POSSIBLE LIMITING FACTORS FOR A SUSTAINABLE CRAPPIE FISHERY IN THE SALT RIVER CHAIN OF RESERVOIRS, ARIZONA

by

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ABSTRACT

The dynamics of crappie populations in southwestern reservoirs are not well documented. In order for managers to enhance a crappie fishery, they need to understand the factors that control populations. I examined potential limiting factors for black crappie in 4 sequential reservoirs on the Salt River, Arizona.

Only in Roosevelt Reservoir, the uppermost reservoir, were crappie relatively abundant. I identified 3 possible limiting factors. Apache, Canyon, and Saguaro reservoirs lacked sufficient spawning substrates. All 4 reservoirs lacked sufficient cover. Finally, the lower 3 reservoirs are less productive during the fall according to chlorophyll a levels than Roosevelt Reservoir. Low productivity may have resulted in fewer zooplankton and possibly a limited forage base for juvenile crappie. Options such as spawning platforms, artificial cover, fertilization, and stocking are discussed as ways to improve the crappie fishery in these reservoirs.

INTRODUCTION

Black crappie (*Pomoxis nigromaculatus*) and white crappie (*P. annularis*) collectively support one of the most popular sport fisheries in North America (Hooe 1991). Managers continually seek to enhance crappie populations in order to meet angling demands, however the task has proven difficult.

Crappie are prolific and tend to overpopulate and "stunt" in small impoundments (Jenkins 1957). They rarely stunt in larger reservoirs but do exhibit population cycles (Swingle and Swingle 1967; Bennett 1971). This "boom" and "bust" phenomenon is caused by missing year classes. Why year classes are sometimes missing is not fully understood.

Factors such as pH, turbidity, and the types and amount of available cover tend to influence the abundance of both black and white crappie, although responses to these factors differ for each species. Even the morphological properties of a reservoir such as basin slope and dendriticness (number of embayments) can greatly influence crappie populations (Mitzner 1991; Guy 1995). The amount of water stored from April through August has recently been shown to have a tremendous influence on recruitment of both crappie species (Cichra et al. 1981; Mitzner 1981, 1991, 1995; Beam 1983; McDonough and Buchanan 1991; Guy 1995). The influence of these physical and chemical factors on crappie populations in southwestern reservoirs has not been well documented. My goal was to identify the factors that limit crappie populations in 4 reservoirs in central Arizona.

HYPOTHETICAL MODEL FOR A BLACK CRAPPIE RESERVOIR

Water Storage

The amount of water stored above conservation pool (the normal water level when the reservoir is full) generally is an important environmental variable affecting the spawning success of crappie (Cichra et al. 1981; Mitzner 1981, 1991, 1995; Beam 1983; McDonough and Buchanan 1991; Guy 1993). An increase in water storage from late spring to mid-summer is beneficial to crappie populations. In years when water levels are high during spawning and larval rearing (late spring through summer), crappie recruitment and year class strength tend to be higher than they are during years with low water levels (McDonough and Buchanan, 1991). Mitzner (1995) found a positive, linear relationship between the density of young crappie and the amount of floodwater stored from April through August. He estimated that density of age-0 crappie increased by 57 per acre for each increase of 1 million acre-feet-days of floodwater storage above conservation pool (acre-feet-days = daily summation of water volume [acre-feet] stored in excess of the conservation pool). Similarly, Schramm et al. (1985) found the strongest year classes when lake water levels were high and the weakest year classes when water levels were low. In addition, water level stability following an initial spring rise is important for producing strong year classes (Beam 1983).

Crappie seem to benefit from increased water levels during the spawning and larval periods due to the additional cover and suitable nest sites provided by flooding previously dry sites. High water levels inundate terrestrial plants which provide cover and possibly additional food sources (Mitzner 1991). Beam (1983) emphasized that an important feature of water management was flooding of vegetation just prior to spawning. His plan required dewatering of 20 percent of the lake basin beginning in mid-July to allow terrestrial plants to recolonize and grow prior to flooding the following spring.

Lake Morphometry

Lakes that are more dendritic (i.e., more embayments) tend to have stable black crappie recruitment (Guy 1993). Embayments provide protection from the effects of wind which can disturb nursery areas and increase turbidities. Embayments may also provide more shallow shoreline for crappie spawning.

Habitat Requirements

The availability of suitable cover seems to have substantial impact on crappie densities. Goodson (1966) states that lakes with a consistently good crappie fishery in California always have considerable cover. Markham et al. (1991) found that logs, stumps, or large rocks were present in every area used heavily by white crappie. Crappie nest sites generally are near some form of cover (Hansen 1965; Ginnelly 1971; Robison and Buchanan 1988).

Cover may be more critical for black crappie than for white crappie. McDonough and Buchanan (1991) found that increased macrophyte coverage contributed to the decline of white crappie and the increase of black crappie in Chickamauga Reservoir, Tennessee. In a similar study, Ball and Kilambi (1972) attributed the decline of black crappie in Beaver Reservoir, Arkansas to a decrease in submerged terrestrial vegetation. Robison and Buchanan (1988) state that black crappie are almost always found near fallen treetops, standing timber, logs, or other cover. Neal (1965) captured black crappie nearer to shore than were white crappie. Age-0 white crappie tend to be more pelagic and leave the littoral zone sooner than age-0 black crappie which tend to stay longer near shoreline cover (Oakey 1986). Therefore, near shore cover may be more critical for age-0 black crappie than white crappie.

Substrate type also has an influence on selection of nesting sites by crappie. Substrates used by white crappie for nesting are silt, clay, and clay overlain by silt. Sand, gravel, and rock are less commonly used (Mitzner 1995). However, there is evidence that black crappie select substrates of sand, gravel, and cobble for nesting (Breder 1936; Ginnelly 1971). Mitzner (1995) used substrate penetration by a 1-inch diameter rod subjected to 20 lbs of downward force as an index to substrate hardness. He found that high CPUE (catch per unit effort) of crappie was associated with moderate substrate penetrations of 4 to 8 in. (10.16 - 20.32 cm).

Water Quality

Dissolved oxygen concentrations of 2.5 mg/l or greater are sufficient for black crappie to spawn and overwinter successfully (Carlson et al. 1978). Seifert et al. (1977) in fact, found successful black crappie spawning down to 2.5 mg/l, but dissolved oxygen below 2.5 mg/l did not allow successful spawning.

Adult black crappie prefer temperatures between 25 and 30 °C, and juveniles prefer temperatures of 27 to 29 °C (Neill and Magnuson 1974). The threshold temperature at which spawning commences seems to vary regionally. Mitzner (1995) found that crappie began spawning at 16.1 °C in Lake Rathbun, Iowa. Commencement of spawning was temperature dependant but temperatures had little effect on spawning duration. In comparison, the optimum spawning temperature in Arkansas was between 17.8 and 20.0 °C (Robison and Buchanan 1988).

The response to pH tends to differ between white and black crappie. When both species are present in a reservoir, black crappie tend to be more abundant at pH values slightly less than 7, while white crappie tend to dominate in water bodies with pH values slightly higher than 7 (Goodson 1966; Robinson and Buchanan 1988).

There is little literature on the relation of conductivity to crappie abundance. In fact, Mathur et al. (1979) found that annual variations in fecundity were not significantly correlated with variations in conductivity.

Turbidity can have a substantial effect on crappie abundance. Using a model ($\log_e Y = -6.766 + 2.204 \log_e X$), Mitzner (1995) found that the number of young crappie (both black and white crappie) decreased geometrically as water clarity decreased. When the secchi disk depth was >63.5 cm (25 in) there was a geometric increase in crappie abundance. Mitzner (1995) predicted that crappie young would not be present when Secchi disk readings were ≤5 cm (2 in).

