period of rapidly increasing density, density in the 5-10 m stratum in both Cebolla and Iola was about 25% of the density in the 0-5 m stratum. Two weeks later in each basin density in the 5-10 m stratum was 62% of density in the 0-5 m stratum.

This pattern was not observed in Sapinero but it is possible that we sampled too late to detect it, *i.e.*, we may have missed the initial period of rapid increase in density in Sapinero. Sapinero already had the highest *Daphnia* density of the three basins when we took our first samples and that was the only time of the season when it had notably more *Daphnia* than the other two basins (Figures 30, 31, 32).

Maximal *Daphnia* density in the top five meters is probably not due to greater food

availability. Chlorophyll-a density (*Daphnia* food) is essentially identical in the 0-5 m and 5-10 m strata (Figure 17). This suggests that if in fact *Daphnia* do initially proliferate at a higher rate in the 0-5 m than in the 5-10 m strata, it is likely due to temperature rather than food availability. Temperature is one of the most important variables determining lake productivity (Brylinsky and Mann 1973). Increased temperatures also have a positive influence on *Daphnia* foraging. Food filtration rate is higher at increasing temperatures up to 25C for *Daphnia pulex* (Burns 1969b, Geller 1975). The rate of egg development also increases with temperature in many planktonic crustaceans (Wetzel 1983). Pennak (1989) notes that active reproduction of *Daphnia* begins at 6-12° C. Furthermore, Hall (1964) (cited in Wetzel 1983) states that the instantaneous rate of population increase in *Daphnia galeata mendotae* is three times higher at 20C than it is at 11C.

Profiles suggest that temperature could explain any possible differential rate of *Daphnia* population increase between the 0-5 m and 5-10 m strata. In Sapinero, on May 21 temperature dropped from 12.6°C at one meter to 11.6°C at the five meter depth and nearly two more degrees to 9.8°C at ten meters. We will investigate this possible vertical gradient in *Daphnia* reproduction. If true then reservoir operation scenarios that allow the upper water column to warm earlier in the spring could benefit the kokanee fishery by giving the *Daphnia* population an earlier start. A lower water level in spring may induce earlier warming in the shallower sections of Cebolla and possibly boost early season *Daphnia* production there. A reservoir thermal model would allow us to assess the potential for earlier warming of the epilimnion under various operations and climate scenarios.

Early in the season large *Daphnia* appeared to be distributed deeper than small *Daphnia*. In all three basins on May 21-23 the mean length of *Daphnia* highest in the 15-30 m stratum

(Figure 33). Only 11% of the total (0-30 m) *Daphnia* density was below 10 m in depth but 75% of the largest zooplankton in the population were within that 11%. Furthermore, when averaged across the first three sampling dates (21 May, 10 June, 22 June) 70% of the egg carrying *Daphnia pulex* were below 10 m in depth and 91% were deeper than 5 m.

Daphnia neonates also showed a trend of higher density with increasing depth in the 21 May sample from Sapinero basin (Figure 34). The data suggest an interesting early season depth distribution pattern of *Daphnia* neonates. On 10 June the data showed that *Daphnia* neonate density was lowest in the 15-30 m stratum, and not much different among the 0-5, 5-10, and 10-15 m stratum. The 22 June sample indicated that neonate density was highest in the 0-5 m stratum, totally opposite of what had been observed on 21 May. Depth segregation of *Daphnia* sizes diminished until the end of June and thereafter there was no apparent segregation of sizes throughout the rest of the season (Figure 33). Since we have not statistically tested these data we can't make inferences as to the significance of these patterns at this time.

Temporal Dynamics- Seasonal/Horizontal

Daphnia density peaked at about the same time in 1994 in the Sapinero and Cebolla basins, during 6-10 June, at 16.6/l and 28.3/l respectively (Figure 21). Iola peaked at 24.3/l about 16 days later on 24 June. *Daphnia* density in Sapinero and Cebolla had dropped off sharply by this time. Variation in *Daphnia* density over the season was less in Sapinero than in the other two basins and ranged from 7.6 to 16.6/l. *Daphnia* density ranged from 5.7 to 28.3/l in Cebolla and 1 to 24/l in Iola (Figures 21).

There were differences among basins in patterns of mean *Daphnia* length. In Sapinero,

there was little change over the season in *Daphnia pulex* mean length (Figure 35). In Cebolla and Iola, changes in mean length of both species tended to track one another (Figures 35, 36). The most notable changes in mean length occurred in Iola, where *Daphnia pulex* mean length dropped precipitously from 1.57 mm on 23 May to 1.15 mm on 01 July.

Large *Daphnia* are the principal prey of kokanee. *Daphnia* > 1.5 mm averaged about 2/l over the sampling season and ranged from <1 to 5/l. Although the results are variable two patterns appear: 1) density drops sharply to a low of less than 2/l in all three basins on 01 July; and 2) in Sapinero density on 17 September had increased to nearly five times what it was on 17 August and density in Iola over this time period nearly doubled (Figure 37).

Temporal Dynamics- Diel

As was suggested from work performed in 1993, cladoceran zooplankton appeared to undergo a slight diel vertical migration (DVM). When the six sampling periods are lumped into morning and evening dark periods (midpoints 0436 h, 2207 h) and light periods (0706 h, 1931 h) it appears that cladocerans (*Daphnia pulex*, *D. galeata mendotae*, and *Bosmina*) were more abundant at shallow depths (< about 6 m) during the day than at night and more abundant at deeper depths during night than day (Figures 38, 39, 40). *Daphnia* length did not appear to change with depth in light vs. dark periods (Figures 41, 42). Diacyclops did not show any consistent diel pattern in abundance by depth (Figure 43). These data have yet to be tested statistically so conclusions regarding DVM are tentative.

Job 1-b Fishery Investigations

METHODS

Vertical Gill Netting

Vertical gill netting was conducted in conjunction with hydroacoustic surveys performed by CSU, CDOW, and USBR-NBS personnel during 6-10 June, 1-5 August, and 10-14 October 1994. A gang of nets was fished overnight at a midlake station (Table 2) once in each lake basin during each month. Nets floated on the surface and extended to within about 1 m of the lake bottom. During June we used vertical gill nets borrowed from G. Mueller (NBS, Denver). These nets were 3 m wide, 60 m long, with one mesh size per net (0.5 in, 0.75 in, 1.0 in, 1.25 in, 1.5 in, or 2.0 in). Nets used during August and October measured 60 m long and 3 m wide but were constructed with two mesh sizes (range same as above) per net. Depth at which each fish was caught was recorded. Gill net caught fish were measured and weighed. Otoliths and stomachs were removed from all kokanee and a subsample of other salmonids. Heads from small kokanee were preserved for whirling disease analysis by CDOW.

Diet Analysis

Stomach samples were obtained from vertical gill net sampling in June, August, and October, and by sampling the angler catch approximately biweekly (during weeks when routine zooplankton samples were taken) at cleaning stations at each lake basin. Stomachs were excised and preserved in 10% formalin. Kokanee samples were grouped into three size classes (<250 mm, 250-349 mm, or >349 mm); approximately five stomachs from fish of each size class from each date and sampling location were aggregated for analysis. Proportions (by volume) of fish,

macroinvertebrate, and zooplankton were visually estimated. Non-zooplankton prey were preserved for future analysis. The zooplankton contents were diluted to a density that would yield approximately 20-30 measurable zooplankters, and one aliquot was placed in a Sedgwick-Rafter cell. All identifiable organisms were counted. Cladocerans of genera *Ceriodaphnia*, *Bosmina*, *Diaphanosoma*, were all lumped into a group called "other *Daphnia*" and counted as such. *Daphnia* were identified to species if possible. The first 10 specimens of each *Daphnia* species encountered was measured. When there was only one species of *Daphnia* present the first 20 individuals of that species was measured. Only *Daphnia* with an intact carapace were measured. If after counting the entire slide 10 measurements of each *Daphnia* species was not obtained we went back through the slide and measured *Daphnia* (the ones that were passed over because they were not identifiable to species) until a total of 20 *Daphnia* measurements were taken and recorded. Copepods were counted as either just "Copepod" or *Leptodiaptomus* spp. or *Diacyclops* depending on how fine a resolution of identification could be obtained.

Hydroacoustics

A BioSonics ES-105 dual beam echo sounder and 420 kHz with 6/15° transducer mounted in a towed body were used to collect hydroacoustic data at night during the new moon on 1-3 August and on 2 October 1994. Data were recorded on a digital audio tape recorder and processed using BioSonics Echo Signal Processing software. Transects (Table 5) coincided with those employed by CDOW on the same nights.

Difficulties getting vertical gill nets set and an inadequate number of personnel prevented us from participating in the June hydroacoustics survey. On 9 July and 10 July and we used the

BioSonics hydroacoustics gear to collect data on the diel variability in the abundance and depth distribution of fishes in front of the Blue Mesa dam outlet structure. Fifty three transects were surveyed at approximately four hour intervals beginning at 10:56 h on 9 July (Table 6). In August, we surveyed standard transects in all three basins. Data were processed by R. Thorne, BioSonics, in 12 depth strata: 2-5 m, at 5-m intervals from 5 to 50 m, at 10 m intervals from 50 to 60 m, and at 20 m intervals from 60 to 80 m. Time constraints and logistic difficulties interfered our plans for the October survey; standard transects were surveyed in Cebolla basin only in October.

RESULTS AND DISCUSSION

Vertical Gill Netting

Kokanee salmon comprised between 82-96% of all fish captured in experimental vertical gill nets (Figures 44, 45 ,46). About 13% of the catch in June was brown trout captured in Iola basin, and longnose sucker, lake trout, and rainbow trout each comprised 1-2% of the June catch (Appendix Table A21). In August lake trout were 1.6% of the catch and rainbow trout 2.4% (Table A22); in October lake trout increased to 3.8% rainbow trout increased to 10.3% of the catch (Table A23). In all months over 97% of the catch was of fish <450 mm (Figures 44, 45, 46).

Greater than 90% of the fish caught in June were taken in water <20 m deep (Table A21). Kokanee were rather evenly distributed throughout the top 20 m in June. During August >90% of the catch was taken in 11-30 m depths and in October fish were more evenly distributed throughout the water column but >80% of the fish occurred at depths <25 m (Table A23).

Rainbow trout were always caught in water < 15 m deep; about 70% were caught in the 0-5 m stratum. The eight lake trout caught were taken at depths of 16-55 m.

Diet Analysis

The preferred prey of kokanee is *Daphnia pulex* (Finnell and Reed 1969). Blue Mesa kokanee of all sizes examined were highly selective for their preferred prey. Kokanee consumed about 97% *Daphnia pulex* and 3% *Daphnia galeata*. No other taxa were found in Kokanee stomachs. Kokanee also appeared to be selective for the larger individuals among the zooplankton populations. Kokanee in BMR fed almost exclusively on *Daphnia pulex* over 1.5 mm in length. Reservoir densities of *D. pulex* in this size class ranged between 1/L and 4/L for all sampling dates except the first week in July when *D. pulex* > 1.5 mm fell near 0.3/L in Iola. The mean size of *Daphnia pulex* in kokanee stomachs was nearly always greater than the mean size of *D. pulex* in the lake (Figures 47, 48, 49). During June and July there was little or no overlap between the lower 25th percentile of *D. pulex* size in guts and the upper 75th percentile of *D. pulex* in the lake at all three basins (Figures 47, 48, 49). The abundance of *Daphnia* over 1.5 mm may be an important variable in quantifying food resources for kokanee.

The extreme selectivity of kokanee for only the largest individuals of a single species of zooplankton, when high densities of other species and size classes were present, suggests that the kokanee population is not food limited, and that during summer kokanee are well below the food-imposed carrying capacity of the lake.

Hydroacoustics

Preliminary analysis of hydroacoustics data collected during the August 1994 survey is provided in Table 7. Maximum fish density in a transect occurred in the 20-25 m stratum in Sapinero (6.30 targets/1000 m³) and in Cebolla (9.55 targets/1000 m³) and in the 15-20 m stratum in Iola (19.03 targets/1000 m³). Average target strength within a stratum ranged from -68.48 to -34.50 dB at Sapinero transects, from -59.58 to -39.19 dB at Cebolla, and from -56.70 to -44.1 dB at Iola. Smallest mean target strengths always occurred in depths of 2-10 m. Many of the targets acquired in the 2-10 m strata are probable zooplankton concentrations rather than fish. Zooplankton sampling showed maximum plankter densities in the top 10 m of the water column in all basins during August. Further analysis of hydroacoustics data will be necessary to produce lakewide abundance estimates.

RECOMMENDATIONS FOR FUTURE STUDY YEARS

More detailed data on the heat budget of BMR will be required, including more precise estimates of inflow, and the temperature of the inflows, to implement the reservoir thermal model we want to test. We should work with B.O.R., U.S.G.S., and a private mining company to obtain inflow records. Thermographs should be placed in the Gunnison above Blue Mesa and its major tributaries. We should collaborate with national experts in reservoir thermal modeling at the Civil Engineering Department at CSU to begin thermal modeling of Blue Mesa Reservoir to evaluate climate and reservoir operations influences on the thermal structure of the lake and its food web.

Routine monitoring of temperature/dissolved oxygen profiles, secchi depth, and chlorophyll concentration should be continued to compare with historic databases on pre-reoperation conditions. Chlorophyll samples (and secchi depths) will also be important indicators of reservoir trophic status.

Although laboratory processing of zooplankton proved to be extremely time consuming, we believe continued plankton sampling is warranted. Zooplankton depth distribution and availability to planktivorous fish such as kokanee could be strongly influenced by reservoir thermal structure. A single species of zooplankton, *Daphnia pulex*, appears to be at the nexus of the Blue Mesa Reservoir food web. Understanding *Daphnia* dynamics will be critical to any evaluation of the productivity of the Blue Mesa sport fishery, and how it might be influenced by reservoir operations.

We should continue to gather information on fish abundance, diet, and growth rates. Creel survey information will be needed to obtain information on mortality rates. The sampling

program implemented in 1994 to gather fish stomach samples and growth information from angler caught fish should be continued. Hydroacoustics for estimating abundance and distribution, and vertical gillnetting for "groundtruthing" hydroacoustics data, species identification and to provide diet samples should be continued.

Two significant challenges presented by this study are first the lack of recent premanipulation data, and second the necessity of determining the relative effects of water reoperation and climatic influences on reservoir physical structure and productivity.

To address the first challenge we will rely on detailed limnological data collected in 1983-1985 (Cudlip et al. 1987) as well as fish and temperature-dissolved oxygen data from Wiltzius' studies (Wiltzius 1971, 1974). We are also fortunate that 1993, the first year of the study, was not unusual in that spring releases did not reduce reservoir volume below historic levels where thermal stratification and warming might be altered.

We should attempt to predict the importance of climate on reservoir structure and function by implementing a reservoir thermal model that predicts thermal structure from weather data, inflow volume and temperatures, and discharge patterns. Our ultimate goal is to then link direct physical effects of reservoir reoperation with the ecological implications via bioenergetics modeling approaches. Once established, this framework would allow us to study the potential interplay between direct anthropogenic and climatic influences in determining reservoir trophic dynamics and productivity, and also to forecast some implications of global climatic change for reservoir management. Additional support will be required to link the reservoir physical models with analyses to project ecological consequences of changing reservoir operations.

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- Table 7. Preliminary results of hydroacoustics survey conducted at standard transects in Sapinero, Cebolla, and Iola basins in Blue Mesa Reservoir during August 1-3, 1994. Fish density is corrected for bottom intrusion into the stratum.

Table 1. Overview of sampling conducted on Blue Mesa Reservoir in 1994.

Parameter	Standard monitoring	Intensive monitoring
Temperature	Profiles Biweekly Jun-Aug, monthly Sep-Oct at sites 1, 3, 5.	Dam and Iola biweekly during Jun-Aug. 9 sites.
Dissolved oxygen	Profiles Biweekly Jun-Aug, monthly Sep-Oct at sites 1, 3, 5.	
Secchi depth	Measurements Biweekly Jun-Aug, monthly Sep-Oct at sites 1, 3, 5.	
Chlorophyll	0-10 m integrated samples 0-5 m integrated samples Biweekly Jun-Aug, monthly Sep-Oct at sites 1, 3, 5.	
Zooplankton	Depth-stratified samples 3 replicate hauls per site at sites 1, 3, 5. Entrainment- sample dam outflow for zooplankton in morning and evening every week.	DVM study- finescale vertical and temporal resolution.
Fish (salmonids)	Vertical gill nets (6 meshes) 1 night per basin in June, August, October Diet sampling at fish cleaning stations every 2 weeks at each basin.	
Hydroacoustics	Experiment with BioSonics gear at dam during June-July. Conduct lakewide survey during August.	

Table 2. Location of sampling stations established on Blue Mesa Reservoir and visited during 1993. GPS coordinates were recorded using Garmen GPS-75 without differential correction.

Station Name	Purpose	Depth (m)	Waypoint Name	GPS Coordinates (UTM)		
				Zone	Easting	Northing
Iola Basin	Zooplankton, chlorophyll, temp-DO profiles, secchi	20	IOLAZP	13 S	0317192	4260939
Iola VGN	Vertical gill nets	21	IOLVGN	13 S	0317379	4260984
Cebolla Basin	Zooplankton, chlorophyll, temp-DO profiles, secchi		CEBZP	13 S	0308310	4261123
Cebolla VGN	Vertical gill nets	50	CEBVGN	13 S	0308329	4261032
Cebolla Arm VGN	Vertical gill nets	23	none	13 S	0308400	4257900
Sapinero Basin	Zooplankton, chlorophyll, temp-DO profiles, secchi		SAPZP	13 S	0298077	4259910
Sapinero VGN	Vertical gill nets	54	SAPVGN	13 S	0297774	4259573

Table 3. Dissolved oxygen (mg/l) profiles at three stations in Blue Mesa Reservoir during May-September, 1994. Values in parentheses were measured at the actual bottom depth (m) of the station.

[illegible]

Table 3 (continued). Dissolved oxygen (mg/l) profiles at three stations in Blue Mesa Reservoir during May-September, 1994. Values in parentheses were measured at the actual bottom depth (m) of the station.

[illegible]

Table 4. Mean *Daphnia* egg counts and standard deviation (SD) grouped by month, station, or depth stratum. Values for June through August are averages of the two sampling dates shown.

Class	<i>Daphnia galeata mendotae</i>		<i>Daphnia pulex</i>	
	Mean	SD	Mean	SD
May 23	0.658	1.522	0.939	2.290
June 8,23	0.682	1.154	0.748	1.323
July 6,18	0.524	1.037	0.979	2.318
Aug 1,16	0.924	1.310	0.421	1.350
Sept 17	0.745	1.040	0.000	0.000
Sapinero basin	0.682	1.111	0.427	1.360
Cebolla basin	0.680	1.337	0.754	1.736
Iola basin	0.636	1.094	1.030	2.102
0-5 m	0.636	1.215	0.866	1.904
5-10 m	0.645	1.180	0.925	1.967
10-15 m	0.626	1.135	0.684	1.655
15-30 m	0.816	1.259	0.000	0.000

Table 5. Standardized transects used during hydroacoustics surveys at Blue Mesa Reservoir during June, August, and October 1994.

Lake Basin	Waypoint Name	UTM Zone	UTM Easting	UTM Northing	Transect Length (m)	Approx. time (min.)
Iola	DOW017	13 S	0319284	4261659	Start	0
	DOW018	13 S	0318334	4260700	1350	14
	DOW019	13 S	0317055	4261339	1430	17
	DOW020	13 S	0316129	4260128	1524	16
	DOW021	13 S	0313657	4259509	?	27
Cebolla	DOW107	13 S	0310067	4259394	Start	0
	DOW108	13 S	0309284	4260817	1624	17
	DOW007	13 S	0307782	4261437	1666	18
	DOW109	13 S	0307404	4259814	1603	18
	DOW110	13 S	0306220	4260894	1582	16
	DOW111	13 S	0305332	4259585	2970	20
Sapinero	DOW010	13 S	0302448	4260294	Start	0
	DOW011	13 S	0301536	4261506	1517	19
	DOW012	13 S	0300093	4260623	1692	18
	DOW013	13 S	0299306	4262244	1802	26
	DOW014	13 S	0298977	4260700	1579	17
	DOW015	13 S	0297348	4259580	1977	21
	DOW016	13 S	0298700	4258534	1709	?

Table 6. Summary of hydroacoustics data gathered in front of Blue Mesa dam on July 9-10, 1994. Up to 11 passes were made along the face of the dam in a north-south or south-north direction on a line passing immediately east of the submerged outlet tower structure starting at a depth of about 5 m on one shore or the other.

Date	Start Time	Finish Time	Number of Transects
09 July 1994	10:23 h	10:56 h	10
09 July 1994	14:30 h	15:08 h	10
09 July 1994	18:40 h	19:26 h	12
09 July 1994	21:25 h	22:05 h	10
10 July 1994	05:56 h	06:35 h	11

Table 7. Preliminary results of hydroacoustics survey conducted at standard transects in Cebolla basin at Blue Mesa Reservoir during August 1-3, 1994. Fish density is corrected for bottom intrusion into the stratum.

Transect	Stratum (m)	Volume/ping	Pings	Targets	Average Target Strength (dB)	Number of fish/1000 m ³
DOW107	2-5	0.72	2291	3	-59.50	1.82
	5-10	5.51		0	--	0.00
	10-15	15.30		23	-51.04	1.64
	15-20	30.00		72	-46.12	3.69
	20-25	49.60		204	-44.00	9.55
	25-30	74.10		38	-41.60	1.52
	30-35	103.50		4	-43.26	0.44
	35-40	138.00		2	-40.00	0.23
	40-45	177.00				
	45-50	221.00				
	50-60					
DOW108	2-5	0.72	2517	0	--	0.00
	5-10	5.51		0	--	0.00
	10-15	15.30		5	-49.70	0.24
	15-20	30.00		42	-45.00	2.17
	20-25	49.60		248	-41.20	9.84
	25-30	74.10		197	-39.78	6.87
	30-35	103.50		40	-41.31	1.35
	35-40	138.00		10	-41.85	0.13
	40-45	177.00		2	-47.90	0.04
	45-50	221.00		1	50.80	0.05
	50-60					
DOW007	2-5	0.72	2370	3	-58.10	1.76
	5-10	5.51		2	-46.75	0.15
	10-15	15.30		1	-46.44	0.03
	15-20	30.00		56	-43.48	2.76
	20-25	49.60		227	-41.70	9.02
	25-30	74.10		162	-40.51	6.48
	30-35	103.50		55	-40.99	1.79
	35-40	138.00		5	-39.19	0.19
	40-45	177.00		1	-43.74	0.03
	45-50	221.00				
	50-60					

Table 7. Continued. Preliminary results of hydroacoustics survey conducted at standard transects in Cebolla basin in Blue Mesa Reservoir during August 1-3, 1994. Fish density is corrected for bottom intrusion into the stratum.

Transect	Stratum (m)	Volume/ping	Pings	Targets	Average Target Strength (dB)	Number of fish/1000 m ³
DOW109	2-5	0.72	2340	1	-58.7	0.59
	5-10	5.51		0	—	0.00
	10-15	15.30		1	-44.90	0.03
	15-20	30.00		26	-44.62	1.37
	20-25	49.60		89	-43.78	5.48
	25-30	74.10		31	-43.57	2.21
	30-35	103.50				
	35-40	138.00				
	40-45	177.00				
	45-50	221.00				
	50-60					
DOW110	2-5	0.72	3440	2	-59.58	0.82
	5-10	5.51		0	—	0.00
	10-15	15.30		0	—	0.00
	15-20	30.00		24	-40.62	0.84
	20-25	49.60		92	-44.42	3.13
	25-30	74.10		124	-41.82	3.22
	30-35	103.50		13	-41.92	0.24
	35-40	138.00		2	-45.23	0.05
	40-45	177.00		--	-56.04	0.00
	45-50	221.00				
	50-60					

Table 7. Preliminary results of hydroacoustics survey conducted at standard transects in Iola basin at Blue Mesa Reservoir during August 1-3, 1994. Fish density is corrected for bottom intrusion into the stratum.

Transect	Stratum (m)	Volume/ping	Pings	Targets	Average Target Strength (dB)	Number of fish/1000 m ³
DOW017	2-5	0.72	1800	19	-53.8	16.20
	5-10	5.51		32	-51.6	4.23
	10-15	15.30		75	-47.5	7.39
	15-20	30.00				
	20-25	49.60				
	25-30	74.10				
	30-35	103.50				
	35-40	138.00				
	40-45	177.00				
	45-50	221.00				
	50-60					
DOW018	2-5	0.72	2333	7	-53.9	4.75
	5-10	5.51		13	-48.2	1.32
	10-15	15.30		31	-48.3	1.67
	15-20	30.00		282	-46.0	19.03
	20-25	49.60		7	-48.8	16.42
	25-30	74.10				
	30-35	103.50				
	35-40	138.00				
	40-45	177.00				
	45-50	221.00				
	50-60					
DOW019	2-5	0.72	2370	4	-56.7	2.29
	5-10	5.51		3	-47.5	0.23
	10-15	15.30		10	-48.6	0.55
	15-20	30.00		99	-45.6	5.57
	20-25	49.60		99	-44.1	7.47
	25-30	74.10				
	30-35	103.50				
	35-40	138.00				
	40-45	177.00				
	45-50					
	50-60					
	60-80					

Table 7. Continued. Preliminary results of hydroacoustics survey conducted at standard transects in Iola basin in Blue Mesa Reservoir during August 1-3, 1994. Fish density is corrected for bottom intrusion into the stratum.

Transect	Stratum (m)	Volume/ping	Pings	Targets	Average Target Strength (dB)	Number of fish/1000 m ³
DOW020	2-5	0.72	3701	4	-56.1	1.50
	5-10	5.51		5	-54.2	0.30
	10-15	15.30		20	-46.9	1.07
	15-20	30.00		169	-43.9	8.95
	20-25	49.60		105	-44.1	11.68
	25-30	74.10				
	30-35	103.50				
	35-40	138.00				
	40-45	177.00				
	45-50	221.00				
	50-60					
	60-80					

Table 7. Preliminary results of hydroacoustics survey conducted at standard transects in Sapinero basin at Blue Mesa Reservoir during August 1-3, 1994. Fish density is corrected for bottom intrusion into the stratum.

Transect	Stratum (m)	Volume/ping	Pings	Targets	Average Target Strength (dB)	Number of fish/1000 m ³
DOW010	2-5	0.72	2713	1	-60.60	0.51
	5-10	5.51		1	-46.40	0.13
	10-15	15.30		3	-61.16	0.17
	15-20	30.00		41	-44.74	2.53
	20-25	49.60		68	-42.49	3.54
	25-30	74.10		51	-43.02	2.52
	30-35	103.50		20	-39.97	0.74
	35-40	138.00		4	-46.93	0.16
	40-45	177.00		2	-36.75	0.03
	45-50	221.00		0	—	0.00
	50-60			0	—	0.00
DOW011	2-5	0.72	2670	2	-66.36	1.04
	5-10	5.51		0	—	0.00
	10-15	15.30		4	-53.93	0.29
	15-20	30.00		27	-49.28	1.40
	20-25	49.60		77	-43.68	3.53
	25-30	74.10		47	-43.02	1.63
	30-35	103.50		13	-40.83	0.37
	35-40	138.00		2	-36.65	0.07
	40-45	177.00		1	-42.42	0.01
	45-50	221.00		0	—	0.00
	50-60			0	—	0.00
	60-80			0	—	0.00
DOW012	2-5	0.72	3368	2	-61.82	0.82
	5-10	5.51		0	-48.97	0.00
	10-15	15.30		0	-42.35	0.00
	15-20	30.00		28	-41.93	1.32
	20-25	49.60		110	-39.63	4.18
	25-30	74.10		58	-34.50	1.73
	30-35	103.50		14	-48.88	0.39
	35-40	138.00		1	-50.46	0.01
	40-45	177.00		1	-47.26	0.02
	45-50	221.00		2	—	0.02
	50-60			1	—	0.00
	60-80			0	—	0.00

Table 7. Continued. Preliminary results of hydroacoustics survey conducted at standard transects in Sapinero basin in Blue Mesa Reservoir during August 1-3, 1994. Fish density is corrected for bottom intrusion into the stratum.

Transect	Stratum (m)	Volume/ping	Pings	Targets	Average Target Strength (dB)	Number of fish/1000 m ³
DOW013	2-5	0.72	2586	2	-68.48	1.07
	5-10	5.51		1	-64.28	0.07
	10-15	15.30		5	-62.64	0.20
	15-20	30.00		31	-47.56	1.84
	20-25	49.60		138	-43.85	6.30
	25-30	74.10		71	-41.56	2.45
	30-35	103.5		14	-39.01	0.38
	35-40	138.00		3	-42.75	0.03
	40-45	177.00		0	--	0.00
	45-50	221.00		0	--	0.00
	50-60			0	--	0.00
	60-80			0	--	0.00
DOW014	2-5	0.72	2792	2	-65.02	0.99
	5-10	5.51		1	-65.57	0.07
	10-15	15.30		4	-56.82	0.28
	15-20	30.00		27	-47.63	1.36
	20-25	49.60		101	-43.78	4.28
	25-30	74.10		69	-41.63	2.42
	30-35	103.50		10	-40.98	0.27
	35-40	138.00		0	--	0.00
	40-45	177.00		1	-56.04	0.01
	45-50	221.00		0	--	0.00
	50-60			0	--	0.00
	60-80			0	--	0.00
DOW015	2-5	0.72	2652	6	-66.01	3.67
	5-10	5.51		3	-54.93	0.48
	10-15	15.30		2	-60.06	0.12
	15-20	30.00		14	-43.93	0.72
	20-25	49.60		53	-45.95	2.43
	25-30	74.10		36	-44.73	1.32
	30-35	103.50		8	-41.48	0.21
	35-40	138.00		0	--	0.00
	40-45	177.00		0	--	0.00
	45-50	221.00		0	--	0.00
	50-60			0	--	0.00
	60-80			0	--	0.00

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Conceptual figure depicting potential mechanisms linking reservoir operations to reservoir production and fish yield.

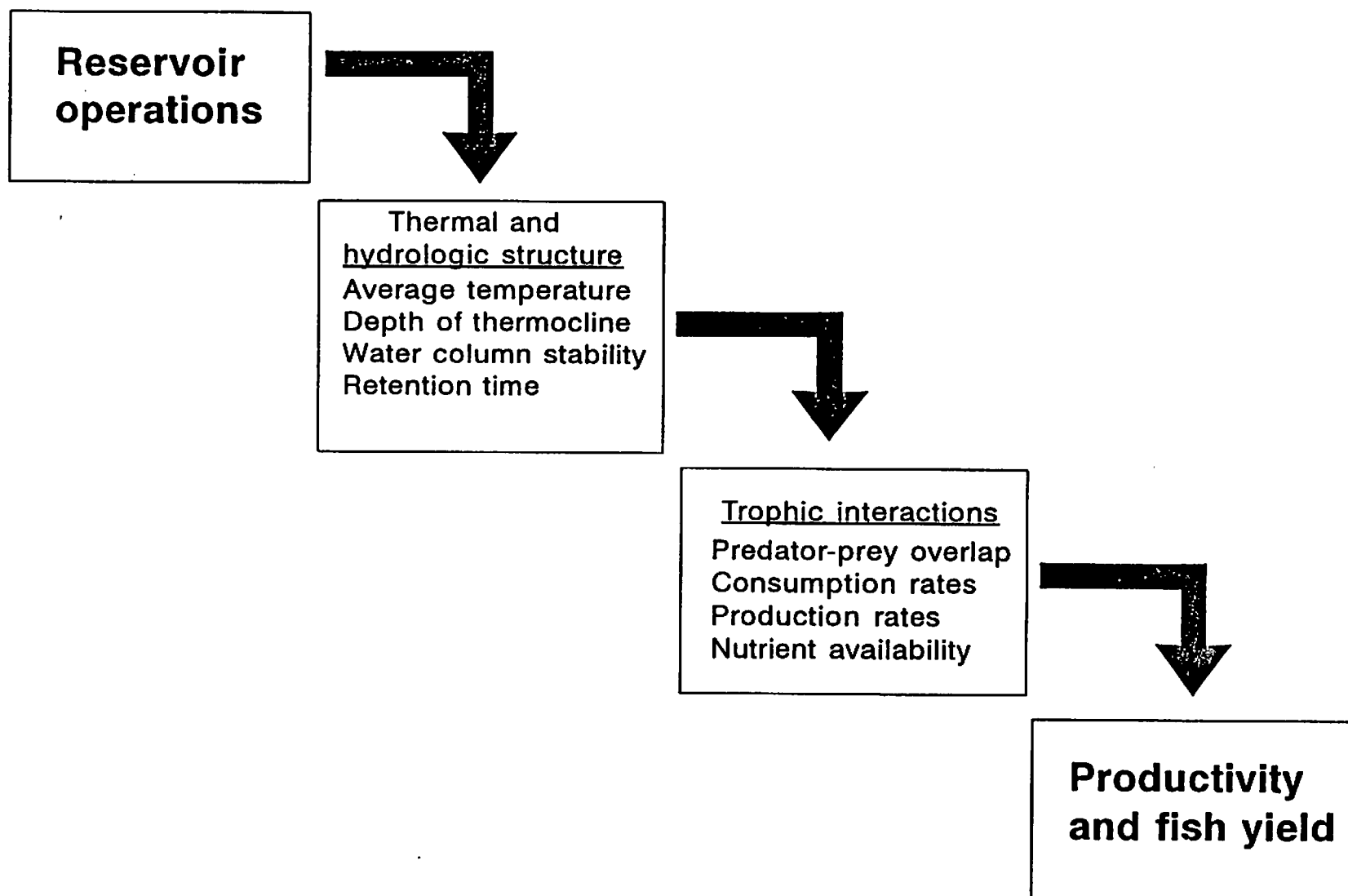


Figure 1.

Links between reservoir operations and sport fisheries

Figure 2.

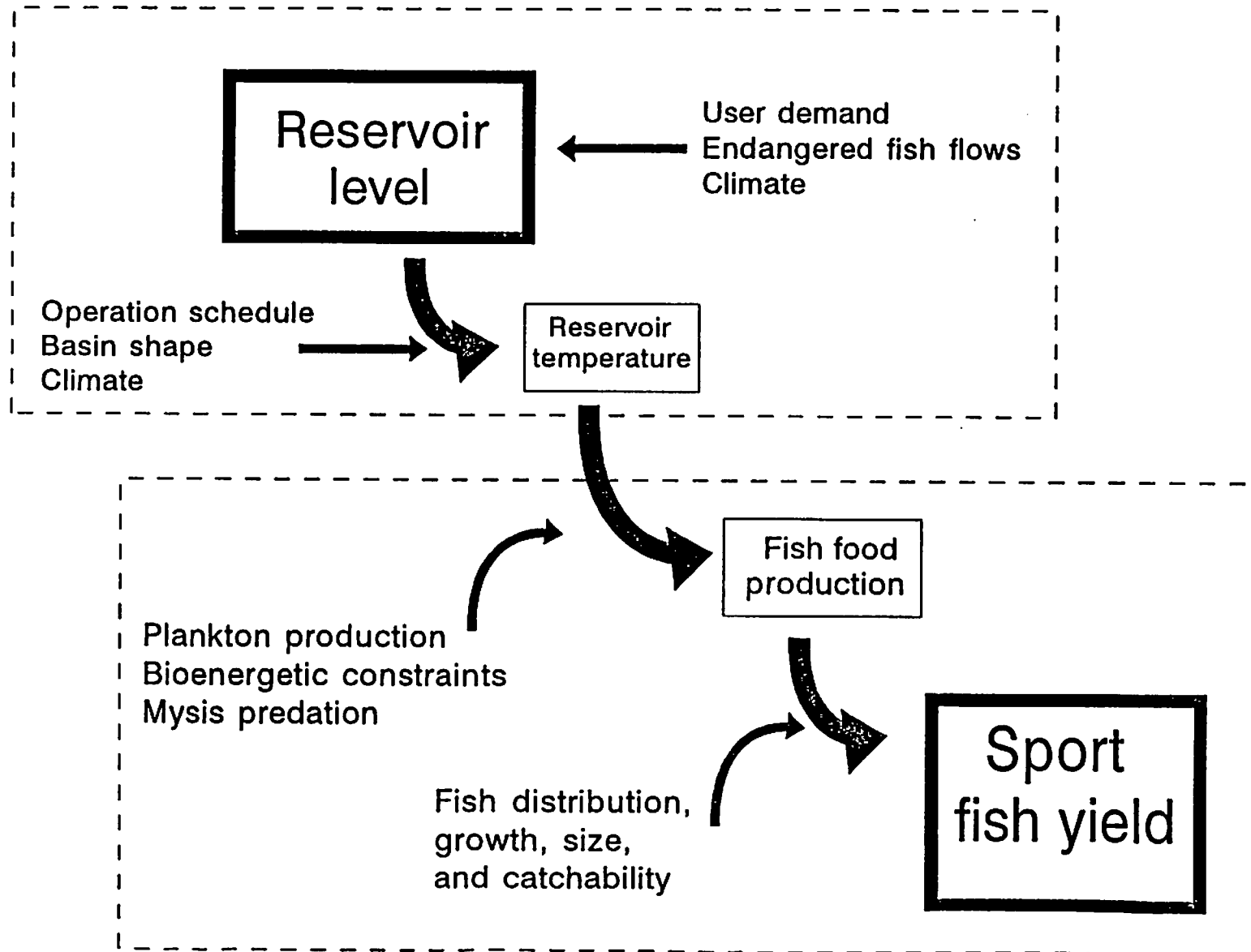
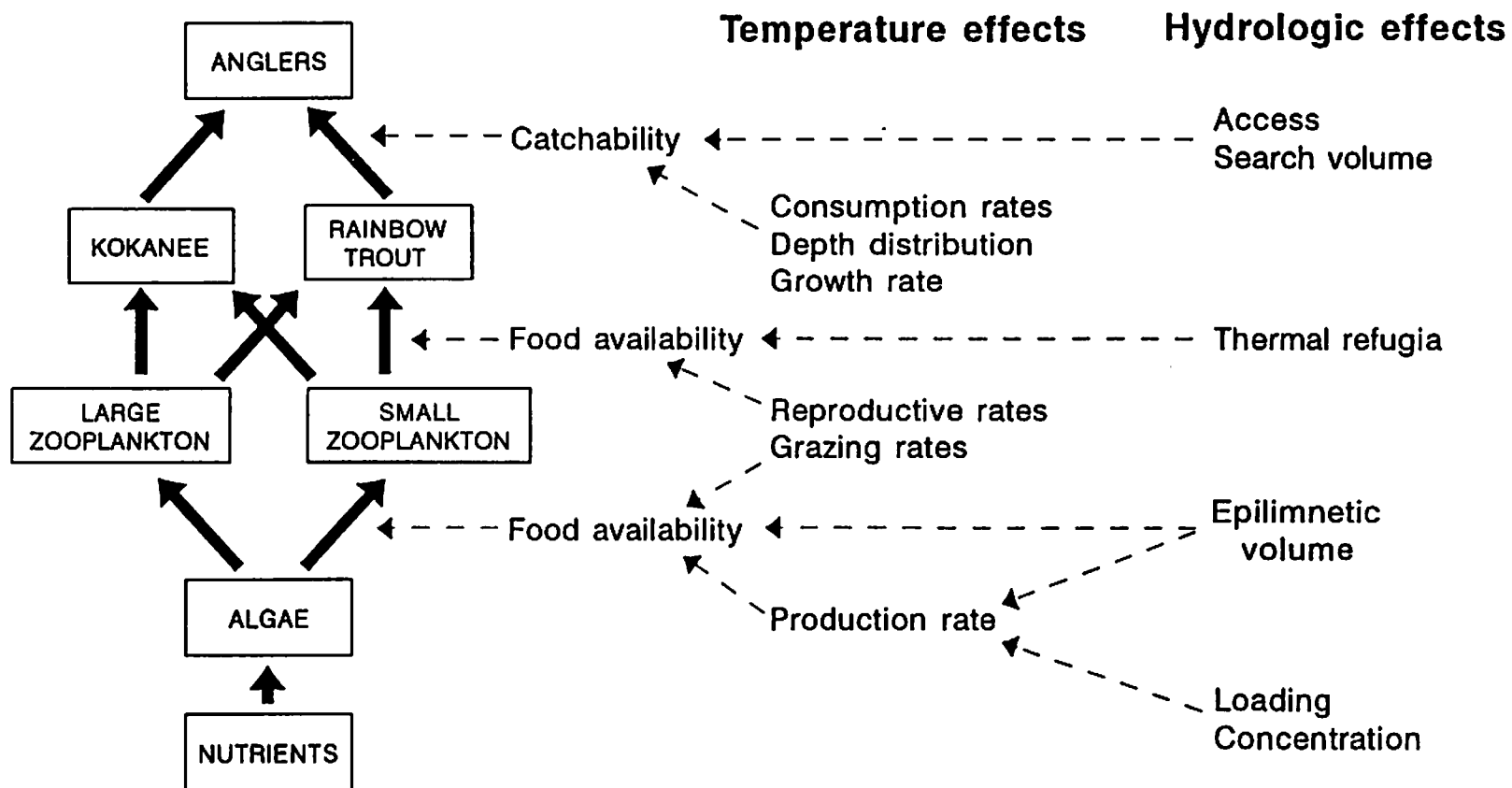


Figure 3.