Black crappie may respond differently to variations in turbidity than white crappie. White crappie seem to replace black crappie as turbidity increases (Neal 1963). It has been suggested that black crappie are unable to forage as efficiently as white crappie under conditions of high turbidity. Ellison (1984) concluded that black crappie >200 mm TL (total length) were unable to capture fish in turbid conditions (65 JTU). Neal (1963) found that condition factors and growth rates of black crappie were low during periods of high turbidity while white crappie condition factors remained constant and growth was good. Conversely, Barefield (1984) concluded that increased turbidities had no differential effect on foraging efficiencies of black and white crappie. Similarly, McInerny and Degan (1991) found that catch rates of black crappie were not correlated with turbidities between 3±1 NTU (nephelometric turbidity unit) to 26±24 NTU.

The trophic state of a reservoir directly influences the growth rate, condition factor, and carrying capacity of the species in the aquatic community. Using chlorophyll a as a relative index to productivity, Maceina et al. (1996) determined that size, growth, and condition factor of crappie were generally higher in eutrophic systems (chlorophyll a $\geq$ 8 mg/m^3 or μ/L). However, angler catch rates of crappie in reservoirs ranging from oligomesotrophic (chlorophyll a $\leq$ 7 mg/m^3) to eutrophic did not vary. Using trap nets, McInerny and Degan (1991) caught 8 to 42 crappie per net set in a 4,900-ha lake with mean summer chlorophyll a levels of 9.9 mg/m^3. These data seem to indicate that black crappie can do well at chlorophyll a levels $\geq$ 8 mg/m^3.

Forage Species and Abundance

Numerous studies have determined what crappie eat and the effects of forage base on crappie population dynamics (McConnell 1964; Ball and Kilambi 1972; Tucker 1972;

Ager 1975; Ellison 1984; Gablehouse 1984; Mearns 1985; Oakey 1986). Adult black crappie are opportunistic feeders on a wide range of food items (May and Thompson 1974). Larval crappie are primarily planktivorous (Oakey 1986), whereas juveniles (60 - 200 mm) feed on insects as well as zooplankton (Ager 1975). As crappie mature, they may become piscivorous (Ball and Kilambi 1972), though the frequency of insects in the diet remains the same (Ager 1975). In fact, Gablehouse (1984b) reported that black crappie can maintain a balanced population on a diet of only zooplankton and aquatic insects. In contrast, Ellison (1984) has argued that crappie must eventually become piscivorous. He found high mortality in crappie >200 mm in a turbid Nebraska lake, and concluded that black crappie unable to switch to eating fish were caught in an energy trap during the summer.

A good black crappie reservoir should have the following: water level fluctuations to inundate terrestrial vegetation during nesting and larval periods (April - August); numerous embayments to protect nesting and nursery areas from wave action, and to provide ample shallow water areas for nest sites; cover in and around nest sites; bottom substrates of sand and gravel for nest sites; dissolved oxygen concentrations >2.5 mg/l; temperatures >16°C during spring and temperatures up to 30°C during summer; turbidity $\leq$ 26 NTU (Nephelometric Turbidity Units); pH $\leq$ 7; chlorophyll a $\geq$ 8 mg/m^3; and abundant zooplankton for juveniles and forage fish (shad, silversides) for adults.

STUDY AREA

Roosevelt Reservoir, the uppermost impoundment on the Salt River, is located about 145 km northeast of Phoenix. With a surface of 7,950 ha at conservation pool (normal operating level of a lake), Roosevelt is the largest impoundment in central Arizona. Apache Reservoir is immediately downstream of Roosevelt Reservoir and has a surface area of 1,080 ha. Canyon Reservoir (390 ha), the next reservoir downstream, is the smallest in the chain. Saguaro, the final reservoir on the Salt River, has a surface area of 510 ha (Figure 1).

All 4 reservoirs produce electricity and provide water for irrigation. Apache and Canyon reservoirs both have pumpback storage capabilities. The lower 3 reservoirs have basins characteristic of deep canyons that were inundated upon impoundment. Roosevelt, however, is a much broader, shallower reservoir over most of its basin and tends to be slightly more turbid due to runoff from the Salt River and Tonto Creek tributaries. All 4 reservoirs experience high recreational use during the warmer months, with Saguaro receiving the heaviest use due to its proximity to Phoenix. Primary recreational uses for all 4 reservoirs include fishing, boating, skiing, and swimming.

The Salt River chain of reservoirs is located in the Sonoran Desert region of central Arizona. The potential effects of a desert climate (low annual rainfall; minimal temperature variation between seasons) on reservoir systems would primarily be low nutrient input from the watershed. The result may be a lower productivity level in desert reservoirs when compared to reservoirs that contain crappie elsewhere in North America.

METHODS

I sampled crappie during the fall of 1996 using trap nets and experimental gill nets.