Blue Mesa Reservoir

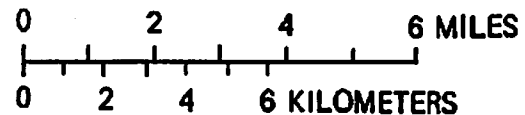
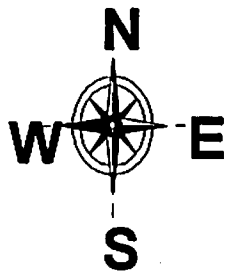
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W. Elk Arm

Gunnison
River

Lake Fork
Arm

Cebolla Arm

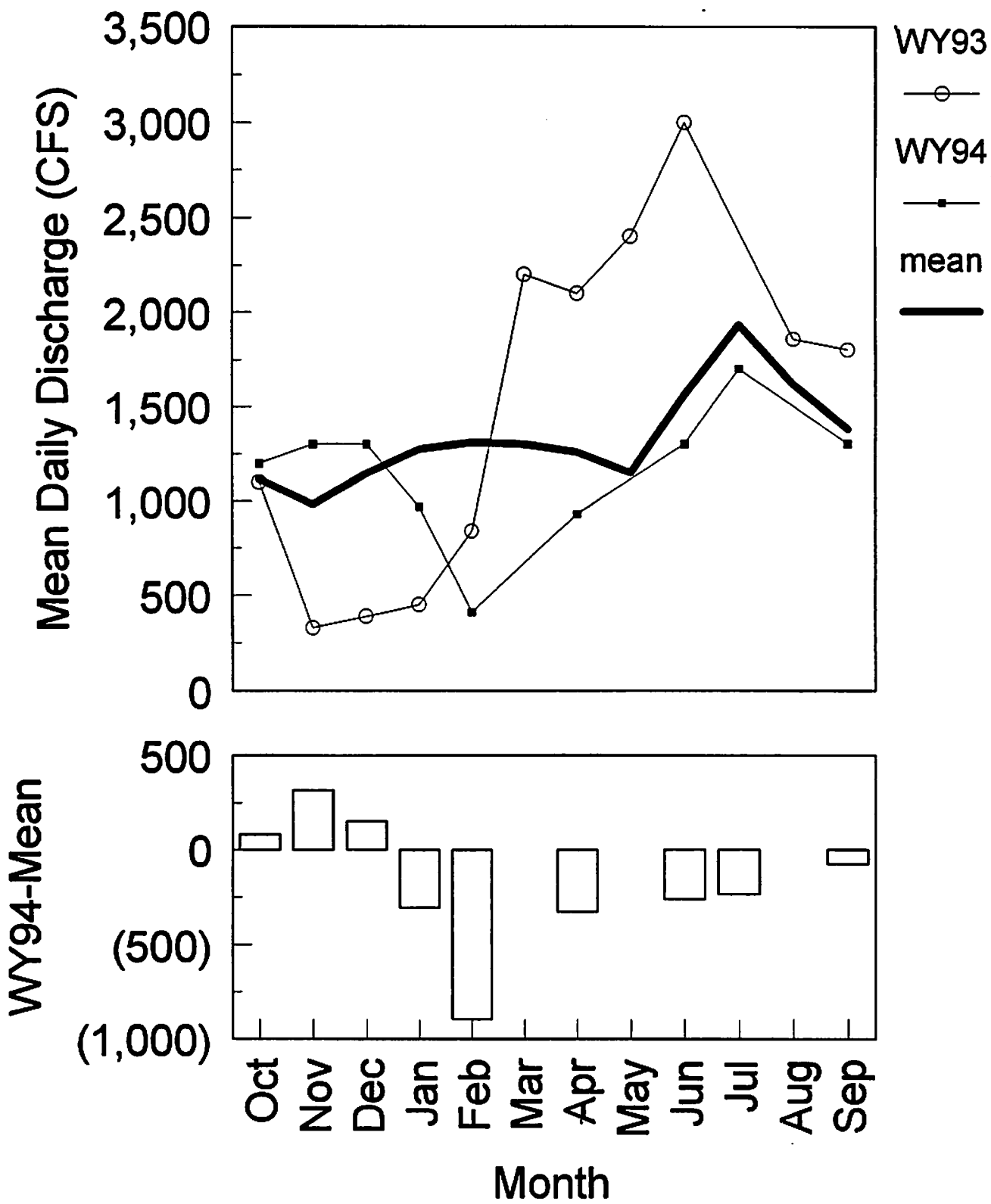


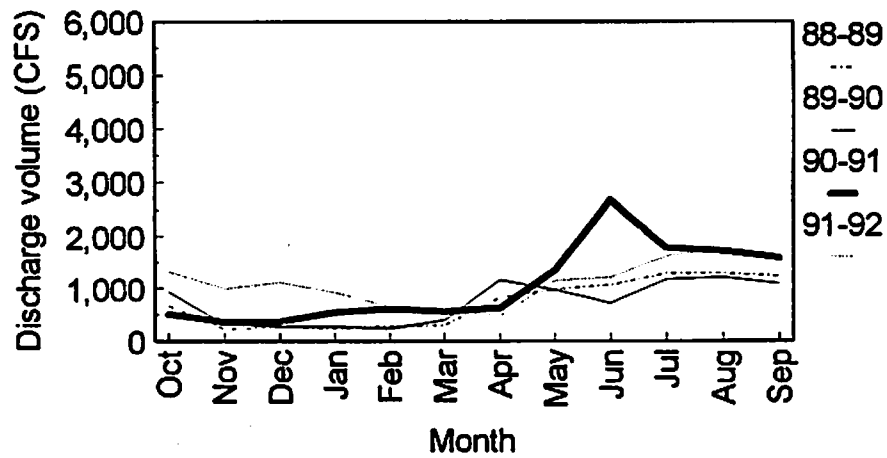
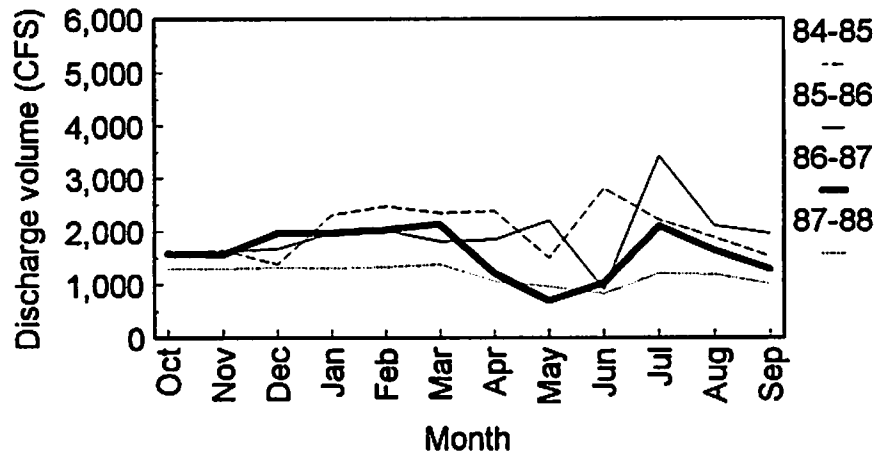
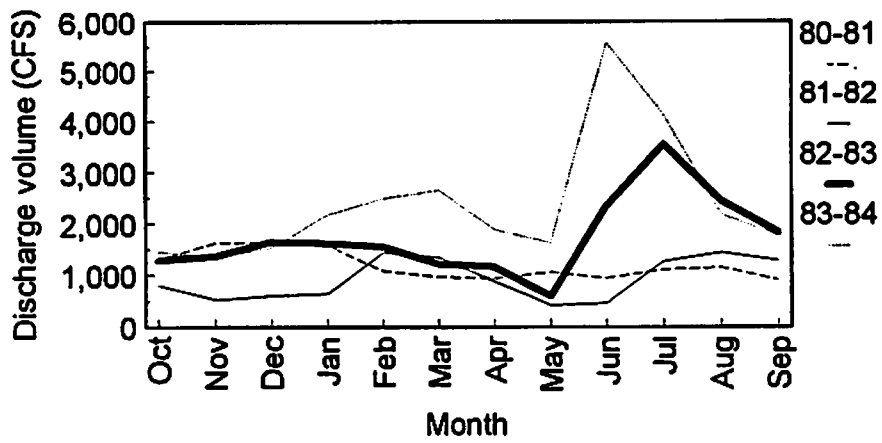
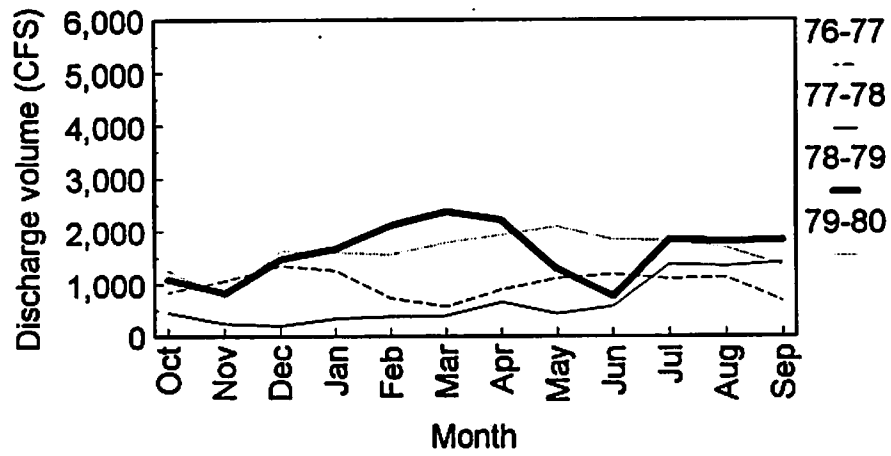
1994 Stations

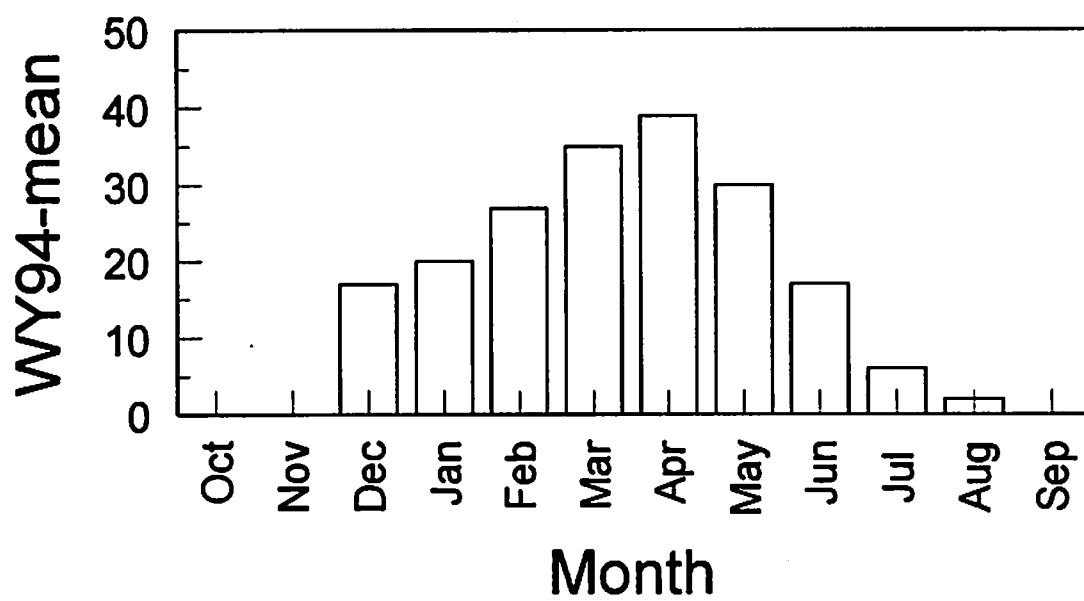
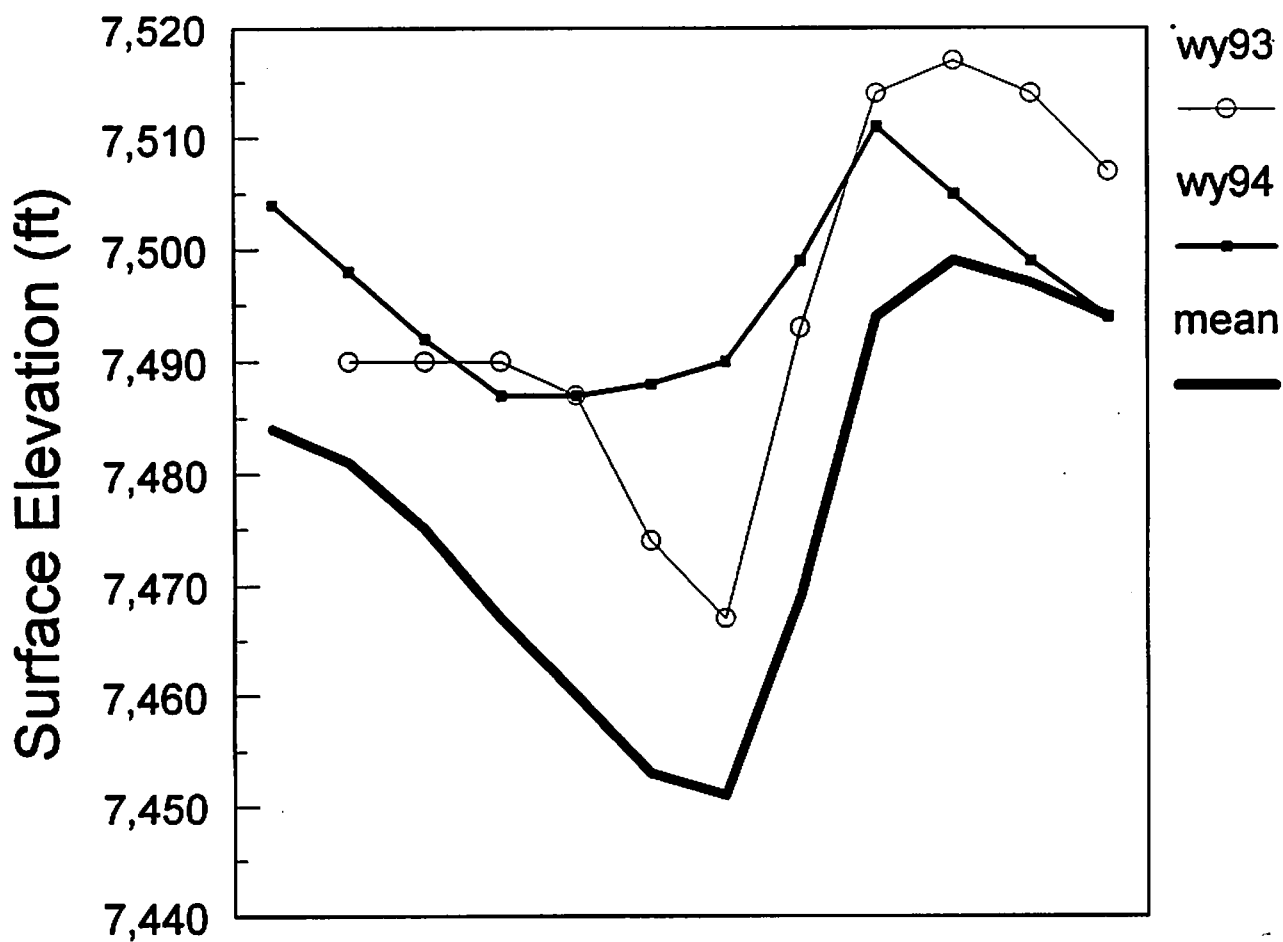
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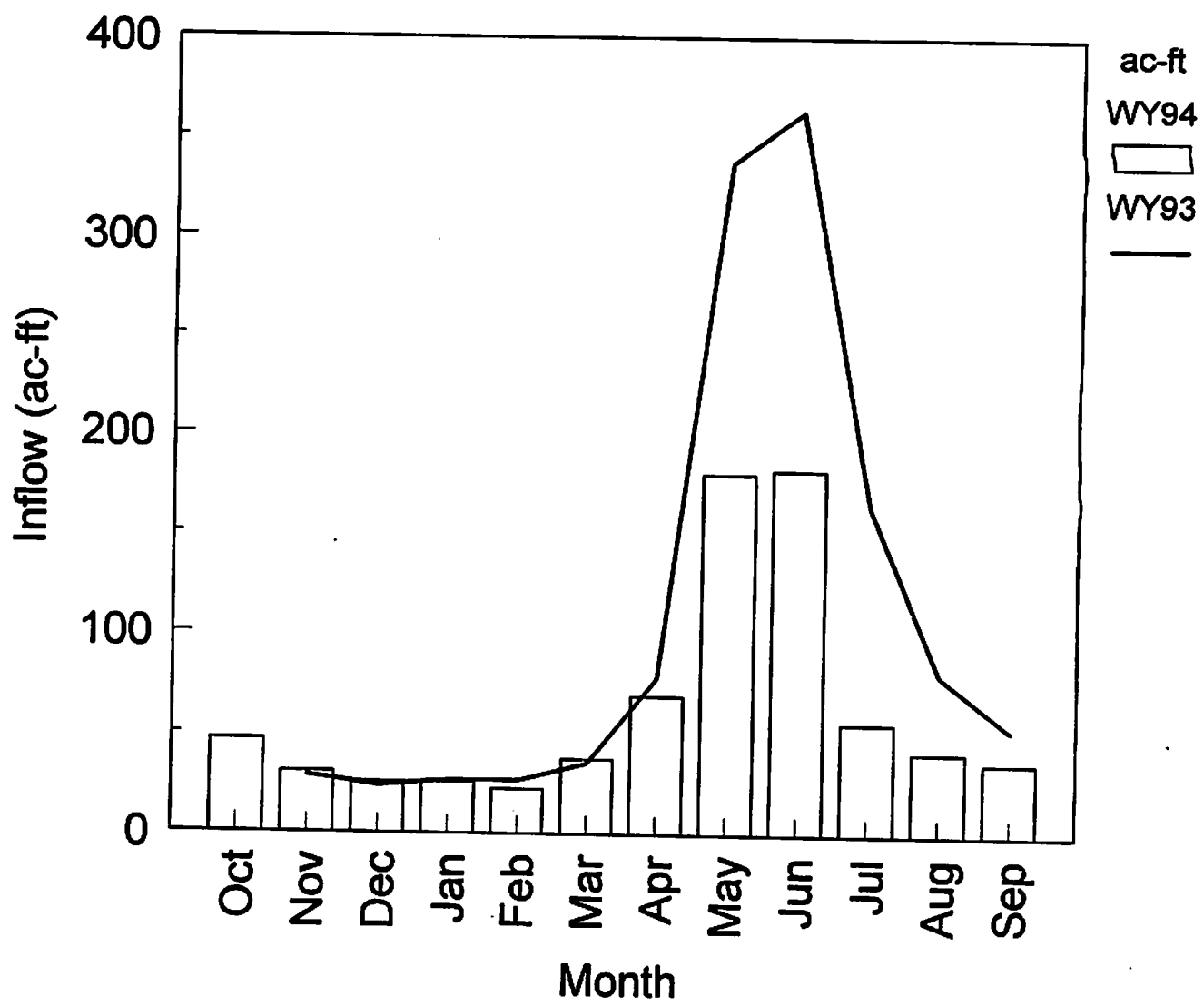
3= Cebolla basin

5= Iola basin

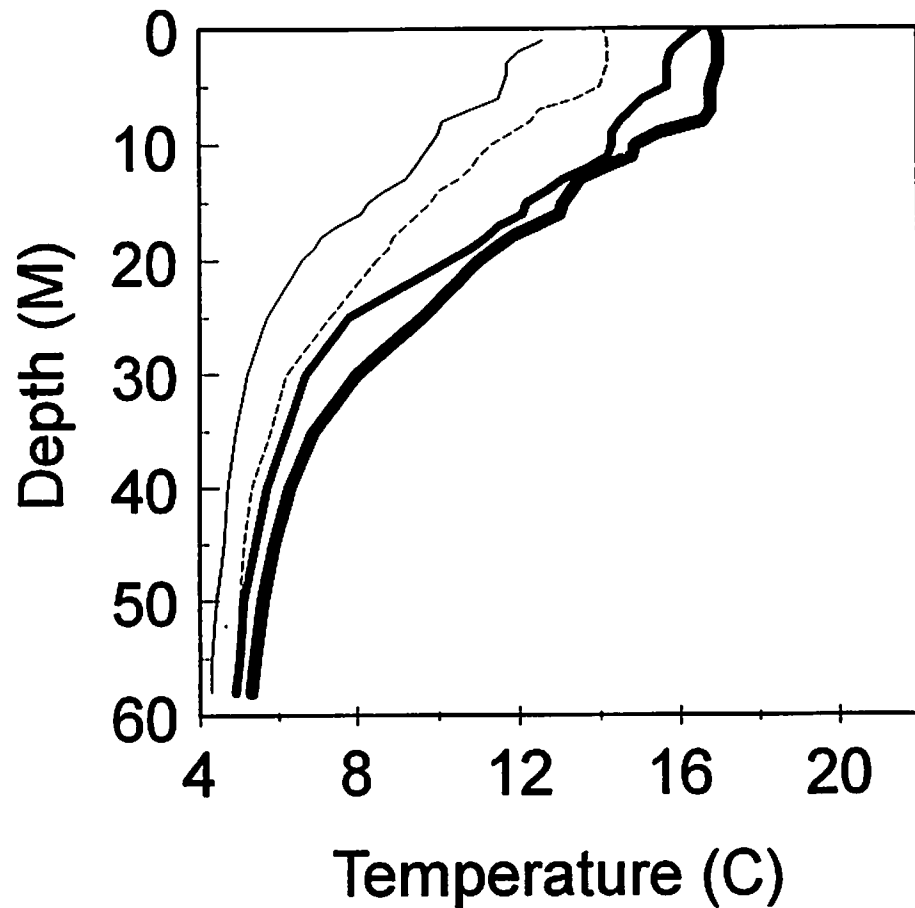






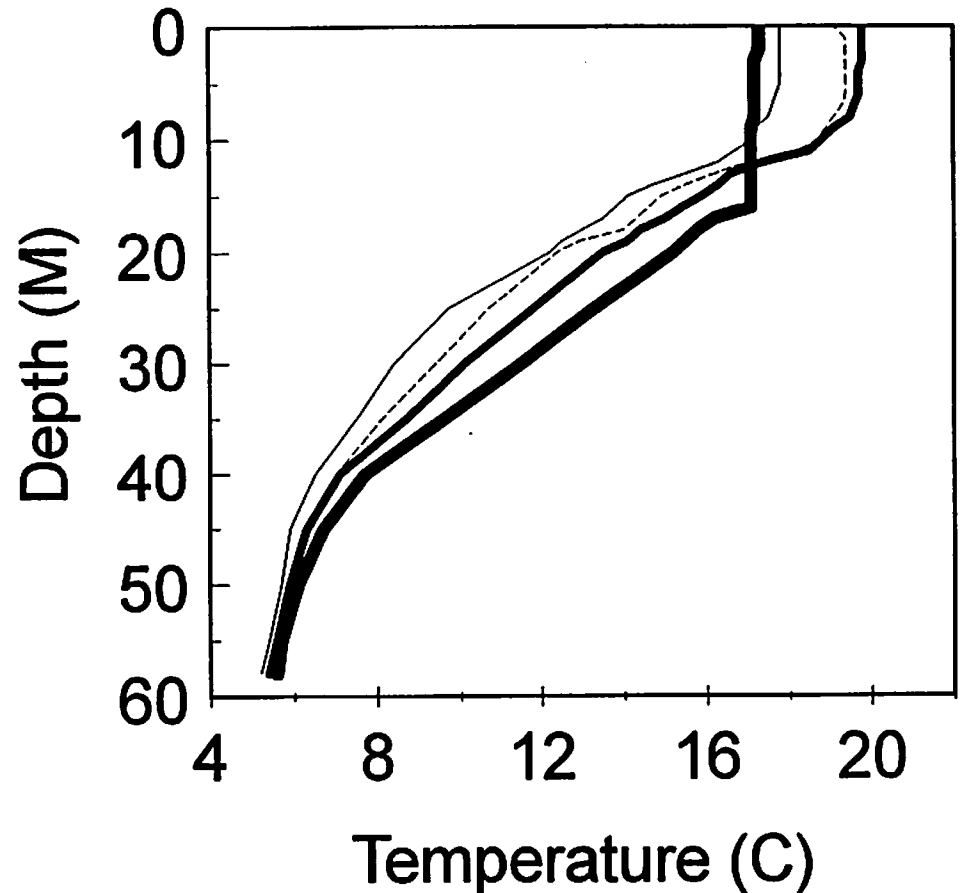


Station 1 - Sapinero



May 24 June 9 June 22 July 7

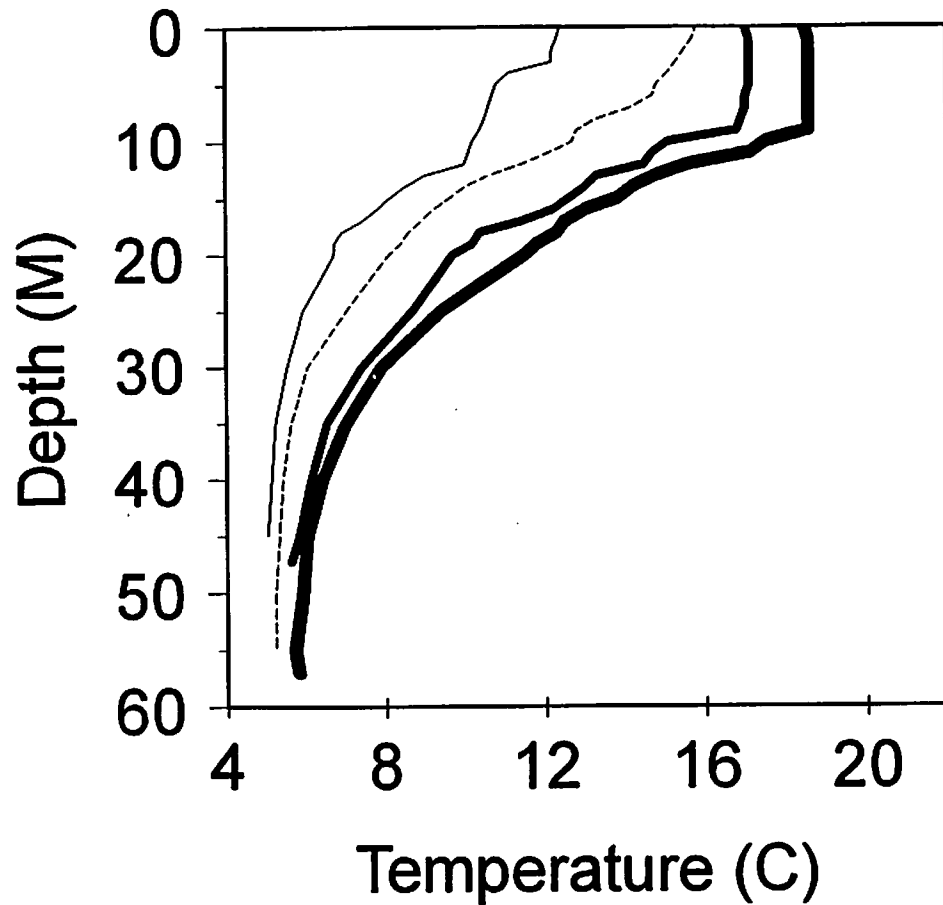
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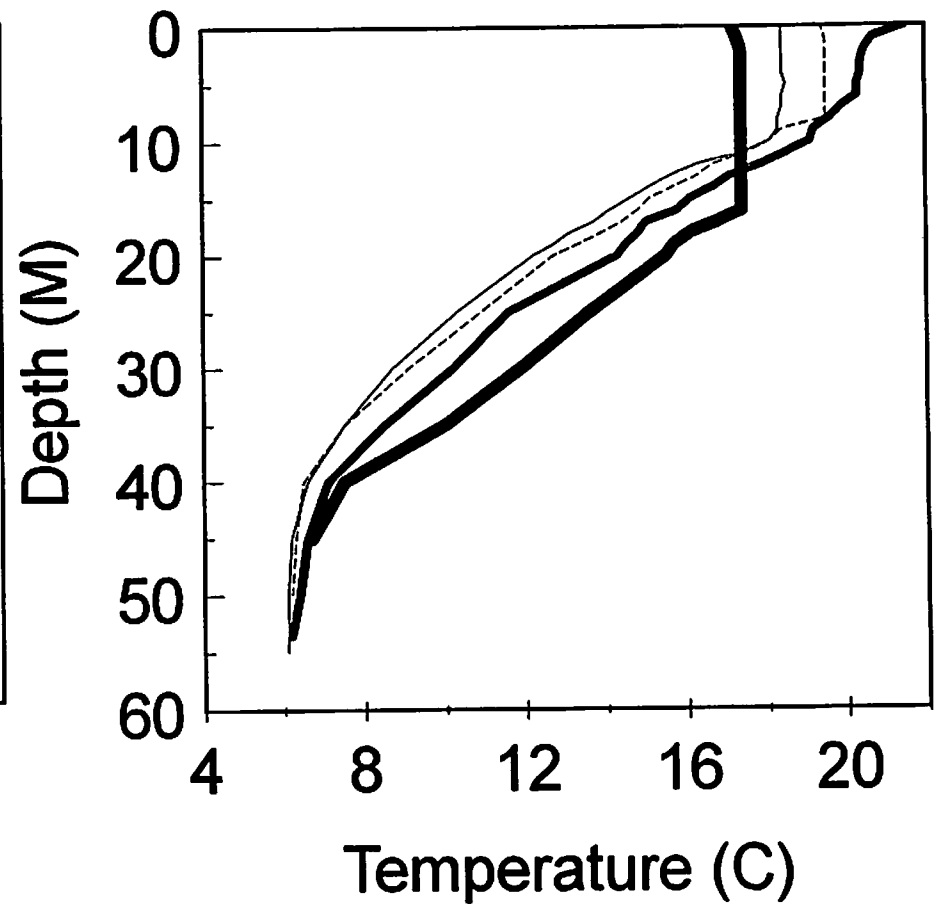
July 21 Aug 1 Aug 18 Sept 16

— - - - — —

Station 3 - Cebolla

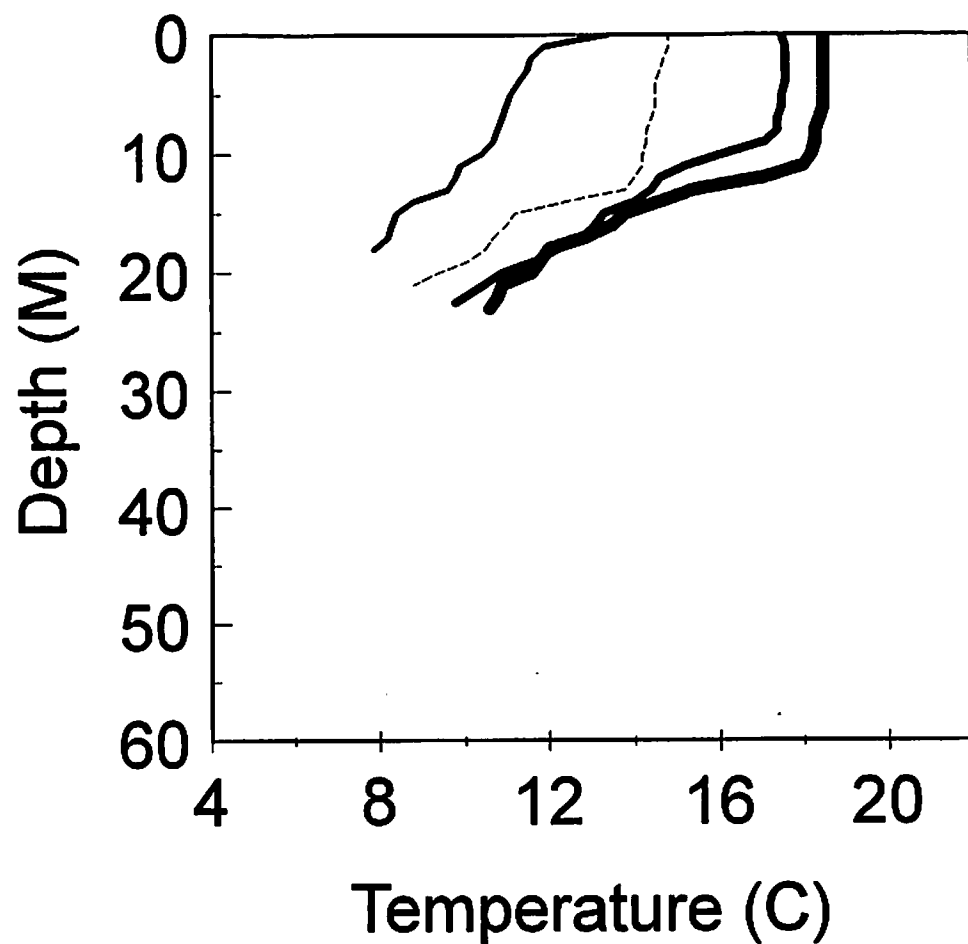


May 23 June 6 June 23 July 5



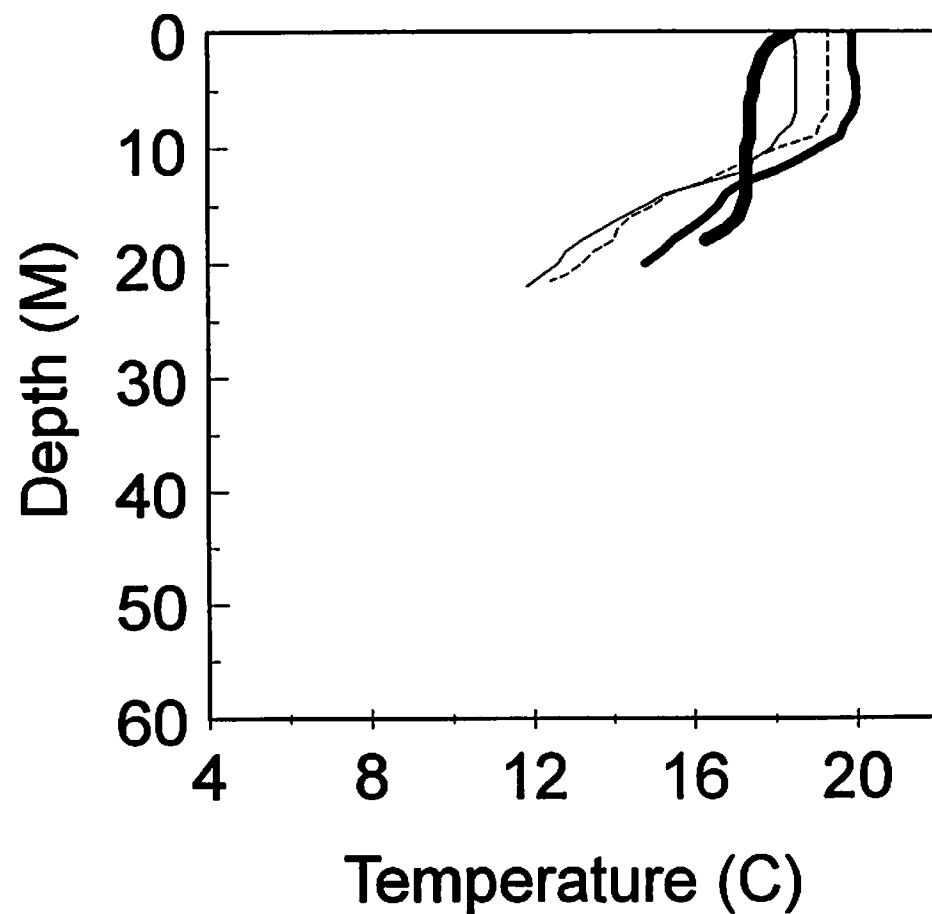
July 18 July 30 Aug 14 Sept 17

Station 5 - Iola



May 23 June 5 June 24 July 6

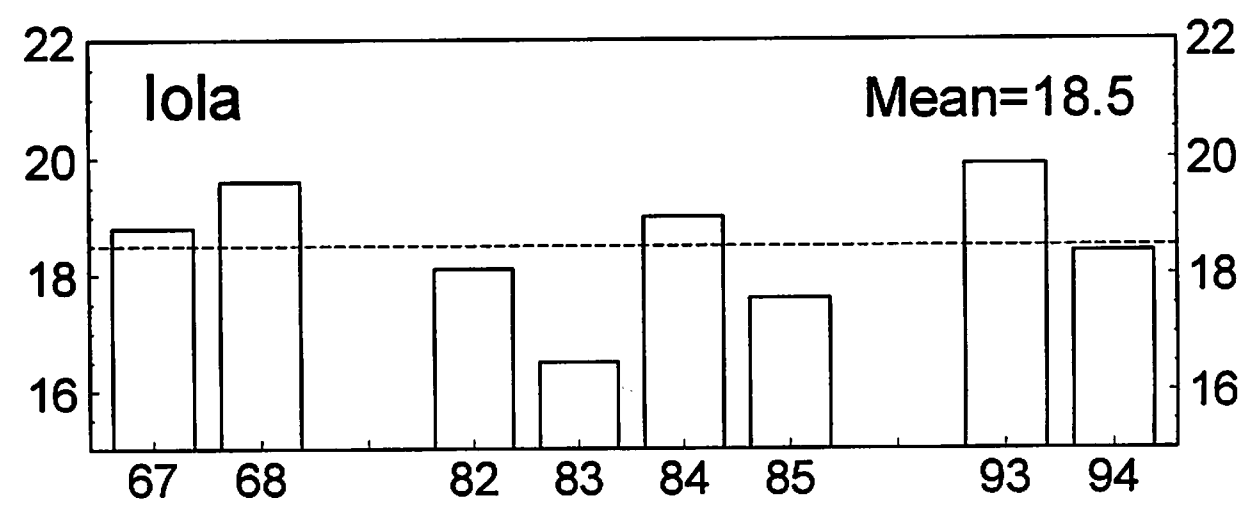
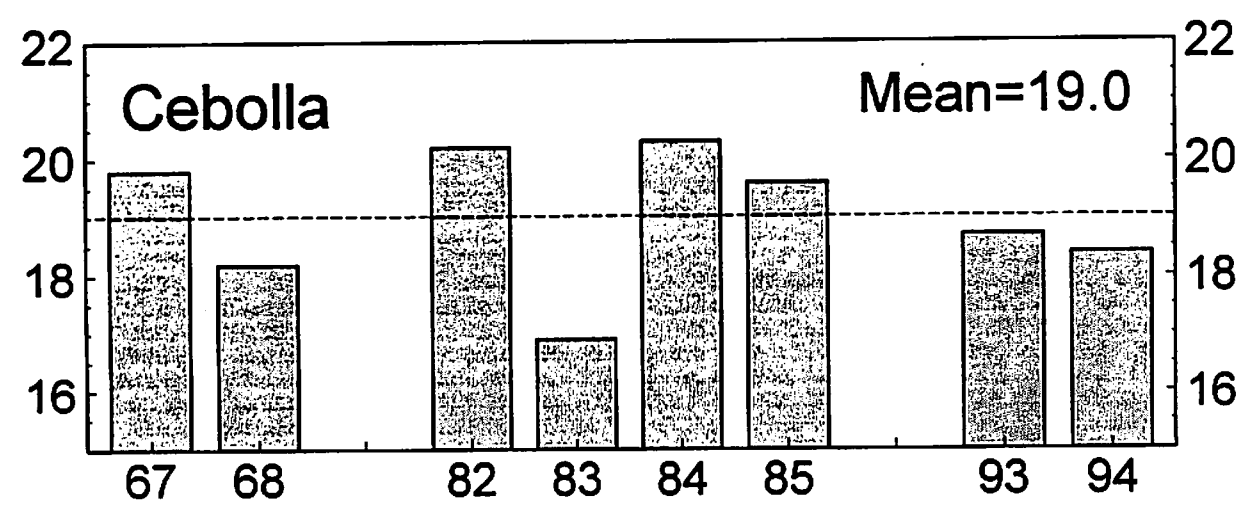
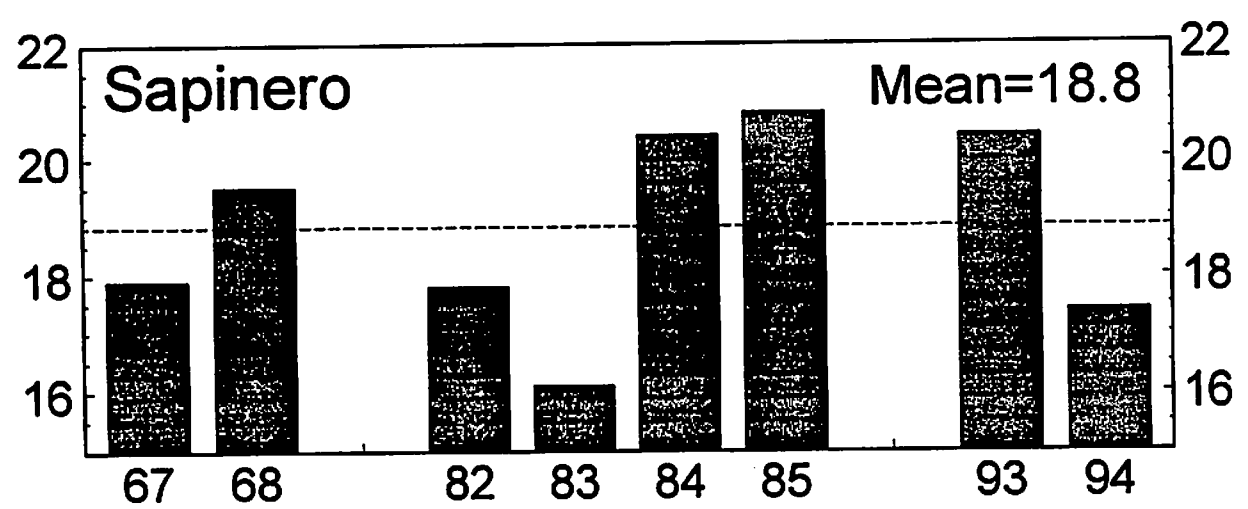
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July 20 July 31 Aug 17 Sept 17

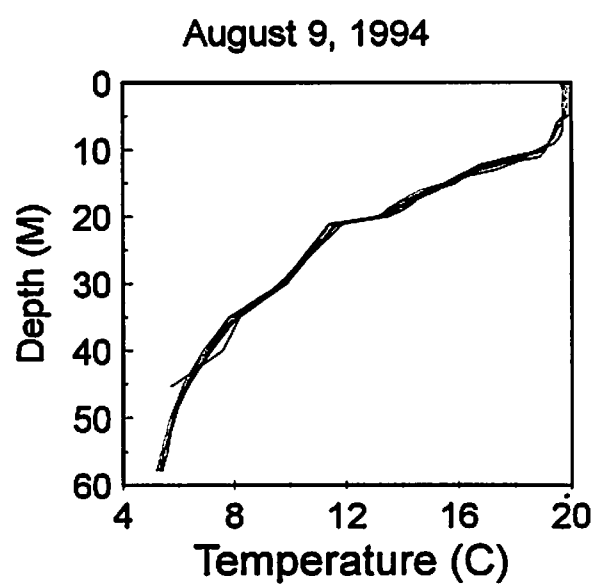
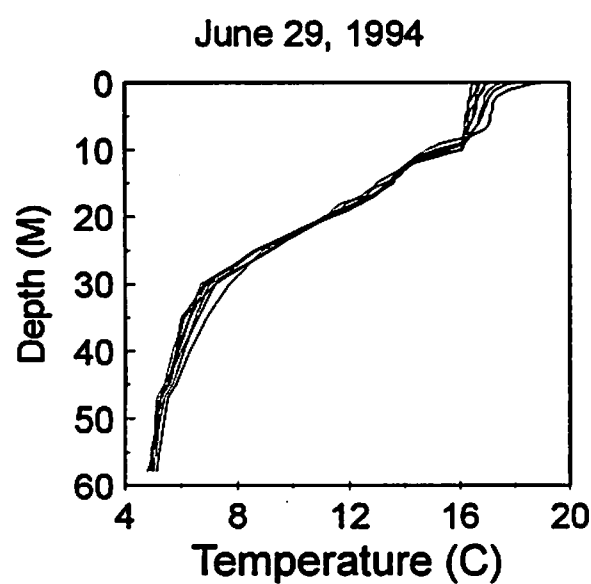
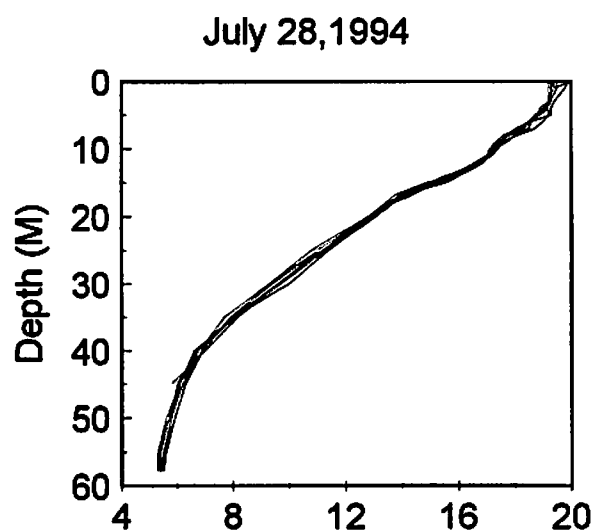
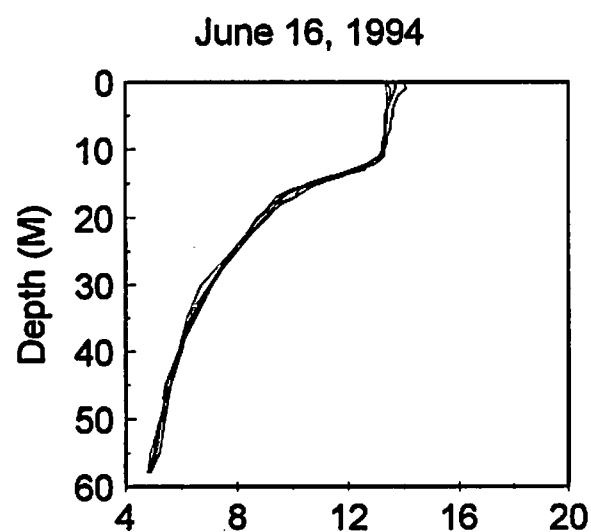
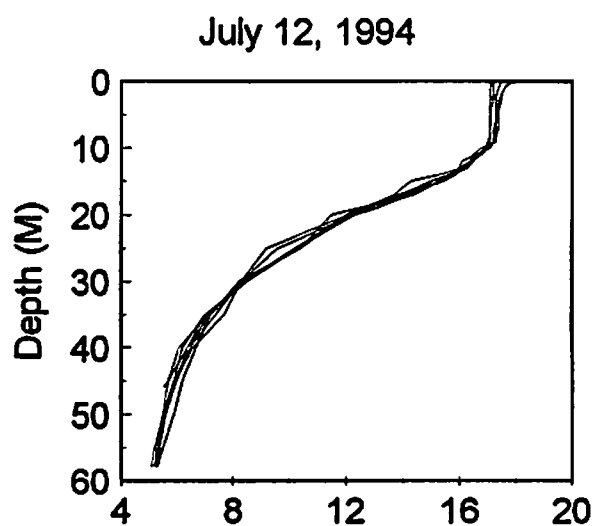
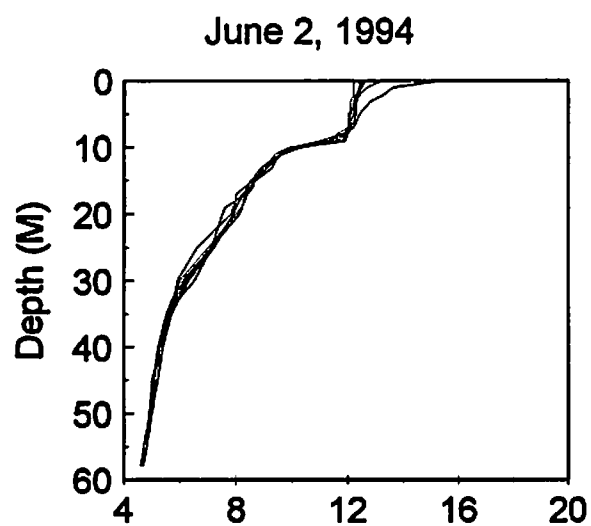
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Temperature (C)