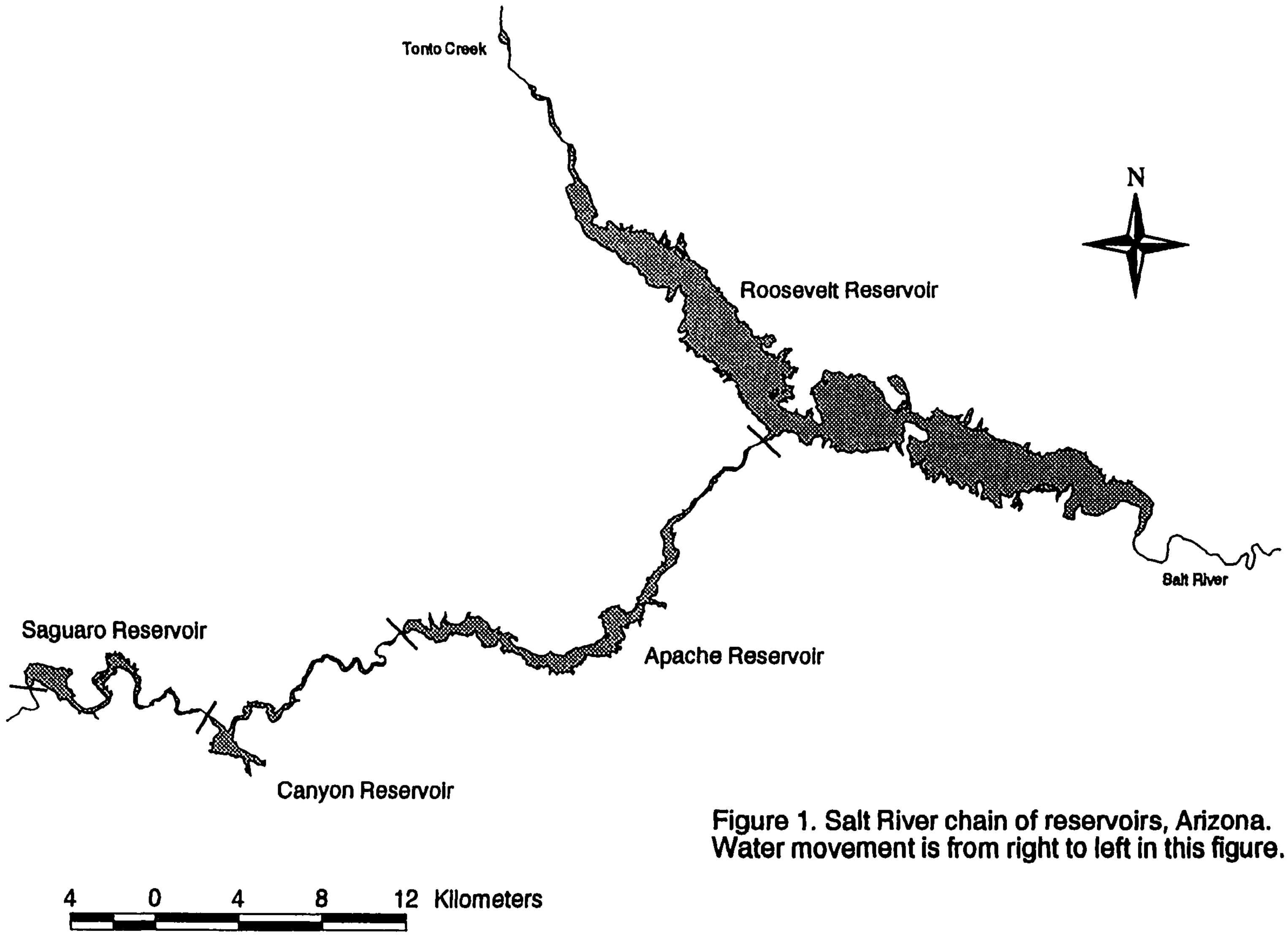

Figure 1. Salt River chain of reservoirs, Arizona.
Water movement is from right to left in this figure.

Boxrucker and Ploskey (1988) found fall trap net samples represented the population structure better than analogous samples taken in spring, and trap nets have been determined to be the most effective method for obtaining a representative sample of crappie regardless of season (Boxrucker and Ploskey 1988; McInerny 1989; Miranda et al. 1990). Trap nets consisted of a 0.9 x 15.2-m lead net attached to the second of 2, 0.9 x 1.2-m steel frames. The two frames were followed by 5, 0.9-m diameter hoops with three throats within the hoops. The lead and the main body of the nets were constructed of 19-mm bar mesh nylon netting. Nets were set at a rate of 10 trap-net-nights (1 trap net set for 1 night) per 405 ha (1,000 A) of surface water during September and October for Roosevelt and Apache reservoirs. Trap nets were the only sampling method I planned to use, however, due to initial low catch rates in Roosevelt and Apache reservoirs, I added gill nets to the sampling protocol. Warnecke (Arizona Game and Fish Dept., District VI, Mesa, AZ; personal communication) suggested that the first 3 panels of experimental gill nets were the most effective at catching crappie in the reservoirs of the Salt River. Therefore I used only the first 3 panels of the gill nets to sample crappie. The first 3 panels consisted of monofilament in 2.5, 3.8, and 5.1-cm bar mesh sizes and each panel was about 1.8 x 7.6 m long. Gill nets were set at a rate of 1.6 gill nets per 1,000 surface acres for Roosevelt Reservoir and 3 gill nets per 1,000 surface acres in Apache, Canyon, and Saguaro reservoirs. I set more gill nets in Apache Canyon, and Saguaro Reservoirs to increase the likelihood of obtaining a representative sample of the crappie population. Both net types were set perpendicular to shore in areas that appeared likely to intercept crappie moving from deep water to inshore feeding areas. Trap nets were used exclusively to sample crappie in September on Roosevelt and Apache reservoirs, but both trap nets and gill nets were used in October on Roosevelt Reservoir. Trap nets were used in Apache during October. Gill nets were the only sampling method used for Roosevelt and Apache reservoirs in November. The Arizona Game and Fish Department sampled Canyon and Saguaro reservoirs in November and December. They used only gill nets due to the apparent ineffectiveness of trap nets in Roosevelt and Apache reservoirs.

Crappie were weighed to the nearest gram and measured to the nearest millimeter. Up to 10 crappie in each 25-mm length group were preserved. Stomachs were removed in the field and preserved in 10% formalin. Heads were removed and preserved in the same solution. Otoliths were later extracted in the laboratory.

I used crappie lengths as an index of the size structure of crappie populations. Length was also used to estimate the "quality" of the crappie fishery via Proportional Stock Density (PSD) and Relative Stock Density (RSD). PSD is a ratio of the abundance of "quality" sized crappie (>200 mm TL) to "stock" sized crappie (>130 mm TL) multiplied by 100. RSD characterized the population into "preferred" (>250 mm TL), "memorable" (>300 mm TL), and "trophy" (>380 mm TL) length groups (Wedge and Anderson 1978) where each category is expressed as a percentage of "stock" sized crappie (>130 mm TL).

The condition of black crappie was indexed using relative weight (<u>Wr</u>) and the regression-line-percentile (RLP) equation suggested by Neumann and Murphy (1991). <u>Wr</u>

= individual fish weight (grams)/standard weight (Ws) X 100, where standard weight is $\log_{10}$ Ws = -5.618 + 3.345 $\log_{10}$ TL (mm). This standard weight (Ws) equation is necessary to reduce length bias. I also calculated relative weight by length category [i.e., stock-quality (S-Q) Wr (130-199 mm), quality-preferred (Q-P) Wr (200-249 mm), preferred-memorable (P-M) Wr (250-299 mm)] in addition to mean Wr for stock-length black crappie (S-Wr) as suggested by Murphy et al. (1990).

I removed otoliths and determined age using the whole otolith method (Williams and Bedford 1974). Age determination based on otoliths is more accurate than that based on scales or length-frequency analysis (Hammer and Miranda 1991). Beers (1965) was unable to age black crappie in Roosevelt Reservoir using scales due to failure of scale annuli to record changes in growth rate over seasons. I submerged otoliths were submerged in a 100% glycerin solution and viewed them through a 10X - 70X variable power dissection microscope. I made up to 3 readings on individual otoliths. The first age estimation allowed me to become familiar with the annuli patterns. All otoliths were then read a second time. If the second estimation agreed with the first, then that value was recorded as the estimated age. If the second age estimation did not agree with the first, the otolith was read a third time. After the third review, any otoliths where the second and third readings did not agree were discarded. The previous estimated age was not reviewed prior to or during the second and third readings of annuli.

Water quality parameters (turbidity, conductivity, pH, dissolved oxygen, temperature, and chlorophyll a) were measured at 9 randomly chosen sites per reservoir twice during the spring (May-June), summer (July-September), and fall (October-November) 1996. Turbidity was recorded using a Hach 2000 turbidimeter. Spring pH was obtained using an Oakton pH meter. A Horiba meter was used for pH measurements during summer and fall. A Horiba meter was also used to measure conductivity and to take dissolved oxygen and temperature profiles for the second set of spring samples and all of the summer and fall samples. Temperature and dissolved oxygen readings for the first set of spring samples were taken with a YSI oxygen and temperature meter. Temperature and dissolved oxygen were taken at 1-m intervals to a depth of 10 m. Turbidity, pH, and conductivity were taken at 0.5 m from the surface. I used chlorophyll a as a relative index of productivity. Chlorophyll a was analyzed using the procedure in Standard Methods for Analysis of Water and Waste Water, 17th edition (1989), and corrected for pheophytin a.