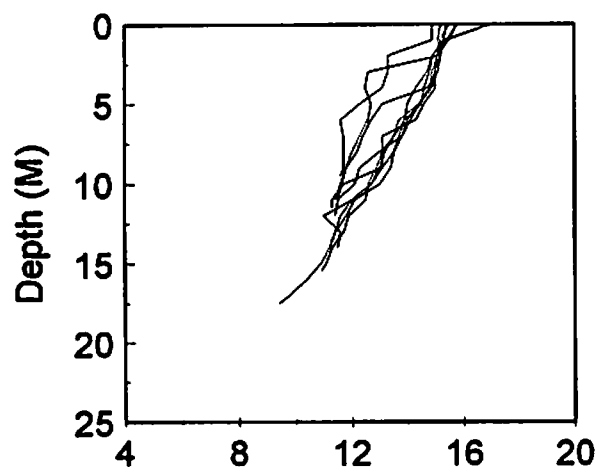
Year

Sapinero Basin

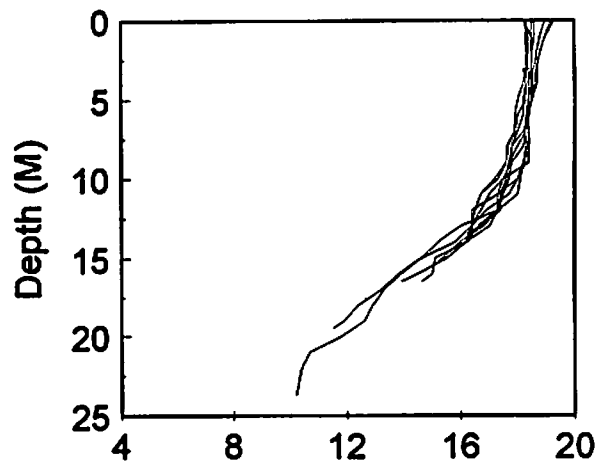


Iola Basin

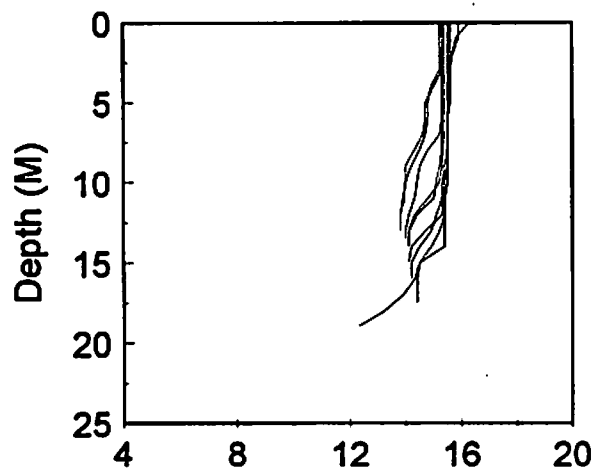
June 3, 1994



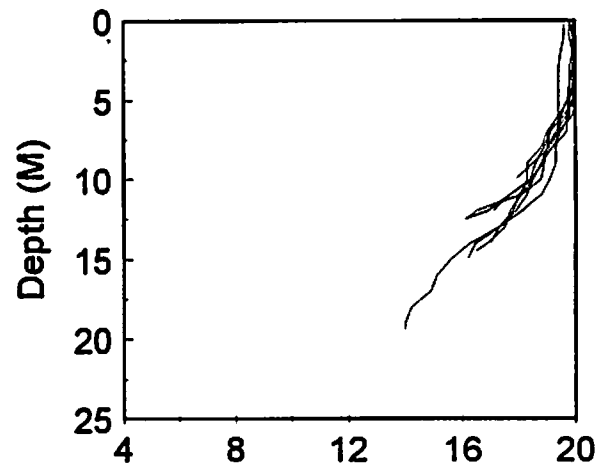
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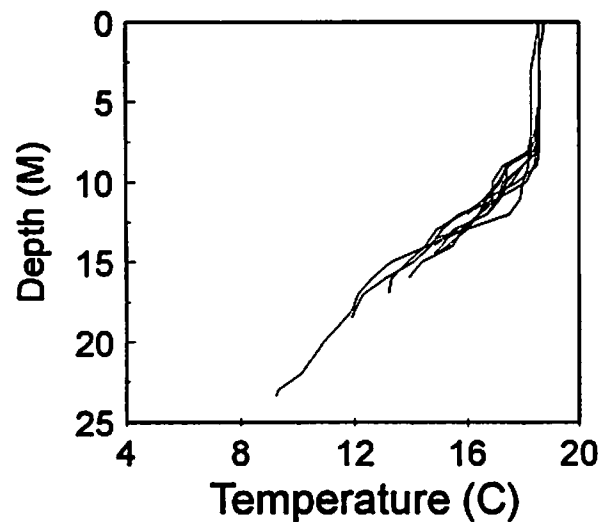
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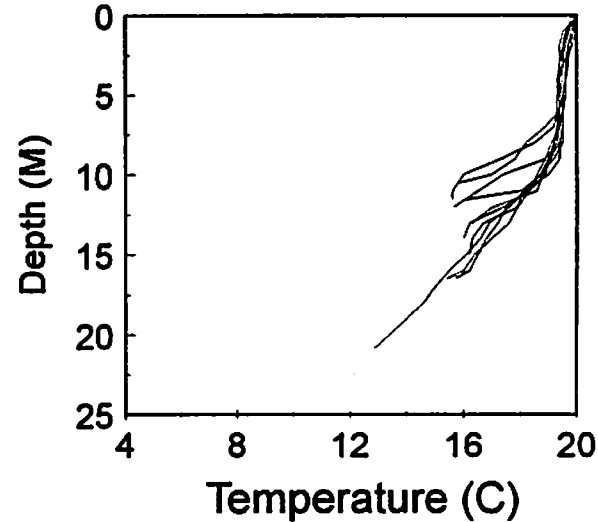
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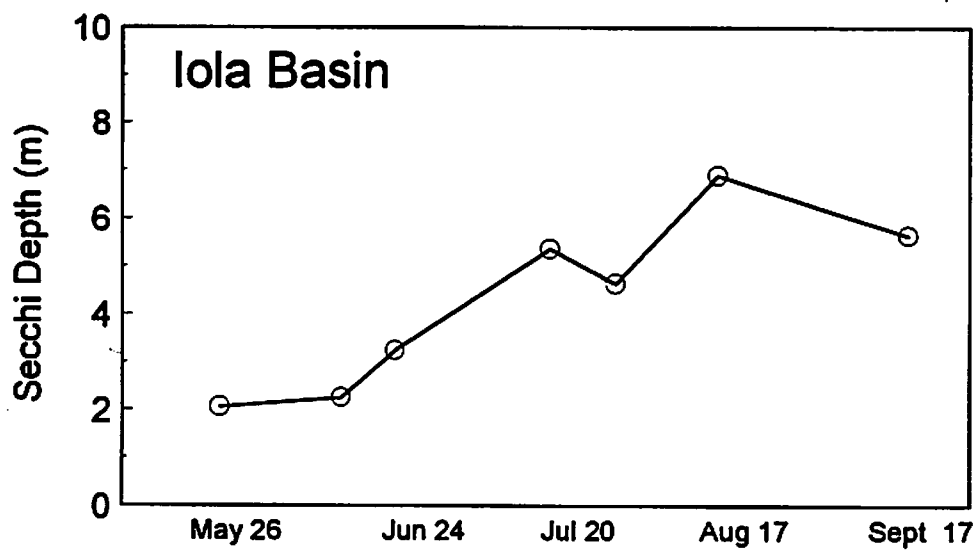
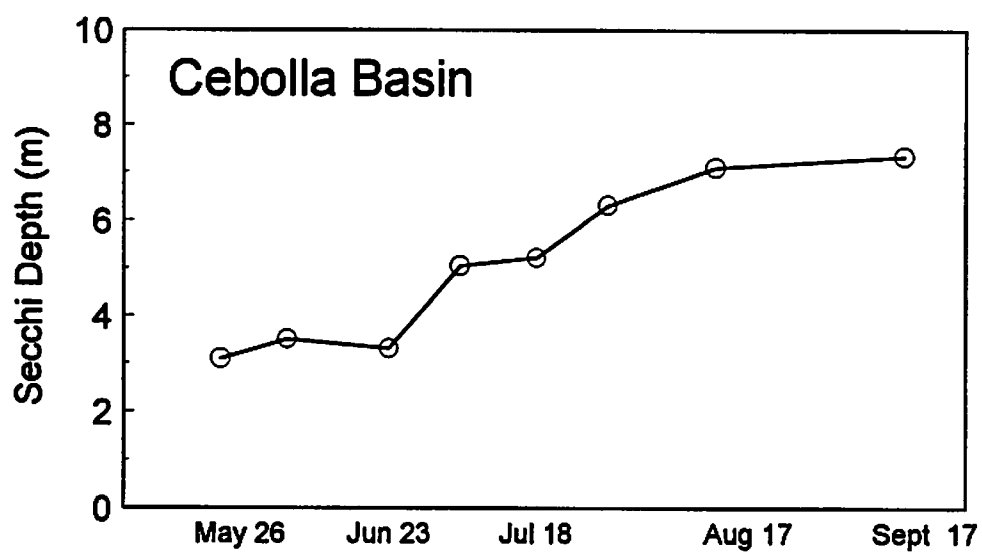
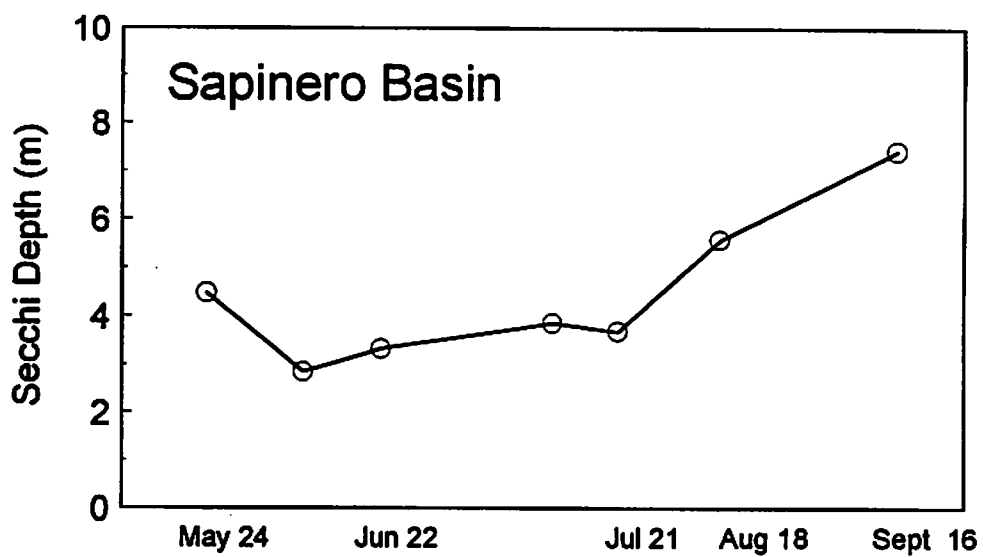


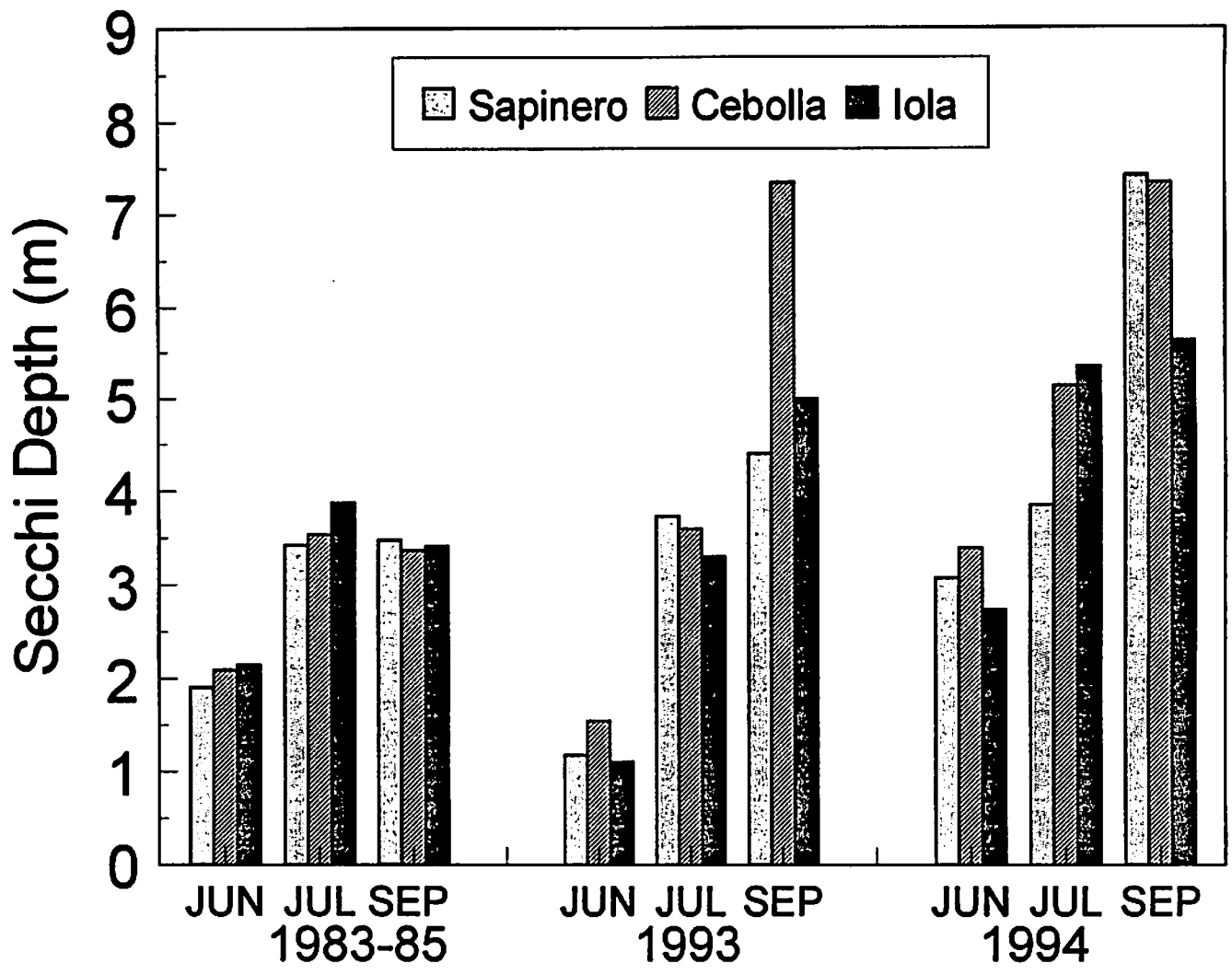
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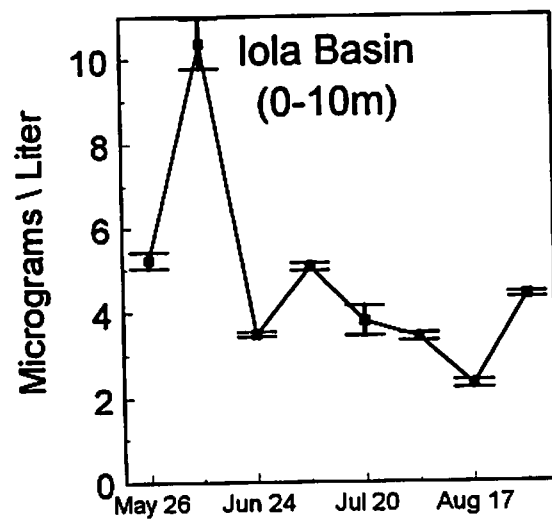
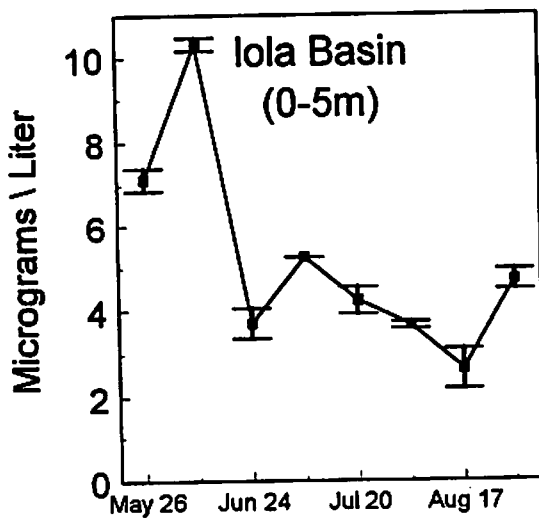
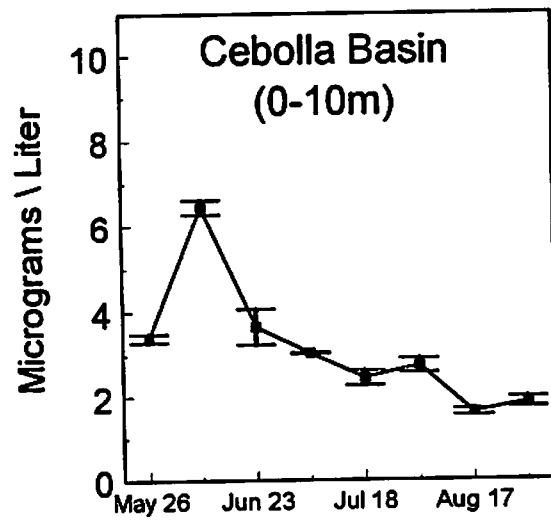
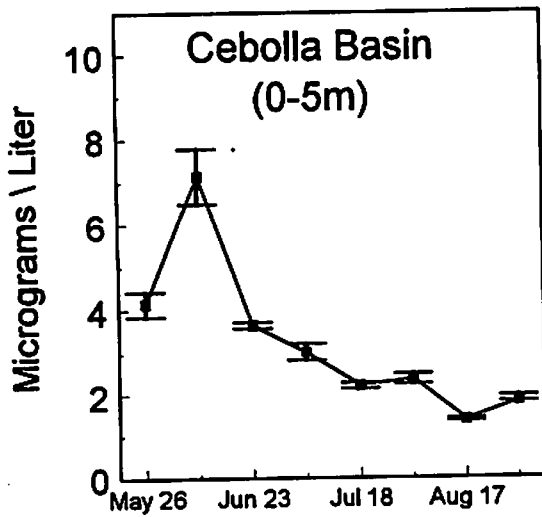
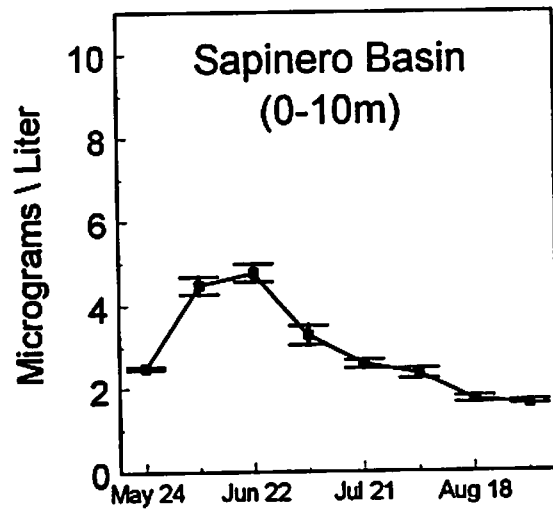
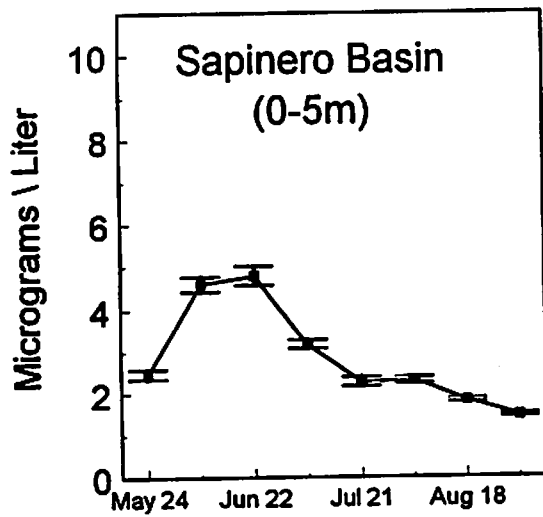


August 9, 1994



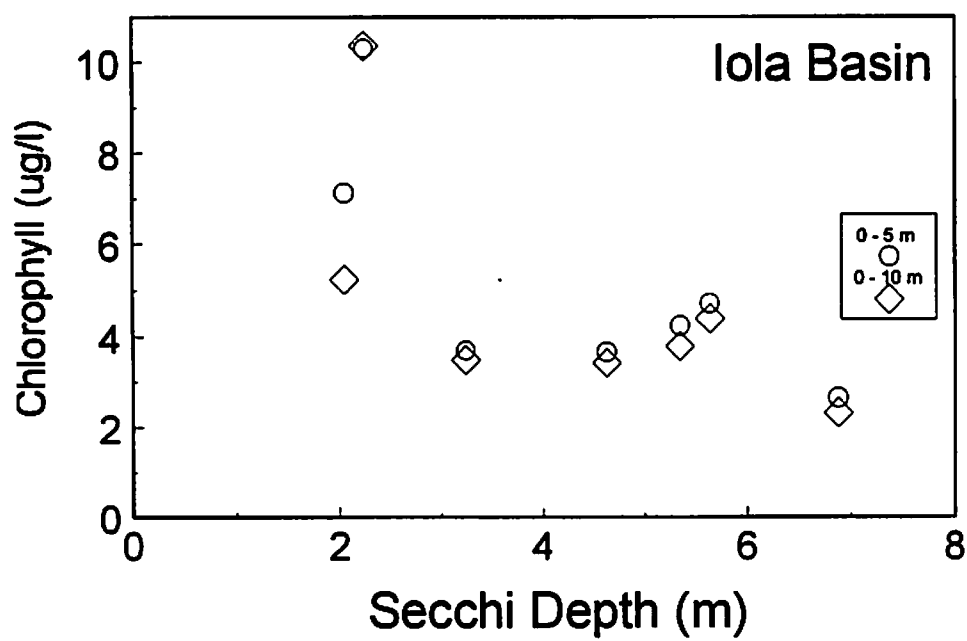
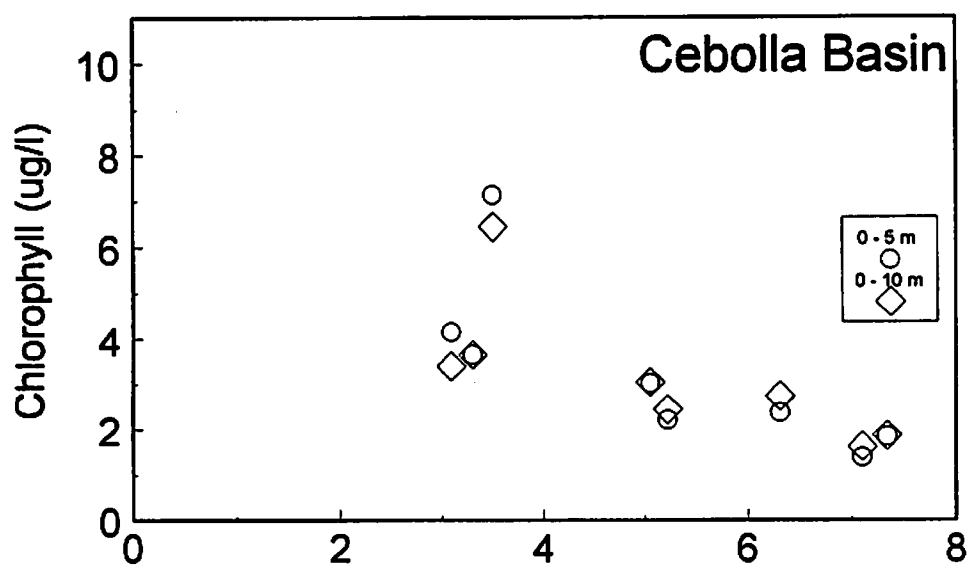
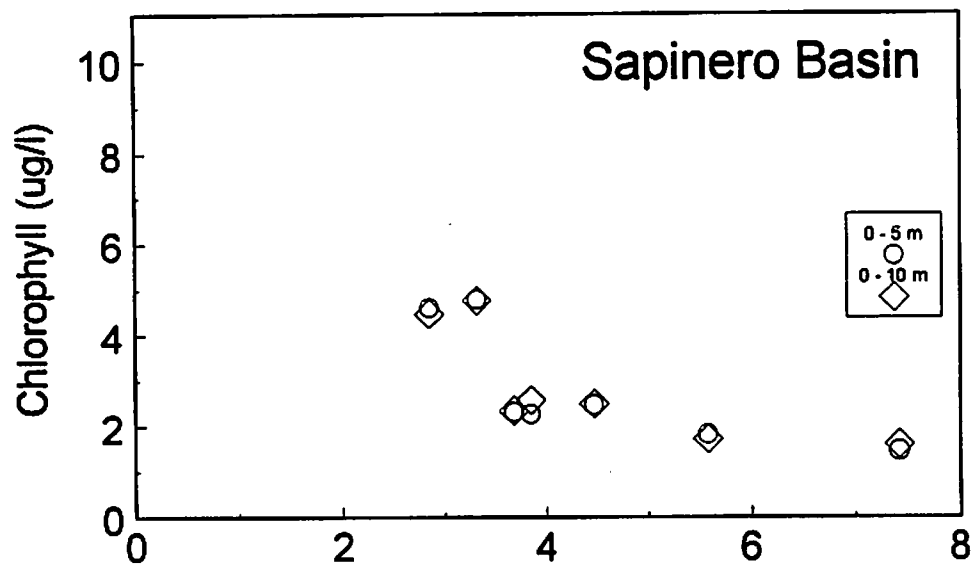






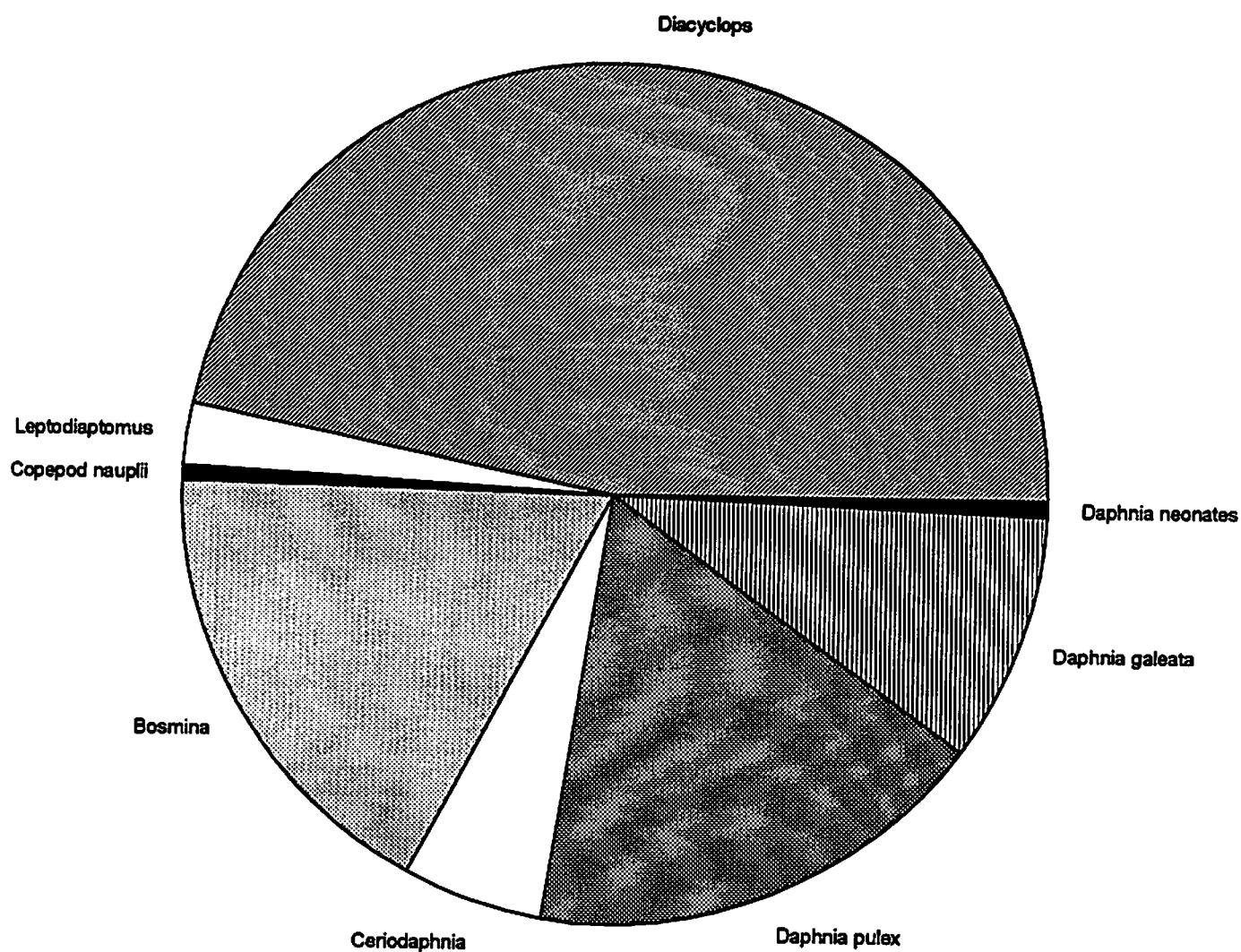
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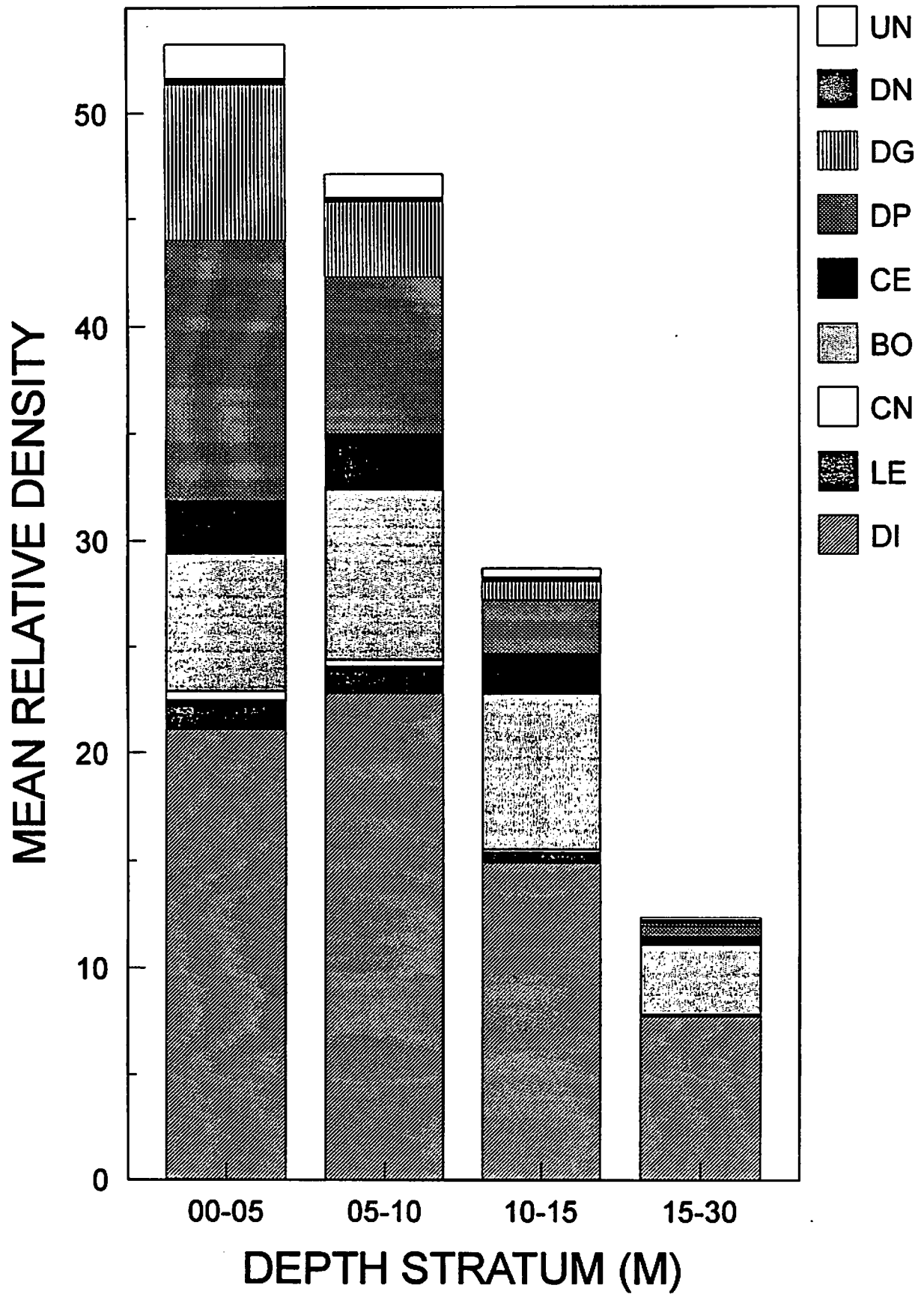
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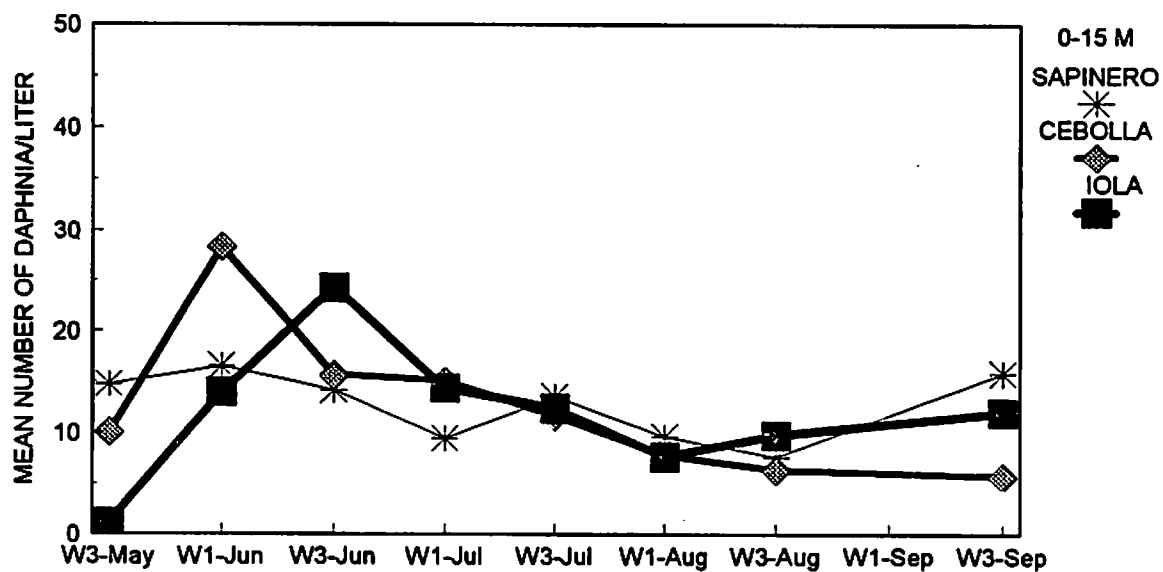
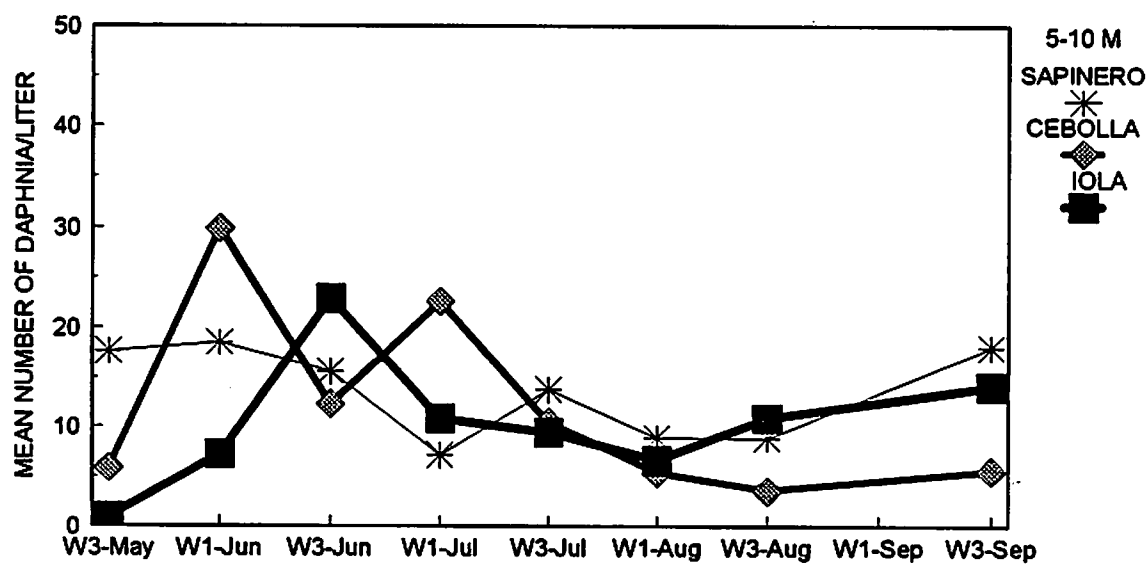
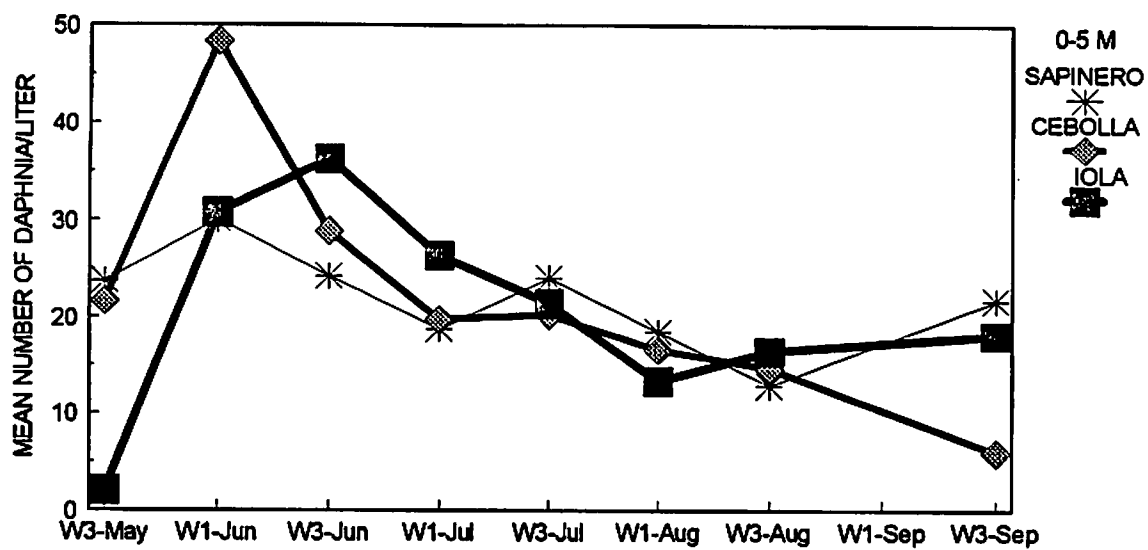


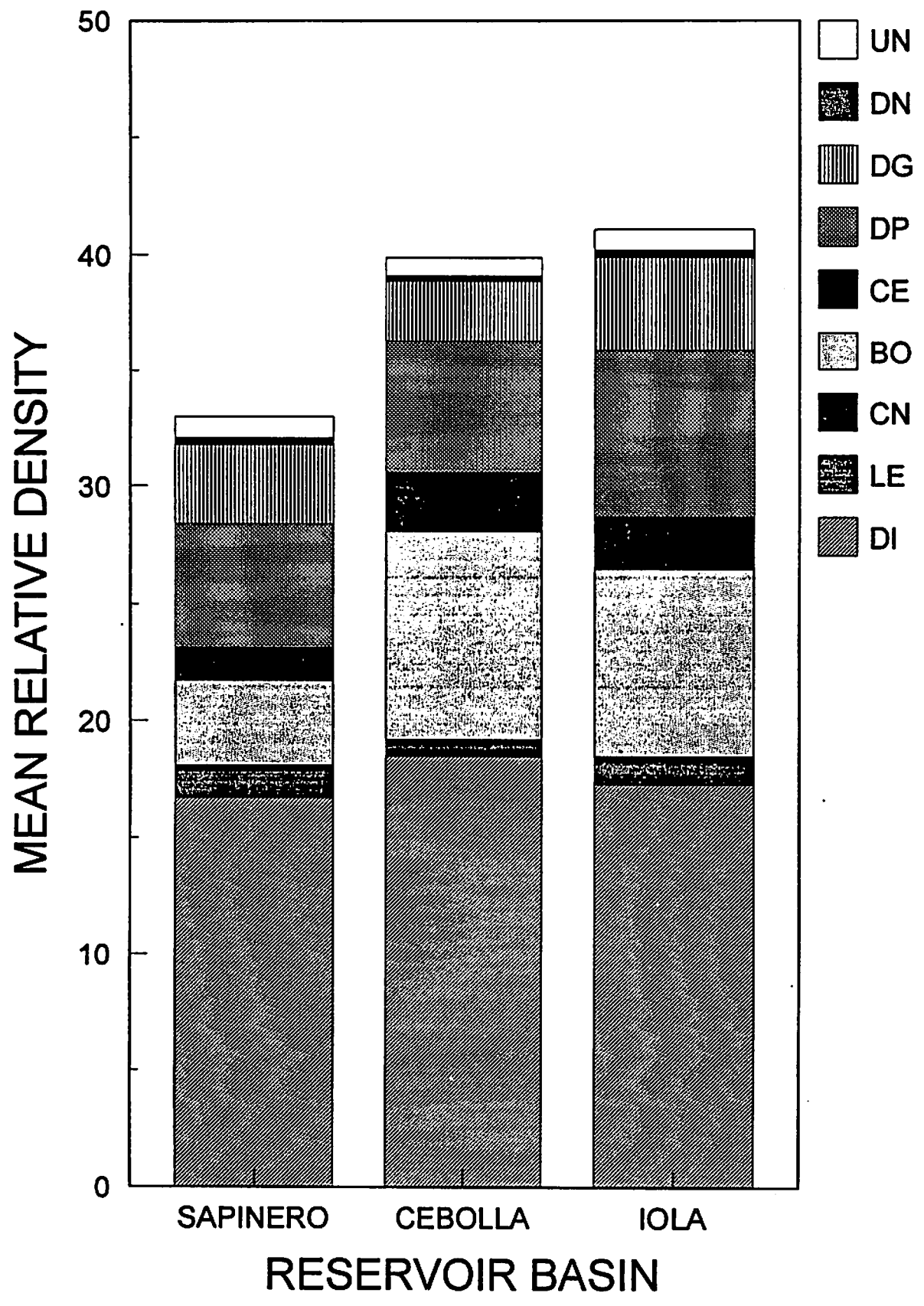
Zooplankton Community Composition

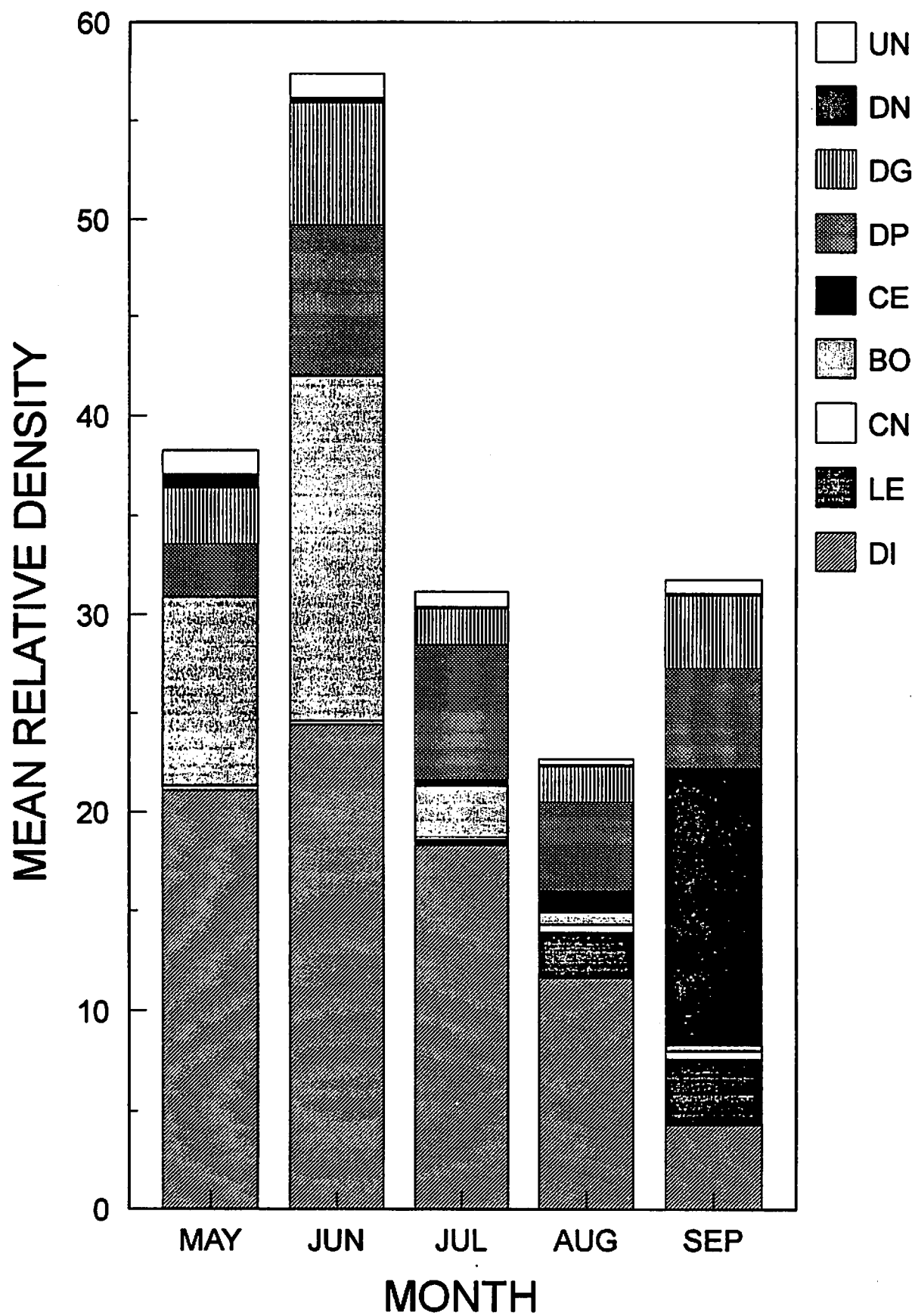
All dates, basins, depths



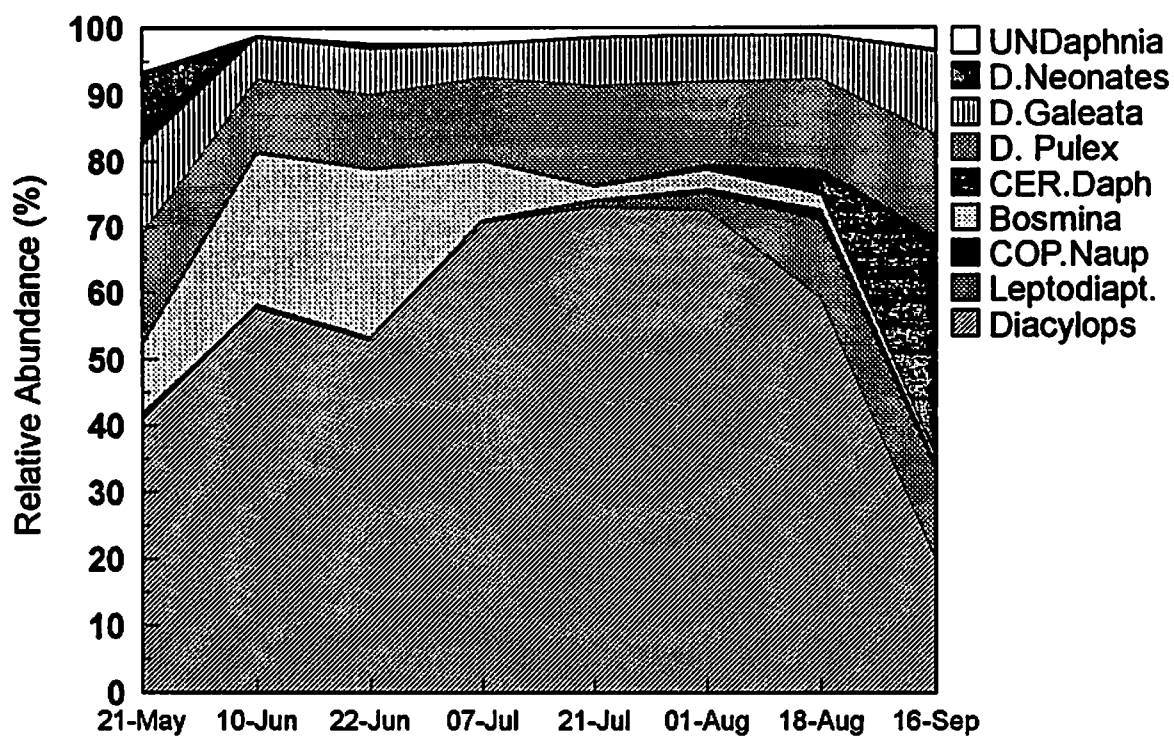




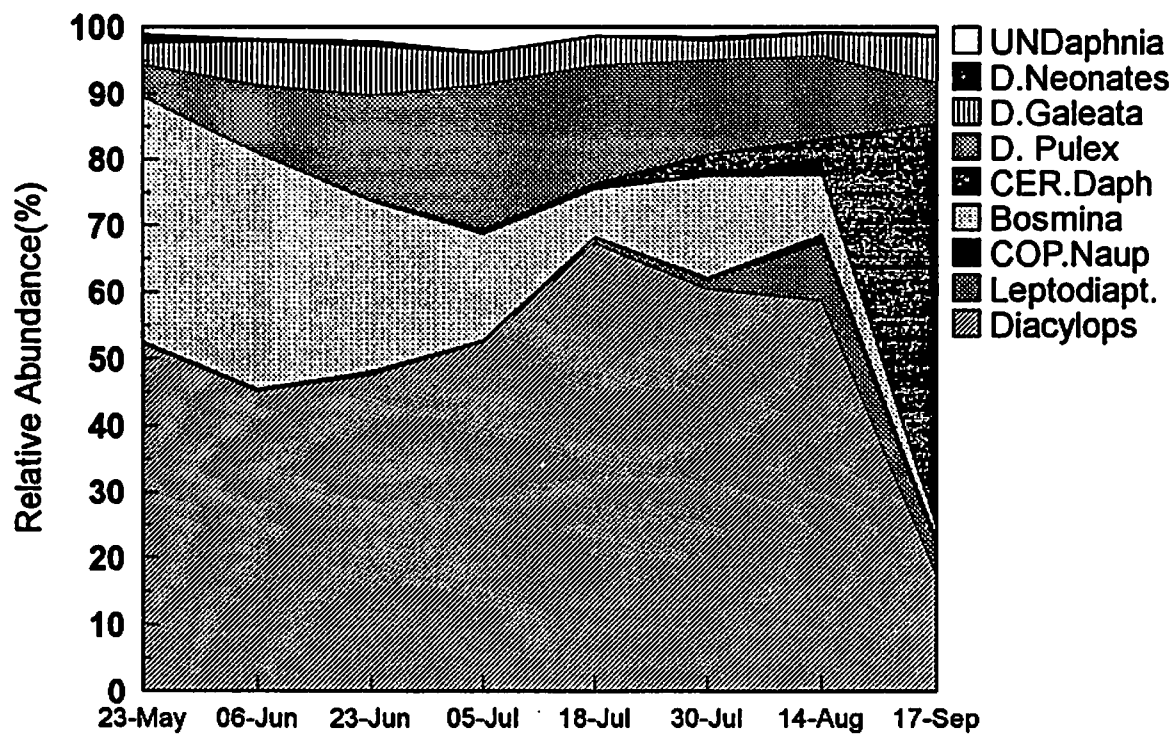


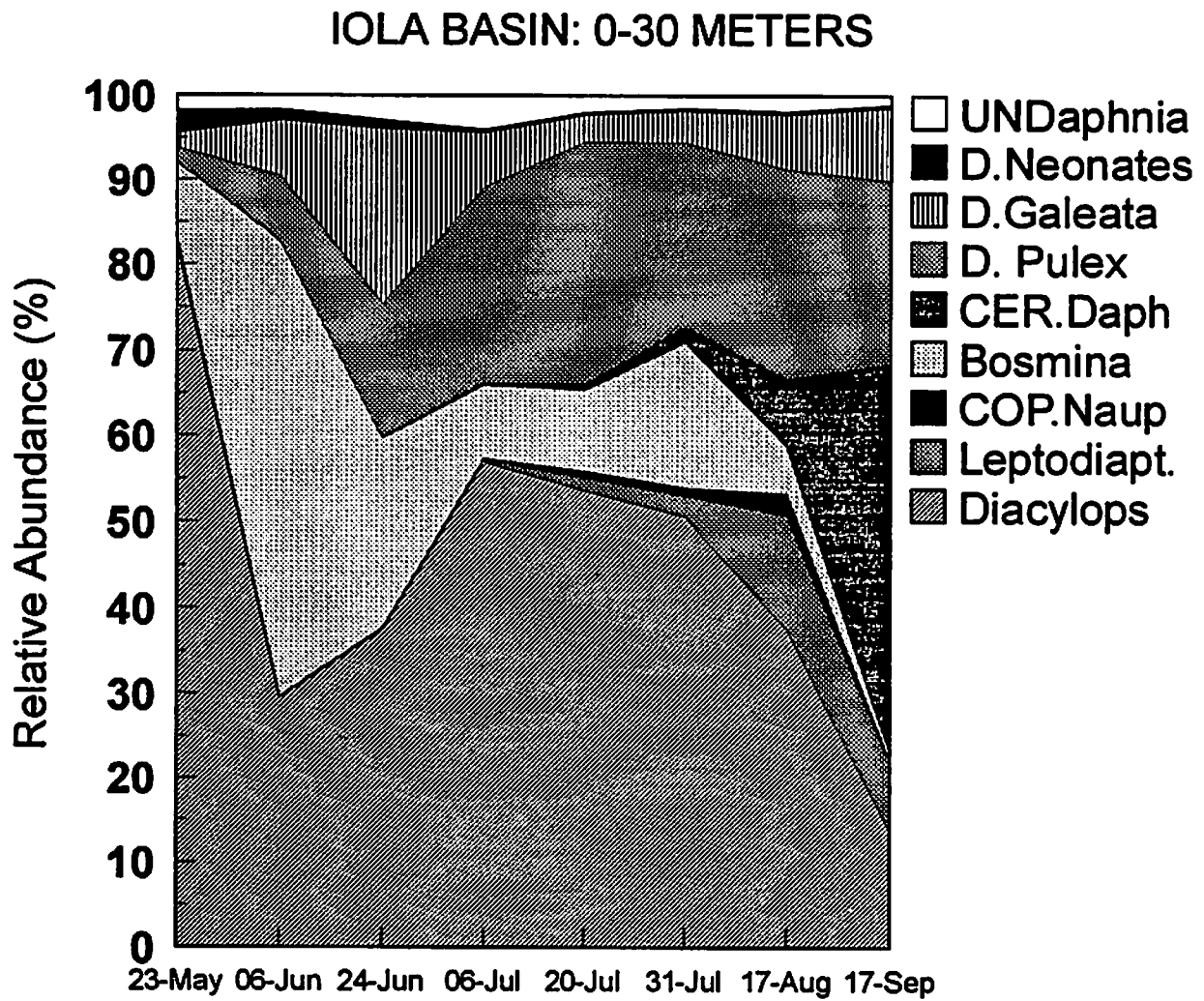


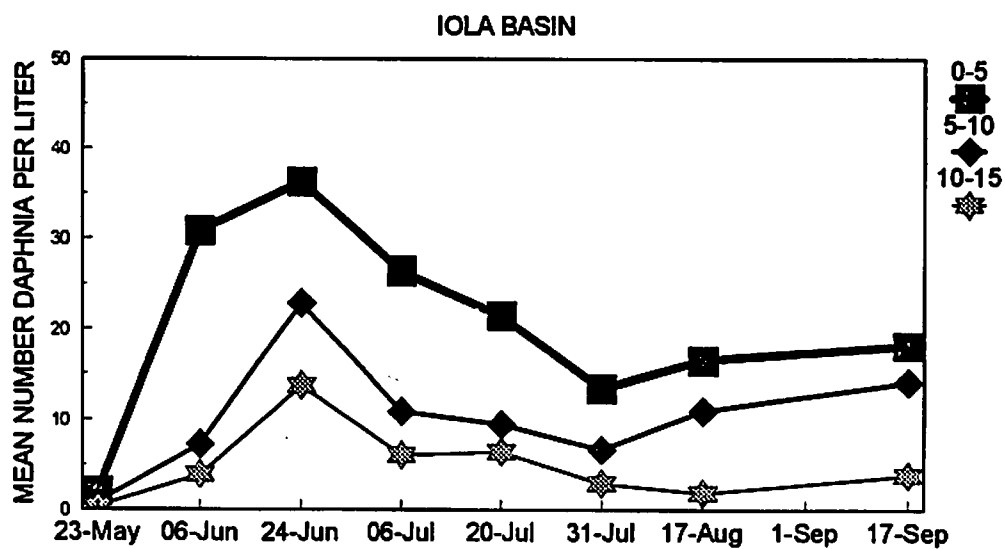
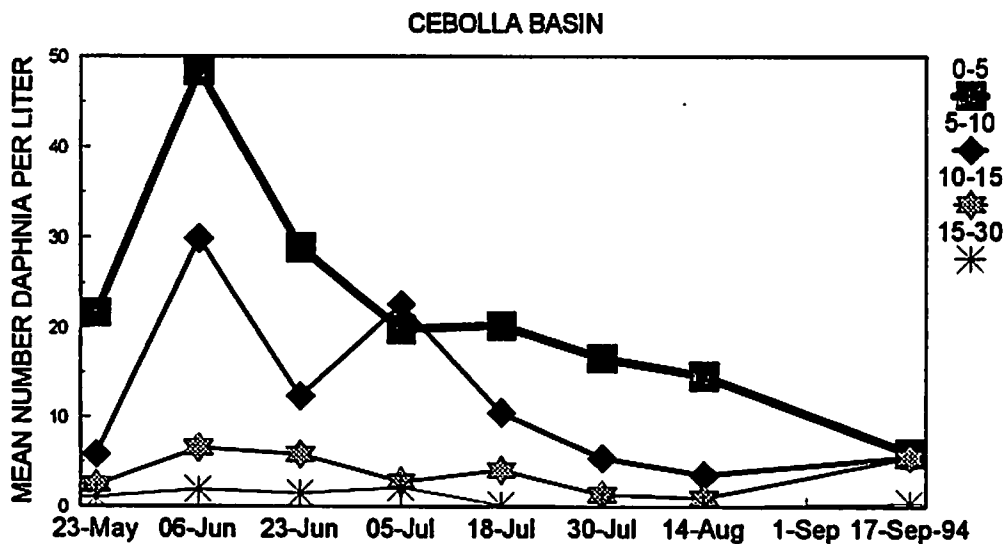
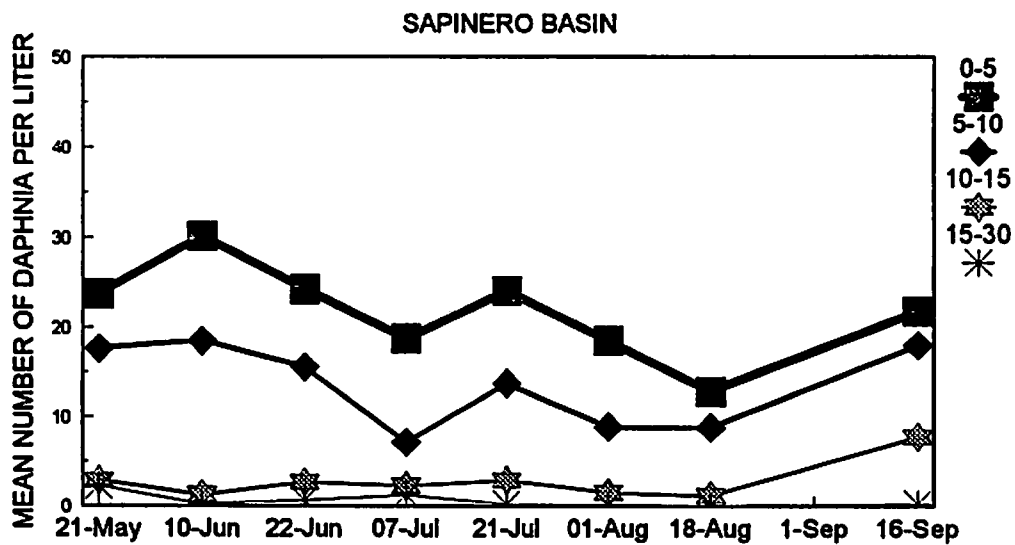
SAPINERO BASIN: 0-30 METERS



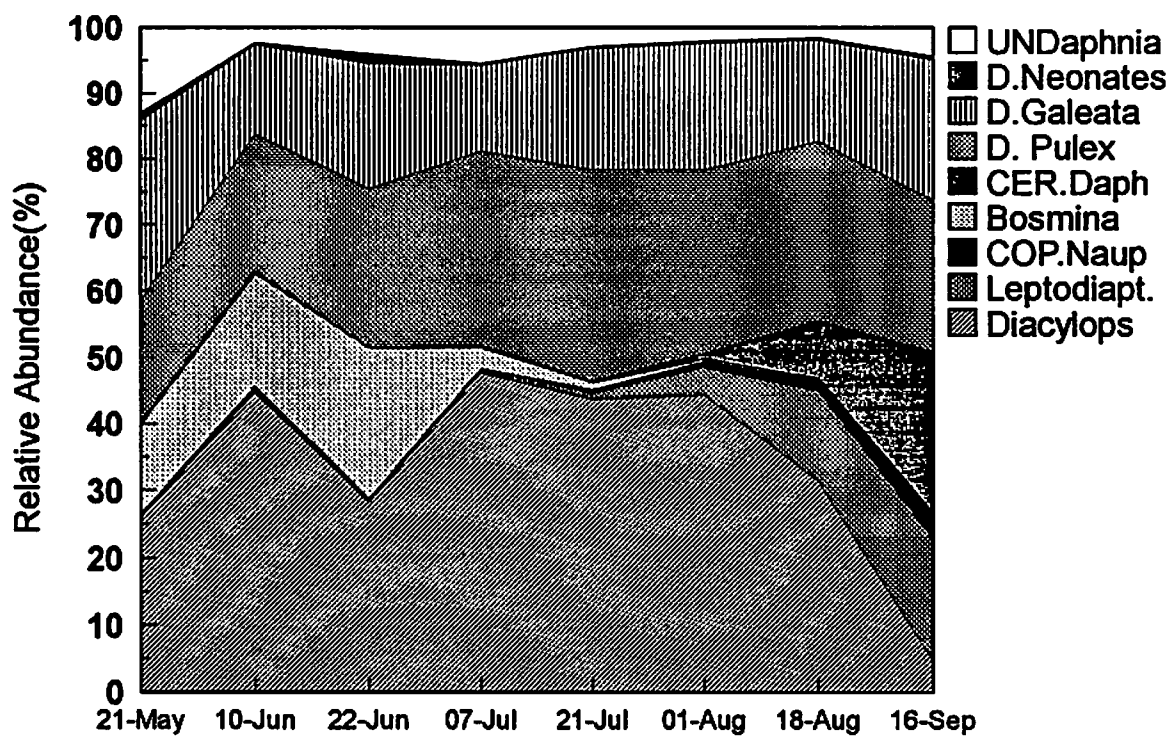
CEBOLLA BASIN: 0-30 METERS



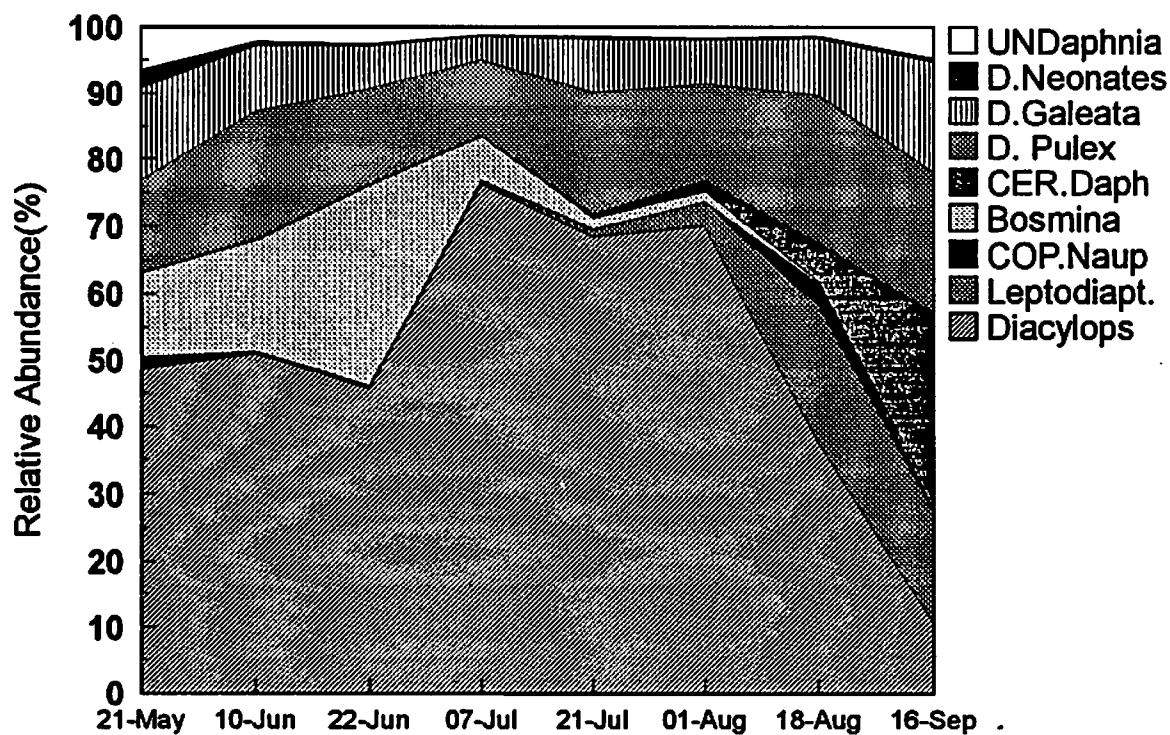




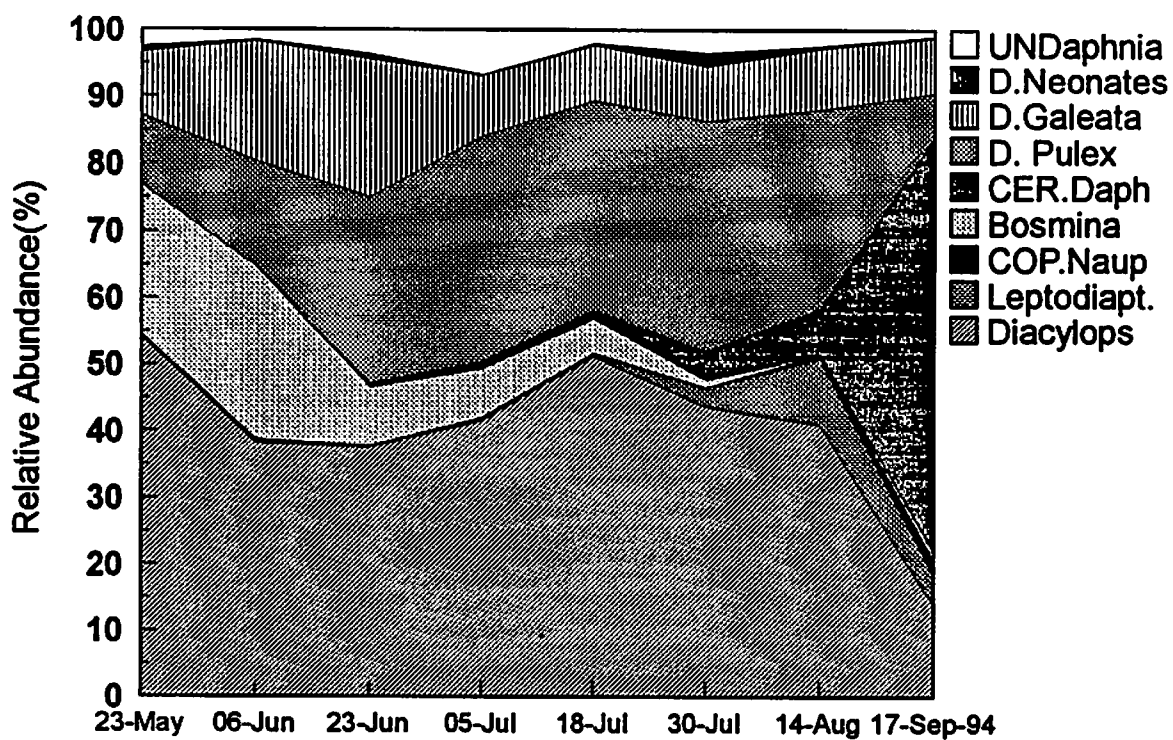
SAPINERO BASIN: 0-5 METERS



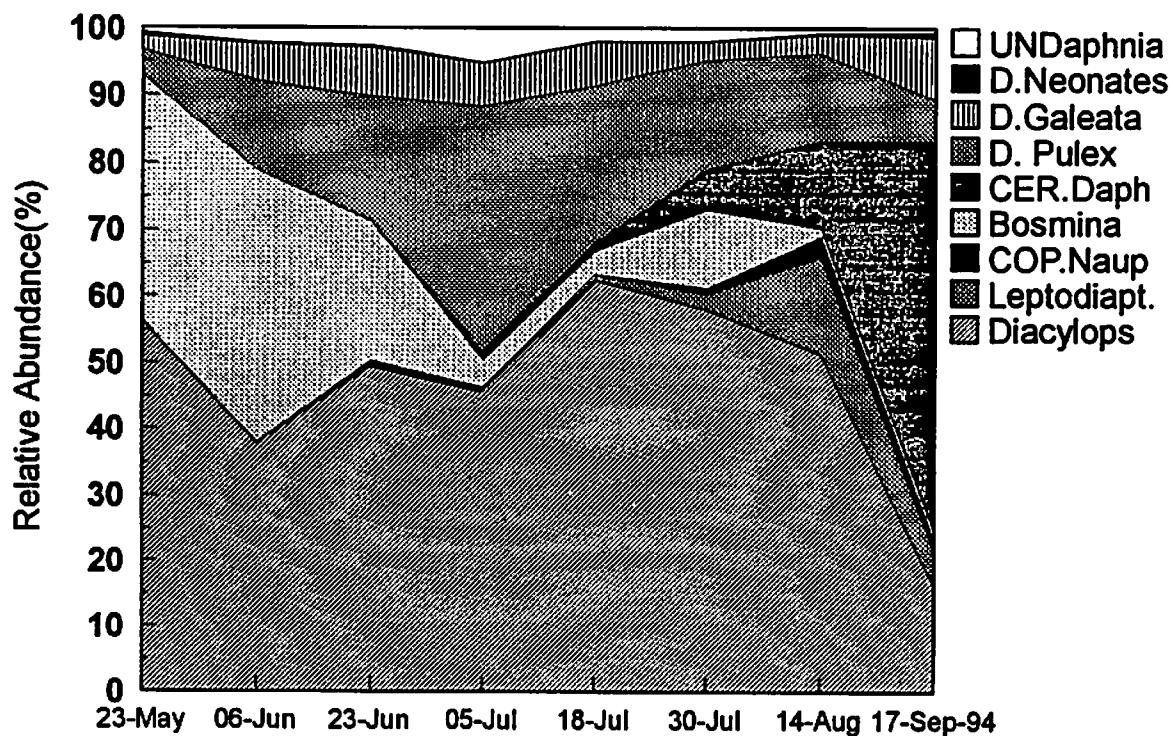
SAPINERO BASIN: 5-10 METERS



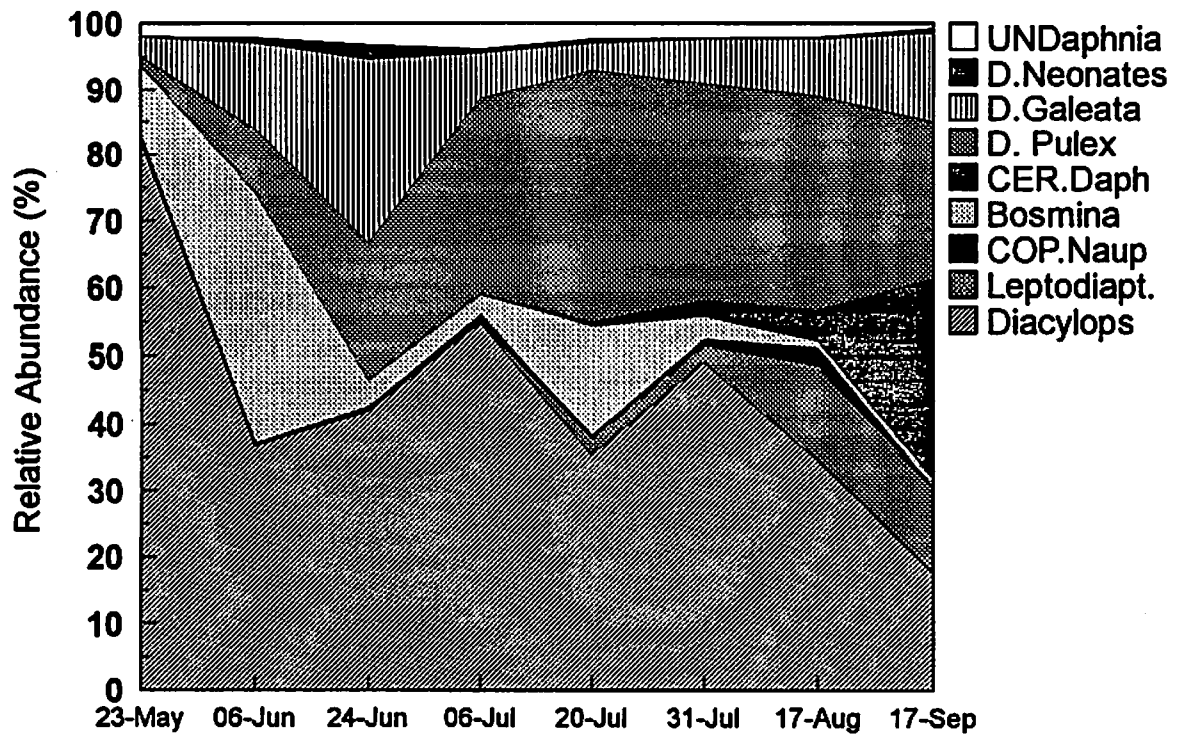
CEBOLLA BASIN: 0-5 METERS



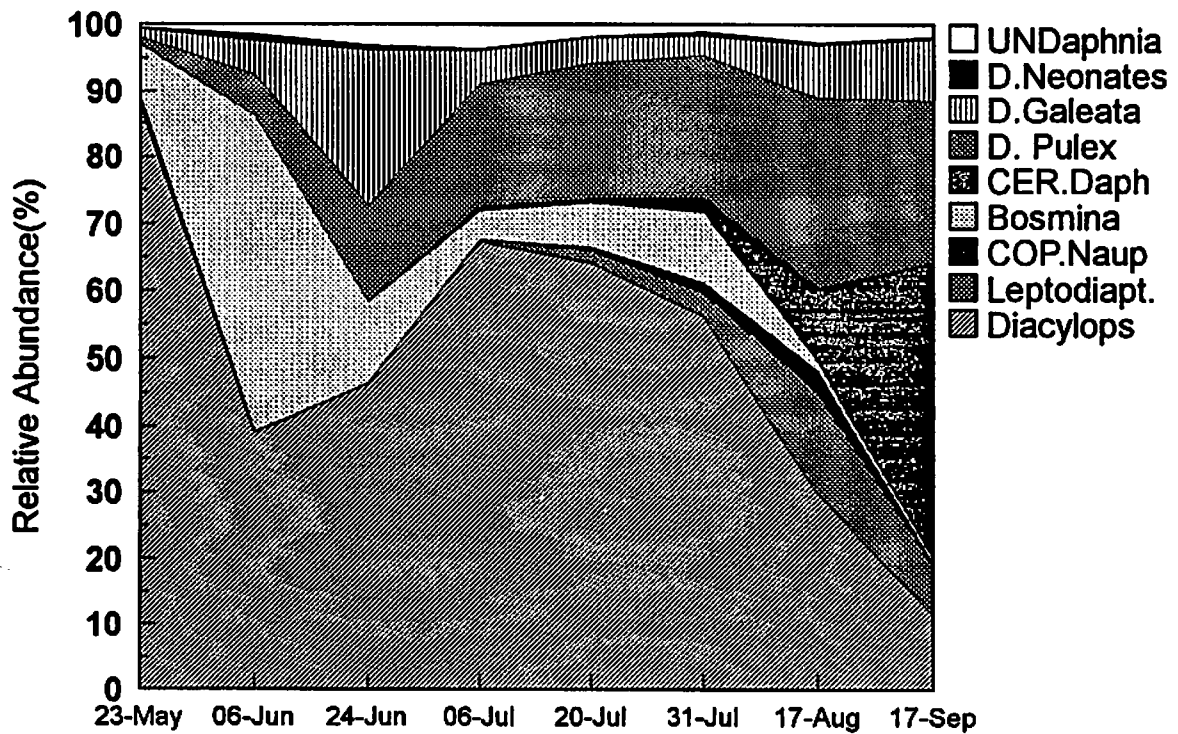
CEBOLLA BASIN: 5-10 METERS



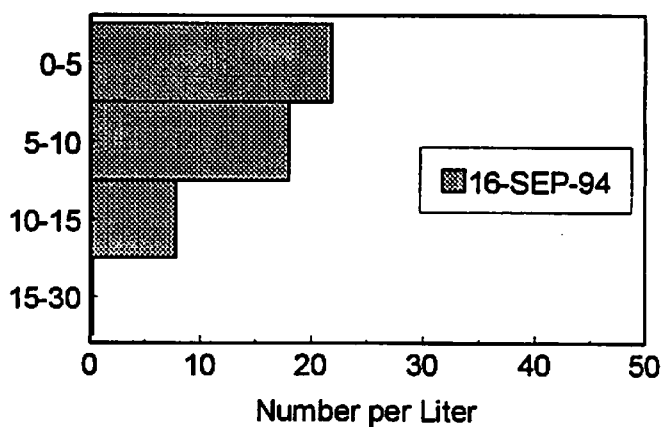
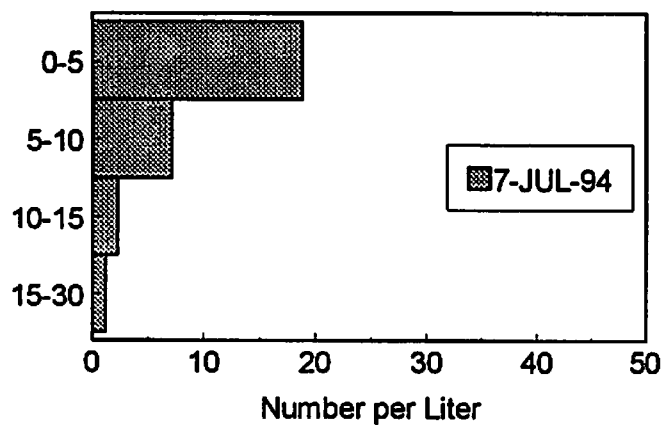
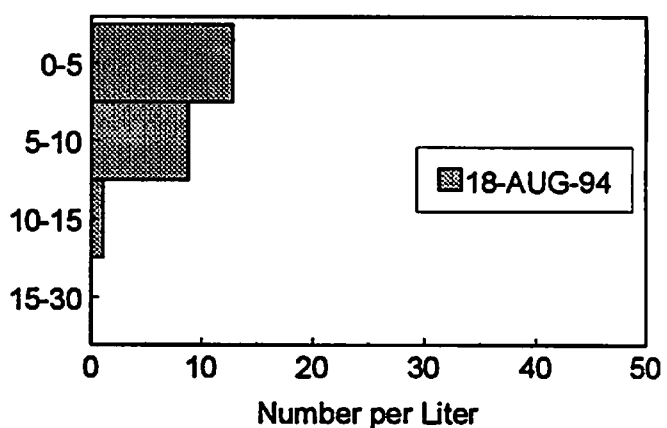
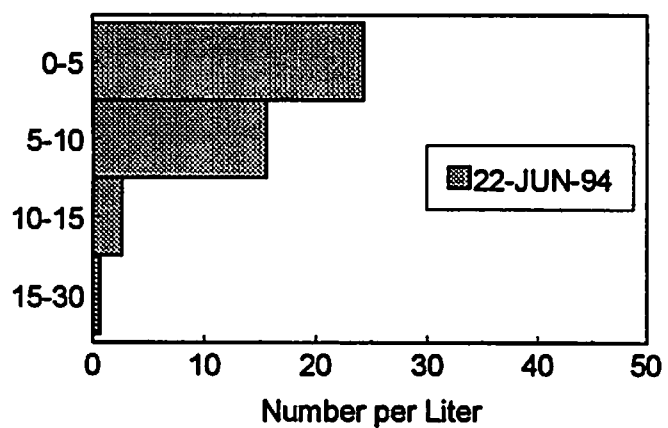
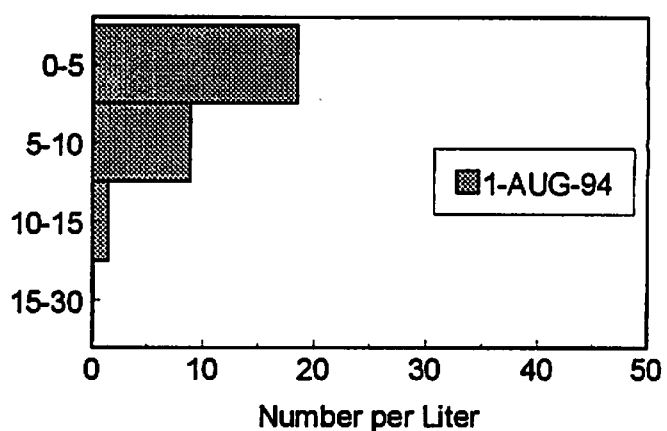
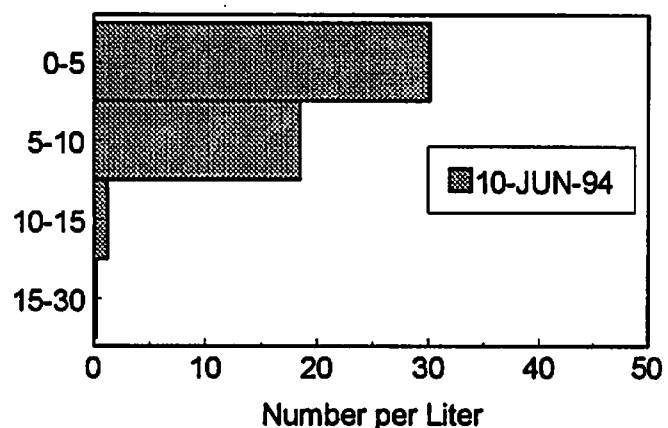
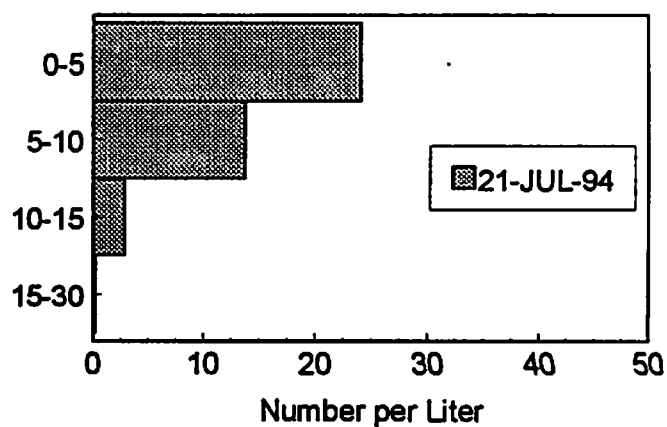
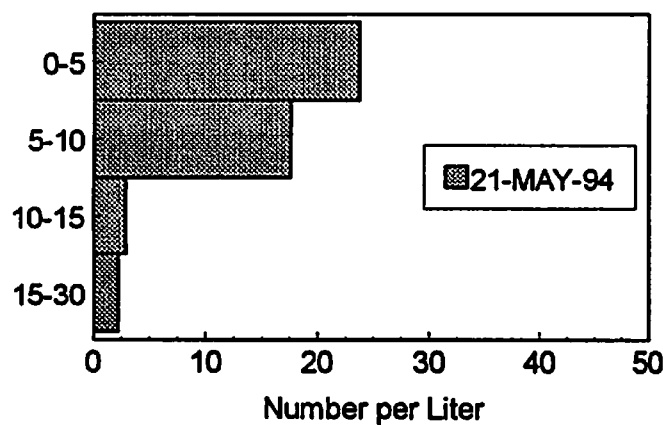
IOLA BASIN: 0-5 METERS