I took vertical plankton tows during the fall to asses differences in zooplankton abundance between reservoirs. Samples were taken with a Wisconsin style plankton net (mesh size =80μm) beginning at a depth of 10 m. In Roosevelt and Apache reservoirs, samples were taken once each during October and November. Ten evenly spaced tows were collected in Roosevelt, and 9 samples were taken at water quality sample sites in Apache. Tows were not made at water quality sites in Roosevelt Reservoir because water quality sample sites 8 and 9 were dry during the sampling period. The contents of individual tows from Roosevelt and Apache reservoirs were preserved in a 25-ml vial in a 10% formalin solution. In Canyon and Saguaro reservoirs, 9 tows were taken at the randomly selected water quality sample sites. Plankton samples were preserved in 70 % isopropyl alcohol. These samples were then concentrated to 25 ml by evaporation. A 1-ml subsample from each 25-ml sample was placed in a Sedgwick-Rafter counting cell. All cladocerans, copepodas, and nauplii were counted and measured using a calibrated ocular micrometer. Cladocera lengths were measured from the top of the head (tip of the helmet spine for *Daphnia lumholtzi*) to the anal spine. Copepoda were measured from the top of the head to the base of the caudal rami. Total carapace lengths were obtained for nauplii. When samples contained low numbers of zooplankton, a second 1-ml subsample was counted to adequately determine species abundance.

I conducted an analysis of substrate penetration, presence of cover, and slope for each reservoir. I evaluated the habitat from the shoreline out to a depth of 10 m. Rinne et al. (1981) previously reported that crappie in Roosevelt and Apache reservoirs were restricted to the upper 10 m of the water column. The shoreline adjacent to each of the 9 randomly selected water quality sites was used for this analysis. Three points were systematically established at each site. Points 1 and 3 were 50 m apart with point 2 located in the middle. From each of these points, I first determined substrate firmness using a 2.54-cm (1-in) diameter rod subjected to 9 kg (20 lbs) of downward force about 5 m out from the shoreline. The water line was marked directly on the rod before and after the force was applied and the distance between the marks was recorded in centimeters. I measured the perpendicular distance from each point to a depth of 10 m as determined by a three-dimensional depth recorder (Hummingbird Wide 3D View). I used the distance to a depth of 10 m to determine percent slope for each site using the equation for the slope of a line (slope = rise [10 m of depth]/run [distance to 10 m of depth]. Cover revealed by depth finder was given a rank value of 1 for submerged terrestrial plants, 2 for boulder piles, and 3 for emergent aquatic macrophytes.

STATISTICAL ANALYSIS

None of the water quality, plankton, or habitat data from Roosevelt Reservoir met the assumptions for normality even after transformations (logarithmic, natural log, and inverse). Therefore, it was impossible to use parametric statistics. The non-normal distributions of the Roosevelt data were due to the uniqueness of conditions adjacent to the Salt River and Tonto Creek tributaries. Retention of Roosevelt outliers was important because they described a significant portion of Roosevelt Reservoir. Data from Apache, Canyon, and Saguaro reservoirs were generally normally distributed. Therefore, I used a nonparametric analysis of variance, Wilcoxon / Kruskal-Wallis Test (Rank Sums), to analyze for differences between reservoirs. If the ChiSquare approximation yielded a significant P-value, a Tukey-Kramer comparison was used to determine which reservoirs differed at the 0.05 alpha level. All data were analyzed using JMP Statistical Discovery Software, version 3.2 for Windows (SAS Institute Inc.).

RESULTS

Crappie

I caught 163 black crappie in Roosevelt Reservoir. Catch per unit effort (CPUE) for trap nets was 0.42 crappie per net night (net night = 1 net set for 1 night). Catch rate using gill nets was significantly higher, CPUE was 5.57 crappie per net night. A total of 12 crappie were captured in Apache Reservoir. Apache Reservoir CPUE using trap nets was 0.22 crappie per-net-night. Gill netting yielded no crappie in Apache, Canyon, or Saguaro reservoirs. Gill nets may have been more effective in Roosevelt due to the higher turbidity levels. Reduced visibility may have hindered the ability of fish to see the net.

In Roosevelt Reservoir there was a dominant age 3 year class (50 % of the 102 crappie aged) with age 4 and 5+ fish less common (41%). A few crappie from Roosevelt Reservoir appeared to be ≥6 years old. However, due to the difficulty of annuli identification past age 5, they were grouped in the 5+ category. Age 2 fish represented only 10 % of the crappie sampled, and age 1 fish were absent from the sample (Figure 2). Average lengths-at-age for Roosevelt Reservoir black crappie are given in Table 1. Age 3, 4, and 5 fish were the most abundant (Figure 3). Too few crappie were taken from Apache Reservoir for an accurate age structure analysis. However, fish ranged from 1 to 6+ years.

Black crappie in Roosevelt Reservoir had a PSD of 93 %. Forty-nine percent of the crappie sampled were in the "preferred" (>250 mm) size class. However, only 3 % were in the "memorable" (>300 mm) size class, and none were in the "trophy" (>380 mm) size class. Too few black crappie were taken from Apache Reservoir to allow an accurate evaluation of PSD's or RSD's.

Mean <u>Wr</u> for stock-length and greater (>130 mm TL) black crappie was 100.75. When grouped by length category, <u>Wr</u> for S-Q, Q-P, and P-M were 101.22, 104.26, and

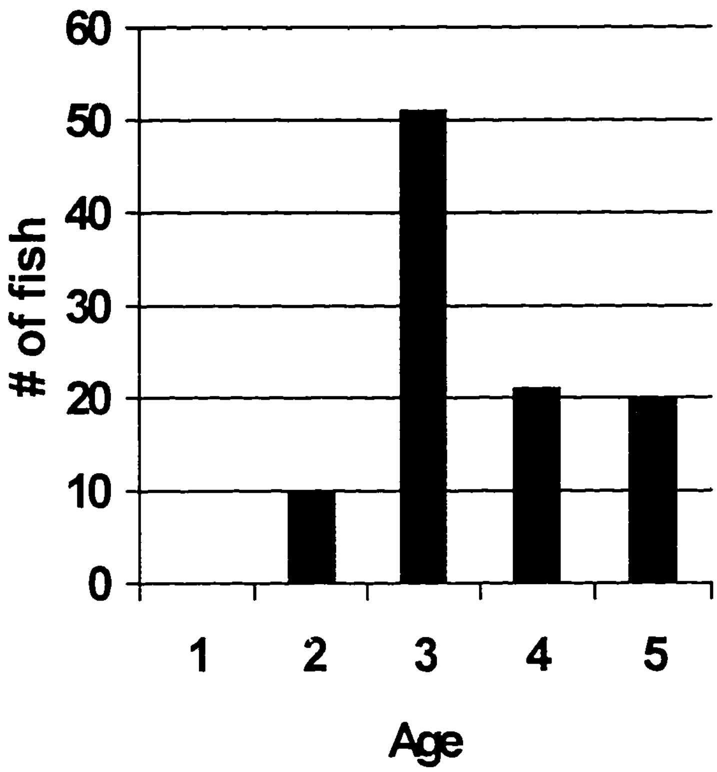

Figure 2. Age distribution of Roosevelt Reservoir black crappie caught in gill nets and trap nets, fall 1996.

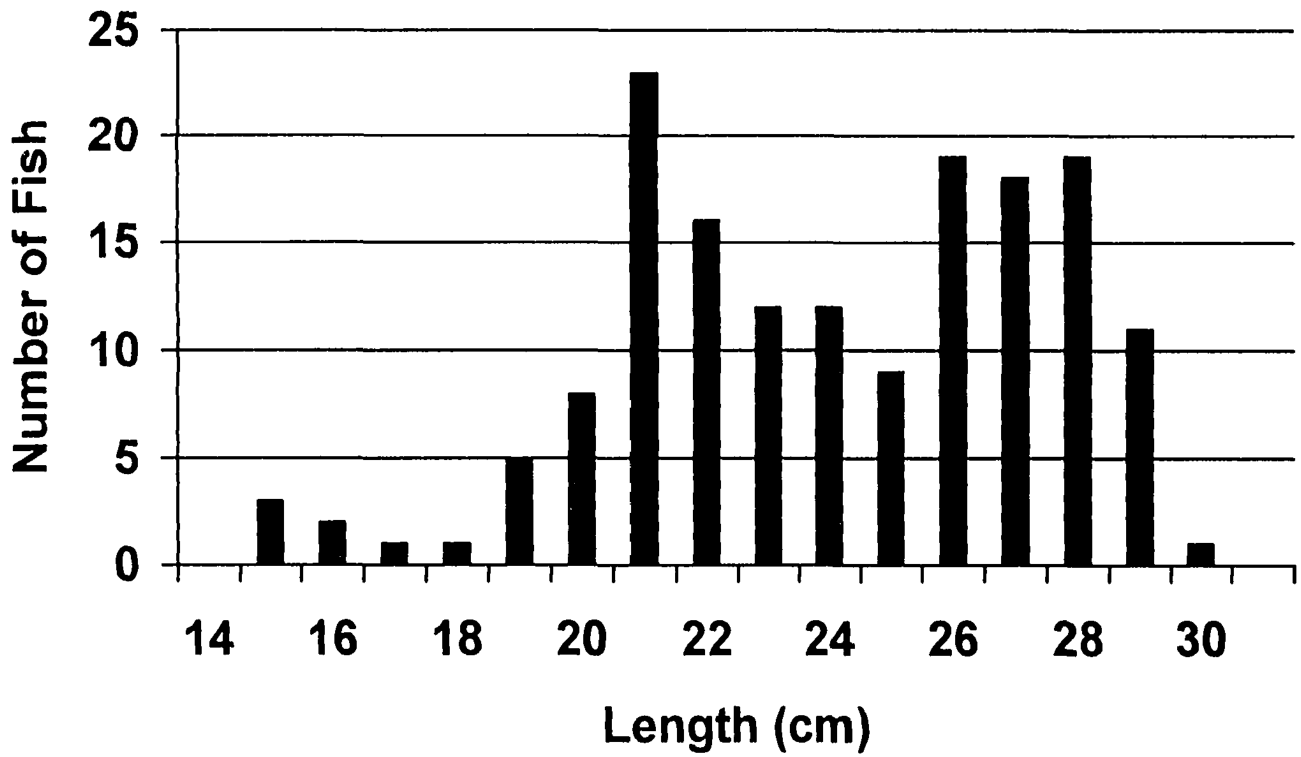

Figure 3. Length-frequency of black crappie in Roosevelt Reservoir caught with gill nets and trap nets, 1996

Table 1. Average length (mm-TL) at age and 95% confidence intervals for black crappie captured in Roosevelt Reservoir with gill nets and trap nets, fall 1996.

Age	# of fish	mean length	95%CI
2	10	174.4	+13.49
3	51	226.4	+5.10
4	21	271.1	+2.73
5	20	292.5	+7.47

Table 2. Mean Wr and 95% confidence intervals for S-Q (130-199 mm TL), Q-P (200-249 mm TL), and P-M (250-300 mm TL) black crappie captured in Roosevelt Reservoir with gill nets and trap nets, fall 1996.

Length Category	# of fish	mean Wr	95%CI
S-Q	12	101.22	+8.01
Q-P	70	104.26	+2.50
P-M	76	98.68	+2.05

98.68, respectively (Table 2).

Zooplankton

A total of 7,551 zooplankton were counted and measured. Roosevelt Reservoir had significantly larger cladocerans (Figure 4; $P<0.05$, $q = 2.636$; mean = 0.4 mm), a higher number of copepodas per liter (Figure 5; $P<0.05$, $q = 2.634$; mean = 2.25 copepods/L), and a higher number of nauplii per liter (Figure 6; $P<0.05$, $q = 2.634$; mean = 16.02 nauplii/L) than the other 3 reservoirs. The average size of copepods was essentially the same for all 4 reservoirs. Nauplii (Figure 7) were significantly larger in Roosevelt and Apache reservoirs than in the other 2 reservoirs ($P<0.05$, $q = 2.635$; Roosevelt = 0.18 mm, Apache = 0.16 mm).

An exotic cladoceran, *Daphnia lumholtzi,* was present in low abundance in all 4 reservoirs (Table 3). Little is known about the ecology of this species, although Havel et al. (1995) found it to be abundant only during the summer in Missouri. Since I sampled during fall, I may have missed the peak population density of *D. lumholtzi.* There was no significant difference between reservoirs in either the number of *D. lumholtzi* per liter or their mean size. This zooplankter ranged from 1.08 - 3.94 mm in total length. *D. lumholtzi* is unique and easily distinguished from native North American *Daphnia* spp. due to the exceptionally long spines that extend from the head (helmet) and anal region (Havel and Hebert 1993).

Water Levels

Reservoir gage height (1991-1996) showed that the water level of Roosevelt

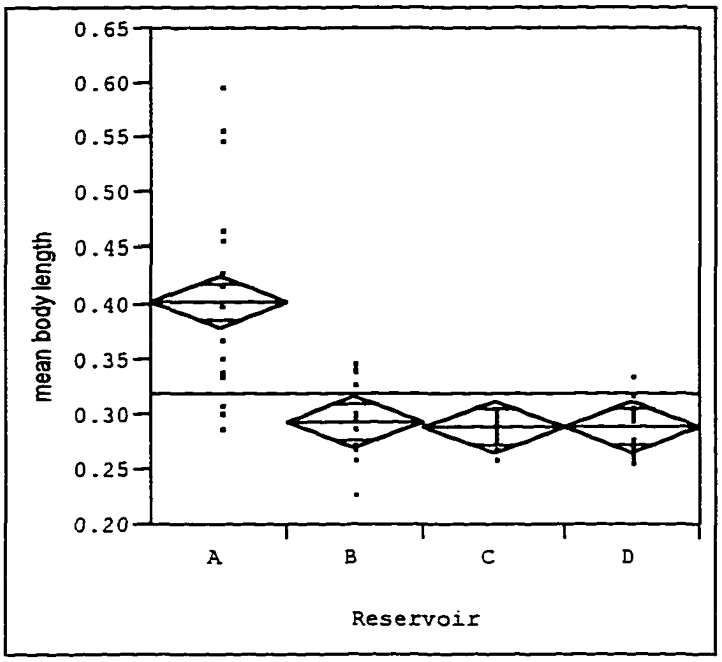

Figure 4. Average size (millimeters) of Cladocera in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

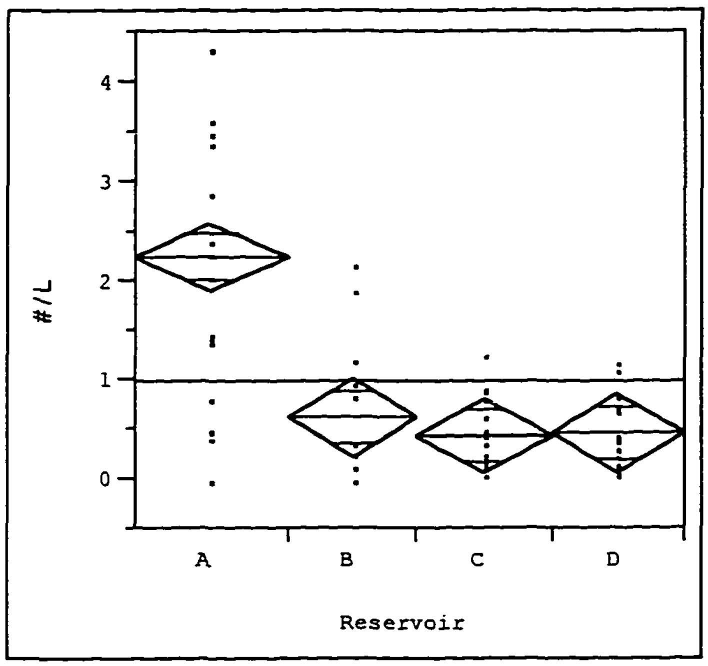

Figure 5. Relative abundance of Copepoda per liter in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