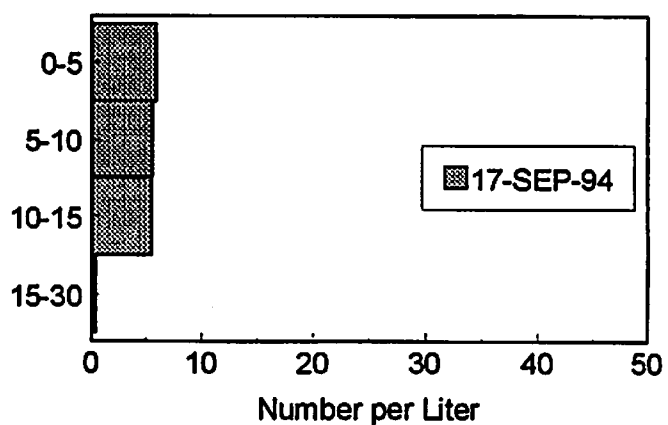
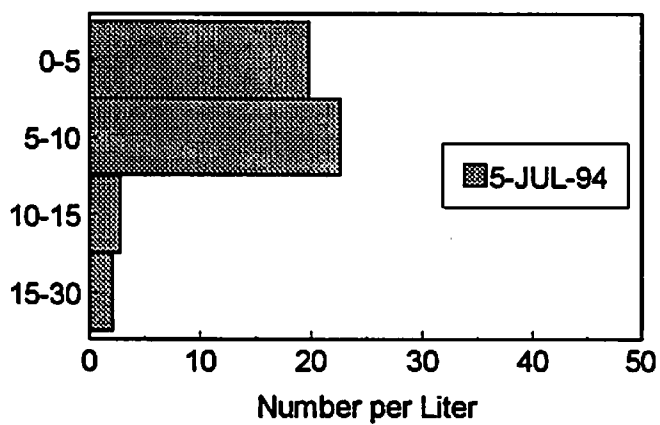
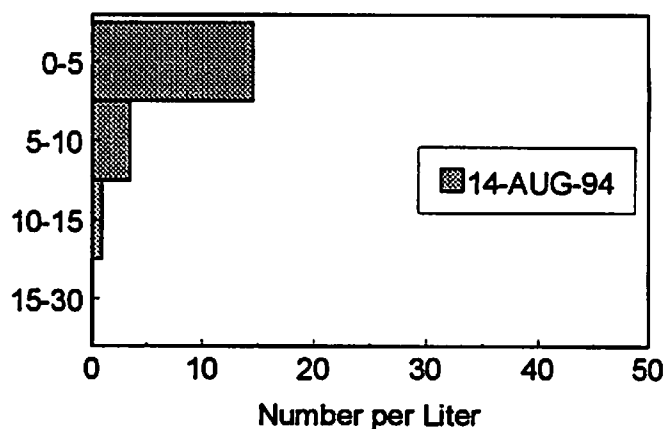
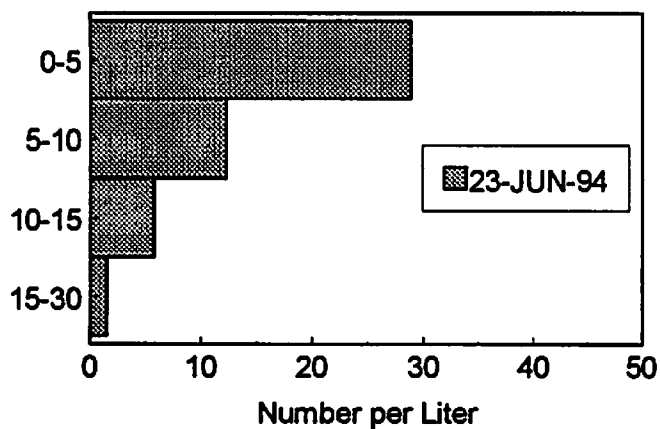
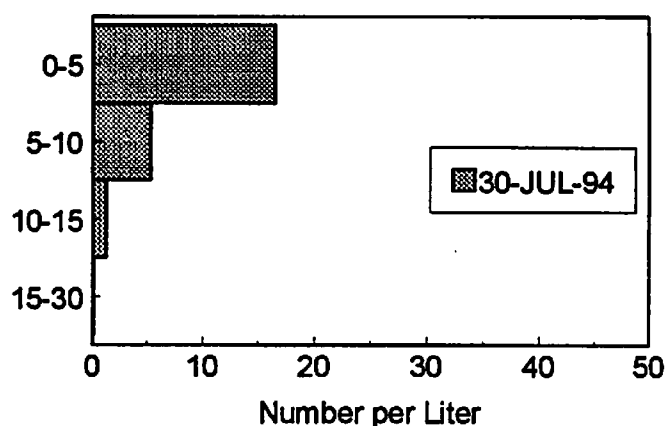
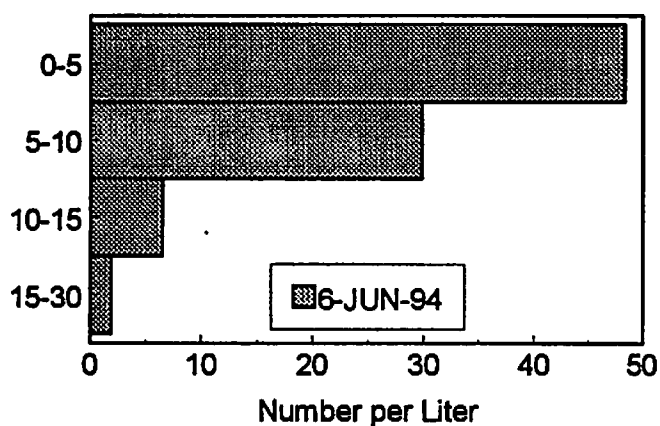
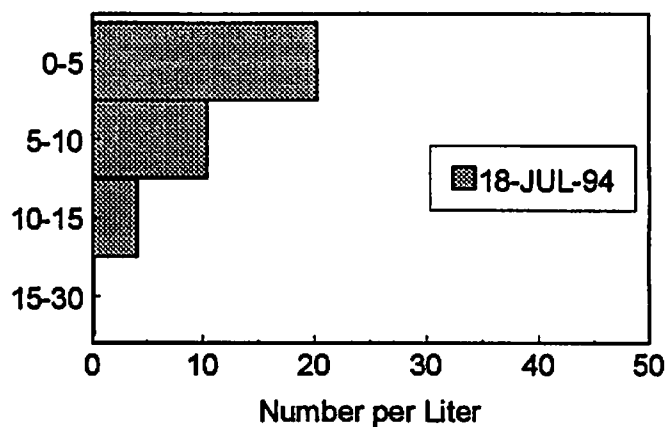
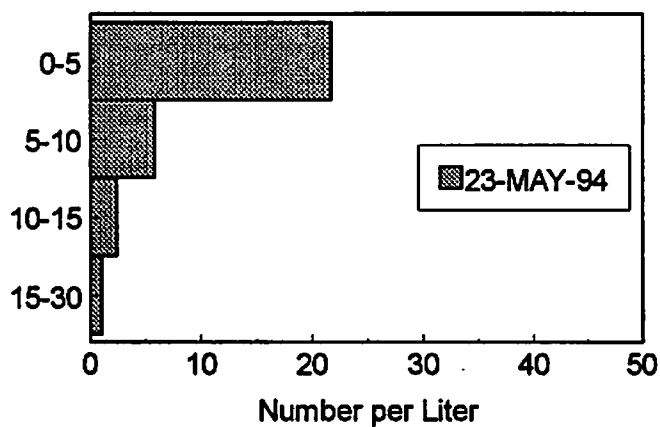
IOLA BASIN: 5-10 METERS



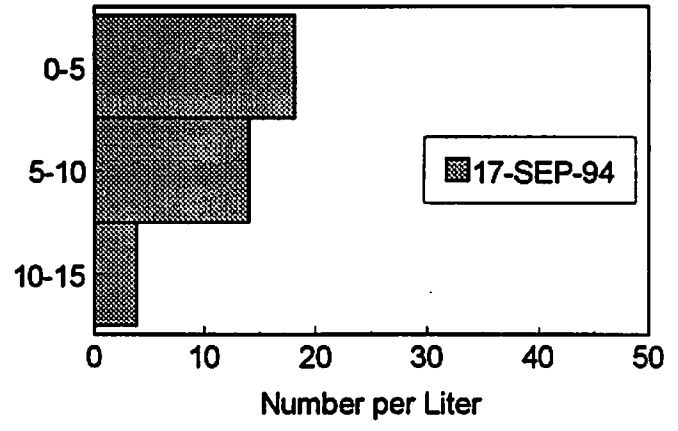
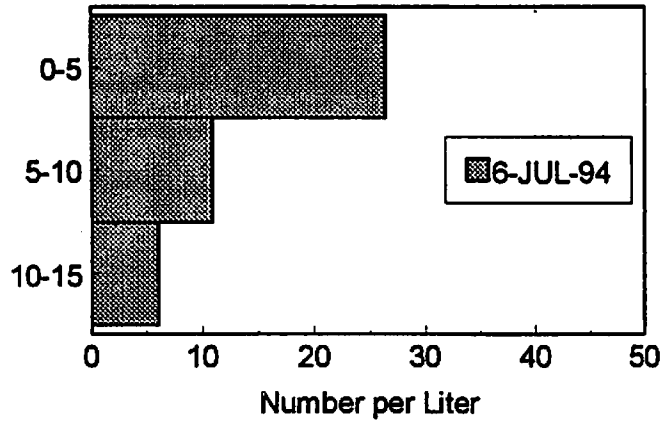
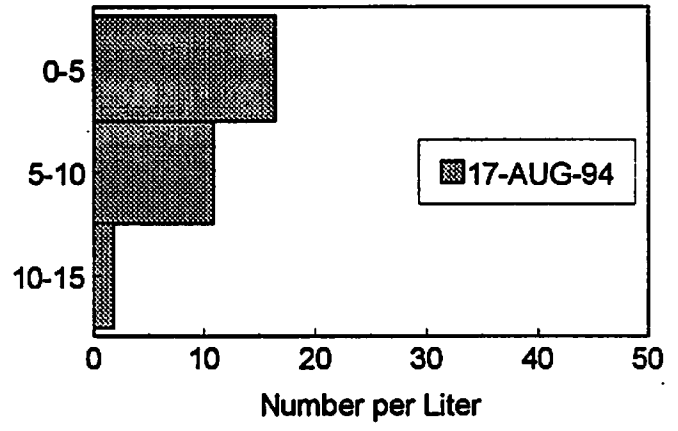
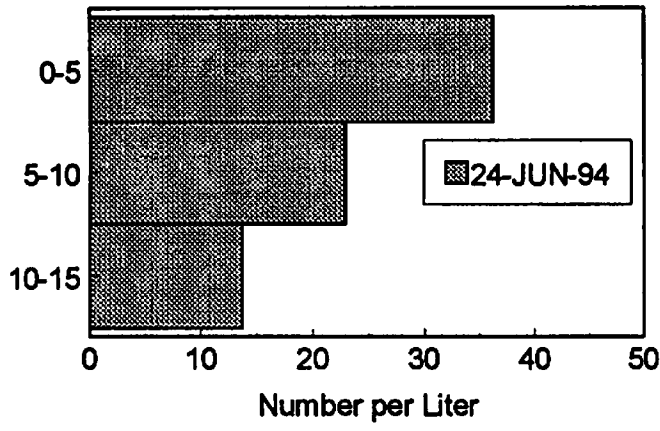
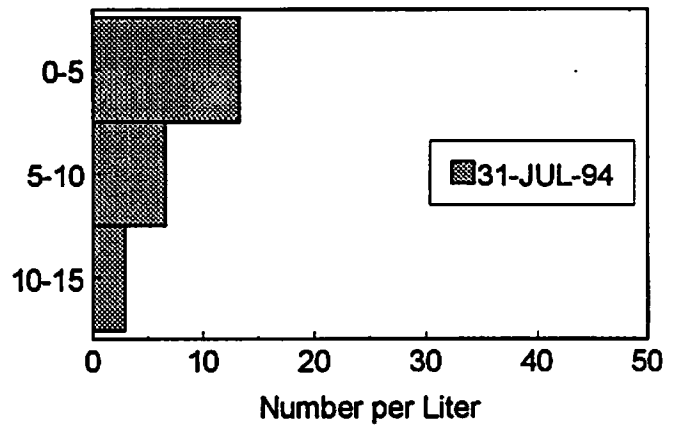
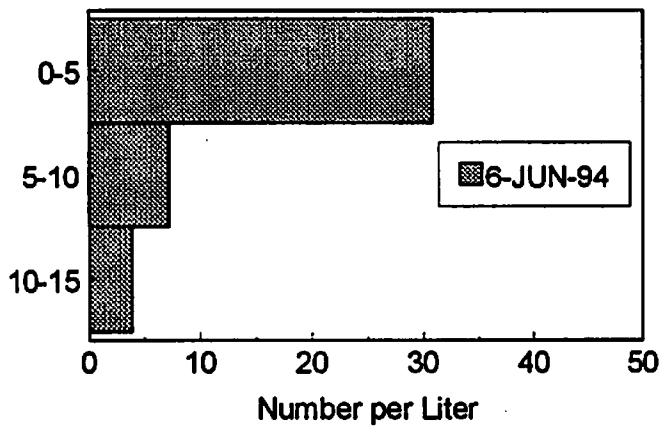
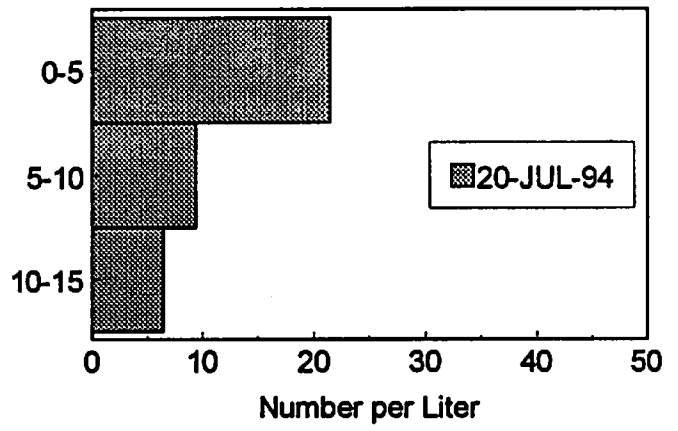
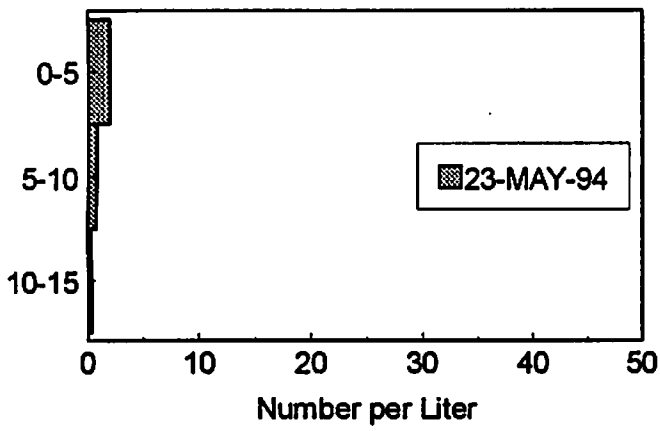
SAPINERO BASIN

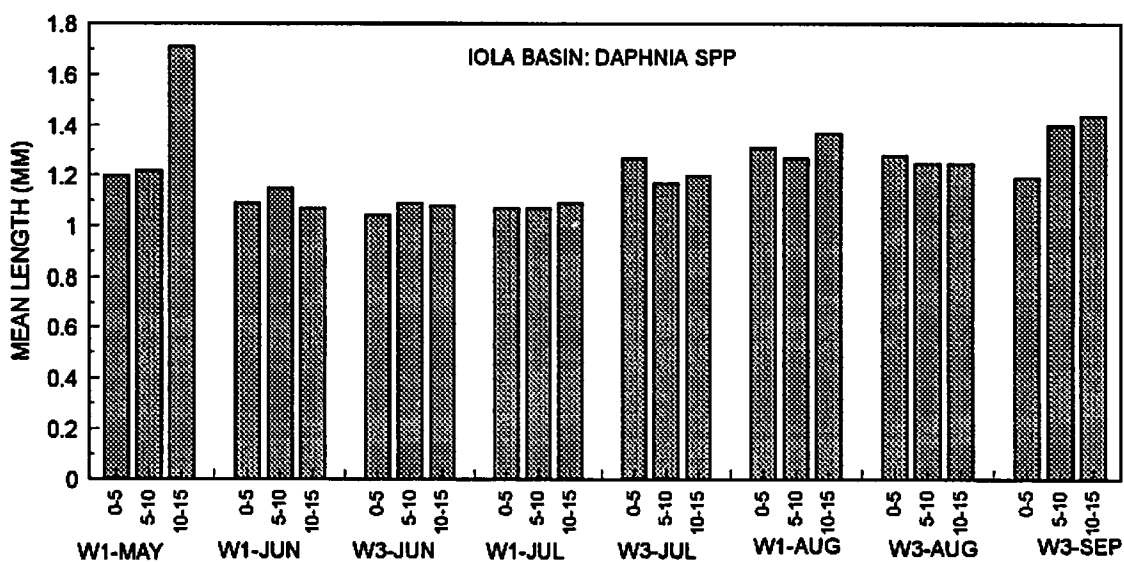
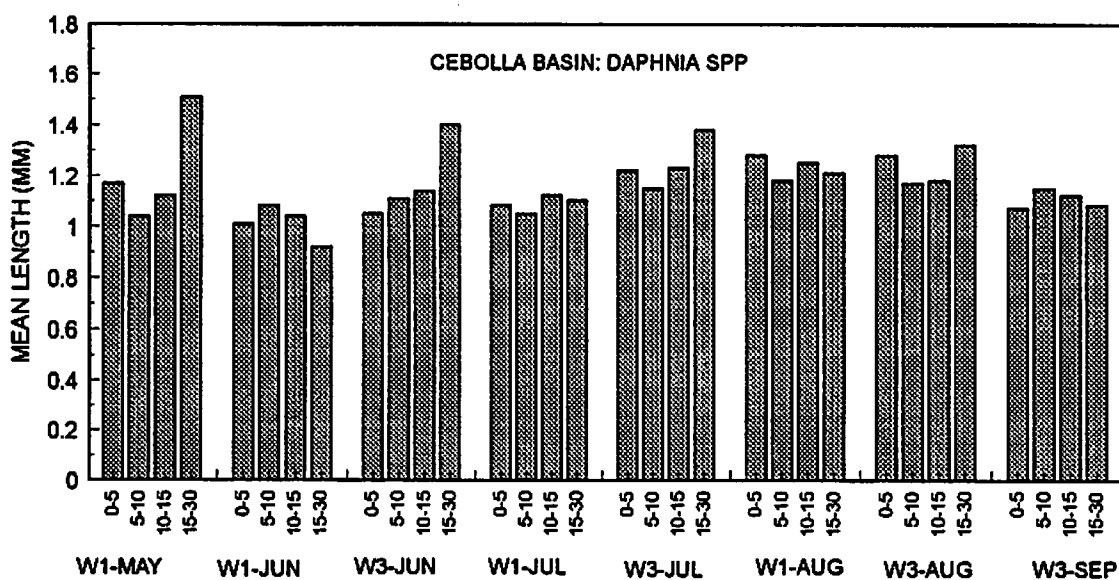
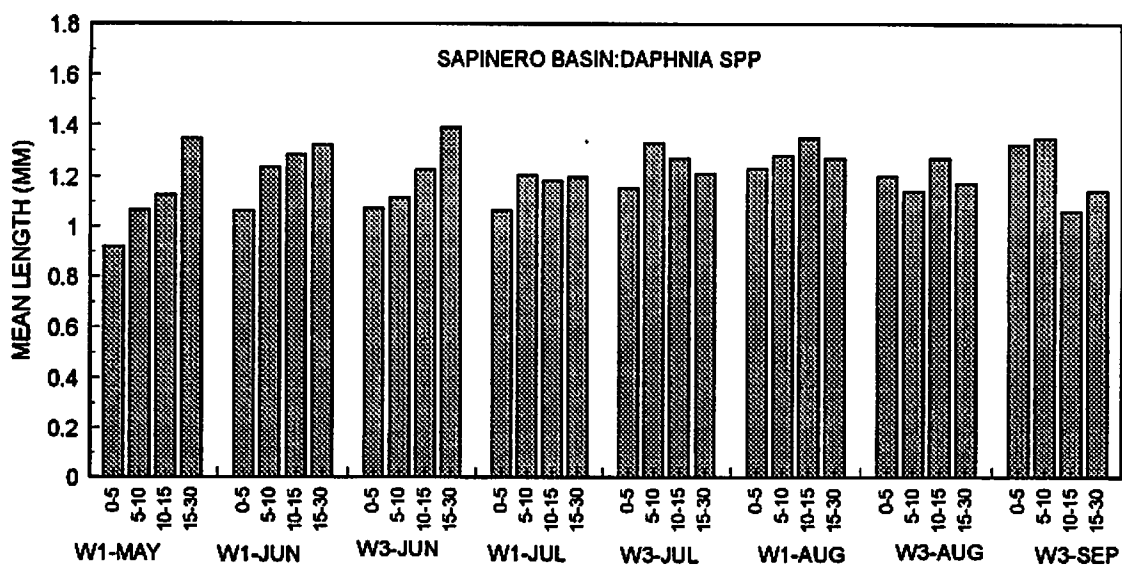


CEBOLLA BASIN

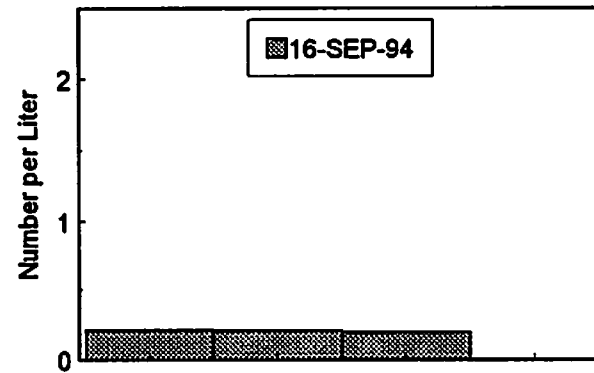
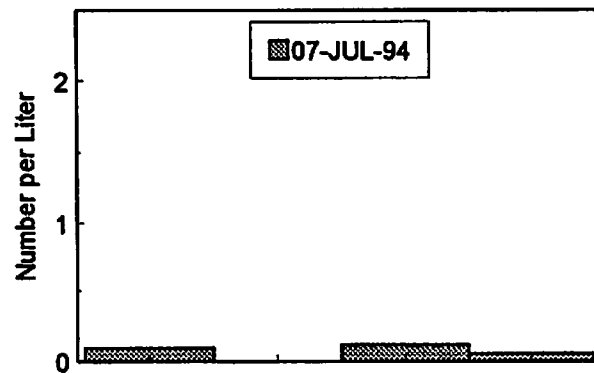
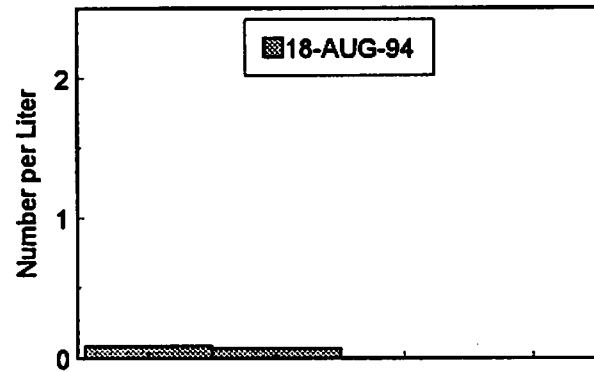
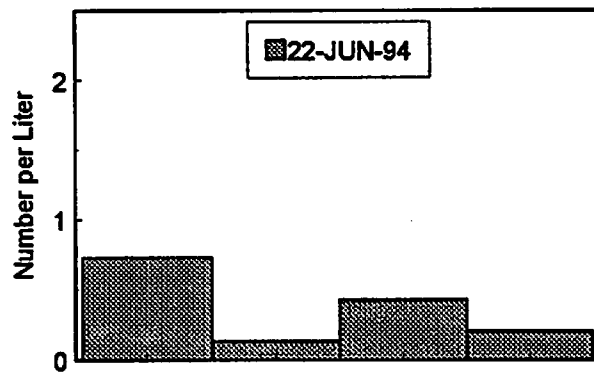
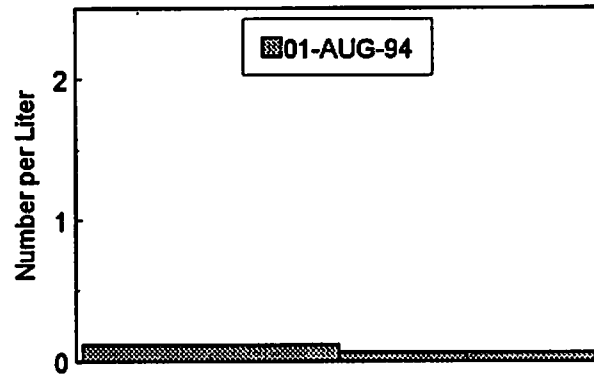
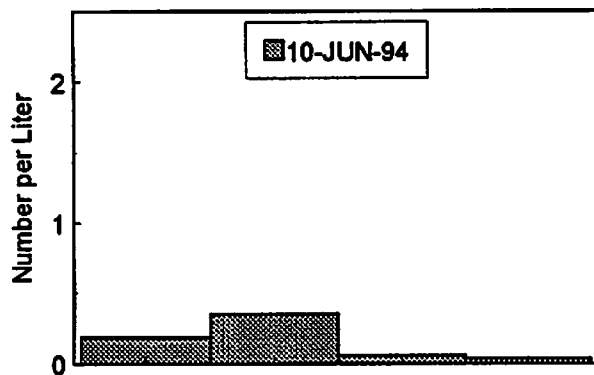
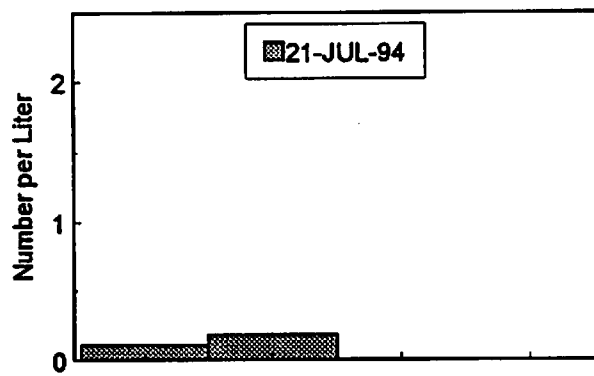
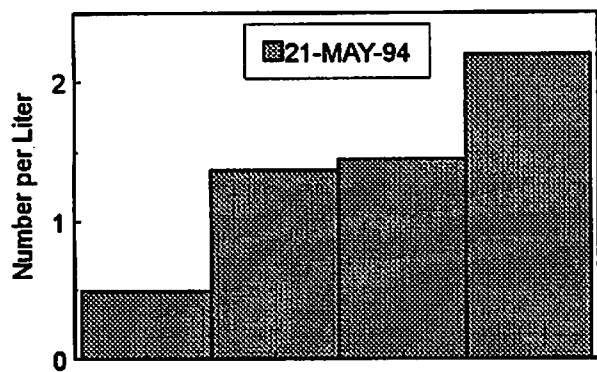


IOLA BASIN





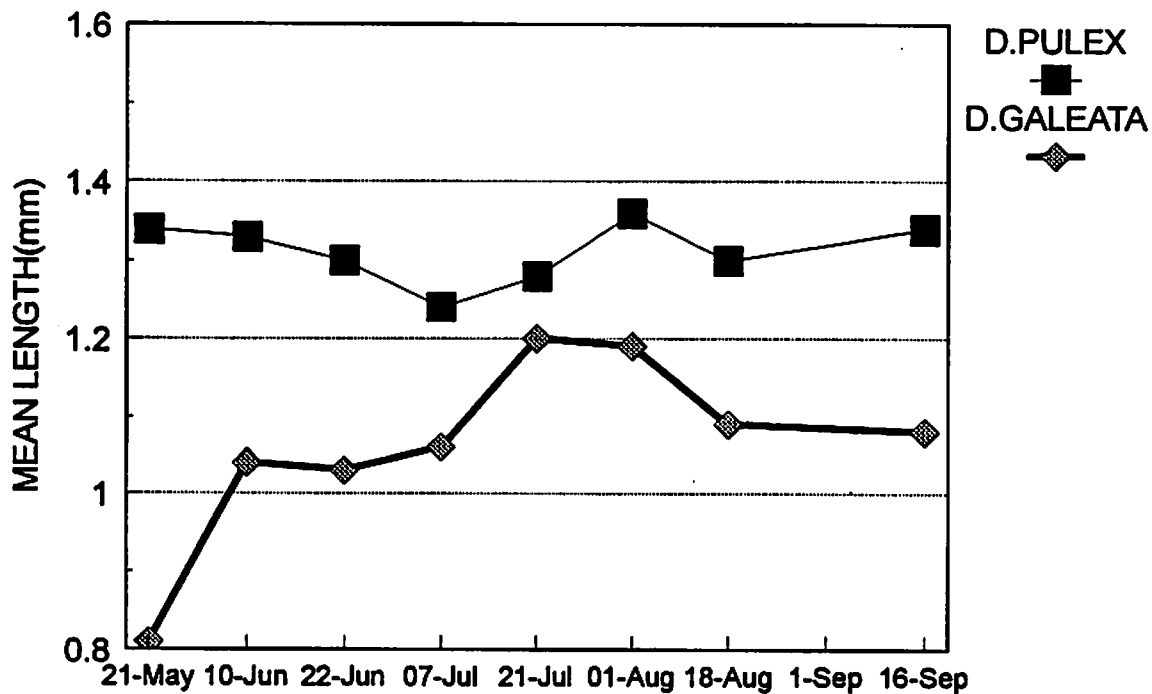
SAPINERO BASIN DAPHNIA NEONATES



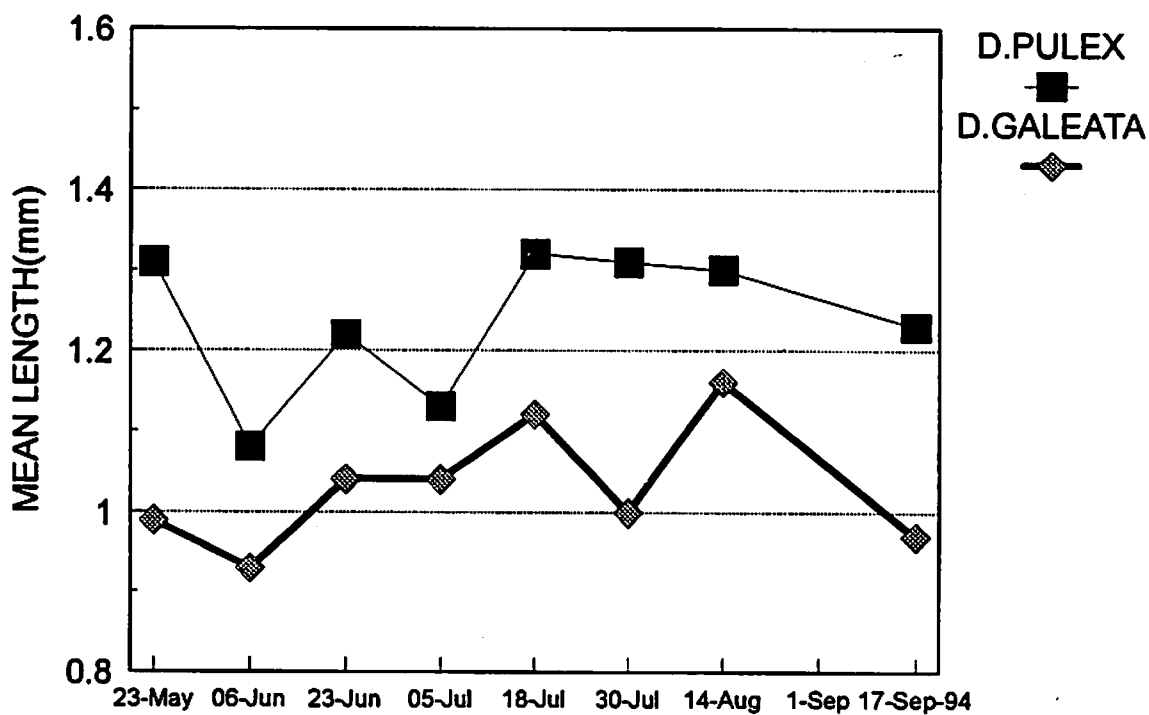
0-5 5-10 10-15 15-30
Depth Stratum(m)

0-5 5-10 10-15 15-30
Depth Stratum(m)

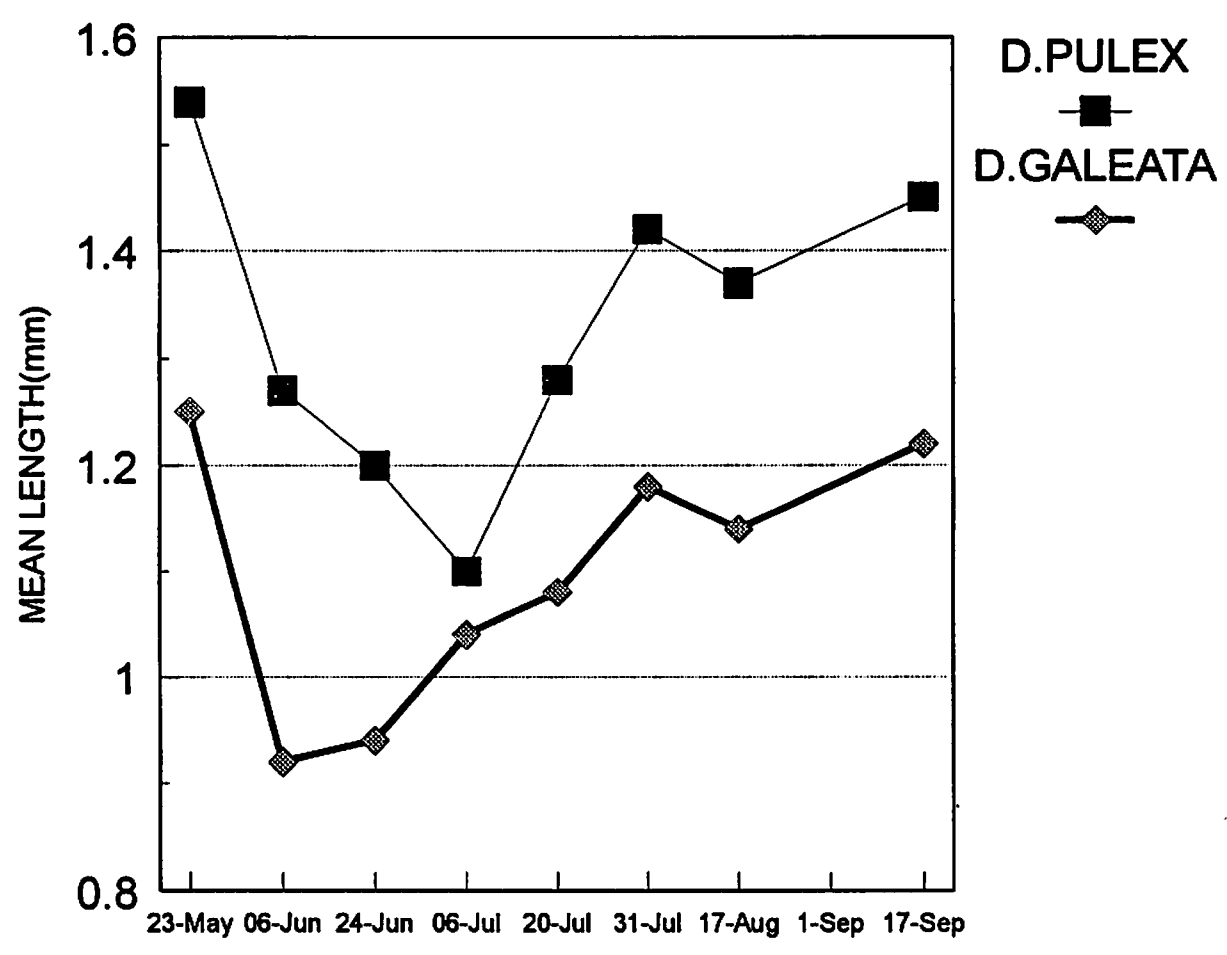
SAPINERO BASIN: 0-30 METERS

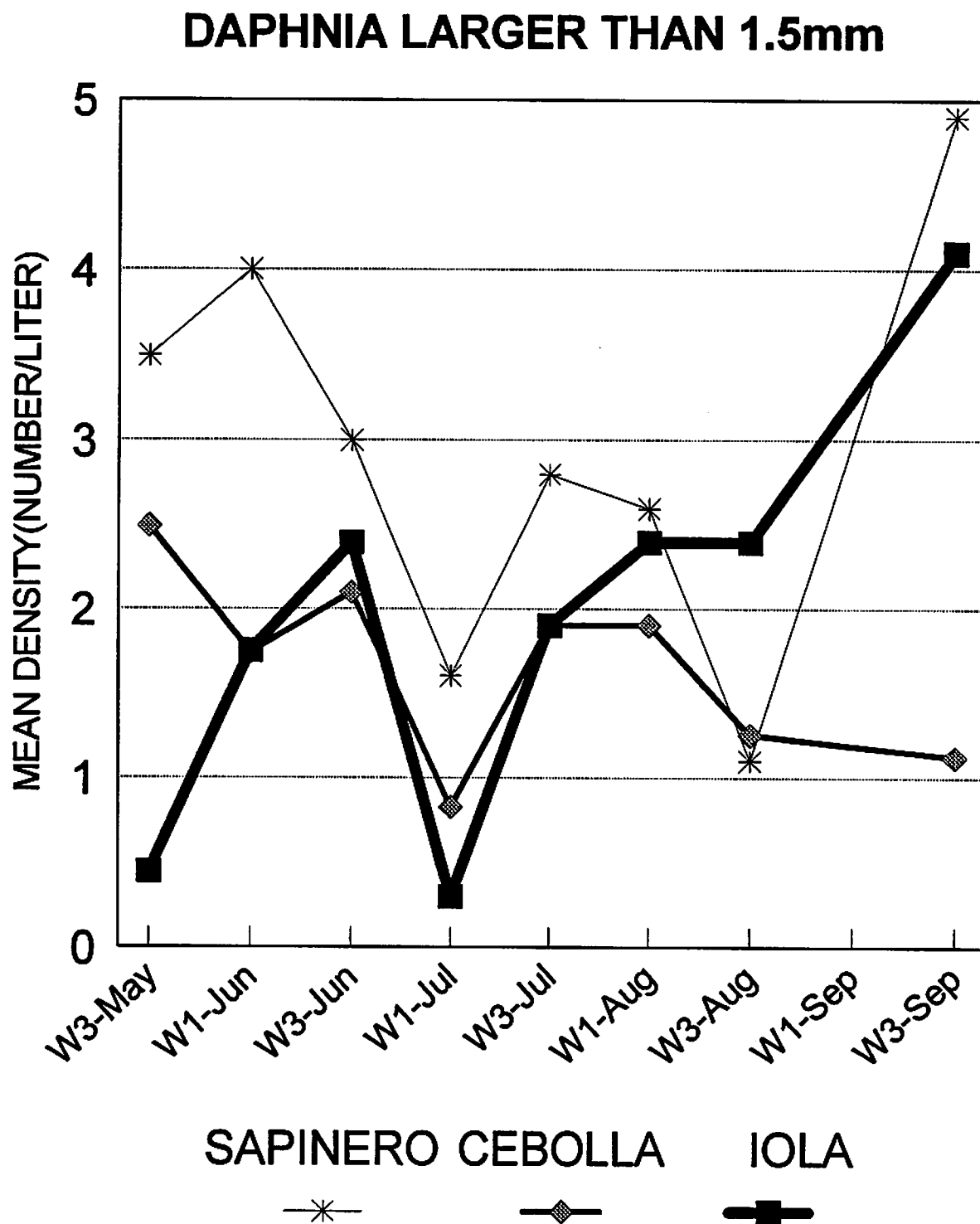


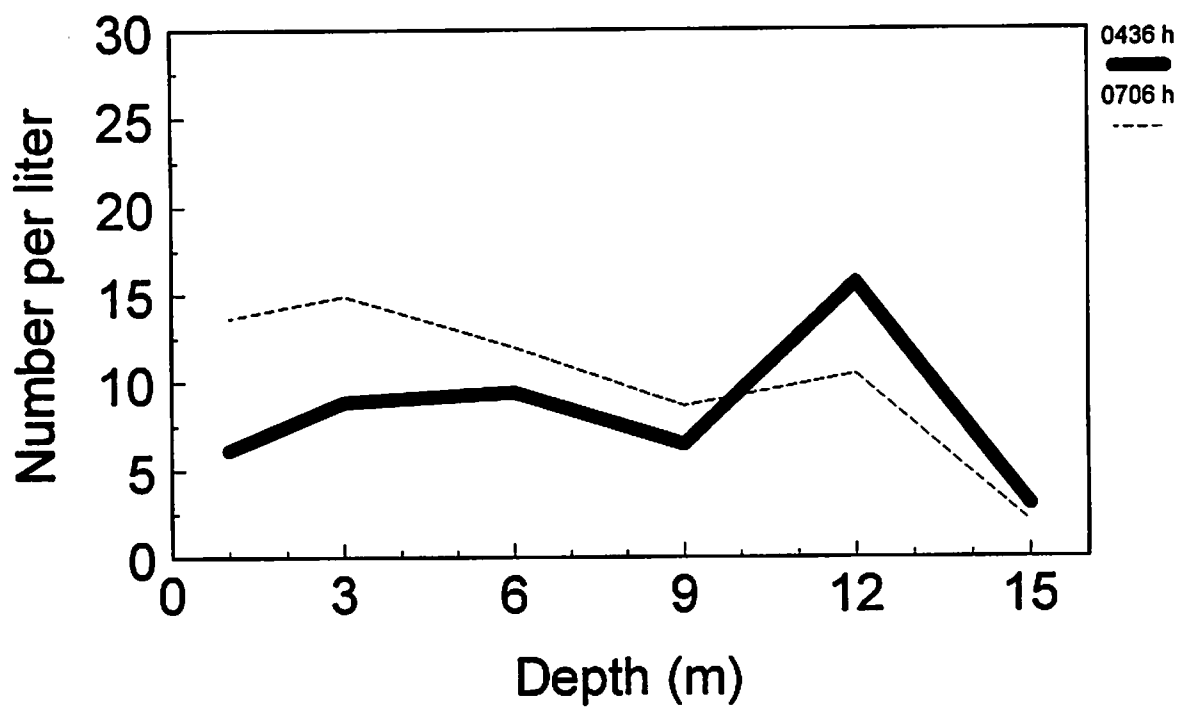
CEBOLLA BASIN: 0-30 METERS



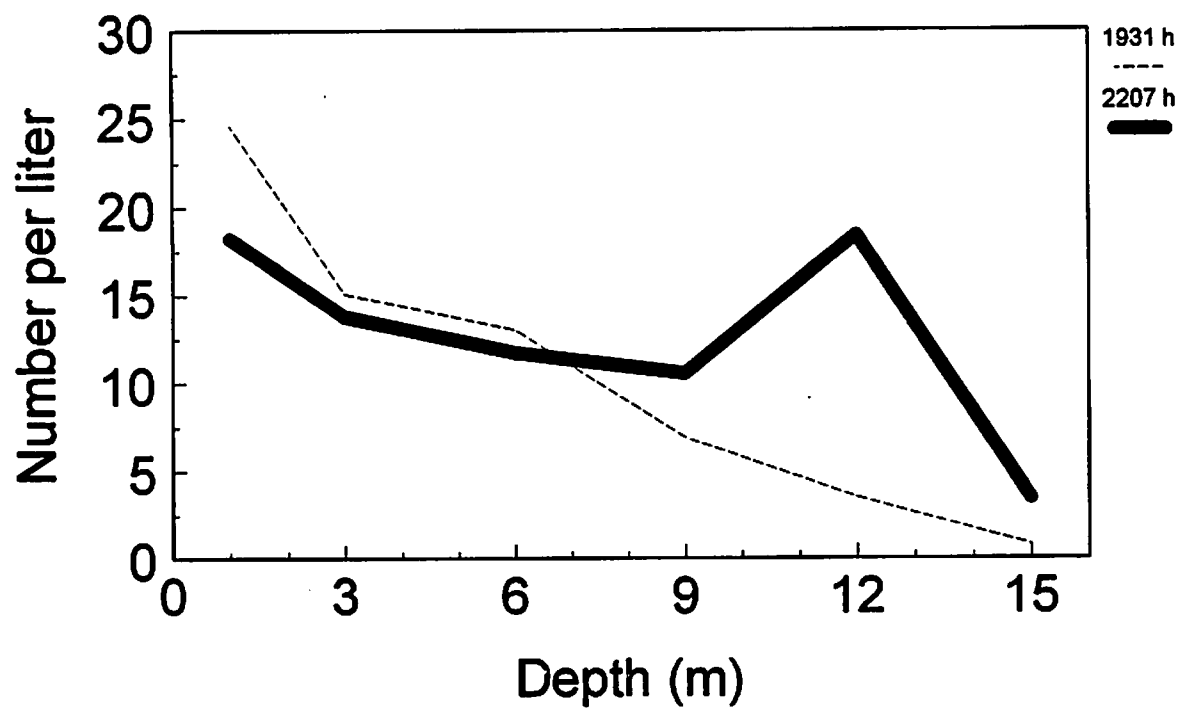
IOLA BASIN: 0-15 METERS



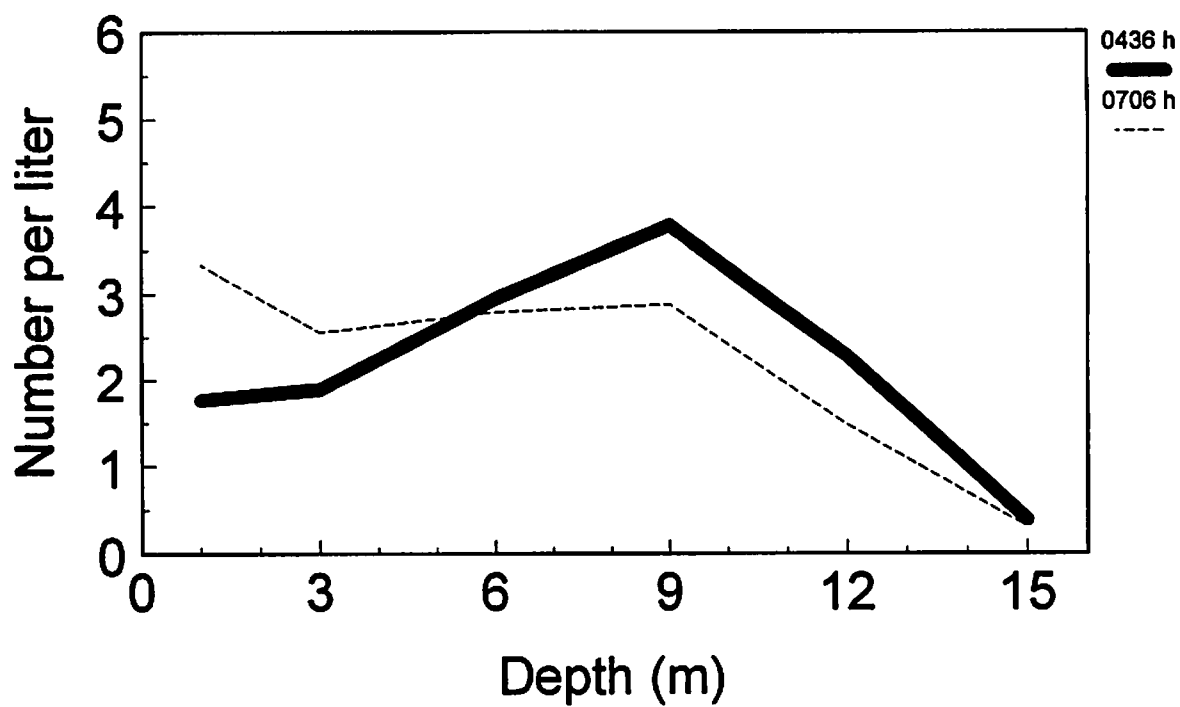
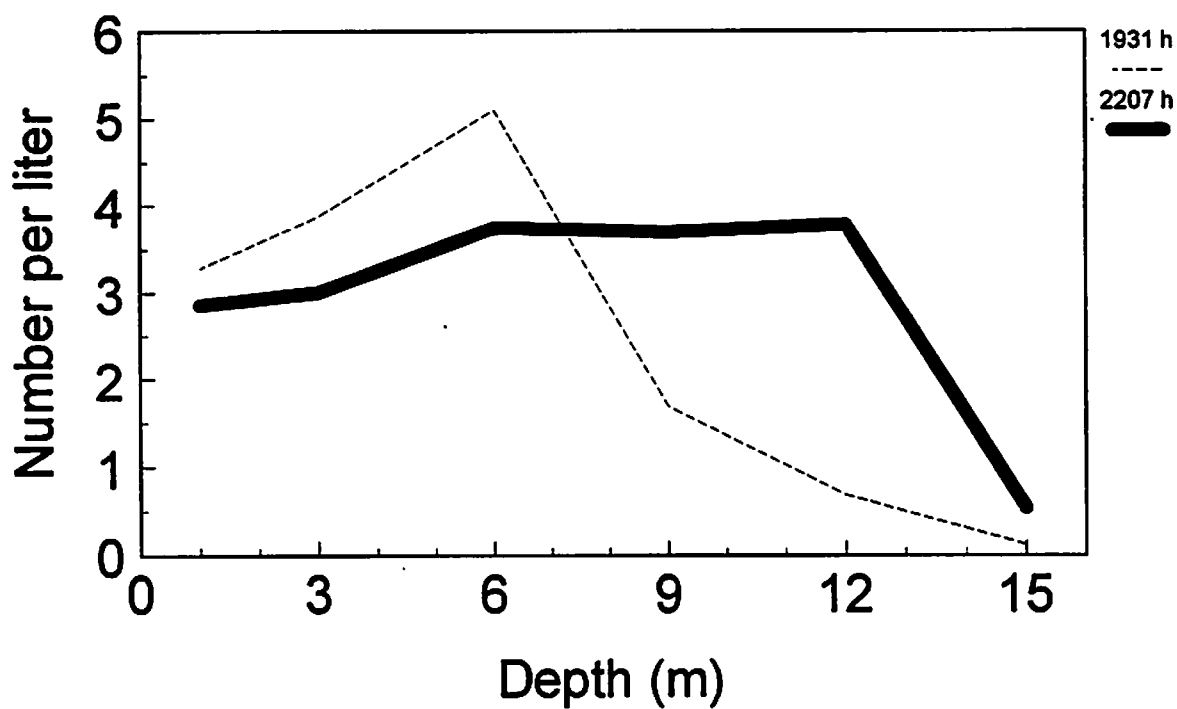