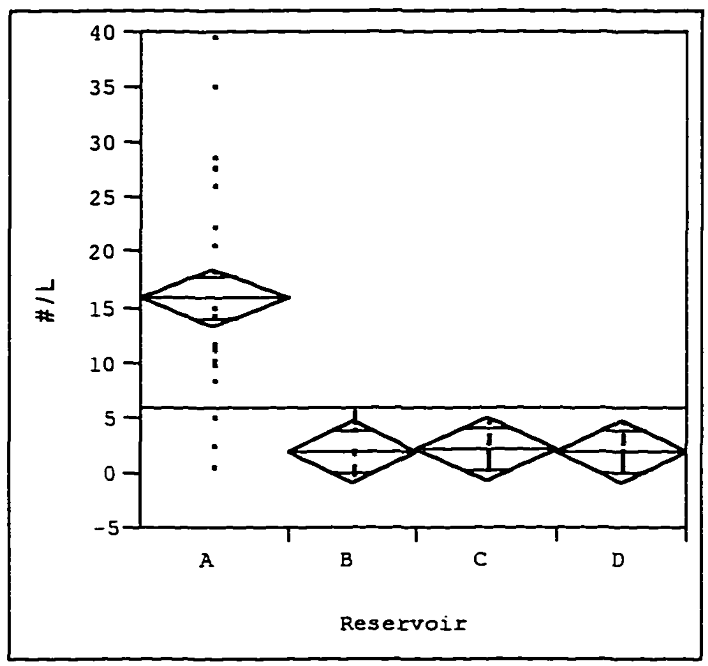

Figure 6. Relative abundance of nauplii per liter in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence intervals. Each dot is a sample mean.

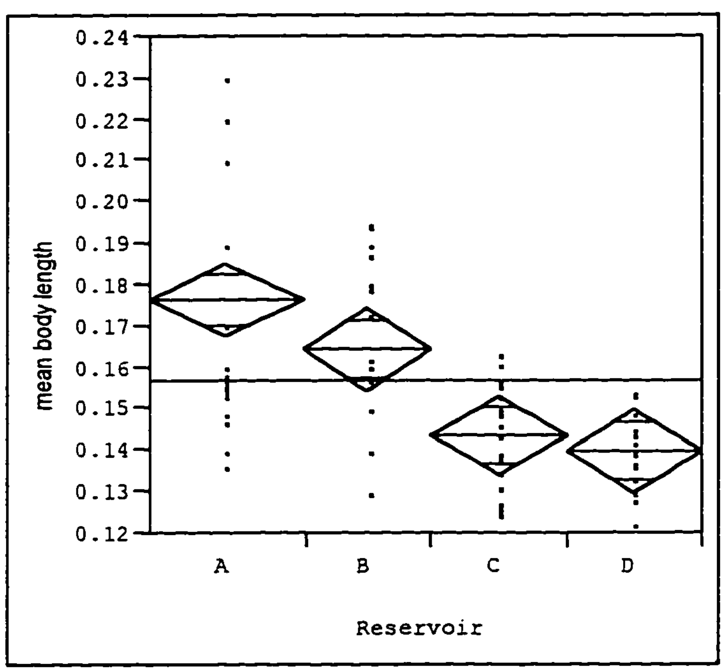

Figure 7. Average size (millimeters) of nauplii in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Ariozna. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence intervals. Each dot is a sample mean.

Table 3. Average number per liter and standard deviation of *Daphnia lumholtzi* in 4 reservoirs on the Salt River, Arizona, Fall 1996.

Reservoir	# of samples	#/liter	Std. Dev.
Roosevelt	20	0.07	0.10
Apache	17	0.05	0.10
Canyon	18	0.04	0.10
Saguaro	17	0.01	0.02

Reservoir fluctuated greatly (max. height = 70.7 m [232 ft], min. height = 50 m [164 ft]), and declined from May 1995 to September 1996. The level of Apache Reservoir fluctuated widely from 1991-1994, but was relatively constant from 1994-1996. Water levels were relatively constant in Canyon and Saguaro reservoirs throughout 1991-1996 (Figure 8). However, Canyon and Saguaro reservoirs undergo daily fluctuations of up to 2.4 m (8 ft) to meet peaking power demands (Dallas Reigle, Salt River Project, Phoenix, AZ, personal communication).

Water Quality

All 4 reservoirs had about equal chlorophyll levels; around 10 mg/m^3 (mg/m^3 = $\mu g/L$), in the spring (Figure 9). All were classified as eutrophic systems (Maceina et al. 1996; Ney 1996). However, in the fall, Roosevelt and Apache reservoirs had chlorophyll a levels of around 6 mg/m^3 while Canyon and Saguaro reservoirs had levels of around 1 - 2 mg/m^3 (Figure 10).

Roosevelt had significantly higher pH during spring ($P<0.05$, $q = 2.644$, pH=8.56; Figure 11) and fall ($P<0.05$, $q = 2.639$, pH=8.31; Figure 12) than the other 3 reservoirs. All 4 reservoirs had similar pH's during summer (Figure 13).