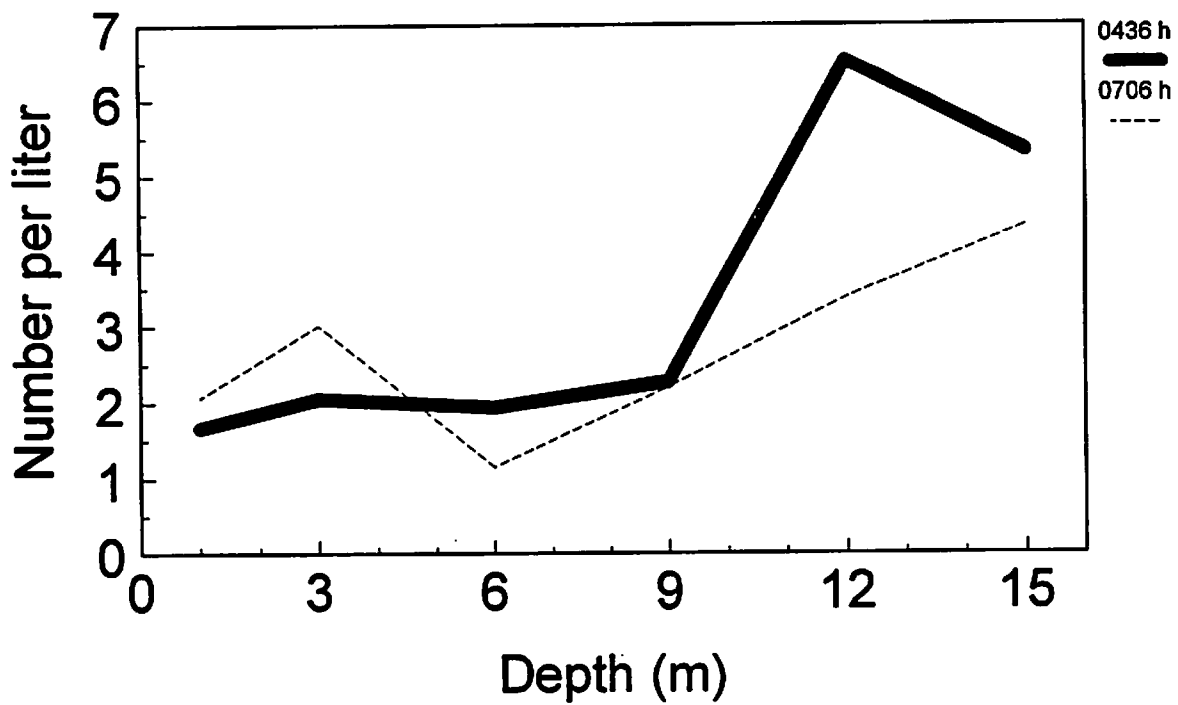


Daphnia pulex

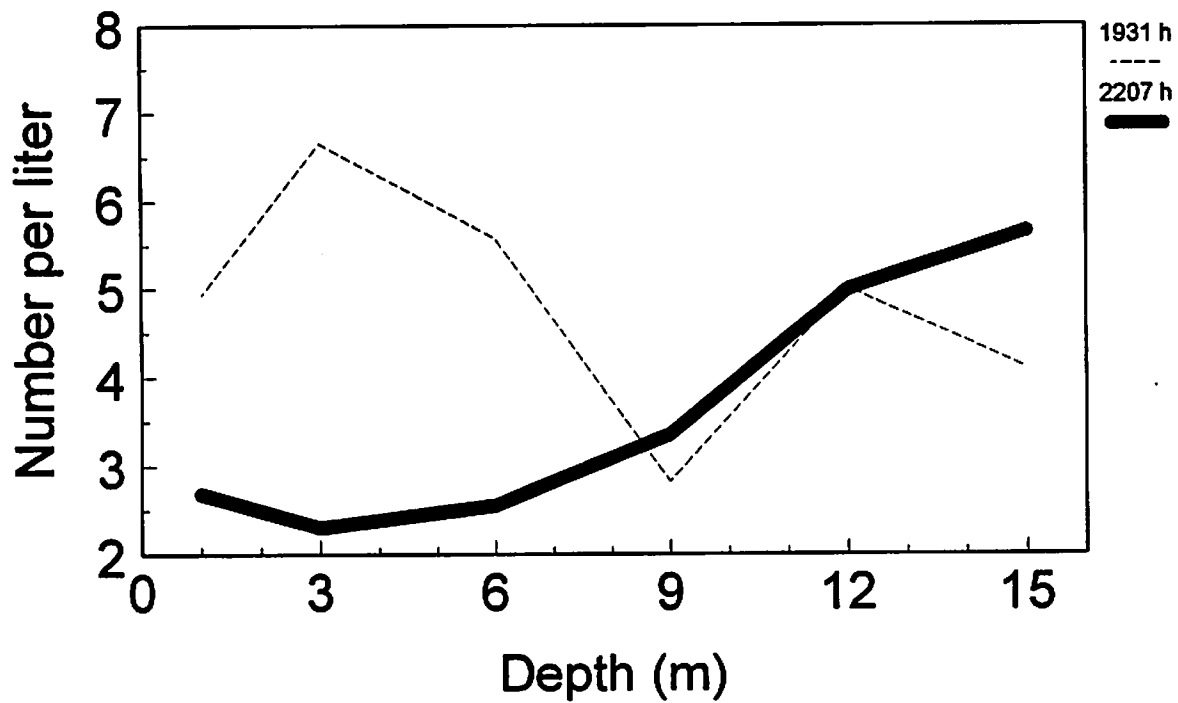


Daphnia pulex

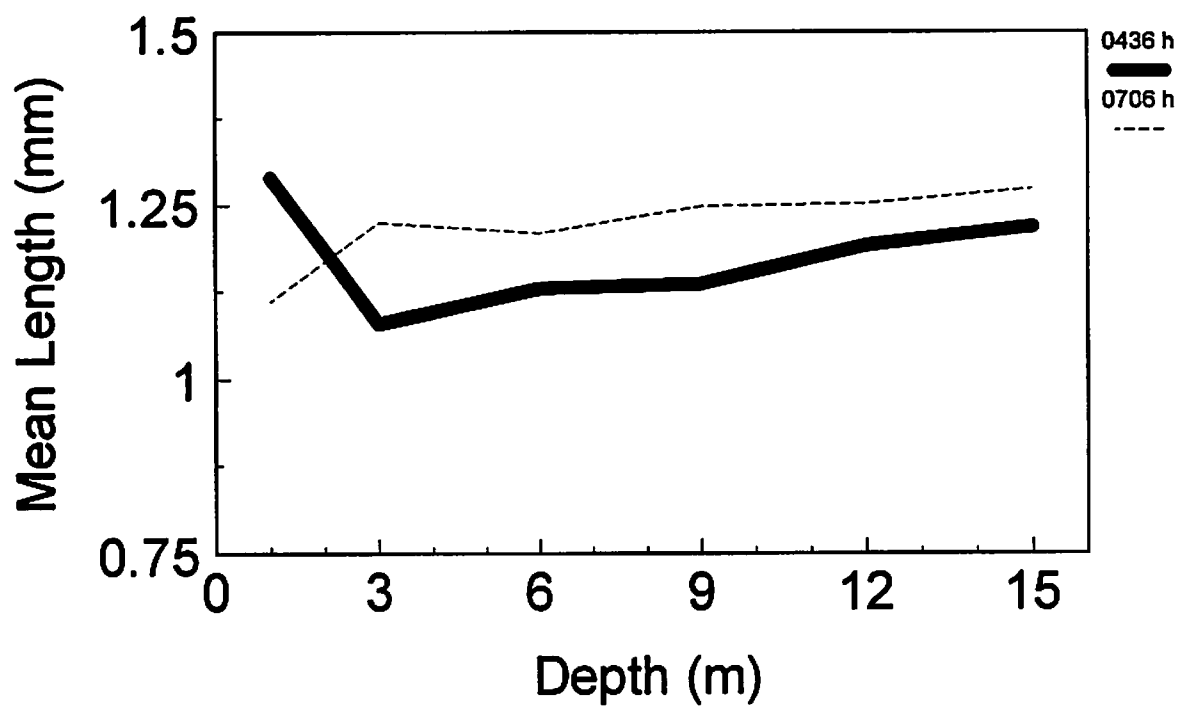
*Daphnia galeata**Daphnia galeata*



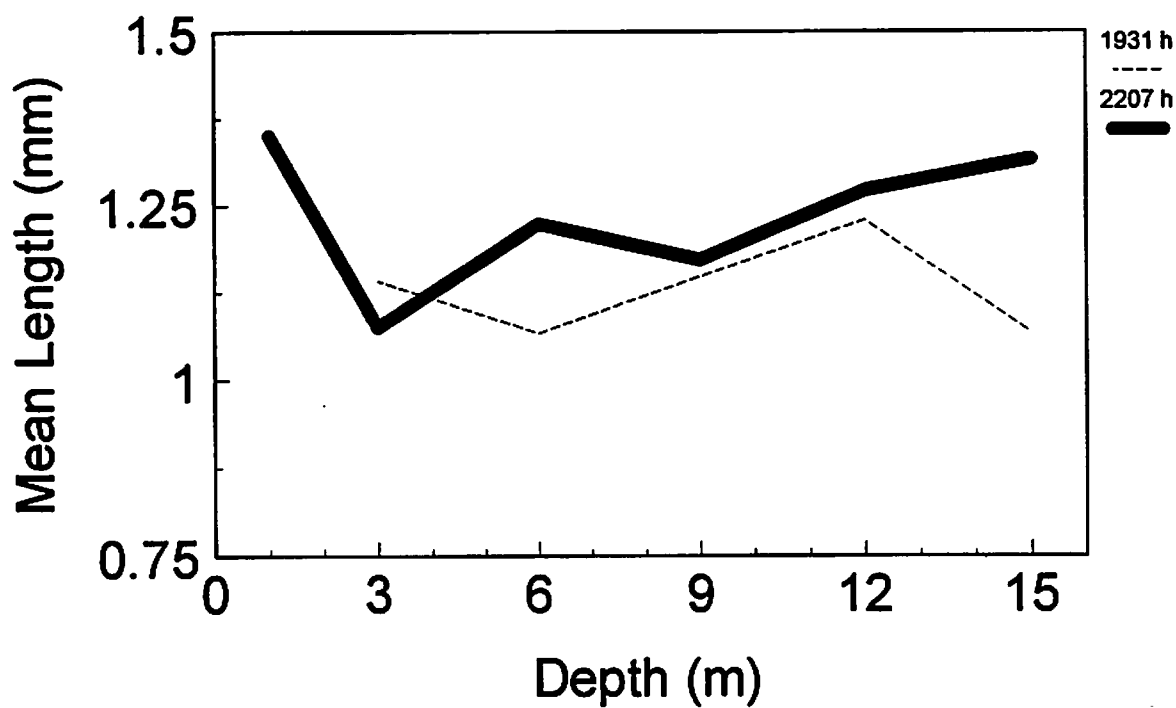
Boemina



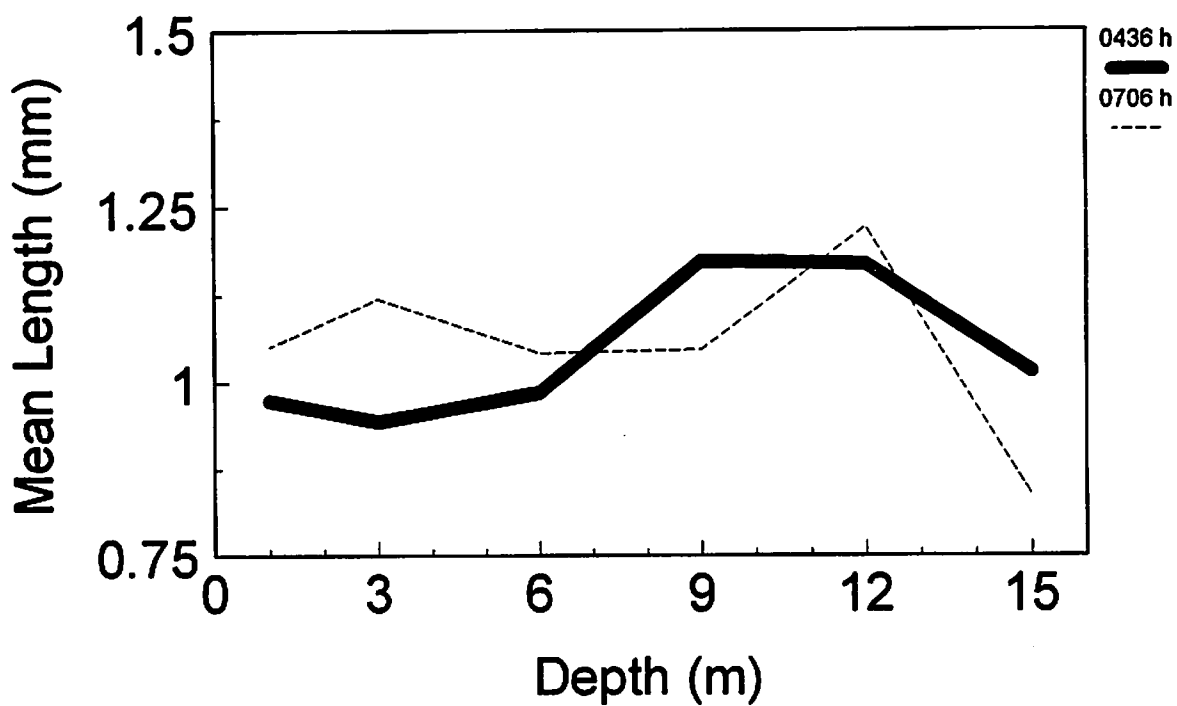
Boemina



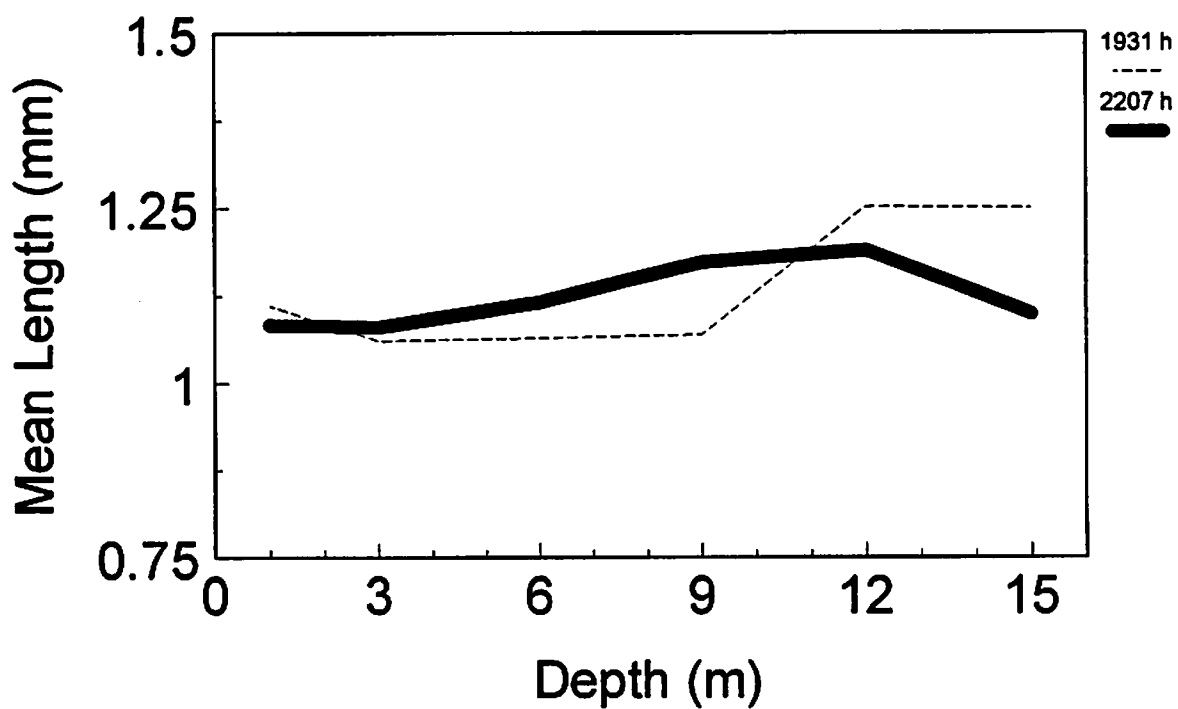
Daphnia pulex



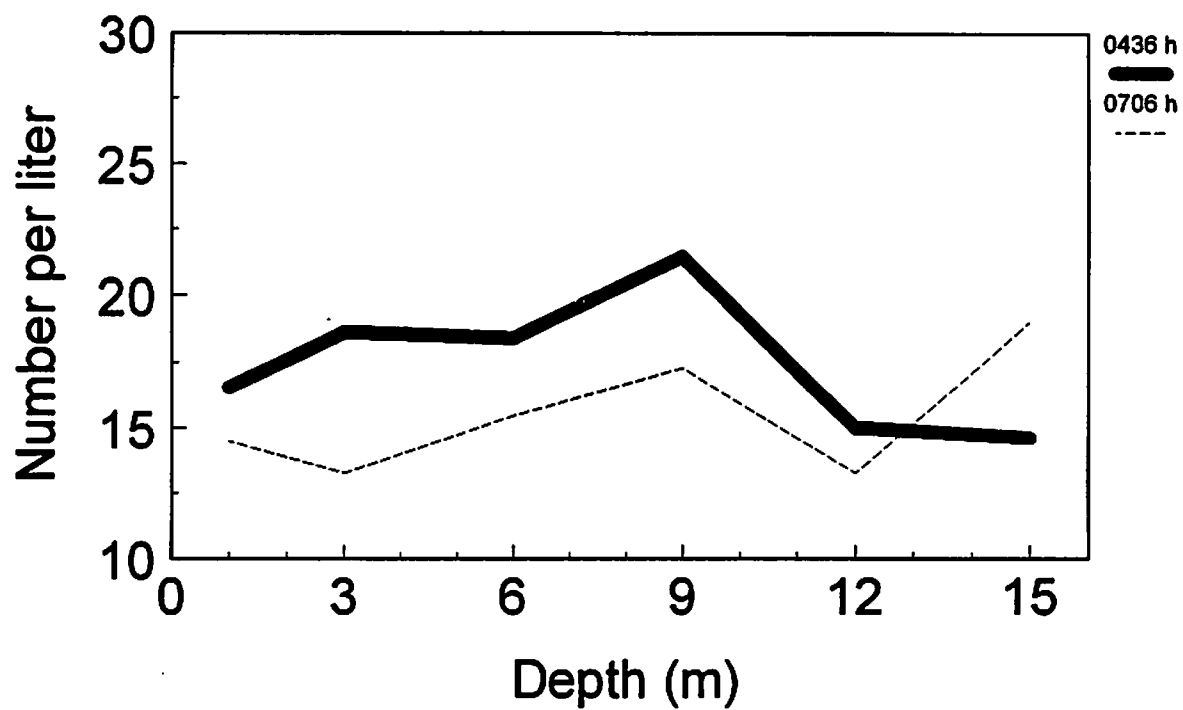
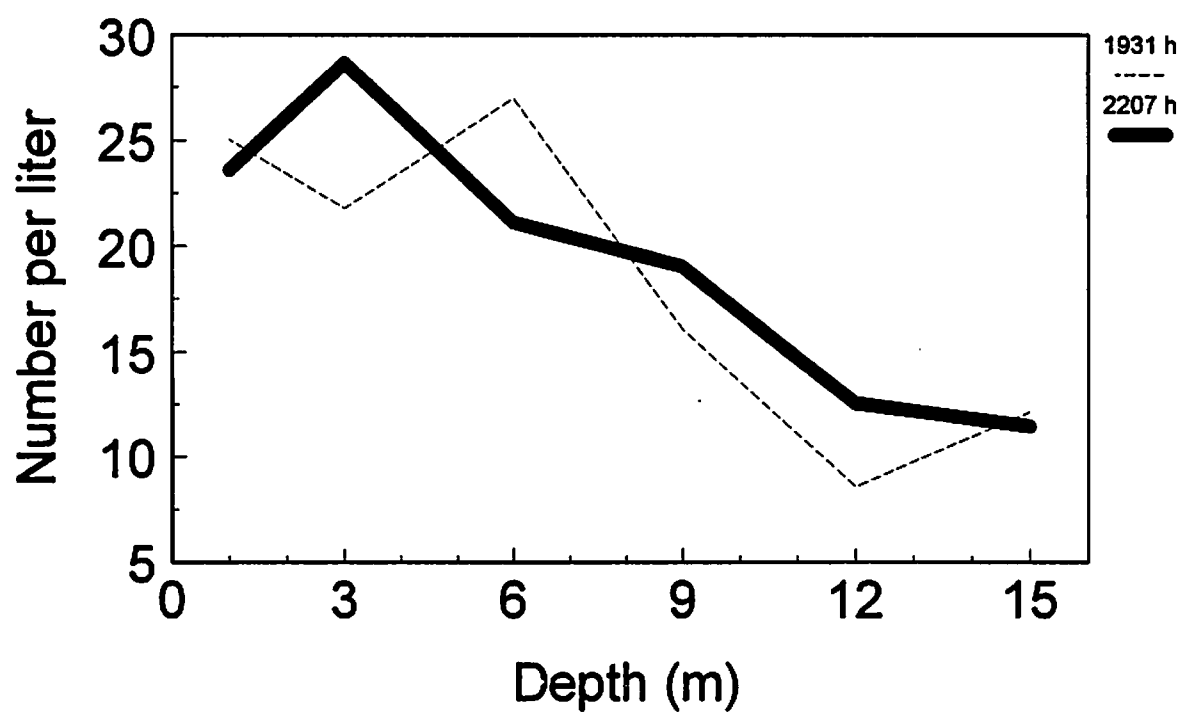
Daphnia pulex



Daphnia galeata

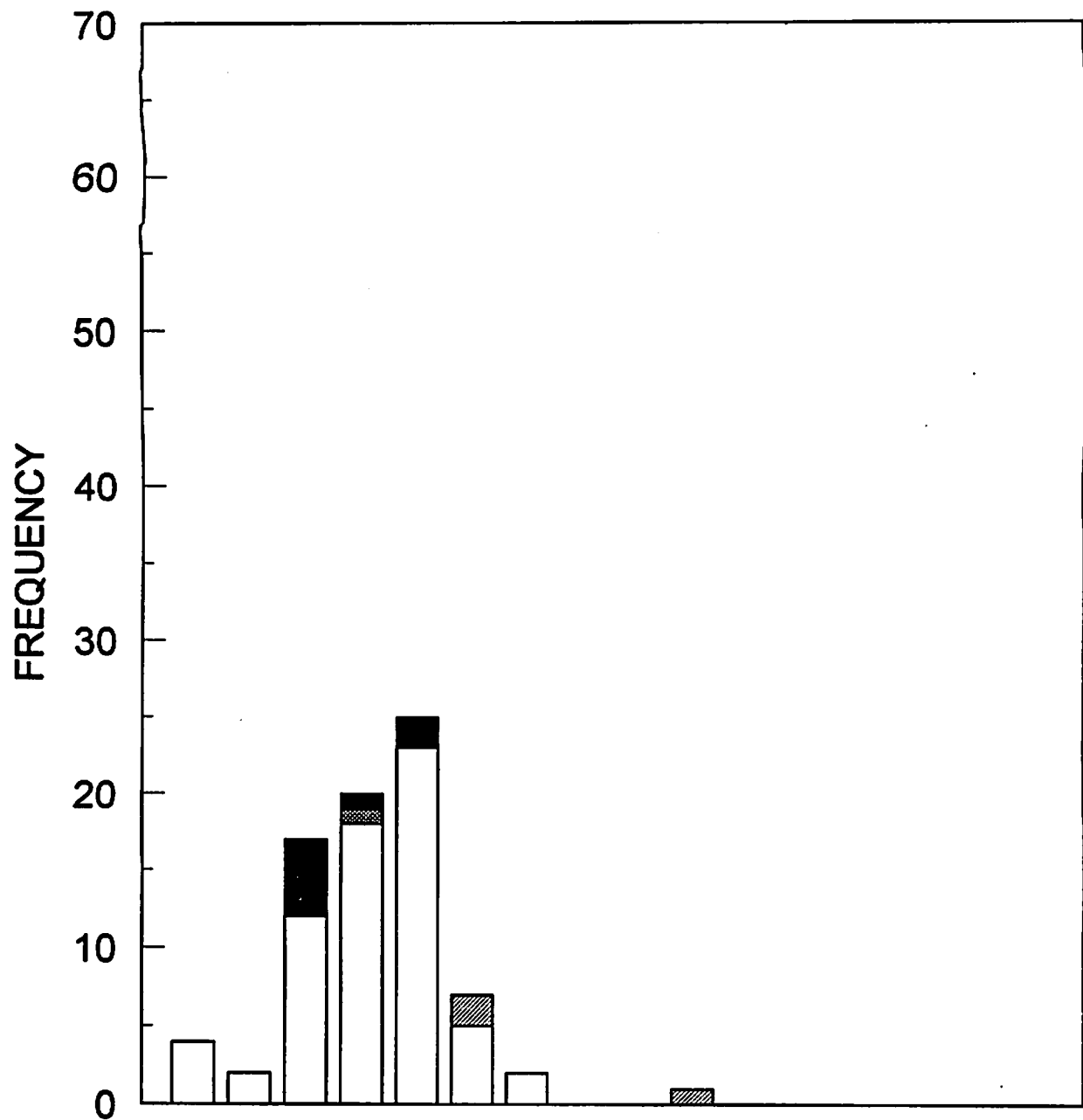


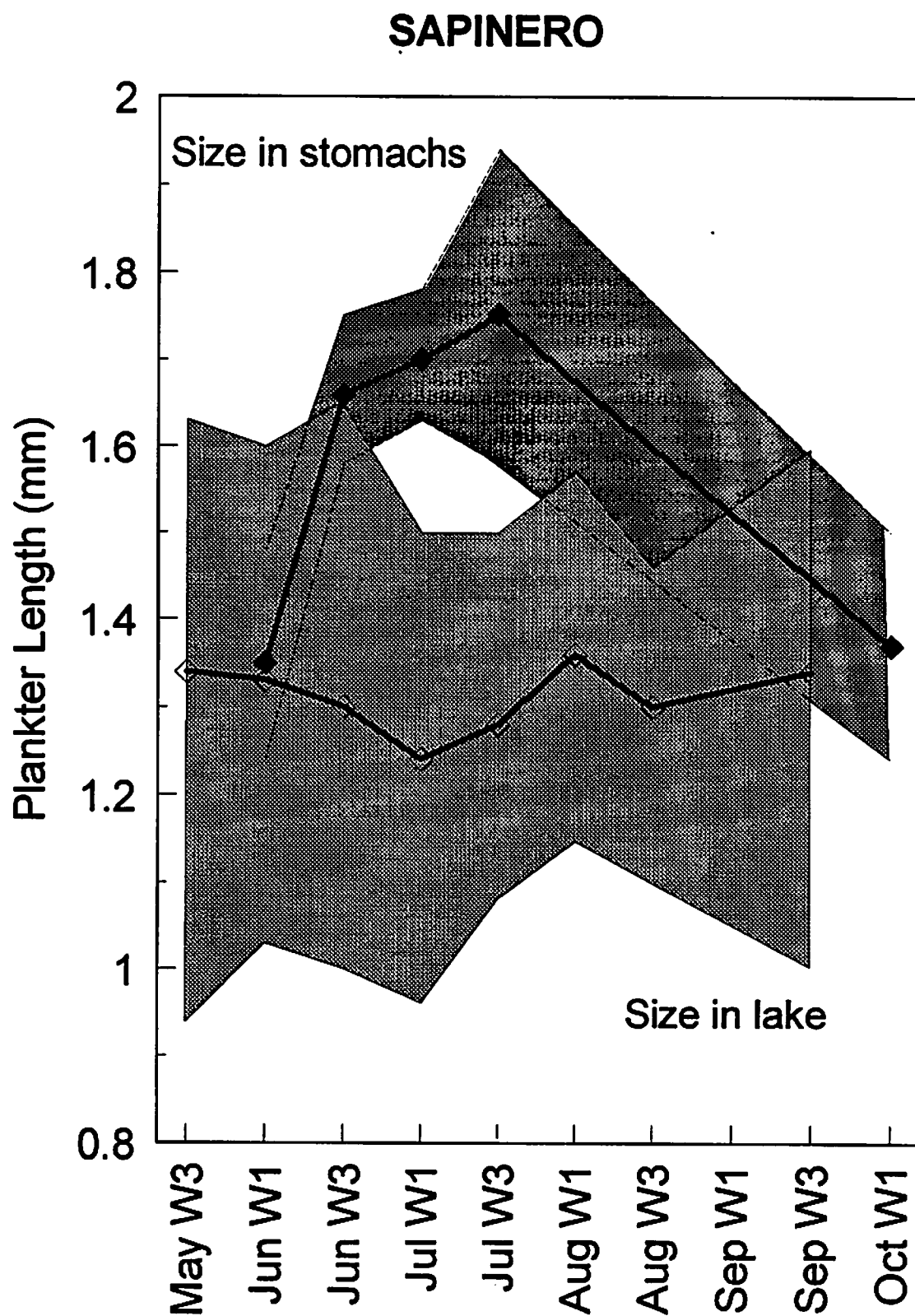
Daphnia galeata

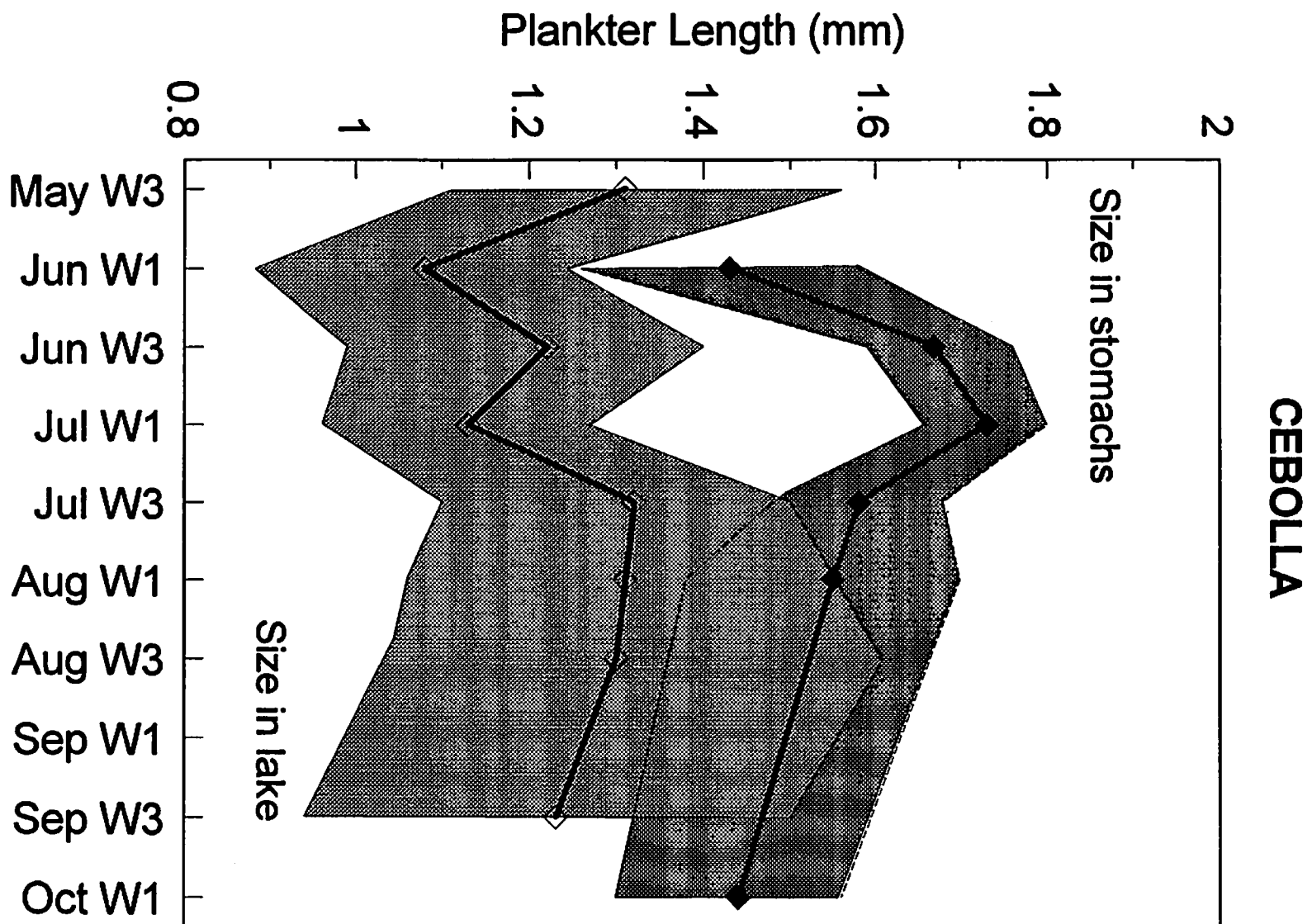
*Di. copepod**Di. copepod*

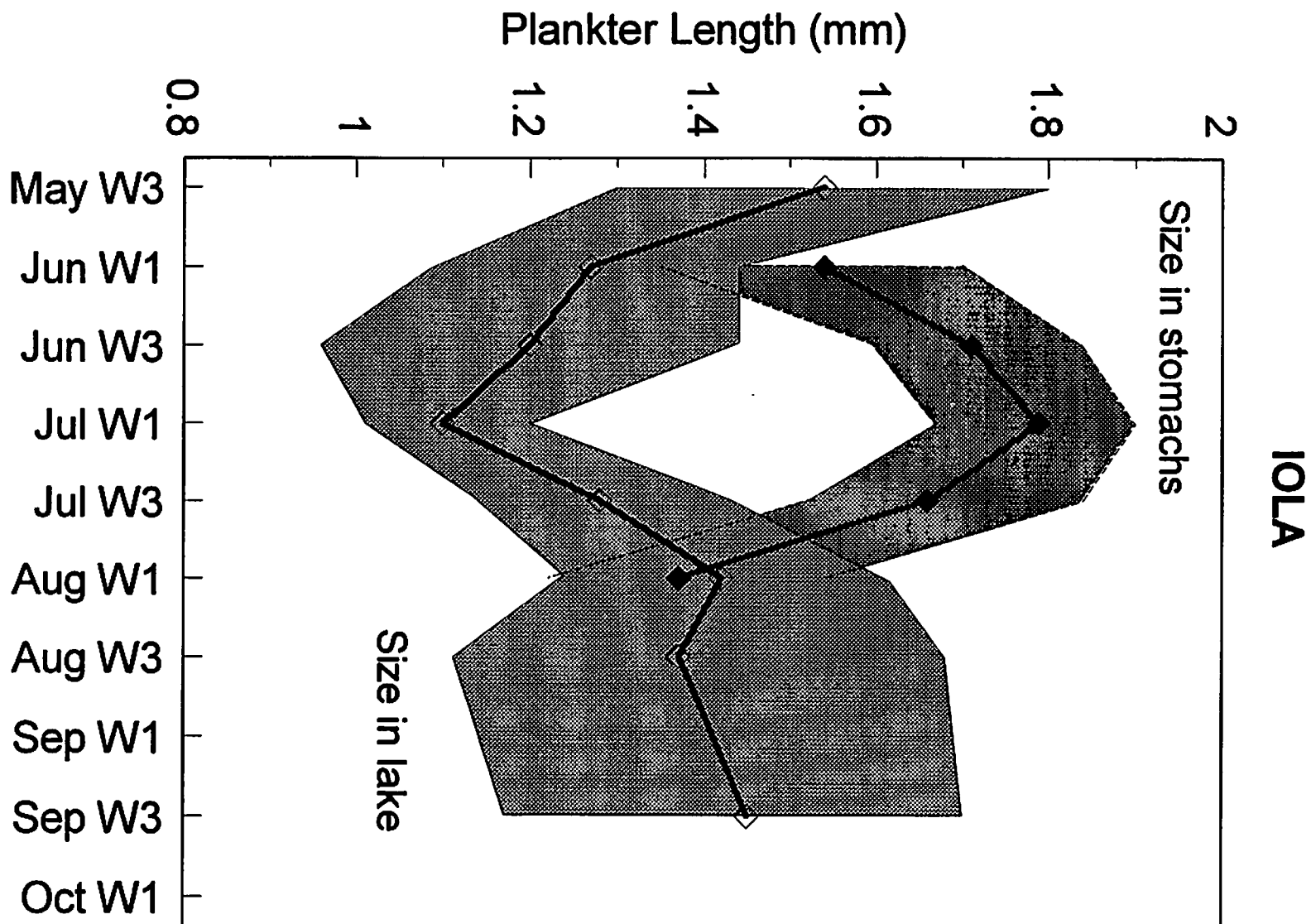
LENGTH-FREQUENCY OF ALL SPP IN VGN
BLUE MESA RESERVOIR -- JUNE 1994

LENGTH-FREQUENCY OF ALL SPP IN VGN
BLUE MESA RESERVOIR -- OCTOBER 1994

[illegible]







APPENDIX A.

Experimental Vertical Gill Net Results

1994 VGN DATA -- BLUE MESA RESERVOIR

11:07 Friday, January 20, 1995 266

SPP=BRN MN=6

TLENGTH
Midpoint

0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
550
575
600
625
650
675
700
725
750
775
800
825
850
875
900
925
950
975
1000

	Freq	Cum. Freq	Percent	Cum. Percent
0	0	0	0.00	0.00
25	0	0	0.00	0.00
50	0	0	0.00	0.00
75	0	0	0.00	0.00
100	0	0	0.00	0.00
125	0	0	0.00	0.00
150	0	0	0.00	0.00
175	0	0	0.00	0.00
200	0	0	0.00	0.00
225	0	0	0.00	0.00
250	1	1	4.35	4.35
275	2	3	8.70	13.04
300	8	11	34.78	47.83
325	4	15	17.39	65.22
350	2	17	8.70	73.91
375	1	18	4.35	78.26
400	3	21	13.04	91.30
425	0	21	0.00	91.30
450	1	22	4.35	95.65
475	1	23	4.35	100.00
500	0	23	0.00	100.00
525	0	23	0.00	100.00
550	0	23	0.00	100.00
575	0	23	0.00	100.00
600	0	23	0.00	100.00
625	0	23	0.00	100.00
650	0	23	0.00	100.00
675	0	23	0.00	100.00
700	0	23	0.00	100.00
725	0	23	0.00	100.00
750	0	23	0.00	100.00
775	0	23	0.00	100.00
800	0	23	0.00	100.00
825	0	23	0.00	100.00
850	0	23	0.00	100.00
875	0	23	0.00	100.00
900	0	23	0.00	100.00
925	0	23	0.00	100.00
950	0	23	0.00	100.00
975	0	23	0.00	100.00
1000	0	23	0.00	100.00

1 2 3 4 5 6 7 8

Frequency

Table A1. Length-frequency of brown trout captured in experimental vertical gill nets in Blue Mesa Reservoir during June 1994.

1994 VGN DATA -- BLUE MESA RESERVOIR

11:07 Friday, January 20, 1995 267

SPP=KOK MN=6

TLENGTH
MidpointCum.
Freq Percent Cum.
Percent

0		0	0	0.00	0.00
25		0	0	0.00	0.00
50		0	0	0.00	0.00
75		0	0	0.00	0.00
100		0	0	0.00	0.00
125		0	0	0.00	0.00
150		0	0	0.00	0.00
175	*****	4	4	2.67	2.67
200	*****	13	17	8.67	11.33
225	*****	15	32	10.00	21.33
250	*****	3	35	2.00	23.33
275	*****	9	44	6.00	29.33
300	*****	14	58	9.33	38.67
325	*****	22	80	14.67	53.33
350	*****	38	118	25.33	78.67
375	*****	27	145	18.00	96.67
400	*****	5	150	3.33	100.00
425		0	150	0.00	100.00
450		0	150	0.00	100.00
475		0	150	0.00	100.00
500		0	150	0.00	100.00
525		0	150	0.00	100.00
550		0	150	0.00	100.00
575		0	150	0.00	100.00
600		0	150	0.00	100.00
625		0	150	0.00	100.00
650		0	150	0.00	100.00
675		0	150	0.00	100.00
700		0	150	0.00	100.00
725		0	150	0.00	100.00
750		0	150	0.00	100.00
775		0	150	0.00	100.00
800		0	150	0.00	100.00
825		0	150	0.00	100.00
850		0	150	0.00	100.00
875		0	150	0.00	100.00
900		0	150	0.00	100.00
925		0	150	0.00	100.00
950		0	150	0.00	100.00
975		0	150	0.00	100.00
1000		0	150	0.00	100.00

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
Frequency

Table A2. Length-frequency of kokanee captured in experimental vertical gill nets in Blue Mesa Reservoir during June 1994.