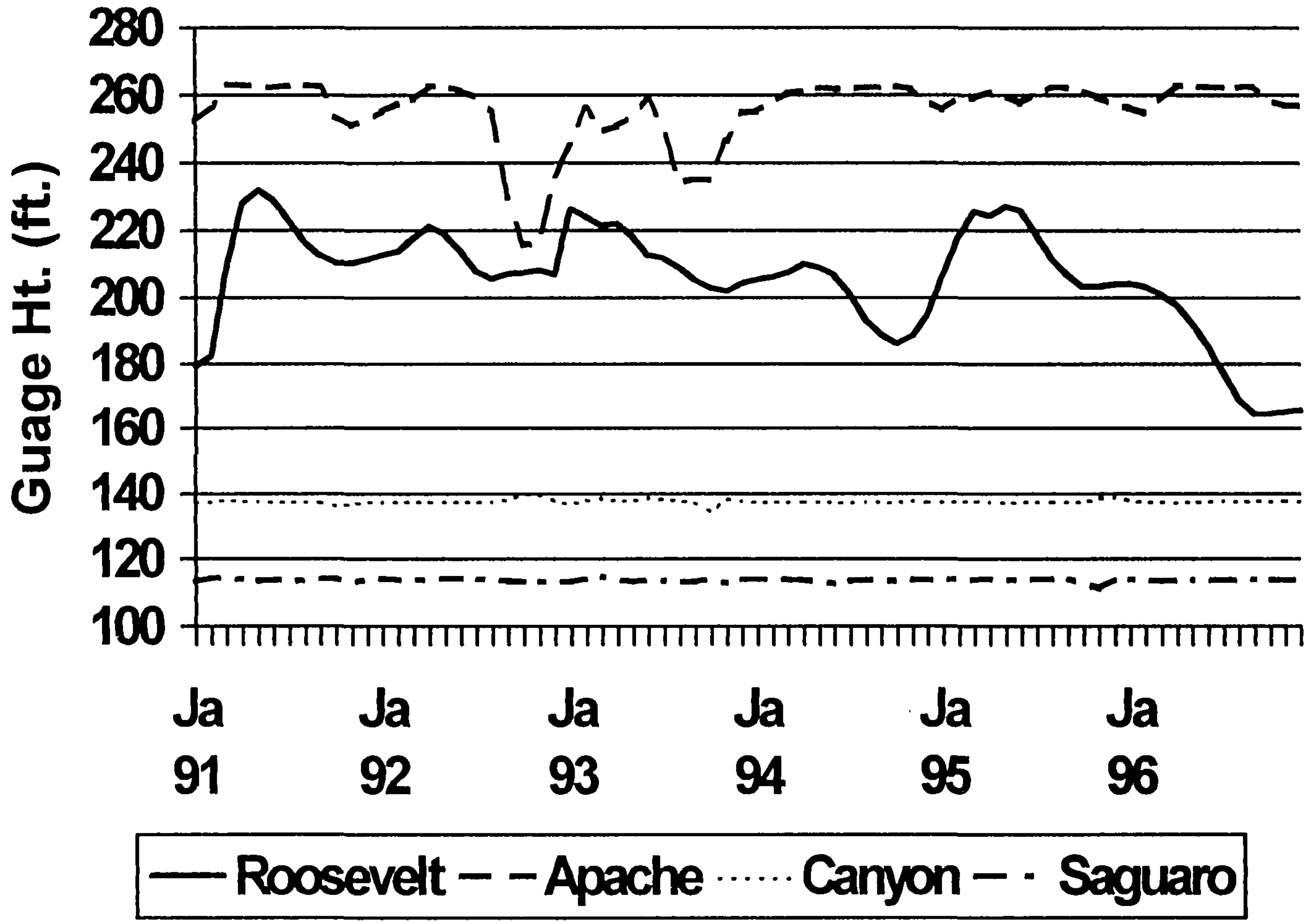

Figure 8. Water levels (1991-1996) in 4 reservoirs on the Salt River, Arizona.

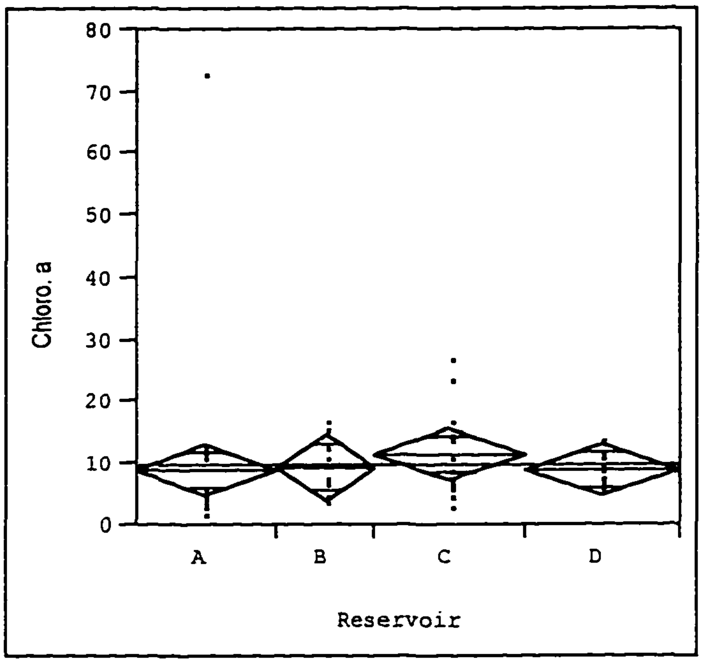

Figure 9. Spring chlorophyll a levels in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents the reservoirs mean. Height of diamond is the 95% confidence interval. Each dot is a sample mean.

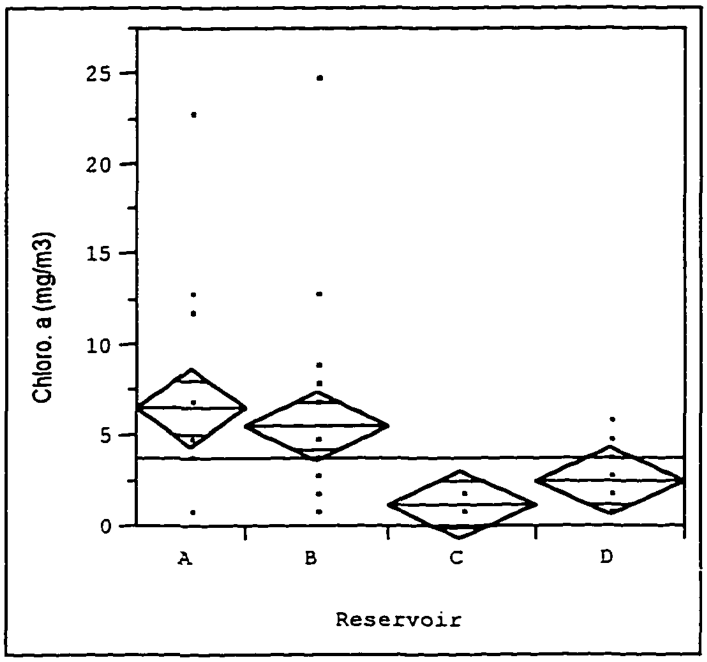

Figure 10. Fall chlorophyll a levels in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents the reservoir mean. Height of diamond is the 95% confidence interval. Each dot is a sample mean.