1994 VGN DATA -- BLUE MESA RESERVOIR

11:07 Friday, January 20, 1995 268

SPP=KOK MN=8

Table A3. Length-frequency of kokanee captured in experimental vertical gill nets in Blue Mesa Reservoir during August 1994.

TLENGTH Midpoint		Freq	Cum. Freq	Percent	Cum. Percent
0		0	0	0.00	0.00
25		0	0	0.00	0.00
50		0	0	0.00	0.00
75		0	0	0.00	0.00
100		0	0	0.00	0.00
125	*****	3	3	2.46	2.46
150		0	3	0.00	2.46
175		0	3	0.00	2.46
200		0	3	0.00	2.46
225	*****	11	14	9.02	11.48
250	*****	9	23	7.38	18.85
275	*****	6	29	4.92	23.77
300	*****	24	53	19.67	43.44
325	*****	18	71	14.75	58.20
350	*****	13	84	10.66	68.85
375	*****	20	104	16.39	85.25
400	*****	16	120	13.11	98.36
425	****	2	122	1.64	100.00
450		0	122	0.00	100.00
475		0	122	0.00	100.00
500		0	122	0.00	100.00
525		0	122	0.00	100.00
550		0	122	0.00	100.00
575		0	122	0.00	100.00
600		0	122	0.00	100.00
625		0	122	0.00	100.00
650		0	122	0.00	100.00
675		0	122	0.00	100.00
700		0	122	0.00	100.00
725		0	122	0.00	100.00
750		0	122	0.00	100.00
775		0	122	0.00	100.00
800		0	122	0.00	100.00
825		0	122	0.00	100.00
850		0	122	0.00	100.00
875		0	122	0.00	100.00
900		0	122	0.00	100.00
925		0	122	0.00	100.00
950		0	122	0.00	100.00
975		0	122	0.00	100.00
1000		0	122	0.00	100.00

Frequency

11:07 Friday, January 20, 1995 269

Table A4. Length-frequency of kokanee captured in experimental vertical gill nets in Blue Mesa Reservoir during October 1994.

LENGTH Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
0	0	0	0.00	0.00
25	0	0	0.00	0.00
50	0	0	0.00	0.00
75	0	0	0.00	0.00
100	0	0	0.00	0.00
125	4	4	6.06	6.06
150	0	4	0.00	6.06
175	2	6	3.03	9.09
200	1	7	1.52	10.61
225	3	10	4.55	15.15
250	13	23	19.70	34.85
275	11	34	16.67	51.52
300	7	41	10.61	62.12
325	16	57	24.24	86.36
350	3	60	4.55	90.91
375	3	63	4.55	95.45
400	2	65	3.03	98.48
425	1	66	1.52	100.00
450	0	66	0.00	100.00
475	0	66	0.00	100.00
500	0	66	0.00	100.00
525	0	66	0.00	100.00
550	0	66	0.00	100.00
575	0	66	0.00	100.00
600	0	66	0.00	100.00
625	0	66	0.00	100.00
650	0	66	0.00	100.00
675	0	66	0.00	100.00
700	0	66	0.00	100.00
725	0	66	0.00	100.00
750	0	66	0.00	100.00
775	0	66	0.00	100.00
800	0	66	0.00	100.00
825	0	66	0.00	100.00
850	0	66	0.00	100.00
875	0	66	0.00	100.00
900	0	66	0.00	100.00
925	0	66	0.00	100.00
950	0	66	0.00	100.00
975	0	66	0.00	100.00

SPP=LGS MN=6

LENGTH
Midpoint

[illegible]

Frequency

1994 VGN DATA -- BLUE MESA RESERVOIR
SPP=LGS MN=10

11:07 Friday, January 20, 1995 271

TLENGTH Midpoint		Freq	Cum. Freq	Percent	Cum. Percent
0		0	0	0.00	0.00
25		0	0	0.00	0.00
50		0	0	0.00	0.00
75		0	0	0.00	0.00
100		0	0	0.00	0.00
125		0	0	0.00	0.00
150		0	0	0.00	0.00
175		0	0	0.00	0.00
200		0	0	0.00	0.00
225		0	0	0.00	0.00
250		0	0	0.00	0.00
275	*****	1	1	100.00	100.00
300		0	1	0.00	100.00
325		0	1	0.00	100.00
350		0	1	0.00	100.00
375		0	1	0.00	100.00
400		0	1	0.00	100.00
425		0	1	0.00	100.00
450		0	1	0.00	100.00
475		0	1	0.00	100.00
500		0	1	0.00	100.00
525		0	1	0.00	100.00
550		0	1	0.00	100.00
575		0	1	0.00	100.00
600		0	1	0.00	100.00
625		0	1	0.00	100.00
650		0	1	0.00	100.00
675		0	1	0.00	100.00
700		0	1	0.00	100.00
725		0	1	0.00	100.00
750		0	1	0.00	100.00
775		0	1	0.00	100.00
800		0	1	0.00	100.00
825		0	1	0.00	100.00
850		0	1	0.00	100.00
875		0	1	0.00	100.00
900		0	1	0.00	100.00
925		0	1	0.00	100.00
950		0	1	0.00	100.00
975		0	1	0.00	100.00
1000		0	1	0.00	100.00

Frequency

1

Table A6. Length-frequency of longnose sucker captured in experimental vertical gill nets in Blue Mesa Reservoir during October 1994.

1994 VGN DATA -- BLUE MESA RESERVOIR

11:07 Friday, January 20, 1995 272

SPP=MAC MN=6

TLENGTH Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
0	0	0	0.00	0.00
25	0	0	0.00	0.00
50	0	0	0.00	0.00
75	0	0	0.00	0.00
100	0	0	0.00	0.00
125	0	0	0.00	0.00
150	0	0	0.00	0.00
175	0	0	0.00	0.00
200	0	0	0.00	0.00
225	0	0	0.00	0.00
250	0	0	0.00	0.00
275	0	0	0.00	0.00
300	1	1	33.33	33.33
325	0	1	0.00	33.33
350	0	1	0.00	33.33
375	0	1	0.00	33.33
400	0	1	0.00	33.33
425	0	1	0.00	33.33
450	0	1	0.00	33.33
475	0	1	0.00	33.33
500	0	1	0.00	33.33
525	0	1	0.00	33.33
550	0	1	0.00	33.33
575	0	1	0.00	33.33
600	0	1	0.00	33.33
625	0	1	0.00	33.33
650	0	1	0.00	33.33
675	0	1	0.00	33.33
700	0	1	0.00	33.33
725	1	2	33.33	66.67
750	0	2	0.00	66.67
775	0	2	0.00	66.67
800	0	2	0.00	66.67
825	0	2	0.00	66.67
850	0	2	0.00	66.67
875	0	2	0.00	66.67
900	1	3	33.33	100.00
925	0	3	0.00	100.00
950	0	3	0.00	100.00
975	0	3	0.00	100.00
1000	0	3	0.00	100.00

Frequency

Table A7. Length-frequency of lake trout captured in experimental vertical gill nets in Blue Mesa Reservoir during June 1994.

TLENGTH Midpoint	Freq	Cum. Freq	Percent	Cum. Percent
0	0	0	0.00	0.00
25	0	0	0.00	0.00
50	0	0	0.00	0.00
75	0	0	0.00	0.00
100	0	0	0.00	0.00
125	0	0	0.00	0.00
150	0	0	0.00	0.00
175	0	0	0.00	0.00
200	0	0	0.00	0.00
225	0	0	0.00	0.00
250	0	0	0.00	0.00
275	0	0	0.00	0.00
300	0	0	0.00	0.00
325	0	0	0.00	0.00
350	0	0	0.00	0.00
375	*****	1	50.00	50.00
400	0	1	0.00	50.00
425	0	1	0.00	50.00
450	0	1	0.00	50.00
475	0	1	0.00	50.00
500	0	1	0.00	50.00
525	*****	1	50.00	100.00
550	0	2	0.00	100.00
575	0	2	0.00	100.00
600	0	2	0.00	100.00
625	0	2	0.00	100.00
650	0	2	0.00	100.00
675	0	2	0.00	100.00
700	0	2	0.00	100.00
725	0	2	0.00	100.00
750	0	2	0.00	100.00
775	0	2	0.00	100.00
800	0	2	0.00	100.00
825	0	2	0.00	100.00
850	0	2	0.00	100.00
875	0	2	0.00	100.00
900	0	2	0.00	100.00
925	0	2	0.00	100.00
950	0	2	0.00	100.00
975	0	2	0.00	100.00
1000	0	2	0.00	100.00

1

Frequency

Table A8. Length-frequency of lake trout captured in experimental vertical gill nets in Blue Mesa Reservoir during August 1994.

1994 VGN DATA -- BLUE MESA RESERVOIR

11:07 Friday, January 20, 1995 274

SPP=MAC MN=10

TLENGTH
MidpointCum.
Freq Freq Percent Percent

0	0	0	0.00	0.00
25	0	0	0.00	0.00
50	0	0	0.00	0.00
75	0	0	0.00	0.00
100	0	0	0.00	0.00
125	0	0	0.00	0.00
150	0	0	0.00	0.00
175	0	0	0.00	0.00
200	0	0	0.00	0.00
225	0	0	0.00	0.00
250	0	0	0.00	0.00
275	0	0	0.00	0.00
300	0	0	0.00	0.00
325	0	0	0.00	0.00
350	0	0	0.00	0.00
375	*****	1	1	33.33
400	*****	1	2	33.33
425		0	2	0.00
450		0	2	0.00
475		0	2	0.00
500		0	2	0.00
525		0	2	0.00
550		0	2	0.00
575		0	2	0.00
600	*****	1	3	33.33
625		0	3	0.00
650		0	3	0.00
675		0	3	0.00
700		0	3	0.00
725		0	3	0.00
750		0	3	0.00
775		0	3	0.00
800		0	3	0.00
825		0	3	0.00
850		0	3	0.00
875		0	3	0.00
900		0	3	0.00
925		0	3	0.00
950		0	3	0.00
975		0	3	0.00
1000		0	3	0.00

Frequency

1

Table A9. Length-frequency of lake trout captured in experimental vertical gill nets in Blue Mesa Reservoir during October 1994.

11:07 Friday, January 20, 1995 275

Freq	Cum. Freq	Percent	Cum. Percent

[illegible]

Table A10. Length-frequency of rainbow trout captured in experimental vertical gill nets in Blue Mesa Reservoir during June 1994.

1994 VGN DATA -- BLUE MESA RESERVOIR

11:07 Friday, January 20, 1995 276

SPP=RBT MN=8

TLENGTH
Midpoint

	Freq	Cum. Freq	Percent	Cum. Percent
0	0	0	0.00	0.00
25	0	0	0.00	0.00
50	0	0	0.00	0.00
75	0	0	0.00	0.00
100	0	0	0.00	0.00
125	0	0	0.00	0.00
150	0	0	0.00	0.00
175	0	0	0.00	0.00
200	1	1	33.33	33.33
225	1	2	33.33	66.67
250	0	2	0.00	66.67
275	0	2	0.00	66.67
300	1	3	33.33	100.00
325	0	3	0.00	100.00
350	0	3	0.00	100.00
375	0	3	0.00	100.00
400	0	3	0.00	100.00
425	0	3	0.00	100.00
450	0	3	0.00	100.00
475	0	3	0.00	100.00
500	0	3	0.00	100.00
525	0	3	0.00	100.00
550	0	3	0.00	100.00
575	0	3	0.00	100.00
600	0	3	0.00	100.00
625	0	3	0.00	100.00
650	0	3	0.00	100.00
675	0	3	0.00	100.00
700	0	3	0.00	100.00
725	0	3	0.00	100.00
750	0	3	0.00	100.00
775	0	3	0.00	100.00
800	0	3	0.00	100.00
825	0	3	0.00	100.00
850	0	3	0.00	100.00
875	0	3	0.00	100.00
900	0	3	0.00	100.00
925	0	3	0.00	100.00
950	0	3	0.00	100.00
975	0	3	0.00	100.00
1000	0	3	0.00	100.00

Frequency

1

Table A11. Length-frequency of rainbow trout captured in experimental vertical gill nets in Blue Mesa Reservoir during August 1994.

TLENGTH
Midpoint

	Freq	Cum. Freq	Percent	Cum. Percent
0	0	0	0.00	0.00
25	0	0	0.00	0.00
50	0	0	0.00	0.00
75	0	0	0.00	0.00
100	0	0	0.00	0.00
125	0	0	0.00	0.00
150	0	0	0.00	0.00
175	0	0	0.00	0.00
200	2	2	25.00	25.00
225	3	5	37.50	62.50
250	0	5	0.00	62.50
275	1	6	12.50	75.00
300	0	6	0.00	75.00
325	2	8	25.00	100.00
350	0	8	0.00	100.00
375	0	8	0.00	100.00
400	0	8	0.00	100.00
425	0	8	0.00	100.00
450	0	8	0.00	100.00
475	0	8	0.00	100.00
500	0	8	0.00	100.00
525	0	8	0.00	100.00
550	0	8	0.00	100.00
575	0	8	0.00	100.00
600	0	8	0.00	100.00
625	0	8	0.00	100.00
650	0	8	0.00	100.00
675	0	8	0.00	100.00
700	0	8	0.00	100.00
725	0	8	0.00	100.00
750	0	8	0.00	100.00
775	0	8	0.00	100.00
800	0	8	0.00	100.00
825	0	8	0.00	100.00
850	0	8	0.00	100.00
875	0	8	0.00	100.00
900	0	8	0.00	100.00
925	0	8	0.00	100.00
950	0	8	0.00	100.00
975	0	8	0.00	100.00
1000	0	8	0.00	100.00

1

2

3

Frequency

Table A12. Length-frequency of rainbow trout captured in experimental vertical gill nets in Blue Mesa Reservoir during October 1994.

Analysis Variable : K

SPP	MN	N Obs	N	Mean	Std Dev	Minimum	Maximum
BRN	6	23	23	0.0808853	0.0105204	0.0583118	0.0984871
KOK	6	150	147	0.0964060	0.0100288	0.0577119	0.1191007
	8	122	122	0.1044601	0.0082792	0.0714666	0.1275635
	10	66	66	0.0962782	0.0120005	0.0591564	0.1178231
LGS	6	4	4	0.1033928	0.0163721	0.0820829	0.1217128
	10	1	1	0.0977626	.	0.0977626	0.0977626
MAC	6	3	3	0.1249196	0.0422953	0.0767818	0.1561268
	8	2	2	0.0837101	0.0194076	0.0699868	0.0974333
	10	3	3	0.0745604	0.0081240	0.0656976	0.0816540
RBT	6	2	2	0.1007850	0.0015088	0.0997181	0.1018519
	8	3	3	0.1140735	0.0186736	0.0951622	0.1325000
	10	8	8	0.1035543	0.0072303	0.0972338	0.1201105

Table A13. Mean condition factor (Fulton's K) of brown trout (BRN), kokanee (KOK), longnose sucker (LGS), lake trout (MAC), and rainbow trout (RBT) captured in experimental vertical gill nets in Blue Mesa Reservoir, June-October 1994.

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Analysis Variable : TLENGTH

MN=6							
SITE	SPP	N Obs	N	Mean	Std Dev	Minimum	Maximum
CEBOLLA	BRN	7	7	315.5714286	68.5659224	270.0000000	468.0000000
	KOK	69	69	278.5507246	70.5481763	173.0000000	390.0000000
	MAC	1	1	306.0000000	.	306.0000000	306.0000000
	RBT	1	1	300.0000000	.	300.0000000	300.0000000
IOLA	BRN	14	14	342.7142857	57.2839467	238.0000000	457.0000000
	KOK	24	24	332.2916667	45.5263700	218.0000000	394.0000000
	LGS	4	4	335.0000000	53.7773186	268.0000000	386.0000000
	RBT	1	1	295.0000000	.	295.0000000	295.0000000
SAPINERO	BRN	2	2	338.0000000	36.7695526	312.0000000	364.0000000
	KOK	57	57	342.2631579	32.6400971	258.0000000	405.0000000
	MAC	2	2	813.5000000	108.1873375	737.0000000	890.0000000

MN=8							
SITE	SPP	N Obs	N	Mean	Std Dev	Minimum	Maximum
CEBARM	KOK	6	6	270.5000000	36.6428711	229.0000000	312.0000000
	RBT	2	2	266.0000000	55.1543289	227.0000000	305.0000000
CEBOLLA	KOK	72	72	326.8333333	49.9653401	220.0000000	410.0000000
	MAC	1	1	535.0000000	.	535.0000000	535.0000000
IOLA	KOK	26	26	315.7692308	92.5398542	114.0000000	420.0000000
	RBT	1	1	200.0000000	.	200.0000000	200.0000000
SAPINERO	KOK	18	18	324.5000000	64.7903860	223.0000000	425.0000000
	MAC	1	1	378.0000000	.	378.0000000	378.0000000

MN=10							
SITE	SPP	N Obs	N	Mean	Std Dev	Minimum	Maximum
CEBOLLA	KOK	37	37	268.1351351	58.4009904	118.0000000	360.0000000
	MAC	2	2	390.0000000	8.4852814	384.0000000	396.0000000
IOLA	KOK	8	8	239.1250000	76.0158583	132.0000000	342.0000000
	LGS	1	1	266.0000000	.	266.0000000	266.0000000
	RBT	8	8	249.2500000	50.8407879	202.0000000	322.0000000
SAPINERO	KOK	21	21	324.4761905	51.6271431	246.0000000	420.0000000
	MAC	1	1	595.0000000	.	595.0000000	595.0000000

Table A14. Mean total length (mm) of brown trout (BRN), kokanee (KOK), longnose sucker (LGS), lake trout (MAC), and rainbow trout (RBT) at four sites in Blue Mesa Reservoir, June-October 1994.

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Analysis Variable : TLENGTH

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MN=6						
FISHDEP	N Obs	N	Mean	Std Dev	Minimum	Maximum
1	1	1	354.0000000	.	354.0000000	354.0000000
2	9	9	286.0000000	68.5127725	187.0000000	372.0000000
3	8	8	293.6250000	33.8861012	224.0000000	342.0000000
4	13	13	346.7692308	63.7170226	190.0000000	457.0000000
5	12	12	303.7500000	63.3792696	204.0000000	374.0000000
6	13	13	280.8461538	61.5911873	188.0000000	380.0000000
7	7	7	285.4285714	81.9448130	214.0000000	383.0000000
8	3	3	320.6666667	85.0078428	223.0000000	378.0000000
9	9	9	333.5555556	59.6722530	222.0000000	392.0000000
10	8	8	322.3750000	53.7479235	216.0000000	366.0000000
11	10	10	293.8000000	59.0984113	190.0000000	384.0000000
12	6	6	284.5000000	96.2844743	173.0000000	386.0000000
13	15	15	306.2000000	67.5607663	193.0000000	405.0000000
14	14	14	324.4285714	57.4546166	176.0000000	378.0000000
15	5	5	283.2000000	44.1497452	222.0000000	344.0000000
16	8	8	393.8750000	208.7660601	219.0000000	890.0000000
17	8	8	338.2500000	35.8319490	278.0000000	379.0000000
18	13	13	343.9230769	46.1075943	293.0000000	468.0000000
19	4	4	359.7500000	15.4569294	341.0000000	378.0000000
20	3	3	281.0000000	83.9106668	186.0000000	345.0000000
21	2	2	351.0000000	25.4558441	333.0000000	369.0000000
22	4	4	369.2500000	19.3110504	346.0000000	390.0000000
24	1	1	358.0000000	.	358.0000000	358.0000000
25	2	2	521.5000000	304.7630227	306.0000000	737.0000000
32	1	1	344.0000000	.	344.0000000	344.0000000
34	1	1	211.0000000	.	211.0000000	211.0000000
43	1	1	361.0000000	.	361.0000000	361.0000000
50	1	1	331.0000000	.	331.0000000	331.0000000

Table A15. Mean total length (mm) by depth of capture (FISHDEP) of all fish sampled in experimental vertical gill nets in Blue Mesa Reservoir in June 1994.

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Table A16. Mean total length (mm) by depth of capture (FISHDEP) of all fish sampled in experimental vertical gill nets in Blue Mesa Reservoir in August 1994.

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Analysis Variable : TLENGTH

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Table A17. Mean total length (mm) by depth of capture (FISHDEP) of all fish sampled in experimental vertical gill nets in Blue Mesa Reservoir in October 1994.

----- MN=10 -----						
FISHDEP	N Obs	N	Mean	Std Dev	Minimum	Maximum
1	1	1	202.0000000	.	202.0000000	202.0000000
2	4	4	294.2500000	33.3903679	252.0000000	322.0000000
3	2	2	299.0000000	108.8944443	222.0000000	376.0000000
4	1	1	245.0000000	.	245.0000000	245.0000000
5	3	3	308.0000000	78.3134727	224.0000000	379.0000000
6	4	4	274.2500000	34.2283995	241.0000000	309.0000000
8	6	6	278.1666667	46.8504714	206.0000000	329.0000000
9	3	3	281.3333333	27.5741425	255.0000000	310.0000000
10	2	2	142.5000000	34.6482323	118.0000000	167.0000000
11	3	3	197.6666667	58.9434757	132.0000000	246.0000000
12	2	2	290.0000000	33.9411255	266.0000000	314.0000000
13	2	2	261.5000000	9.1923882	255.0000000	268.0000000
14	4	4	235.0000000	78.4984076	124.0000000	307.0000000
15	7	7	270.2857143	38.5776891	212.0000000	330.0000000
16	4	4	290.5000000	74.9333037	180.0000000	342.0000000
18	2	2	223.0000000	145.6639969	120.0000000	326.0000000
19	3	3	300.0000000	31.4324673	264.0000000	322.0000000
20	4	4	301.7500000	74.7278395	228.0000000	384.0000000
22	2	2	271.5000000	68.5893578	223.0000000	320.0000000
23	1	1	228.0000000	.	228.0000000	228.0000000
24	2	2	364.5000000	64.3467171	319.0000000	410.0000000
25	1	1	335.0000000	.	335.0000000	335.0000000
27	1	1	269.0000000	.	269.0000000	269.0000000
29	1	1	287.0000000	.	287.0000000	287.0000000
30	2	2	342.5000000	24.7487373	325.0000000	360.0000000
31	2	2	285.0000000	65.0538239	239.0000000	331.0000000
32	1	1	321.0000000	.	321.0000000	321.0000000
33	4	4	408.5000000	134.8344664	273.0000000	595.0000000
36	2	2	372.5000000	67.1751442	325.0000000	420.0000000
37	1	1	257.0000000	.	257.0000000	257.0000000
44	1	1	396.0000000	.	396.0000000	396.0000000

Analysis Variable : TLENGTH

Table A18. Mean total length (mm) of all fish sampled in 5-m depth strata at four sites in Blue Mesa Reservoir, June-October 1994 (MN=month).

SITE=CEBARM							
MN	STRATUM	N Obs	N	Mean	Std Dev	Minimum	Maximum
8	06-10 m	1	1	227.0000000	.	227.0000000	227.0000000
	11-15 m	2	2	270.5000000	48.7903679	236.0000000	305.0000000
	16-20 m	5	5	277.4000000	36.3496905	229.0000000	312.0000000
SITE=CEBOLLA							
MN	STRATUM	N Obs	N	Mean	Std Dev	Minimum	Maximum
6	00-05 m	15	15	252.3333333	53.4945480	187.0000000	342.0000000
	06-10 m	18	18	262.2222222	56.9515331	188.0000000	366.0000000
	11-15 m	20	20	258.7000000	68.4590542	173.0000000	378.0000000
	16-20 m	16	16	329.6250000	67.2536244	186.0000000	468.0000000
	21-25 m	7	7	358.5714286	27.2265627	306.0000000	390.0000000
	31-35 m	1	1	211.0000000	.	211.0000000	211.0000000
	41-45 m	1	1	361.0000000	.	361.0000000	361.0000000
8	00-05 m	2	2	294.5000000	92.6309883	229.0000000	360.0000000
	11-15 m	5	5	338.0000000	49.0102030	298.0000000	400.0000000
	16-20 m	19	19	328.7368421	47.8398278	243.0000000	410.0000000
	21-25 m	19	19	338.1578947	53.5197400	227.0000000	405.0000000
	26-30 m	23	23	319.0434783	45.2060719	220.0000000	398.0000000
	36-40 m	1	1	395.0000000	.	395.0000000	395.0000000
	46-50 m	3	3	351.6666667	160.5750084	236.0000000	535.0000000
10	00-05 m	3	3	272.6666667	42.0039681	245.0000000	321.0000000
	06-10 m	7	7	261.2857143	69.0789748	118.0000000	317.0000000
	11-15 m	13	13	263.4615385	52.6380968	124.0000000	330.0000000
	16-20 m	8	8	280.5000000	83.5498141	120.0000000	384.0000000
	21-25 m	2	2	225.5000000	3.5355339	223.0000000	228.0000000
	26-30 m	2	2	323.5000000	51.6187950	287.0000000	360.0000000
	31-35 m	3	3	297.0000000	50.4777179	239.0000000	331.0000000
	41-45 m	1	1	396.0000000	.	396.0000000	396.0000000

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Analysis Variable : TLENGTH

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Table A19. Mean total length (mm) of all fish sampled in 5-m depth strata at four sites in Blue Mesa Reservoir, June-October 1994 (MN=month).

----- SITE=IOLA -----							
MN	STRATUM	N Obs	N	Mean	Std Dev	Minimum	Maximum
6	00-05 m	9	9	356.6666667	52.9646108	295.0000000	457.0000000
	06-10 m	5	5	301.4000000	76.5362659	218.0000000	388.0000000
	11-15 m	15	15	327.8666667	45.2735600	238.0000000	394.0000000
	16-20 m	14	14	340.9285714	34.9955256	278.0000000	407.0000000
8	06-10 m	3	3	226.3333333	122.6390367	119.0000000	360.0000000
	11-15 m	8	8	335.0000000	89.8029589	125.0000000	390.0000000
	16-20 m	13	13	304.6923077	93.2321338	114.0000000	420.0000000
	21-25 m	3	3	363.3333333	25.6580072	335.0000000	385.0000000
10	00-05 m	6	6	262.1666667	53.0072322	202.0000000	322.0000000
	06-10 m	5	5	244.2000000	62.9261472	167.0000000	329.0000000
	11-15 m	4	4	214.2500000	58.6763723	132.0000000	266.0000000
	16-20 m	2	2	261.0000000	114.5512986	180.0000000	342.0000000

Analysis Variable : TLENGTH

----- SITE=SAPINERO -----							
MN	STRATUM	N Obs	N	Mean	Std Dev	Minimum	Maximum
6	00-05 m	19	19	338.6842105	31.7840852	281.0000000	386.0000000
	06-10 m	17	17	350.8823529	37.3879699	258.0000000	392.0000000
	11-15 m	15	15	340.2666667	34.5821314	279.0000000	405.0000000
	16-20 m	6	6	427.1666667	227.4813545	312.0000000	890.0000000
	21-25 m	2	2	535.0000000	285.6711396	333.0000000	737.0000000
	31-35 m	1	1	344.0000000	.	344.0000000	344.0000000
	46-50 m	1	1	331.0000000	.	331.0000000	331.0000000
8	11-15 m	1	1	409.0000000	.	409.0000000	409.0000000
	16-20 m	4	4	324.7500000	74.2130941	224.0000000	385.0000000
	21-25 m	9	9	307.4444444	64.8808737	223.0000000	406.0000000
	26-30 m	4	4	341.5000000	58.4494083	290.0000000	425.0000000
	51-55 m	1	1	378.0000000	.	378.0000000	378.0000000
10	00-05 m	2	2	377.5000000	2.1213203	376.0000000	379.0000000
	06-10 m	3	3	281.6666667	30.3534732	249.0000000	309.0000000
	11-15 m	1	1	246.0000000	.	246.0000000	246.0000000
	16-20 m	3	3	316.3333333	8.7368949	309.0000000	326.0000000
	21-25 m	4	4	346.0000000	43.2897216	319.0000000	410.0000000
	26-30 m	2	2	297.0000000	39.5979797	269.0000000	325.0000000
	31-35 m	4	4	408.5000000	134.8344664	273.0000000	595.0000000
	36-40 m	3	3	334.0000000	81.8718511	257.0000000	420.0000000

Table A20. Mean total length (mm) of all fish sampled in 5-m depth strata at four sites in Blue Mesa Reservoir, June-October 1994 (MN=month).

MN=6

TABLE OF SPP BY STRATUM

SPP	STRATUM								
Frequency Percent Row Pct Col Pct	00-05 m	06-10 m	11-15 m	16-20 m	21-25 m	31-35 m	41-45 m	46-50 m	Total
BRN	5	2	5	11	0	0	0	0	23
	2.75	1.10	2.75	6.04	0.00	0.00	0.00	0.00	12.64
	21.74	8.70	21.74	47.83	0.00	0.00	0.00	0.00	
	11.63	5.00	10.00	30.56	0.00	0.00	0.00	0.00	
KOK	36	38	44	21	7	2	1	1	150
	19.78	20.88	24.18	11.54	3.85	1.10	0.55	0.55	82.42
	24.00	25.33	29.33	14.00	4.67	1.33	0.67	0.67	
	83.72	95.00	88.00	58.33	77.78	100.00	100.00	100.00	
LGS	0	0	1	3	0	0	0	0	4
	0.00	0.00	0.55	1.65	0.00	0.00	0.00	0.00	2.20
	0.00	0.00	25.00	75.00	0.00	0.00	0.00	0.00	
	0.00	0.00	2.00	8.33	0.00	0.00	0.00	0.00	
MAC	0	0	0	1	2	0	0	0	3
	0.00	0.00	0.00	0.55	1.10	0.00	0.00	0.00	1.65
	0.00	0.00	0.00	33.33	66.67	0.00	0.00	0.00	
	0.00	0.00	0.00	2.78	22.22	0.00	0.00	0.00	
RBT	2	0	0	0	0	0	0	0	2
	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10
	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	4.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total	43	40	50	36	9	2	1	1	182
	23.63	21.98	27.47	19.78	4.95	1.10	0.55	0.55	100.00

Table A21. Number of brown trout (BRN), kokanee (KOK), longnose sucker (LGS), lake trout (MAC), and rainbow trout (RBT) caught in 5-m depth strata with experimental vertical gill nets in Blue Mesa Reservoir, June 1994.

MN=8

TABLE OF SPP BY STRATUM

SPP	STRATUM									
Frequency										
Percent										
Row Pct										
Col Pct	00-05 m	06-10 m	11-15 m	16-20 m	21-25 m	26-30 m	36-40 m	46-50 m	51-55 m	Total
KOK	2	2	15	41	31	27	1	2	0	121
	1.59	1.59	11.90	32.54	24.60	21.43	0.79	1.59	0.00	96.03
	1.65	1.65	12.40	33.88	25.62	22.31	0.83	1.65	0.00	
	100.00	50.00	93.75	100.00	100.00	100.00	100.00	66.67	0.00	
MAC	0	0	0	0	0	0	0	1	1	2
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.79	1.59
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00	50.00	
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.33	100.00	
RBT	0	2	1	0	0	0	0	0	0	3
	0.00	1.59	0.79	0.00	0.00	0.00	0.00	0.00	0.00	2.38
	0.00	66.67	33.33	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	50.00	6.25	0.00	0.00	0.00	0.00	0.00	0.00	
Total	2	4	16	41	31	27	1	3	1	126
	1.59	3.17	12.70	32.54	24.60	21.43	0.79	2.38	0.79	100.00

Frequency Missing = 1

Table A22. Number of brown trout (BRN), kokanee (KOK), longnose sucker (LGS), lake trout (MAC), and rainbow trout (RBT) caught in 5-m depth strata with experimental vertical gill nets in Blue Mesa Reservoir, August 1994.

MN=10

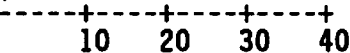
TABLE OF SPP BY STRATUM

SPP	STRATUM									
Frequency Percent Row Pct Col Pct	00-05 m	06-10 m	11-15 m	16-20 m	21-25 m	26-30 m	31-35 m	36-40 m	41-45 m	Total
KOK	5	14	16	12	6	4	6	3	0	66
	6.41	17.95	20.51	15.38	7.69	5.13	7.69	3.85	0.00	84.62
	7.58	21.21	24.24	18.18	9.09	6.06	9.09	4.55	0.00	
	45.45	93.33	88.89	92.31	100.00	100.00	85.71	100.00	0.00	
LGS	0	0	1	0	0	0	0	0	0	1
	0.00	0.00	1.28	0.00	0.00	0.00	0.00	0.00	0.00	1.28
	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	
	0.00	0.00	5.56	0.00	0.00	0.00	0.00	0.00	0.00	
MAC	0	0	0	1	0	0	1	0	1	3
	0.00	0.00	0.00	1.28	0.00	0.00	1.28	0.00	1.28	3.85
	0.00	0.00	0.00	33.33	0.00	0.00	33.33	0.00	33.33	
	0.00	0.00	0.00	7.69	0.00	0.00	14.29	0.00	100.00	
RBT	6	1	1	0	0	0	0	0	0	8
	7.69	1.28	1.28	0.00	0.00	0.00	0.00	0.00	0.00	10.26
	75.00	12.50	12.50	0.00	0.00	0.00	0.00	0.00	0.00	
	54.55	6.67	5.56	0.00	0.00	0.00	0.00	0.00	0.00	
Total	11	15	18	13	6	4	7	3	1	78
	14.10	19.23	23.08	16.67	7.69	5.13	8.97	3.85	1.28	100.00

Table A23. Number of brown trout (BRN), kokanee (KOK), longnose sucker (LGS), lake trout (MAC), and rainbow trout (RBT) caught in 5-m depth strata with experimental vertical gill nets in Blue Mesa Reservoir, October 1994.

Table A24. Length-frequency histogram of all fish captured in experimental vertical gill nets in Blue Mesa Reservoir during June 1994.

TLENGTH Midpoint		Freq	Cum. Freq	Percent	Cum. Percent
0		0	0	0.00	0.00
25		0	0	0.00	0.00
50		0	0	0.00	0.00
75		0	0	0.00	0.00
100		0	0	0.00	0.00
125		0	0	0.00	0.00
150		0	0	0.00	0.00
175	**	4	4	2.20	2.20
200	*****	13	17	7.14	9.34
225	*****	15	32	8.24	17.58
250	**	4	36	2.20	19.78
275	*****	12	48	6.59	26.37
300	*****	25	73	13.74	40.11
325	*****	27	100	14.84	54.95
350	*****	40	140	21.98	76.92
375	*****	30	170	16.48	93.41
400	****	8	178	4.40	97.80
425		0	178	0.00	97.80
450	*	1	179	0.55	98.35
475	*	1	180	0.55	98.90
500		0	180	0.00	98.90
525		0	180	0.00	98.90
550		0	180	0.00	98.90
575		0	180	0.00	98.90
600		0	180	0.00	98.90
625		0	180	0.00	98.90
650		0	180	0.00	98.90
675		0	180	0.00	98.90
700		0	180	0.00	98.90
725	*	1	181	0.55	99.45
750		0	181	0.00	99.45
775		0	181	0.00	99.45
800		0	181	0.00	99.45
825		0	181	0.00	99.45
850		0	181	0.00	99.45
875		0	181	0.00	99.45
900	*	1	182	0.55	100.00
925		0	182	0.00	100.00



Frequency

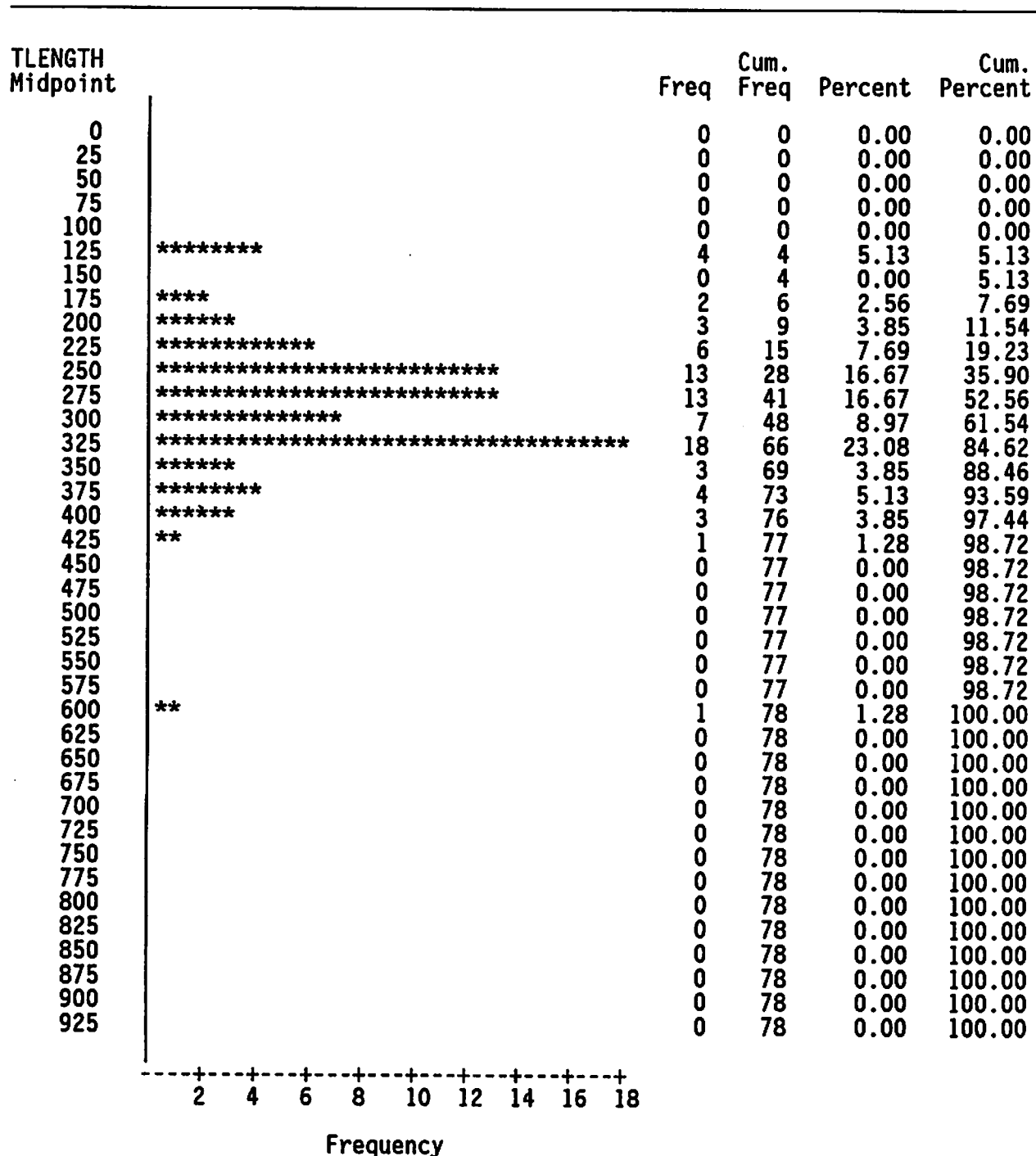
Table A25. Length-frequency histogram of all fish captured in experimental vertical gill nets in Blue Mesa Reservoir during August 1994.

TLENGTH Midpoint		Freq	Cum. Freq	Percent	Cum. Percent
0		0	0	0.00	0.00
25		0	0	0.00	0.00
50		0	0	0.00	0.00
75		0	0	0.00	0.00
100		0	0	0.00	0.00
125	***	3	3	2.36	2.36
150		0	3	0.00	2.36
175		0	3	0.00	2.36
200	*	1	4	0.79	3.15
225	*****	12	16	9.45	12.60
250	*****	9	25	7.09	19.69
275	*****	6	31	4.72	24.41
300	*****	25	56	19.69	44.09
325	*****	18	74	14.17	58.27
350	*****	13	87	10.24	68.50
375	*****	21	108	16.54	85.04
400	*****	16	124	12.60	97.64
425	**	2	126	1.57	99.21
450		0	126	0.00	99.21
475		0	126	0.00	99.21
500		0	126	0.00	99.21
525	*	1	127	0.79	100.00
550		0	127	0.00	100.00
575		0	127	0.00	100.00
600		0	127	0.00	100.00
625		0	127	0.00	100.00
650		0	127	0.00	100.00
675		0	127	0.00	100.00
700		0	127	0.00	100.00
725		0	127	0.00	100.00
750		0	127	0.00	100.00
775		0	127	0.00	100.00
800		0	127	0.00	100.00
825		0	127	0.00	100.00
850		0	127	0.00	100.00
875		0	127	0.00	100.00
900		0	127	0.00	100.00
925		0	127	0.00	100.00

5 10 15 20 25

Frequency

Table A25. Length-frequency histogram of all fish captured in experimental vertical gill nets in Blue Mesa Reservoir during October 1994.



APPENDIX B.

Zooplankton Entrainment Study

INTRODUCTION

Blue Mesa Reservoir supports a productive and popular reservoir sport fishery consisting mainly of kokanee salmon (Oncorhynchus nerka), rainbow trout (Oncorhynchus mykiss), brown trout (Salmo trutta), and lake trout (Salvelinus namaycush). The kokanee fishery is almost entirely supported by the presence of a rich reservoir-wide zooplankton community. For example, diet analysis showed that about 97% of kokanee diets consisted of Daphnia pulex (Johnson et al. 1995). It is therefore apparent how important the maintenance of the present zooplankton community is to the sustenance of the kokanee population. Understandably, it is of some concern how modified dam operations, namely increased discharge, might affect the zooplankton community, and in turn, possibly affect the reservoir fishery.

The goal of my independent study is to answer several questions related to how operations of Blue Mesa Dam might affect the zooplankton community near the dam and possibly throughout the Sapinero Basin. First, what zooplankton species are being entrained, and at what percentage of total composition? Second, does species composition shift from morning to evening or throughout the season? Third, at what depth in the reservoir is the outflow water being pulled from and might this affect the Daphnia constituents of the zooplankton community? And finally, how much Daphnia biomass is being entrained, and how might entrained biomass estimates shift throughout the season? A better understanding of these variables will help determine if dam entrainment of Daphnia should be of concern in planning for and maintaining the future of the productive reservoir kokanee fishery.

METHODS

Study Site

Blue Mesa Reservoir, located on the Gunnison River approximately 25 miles west of Gunnison, Colorado, is the largest of three reservoirs in the operating Curecanti Unit. It is currently the largest reservoir in Colorado, with a capacity of 940,700 acre ft, and retains a lake surface area of 14.3 square miles with a shoreline of approximately 96 miles (BOR 1975). It was primarily designed for water storage for use in generating hydroelectric power, and is designated as the primary unit for flood control and river regulation of the Gunnison River. Blue Mesa Dam crests at 342 ft above the river bed with an inlet structure rising from 7,358 ft to 7,528 ft above sea level (BOR 1975). The open face of the water inlet rises to a height of 134 ft (41.36 m) (BOR 1975).

Zooplankton Entrainment Sampling

I collected eighteen zooplankton entrainment samples between May 27, 1994 and July 19, 1994 in the outflow of Blue Mesa Dam. I collected an additional sample on September 16, 1994. Normal sampling consisted of taking a paired morning and afternoon sample. Outflow sampling was scheduled to coincide with biweekly zooplankton sampling in the Sapinero basin of the reservoir.

Zooplankton samples were collected with a Wisconsin net (125 mm diameter opening and a 153 micron mesh net) attached to a weighted depressor plate. I lowered the net into the dam's outflow from the northwest corner of the water control structure (jet tube discharge), to a submerged depth of approximately one meter. I experimented with different

sampling durations, and determined that the best results were obtained with a duration of approximately ten minutes. Beginning on July 8, 1994 all samples were of at least a 10 minute duration. Starting time, sampling duration, and observed water level were recorded.

Reservoir Zooplankton Sampling

Zooplankton were collected by oblique tows using a Wildco model 37-C15 Clark-Bumpus plankton sampler with 130 mm diameter opening and 153 micron mesh net. Samples were taken bi-weekly, in the center of the Sapinero basin GPS coordinates: N38 27' 37.5" W107 18' 46.6". Two replicate samples were taken at each of four depth strata: 0-5 m, 5-10 m, 10-15 m, and 15-30 m. On July 21, 1994, two deep samples, 30-45 m and 45-55 m, were taken in the reservoir, in front of the dam tower, in order to compare deep water species composition with samples taken at the dam outflow.

Zooplankton Processing

All zooplankton samples were preserved in sugared, buffered formalin to prevent osmotic explosion. Samples were subsampled into 1 ml aliquots with a Hansen-Stemple pipette, and all species were identified and enumerated in Sedgewick-Rafter cells under a compound microscope. Zooplankton were identified to genus, and Daphnia were identified to species. Total length and number of eggs per female were measured for each Daphnia species in every subsample. Daphnia total length was measured from the anterior margin of the head to the base of the posterior spine.

Determination of Sample Volume

Due to the unavailability of a flow meter, I had to calculate water velocity in the outflow from a mean discharge (cfs) and outflow cross sectional area (ft²) at the time of each sample:

$$Velocity = \frac{Discharge}{Area}$$

Where: Discharge= a measure of mean outflow (cfs).

Area= outflow cross sectional area (ft²)

Due to low sensitivity in the instrument monitoring discharge which produced zero cfs in low river flows, I modified BOR discharge values of the A.M. sample taken on June 11 and the A.M. sample taken on June 22 with an assumed value of 44 cfs. Although I computed a linear regression of discharge (cfs) versus outflow elevation (ft) in order to estimate a truer discharge (Figure B1), this analysis produced negative cfs values at the observed outflow elevations. Therefore, the modification of discharge to 44 cfs appeared a more accurate estimation because tail water elevations at the times sampled deviated from a known tail water elevation of 7155.63 ft. at 44 cfs by only 0.05 ft. and 0.01 ft. respectively.

Calculations of river cross sectional area were obtained by multiplying fluctuating outflow water depths with a consistent river width of 86.8 ft, in a rectangular cross section at the SW corner of the water control structure. A rectangular cross sectional river geometry seemed plausible due to the vertical characteristics of the canyon wall/water interface and

construction characteristics of the water control structure. Due to river channelization below the dam outflow works and the construction characteristics of the stilling basin, the river floor approximated a horizontal base at an elevation of 7147.0 ft above sea level. Water depths were obtained by calculating the difference between fluctuating outflow water surface elevations and the known base elevation at the foot of the water control structure at 7147.0 ft. Hourly effluent water surface elevations and dam discharge were obtained through the Western Area Power Authority (WAPA).

Daphnia Density

Mean numbers of Daphnia pulex and Daphnia galeata mendotae per liter sampled were calculated using methods described in Lind (1979). I computed the number of Daphnia sampled by the Wisconsin net per day by the equation:

$$N = n \cdot d$$

Where :

N= total number of Daphnia entrained per day

n= mean number of Daphnia per liter sampled

d= daily discharge (liters)

Biomass Estimates

I estimated biomass of entrained Daphnia pulex and Daphnia galeata mendotae using a length-dry weight relationship of a comparable zooplankton species, Daphnia retrocurva

(Rosen 1981). Daphnia retrocurva is a species whose range of lengths closely matches that of both sampled Daphnia pulex and Daphnia galeata mendotae. Entrained biomass (B) was computed with the following equation:

$$B = 10^{[\text{Log}_{10}(L) * 3.129 - 5.378]} * N$$

Where:

B= biomass entrained per day (grams dry weight)

L= Daphnia length (mm)

N= estimated number of Daphnia entrained per day

Dry weight biomass was converted to wet weight biomass by assuming Daphnia dry weights were 11% of wet weights (Dumont et al. 1975).

Biomass of Daphnia in the reservoir on May 21, at peak entrainment, was crudely estimated from the mean density (20.2/liter), average length (1.0 mm), average wet weight (3.8×10^{-5} g) of Daphnia in the top 10 m (where most Daphnia reside) of the reservoir at Sapinero basin extrapolated to a lakewide estimate using the entire volume of the reservoir in the 0-10 m stratum (3.129×10^{11} L) to yield a lakewide standing stock of 2.40×10^5 kg.

RESULTS

Species Composition

Six zooplankton species were identified: Daphnia pulex (DP), Daphnia galeata mendotae (DG), Bosmina longirus (BO), Diatom sp. (DI), Leptodiatomus sp. (LE), and

Ceriodaphnia sp.. Copepod nauplii and unknown Daphnia neonates were also counted.

Daphnia neonates, unknown Daphnia, Ceriodaphnia, and copepod nauplii were lumped and categorized (OT).

Both A.M and P.M. outflow samples were compared over time (Figure B2). These samples were composed mostly of a high percentage of DI and BO. All A.M. samples were mostly comprised of DI and BO with a relatively small composition of other species (Figure B2). Analysis of samples on June 11 and June 14 revealed approximately equal compositions of DI and BO (46% to 52%) with no, to relatively few other species present. The June 22 sample revealed a high percentage of BO(74%) with a lower percentage of DI(21%) and a small, yet slightly higher composition of other species. Samples on June 30, July 15, and July 19 were comprised of mostly of DI (83%, 66%, and 78%) with a lower percentage of BO, and relatively few other species. Samples taken on May 27 and June 1 were comprised of an unusually high percentage of DP (8% and 7%) and OT (14% and 13%). The high percentage of the OT was primarily attributed to a high frequency of Daphnia neonates. BO were maintained at 31%. Analysis of the early June sample revealed a slight decrease in DI, from 44% to 37% of total zooplankton composition. Analysis of this sample also revealed an increase in both DG, from 1% to 7%, and LE, from 0 to 13%.

P.M. outflow samples were also comprised mostly of DI and BO (Figure B2). The June 1 sample was comprised of a high percentage of BO(34%) with a comparably high percentage of LE(13%), DP(7%), DG(7%), and OT(13%) as compared to other samples. Analysis of the September 16 sample also revealed an increased percentage of DG(3%), DP(5%), and OT(9%), as compared to earlier samples.

Comparison between A.M. and P.M. samples revealed similar zooplankton compositions, except June 22 where zooplankton composition shifted from being composed primarily by BO(74%) in the A.M., to becoming composed primarily by DI(68%) in the P.M..

Analysis of species composition of the reservoir fauna in the Sapinero basin on July 21 revealed samples comprised of mostly DI with a lower percentage of all other identified species (Figure B3). Samples from the 0-5 m stratum were comprised of DI(43%), BO(1%), DP(32%), DG(19%), LE(4%), and OT(1%). Samples from the 5-10 m stratum contained DI(68%), BO(2%), DP(19%), DG(8%), LE(3%), and OT(1%). Samples from the 10-15 m stratum were comprised of DI(85%), BO(3%), DP(8%), DG(1%), LE(1%), and OT(1%). Samples from the 15-30 m stratum contained DI(95%), BO(2%), DP(1%), and DG(1%). Samples from the 30-45 m stratum were comprised of DI(84%), BO(9%), DP(3%), DG(1%), and OT(1%). Samples from the 45-55 m stratum contained DI(60%), BO(34%), DP(2%), DG(2%), LE(1%), and OT(1%). Species composition of outflow samples on July 19 were intermediate to those observed in the 30-45 m and 45-55 m samples from Sapinero on July 21 (Figure B3).

Zooplankton Lengths

Two tailed t-tests, assuming unequal variances, on samples taken June 1, June 14, and July 19 showed no significant difference between A.M and P.M. outflow samples.

Therefore, I pooled morning and afternoon samples mean length measurements (Figure B4). DP appeared to be larger earlier in the season (May 27 through June 22) with mean lengths

ranging from 1.61mm to 1.5mm. Mean lengths of DP seemed considerably smaller in the second half of the season (July 8 through September 16), ranging between 1.19mm to 0.83mm. DG mean lengths cycled from highs of 1.16mm and 1.09mm on May 27 and July 15, to lows of 0.63mm and 0.76mm on June 1 and September 16. No DP were collected on June 10 and June 30.

DP mean lengths, on depth strata reservoir samples taken July 21, measured 0.92mm at the 30-45m depth stratum and 1.24mm at the 45-55m depth stratum. DG mean lengths, on depth samples taken in the reservoir, measured 1.08mm at the 30-45m stratum and 1.06mm at the 45-55m stratum. Performing a t-test, I analyzed Daphnia species mean length between the two different depth strata and calculated a significant difference of 0.02 only among the DP between the 30-45m and 45-55m strata samples. I calculated no significant difference among the DG between the 30-45m and 45-55m depth strata samples.

I could not determine a significant difference among DP between the July 19 outflow sample and either the 30-45m or 45-55m reservoir depth samples. I did detect a significant difference of 0.02 among the DG between the July 19 outflow sample and both the 30-45m and the 45-55m reservoir depth samples.

Daphnia density

Densities of Daphnia of the A.M and P.M. outflow samples taken on July 19 were compared here also with the 30-45m and 45-55m depth reservoir samples taken on July 21 (Figure B5). DP densities were estimated to be 0.59 animals/cu.ft. (0.0210 animals/L) and 0.66 animals/cu.ft. (0.0234 animals/L) on July 19, A.M and P.M outflow samples, and 2.90

animals/cu.ft.(0.0897 animals/L) and 2.53 animals/cu.ft. (0.0893 animals/L) on July 21, 30-45m and 45-55m depth strata samples. Performing a Chi square test, I found no similarities among densities of both the A.M. and P.M. outflow samples and either the 30-45m or 45-55m depth strata samples. These differences in density may be due to unequal sampling efficiency of the Wisconsin net used in the outflow and the Clark-Bumpus sampler in the reservoir.

DISCUSSION

With the exception of samples taken on June 22, paired A.M. and P.M. outflow samples were fairly equivalent in percentages of species abundance. All samples consisted primarily of DI and BO on all dates. Percentages of DP and DG were consistently low, and Daphnia were present in an appreciable number only on May 27, June 1 and September 16. Community composition of outflow samples taken on July 19 appeared to best compare to some depth between 30-45 m and 45-55m, when compared to all samples taken within the Sapinero basin on July 21. This may indicate that entrained water originates at reservoir depths of 30-55 m. This hypothesis is supported by the high percentage of DI as well as BO rather than DP and DG, which comprise a higher percentage of the upper strata communities (0-15m). The high percentage of BO also implies that water is being entrained from a depth below the 15-30m depth stratum.

The peak in DP biomass entrained on May 27 and June 1 (Figure B6) may be due to reservoir overturn, high dam water output producing some unique mixing patterns within the reservoir, deeper distribution of DP on these dates, or a possible combination of these

factors. Although increased flows coincide with this peak in density and biomass (Figure B8), this explanation alone seems unlikely for several reasons: 1) the specific increase in only DP, as compared to other upper strata species, and 2) stratification in the Sapinero basin had apparently developed by at least May 24 (Figure B7a). Analysis of intensive thermal samples of the same time period also support that stratification had been maintained and was consistent through at least June 2 (Figure B7b). Consistency of the thermal stratification suggests that no unusual mixing had taken place. Another more plausible explanation for the peak in biomass estimates may be attributed to a unique life history trait or behavioral modification within the DP population. This may be supported by: 1) the specific increase in DP only, and 2) that I recorded the highest egg counts within individuals of DP and the highest number of Daphnia neonates on samples taken on May 27. Therefore, it appears that DP migrate to deeper waters during this time period to reproduce, and were subsequently entrained in higher number at this unusual depth. Daphnia depth distribution data from the reservoir in May support this hypothesis (Johnson et al. 1995).

The dates of high discharge coincide with this depth migration in DP. It seems reasonable that the early stratification period of mid-May to early June may be when the potential for Daphnia entrainment is most significant. However, with such low densities of DP and DG in the outflow, it appears that very little of the reservoir's Daphnia biomass is being flushed from the reservoir during the period of study. The highest daily entrainment biomass was about 152 kg wet weight on May 27. This is probably an underestimate because of low net efficiency but it compares to a rough estimate of Daphnia standing stock in the top 10 m of the lake of about 240,000 kg on May 21. Thus, the equivalent of only

about 0.06% of the lake's standing stock of *Daphnia* in the top 10 m is being entrained during peak entrainment in May. Further study will be needed to determine if maximal entrained biomass in the early summer is a regular event; however, at this point it does not appear that the quantities of biomass being entrained are significant enough to be cause for concern.

RECOMMENDATIONS

If this study is to be repeated, modifications to methods and sampling schedule should be considered. Due to small counts of DP and DG in the samples, density and biomass estimates may deviate significantly from actual values. Since small counts seemed to be the weakest aspect of this study, I suggest modifying the sampling methods and schedule in order to increase *Daphnia* counts. First, I would increase sampling efficiency by choosing a plankton net that is made to sample horizontally, regardless of the amount of flow passing through it. Second, I would try to replicate samples by adding an additional net near the original sampling location. Third, I would modify the sampling schedule by increasing the number of sampling days, particularly during the May period of highest entrainment. And fourth, I would improve sampling within the reservoir by taking more comparable depth samples. With modification, the sampling techniques should give an accurate representation of the amount and species composition of zooplankton being entrained through Blue Mesa Dam.

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LIST OF FIGURES

Figure B1. Regression of effluent elevation and discharge on sampling dates May 27, 1994 through September 16, 1994. Regression formula: $\text{Discharge} = 369.34 * (\text{Elevation}) - 2642940$ with $R^2 = 0.96$.

Figure B2. Relative abundance (%) of zooplankton species in AM and PM outflow samples over all dates sampled.

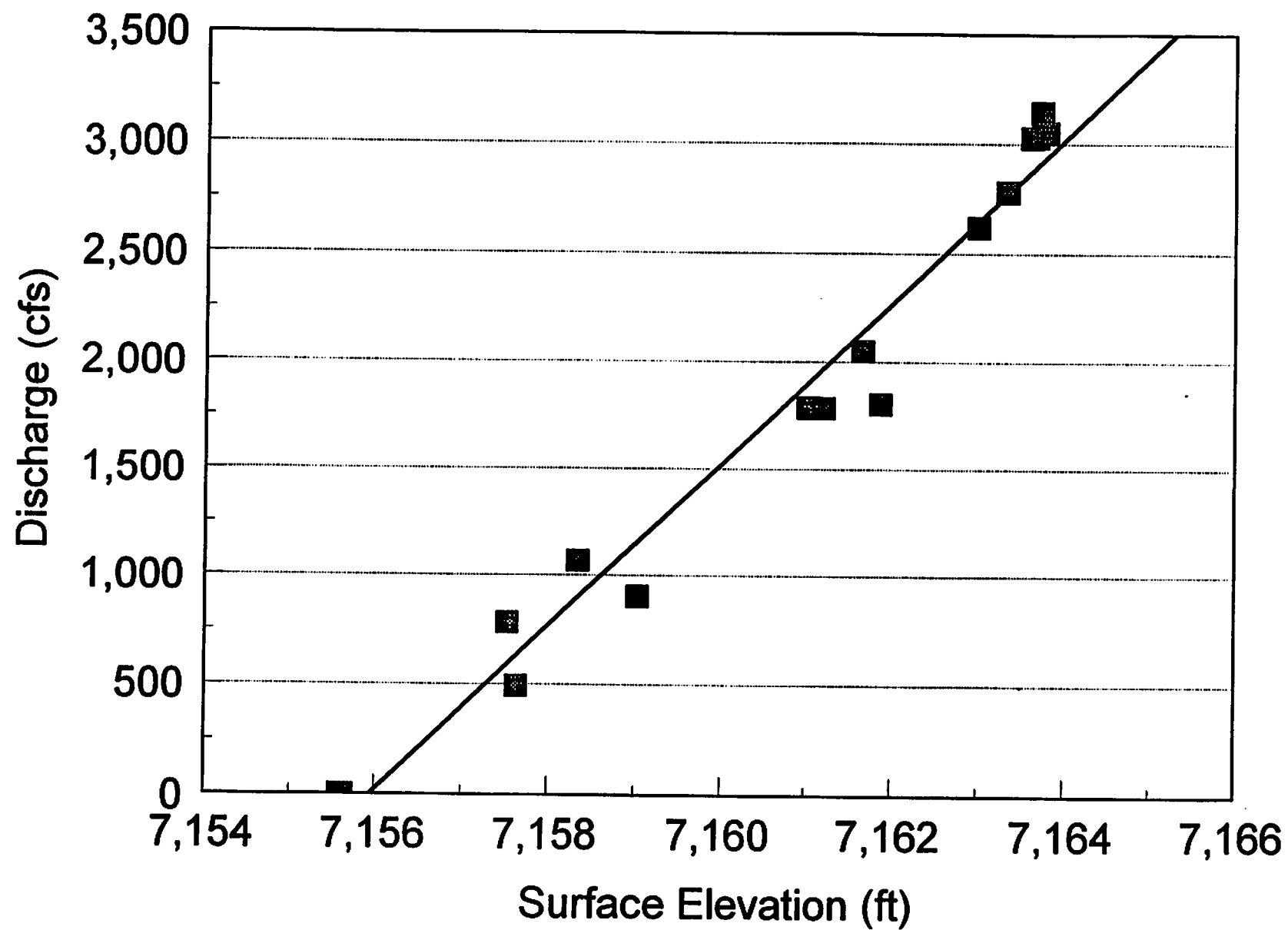
Figure B 3. Relative abundance (%) of zooplankton species in AM and PM outflow samples of July 19, 1994 compared against relative abundance (%) of zooplankton species in samples taken at depths of 0-5m, 5-10m, 10-15m, 15-30m, 30-45m, and 45-55m from the Sapinero basin on July 21, 1994.

Figure B 4. Daphnia pulex and Daphnia galeata mendotae mean lengths in lumped AM and PM outflow samples over all dates sampled.

Figure B 5. Comparison of Daphnia density per cubic foot in lumped AM and PM outflow samples, over all dates sampled, against reservoir samples taken at depths of 30-45m and 45-55m on July 21, 1994.

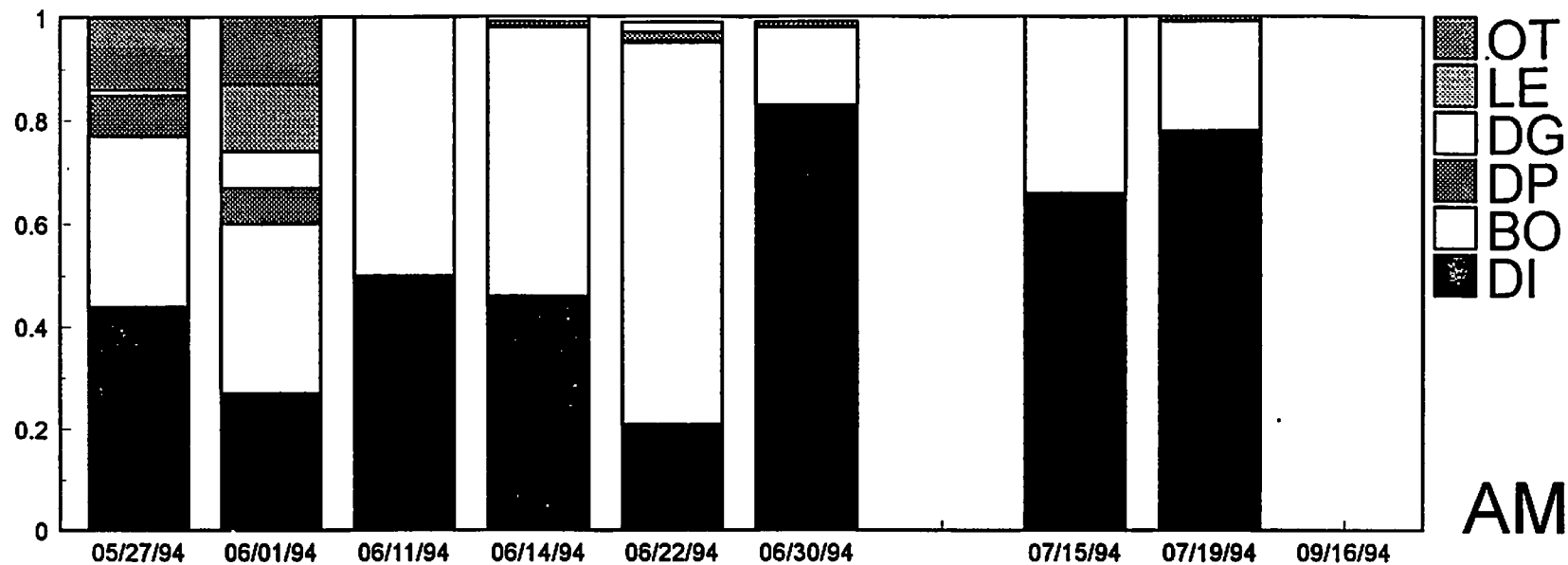
Figure B 6. Blue Mesa dam discharge (ac-ft; panel A) and estimated total biomass of Daphnia entrained per day (panel B) from May 25, 1994 and July 27, 1994.

Figure B 7a. Thermal stratification of Blue Mesa Reservoir at Central Sapinero Basin on May 24, 1994 (panel A) and at distances of zero meters, 100m, 200m, 300m, 400m, and 650m from Blue Mesa Dam on June 2, 1994 (panel B).

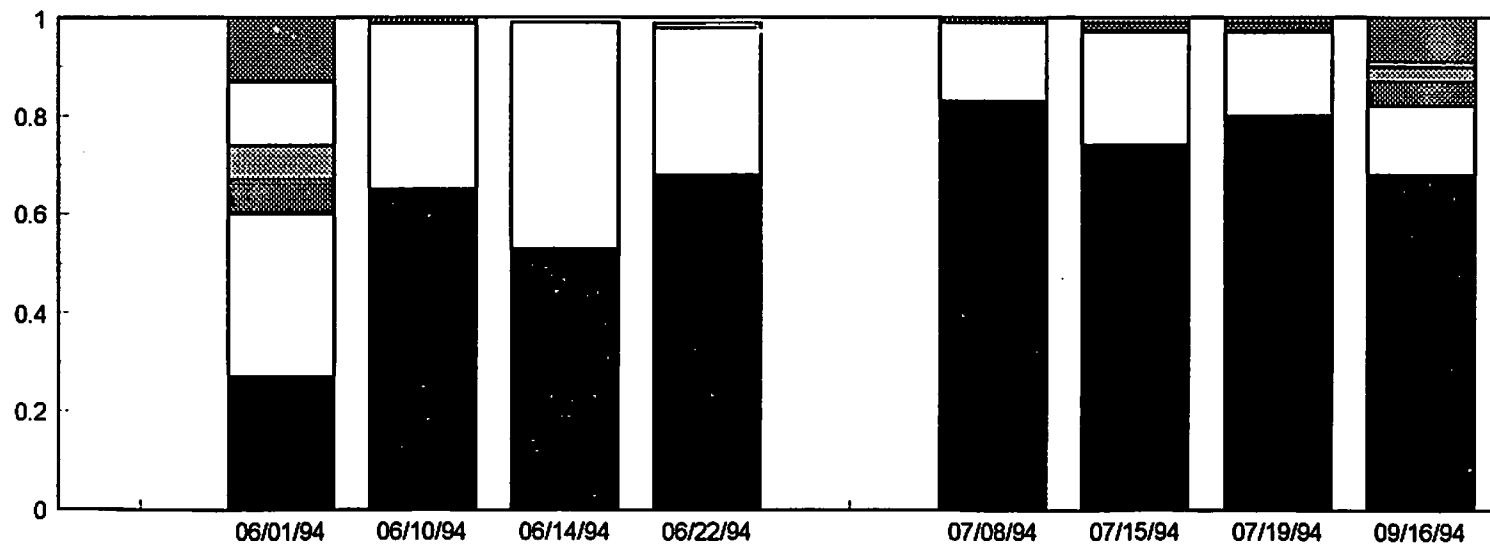


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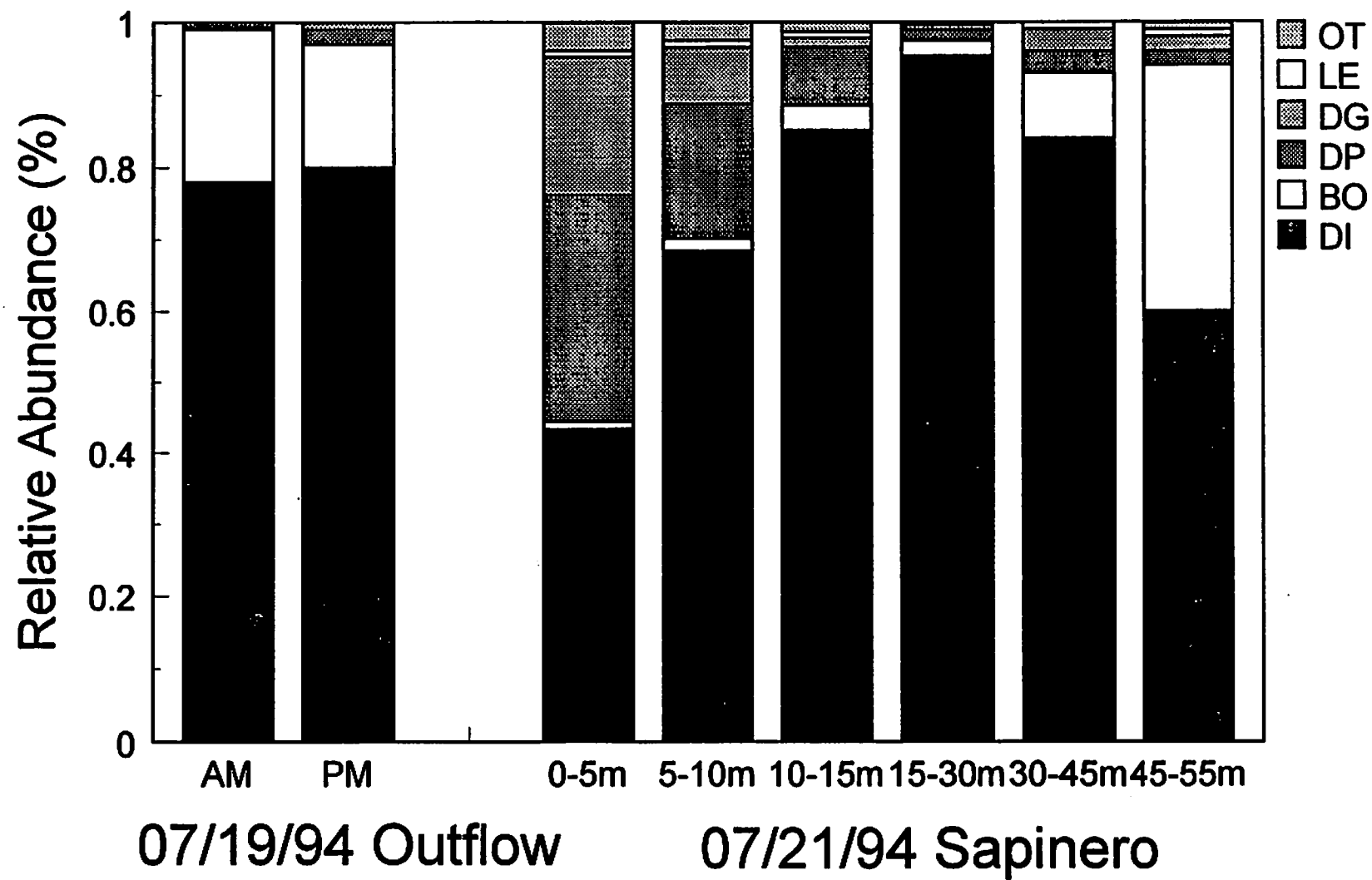
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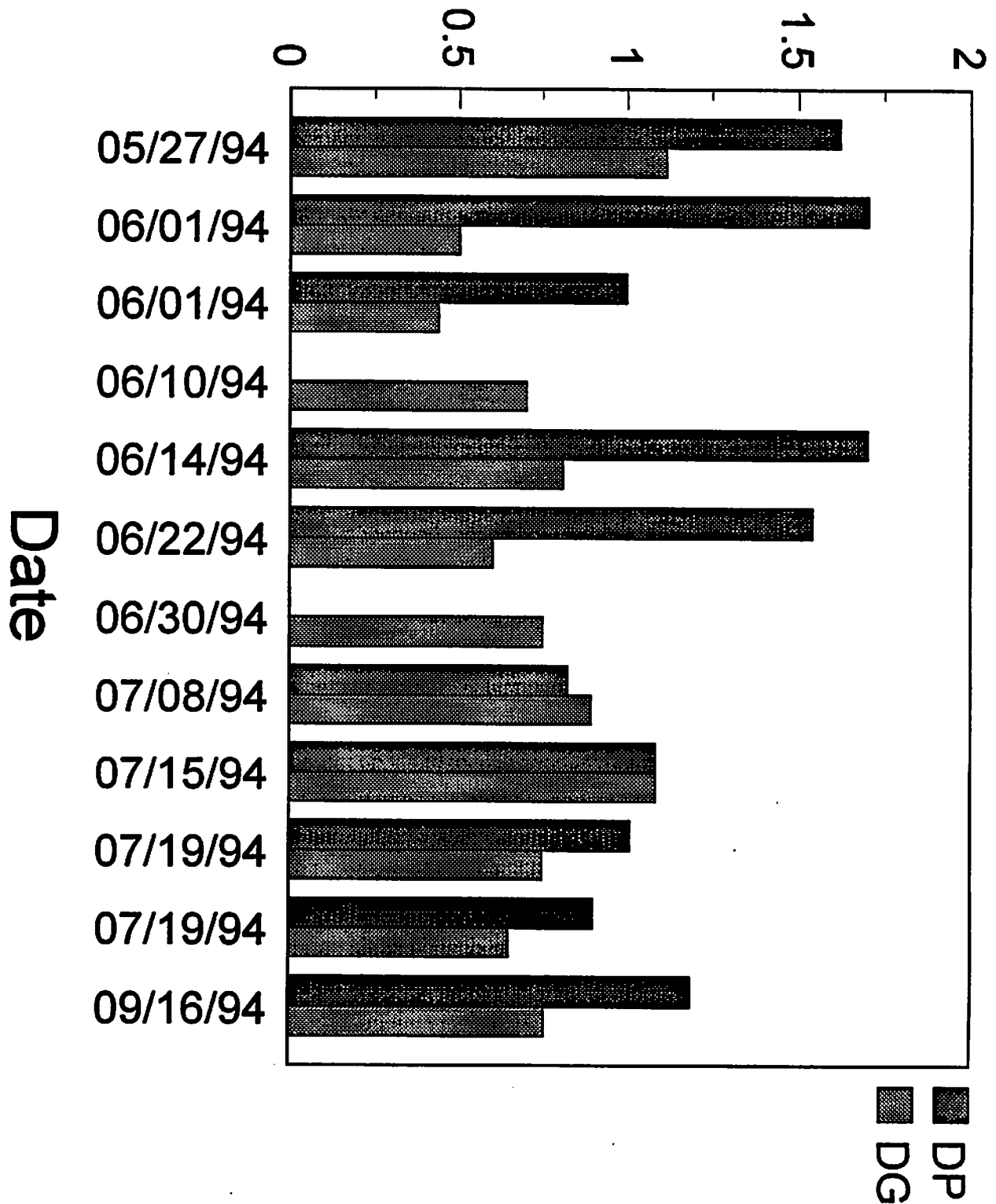
AM

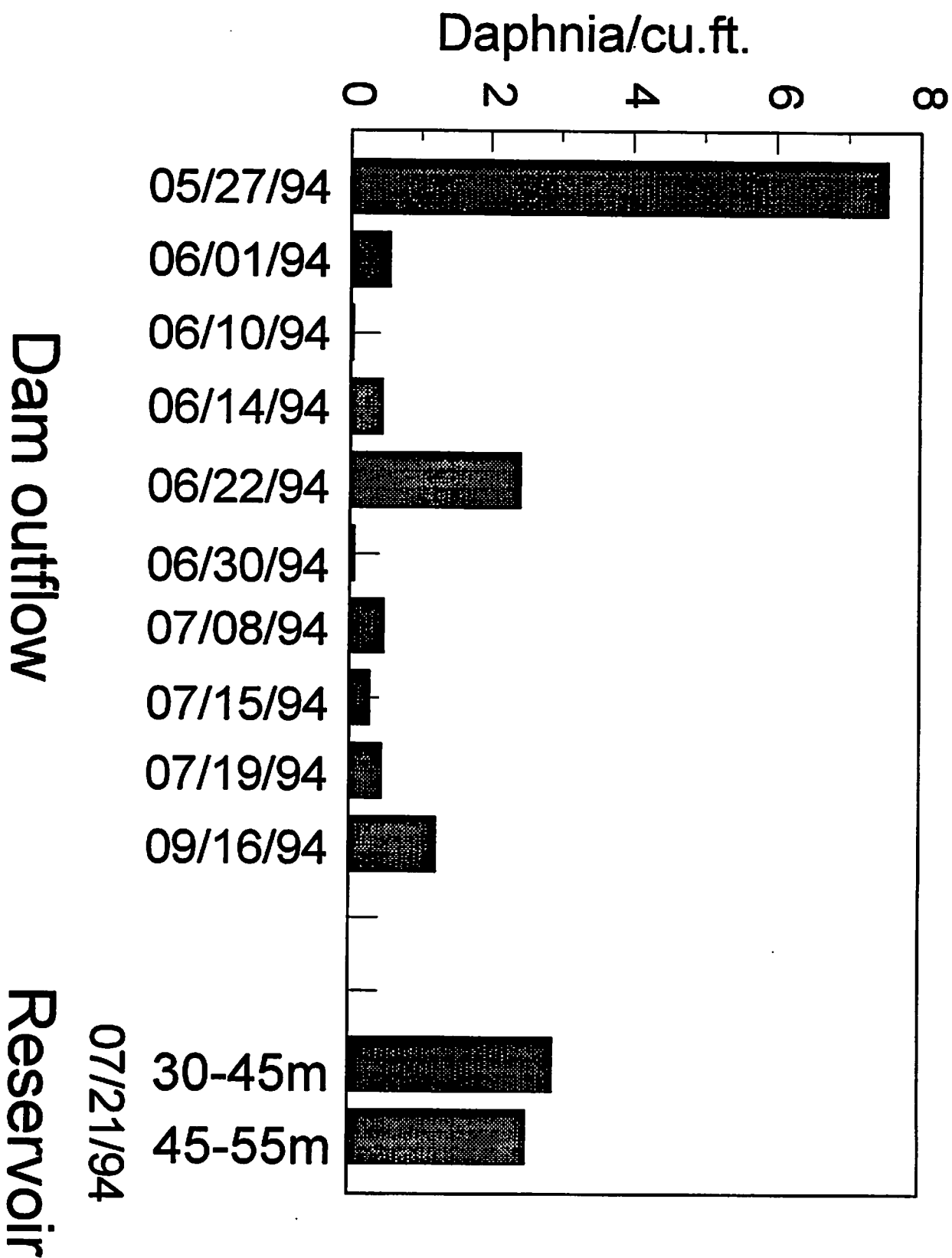


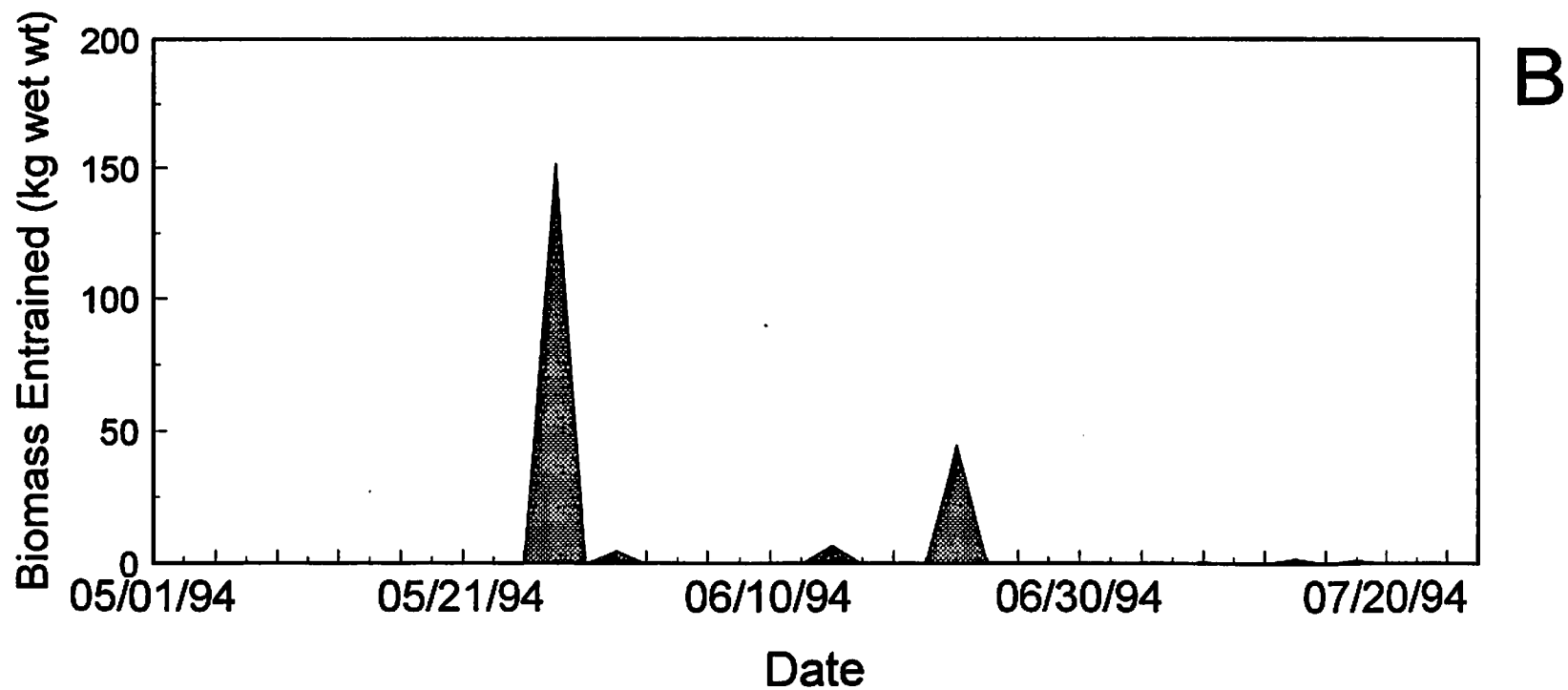
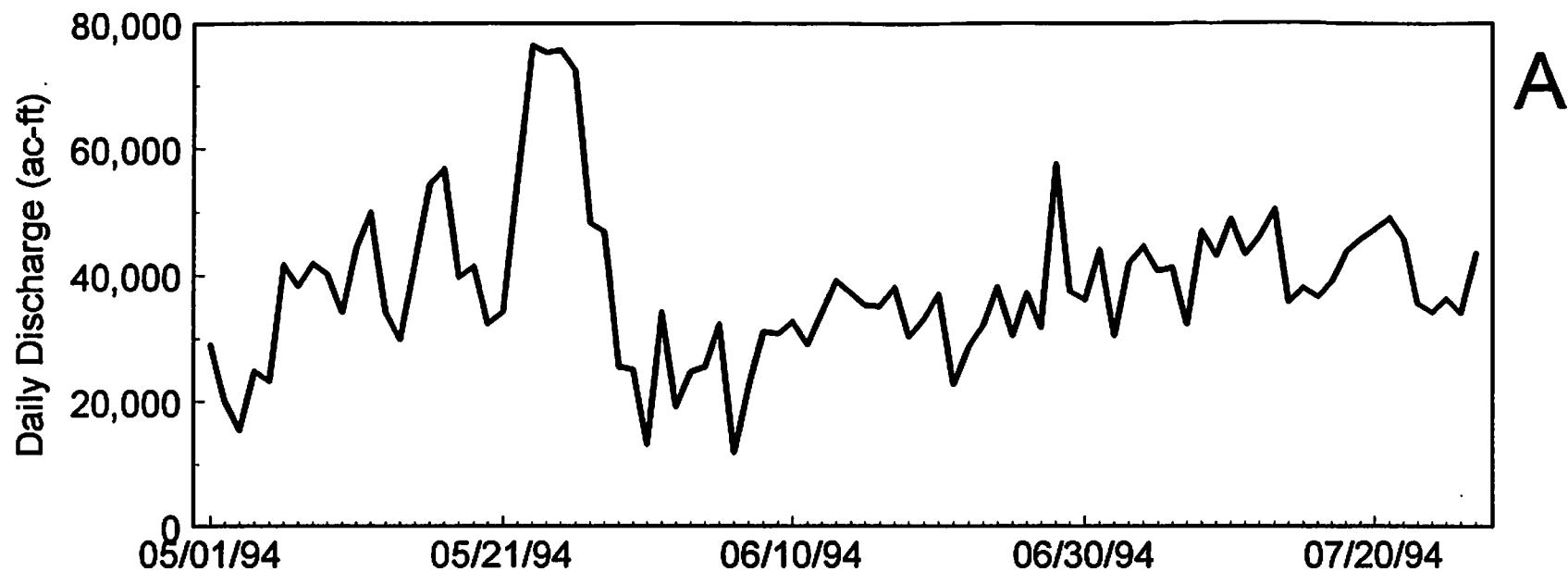
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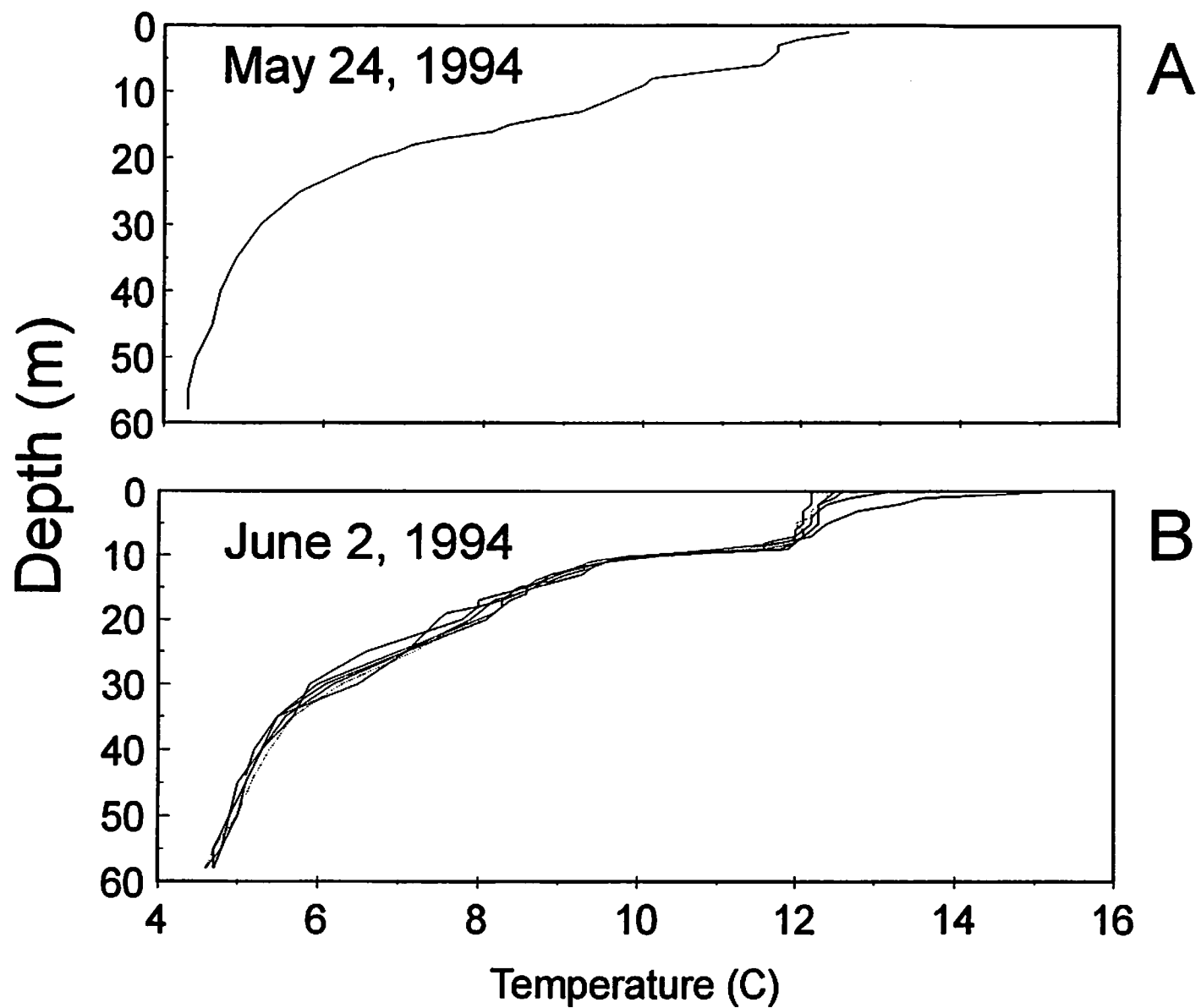
Daphnia Length (mm)







B6



dam 100m 200m 300m 400m 650m