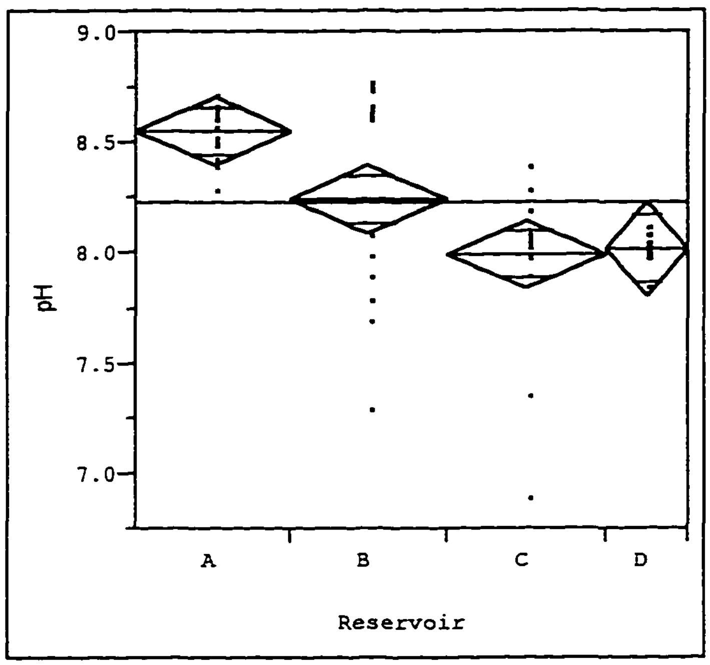

Figure 11. Spring pH in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

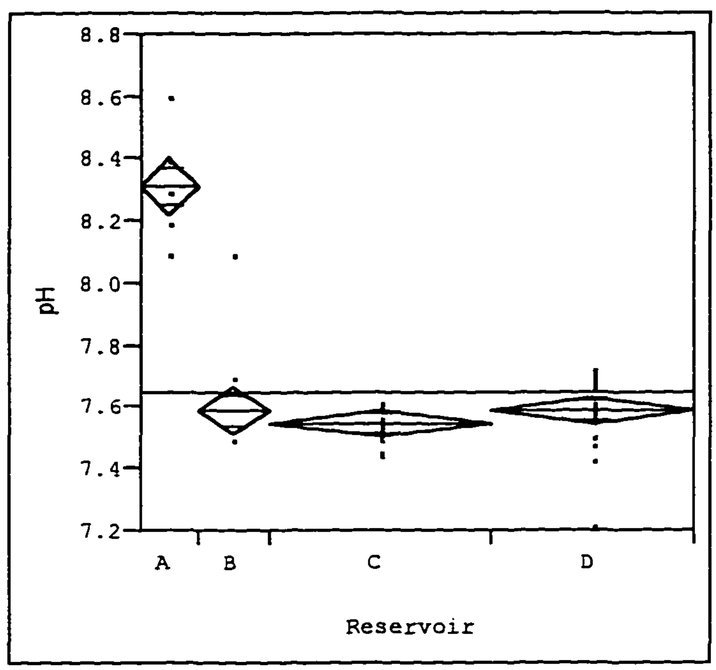

Figure 12. Fall pH in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

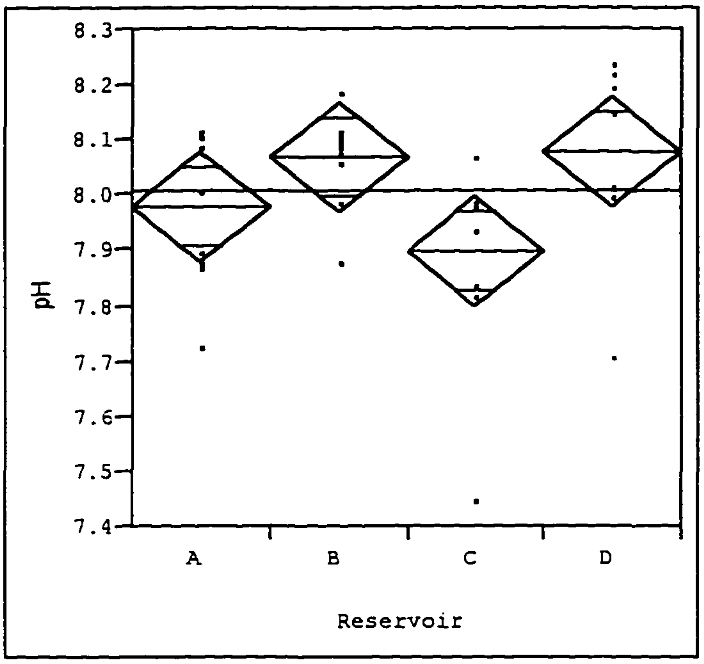

Figure 13. Summer pH in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

Roosevelt Reservoir had the highest turbidity during all 3 seasons. The highest average turbidity for Roosevelt was 17.6 NTUs (Nephelometric Turbidity Units) (Figures 14, 15, 16). Roosevelt Reservoir also had the highest conductivity during all 3 seasons (Figures 17, 18, 19).

Roosevelt Reservoir had the deepest summer epilimnion (about 10 m, Figures 20 and 21) of the reservoirs. Apache Reservoir had a summer epilimnion depth of 5 m (Figures 22 and 23). Rinne et al. (1981) found similar epilimnion depths in Roosevelt and Apache reservoirs. These authors attributed the deeper epilimnion in Roosevelt to wind action and warm inflows from the Salt River and Tonto Creek. The epilimnion in Canyon and Saguaro was around 4 m (Figures 24, 25, 26, 27) during the summer.

Habitat Analysis

The substrate in Roosevelt Reservoir allowed a significantly higher penetration than the substrate in the lower reservoirs (Figure 28; $P<0.05$, $q = 2.614$, Roosevelt penetration = 4.9 cm). The deepest penetration (36 cm) in Roosevelt Reservoir occurred at the Tonto Creek confluence. Average substrate penetration on Roosevelt Reservoir was probably underestimated because 2 sites near the Salt River confluence were above the water level when samples were taken. The lower 3 reservoirs had substrate penetration depths of < 1 cm.

Roosevelt also had a significantly more gradual slope (Figure 29; $P<0.05$, $q = 2.614$, average slope = 0.16) out to a depth of 10 m. The lower 3 reservoirs had slopes

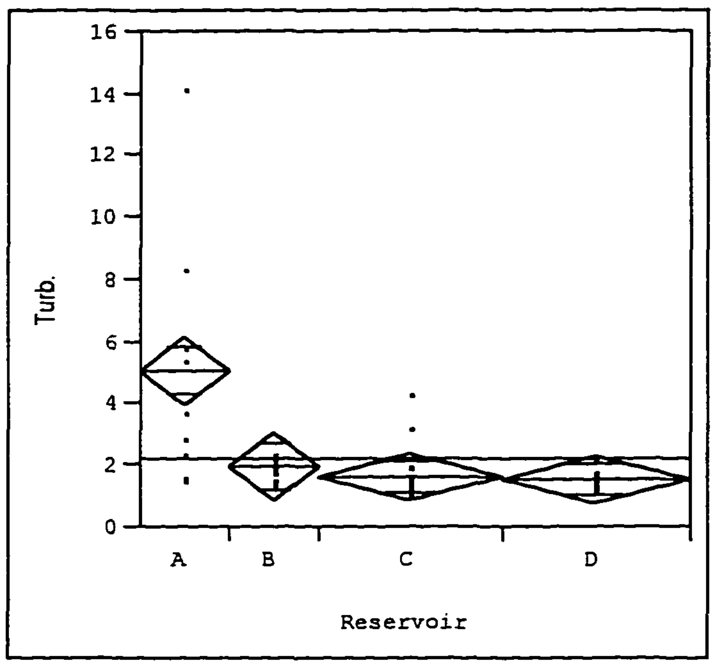

Figure 14. Spring Turbidity levels in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

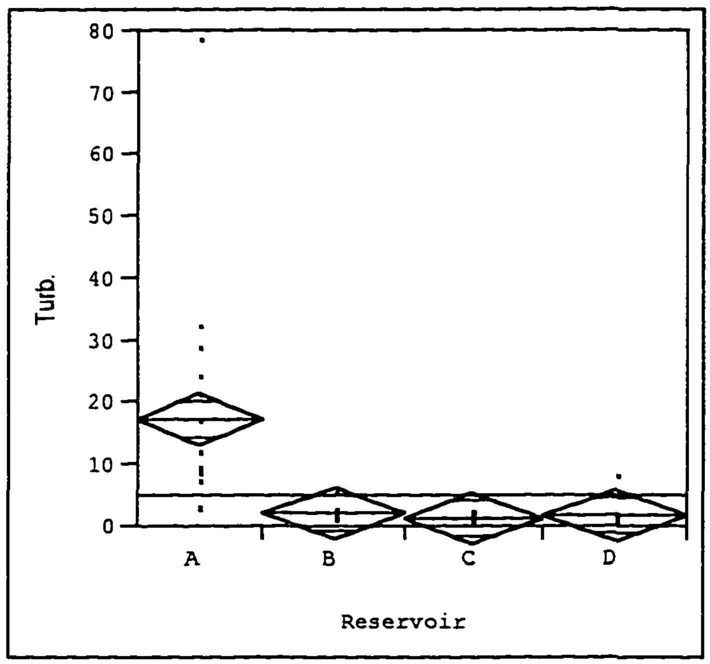

Figure 15. Summer turbidity levels in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

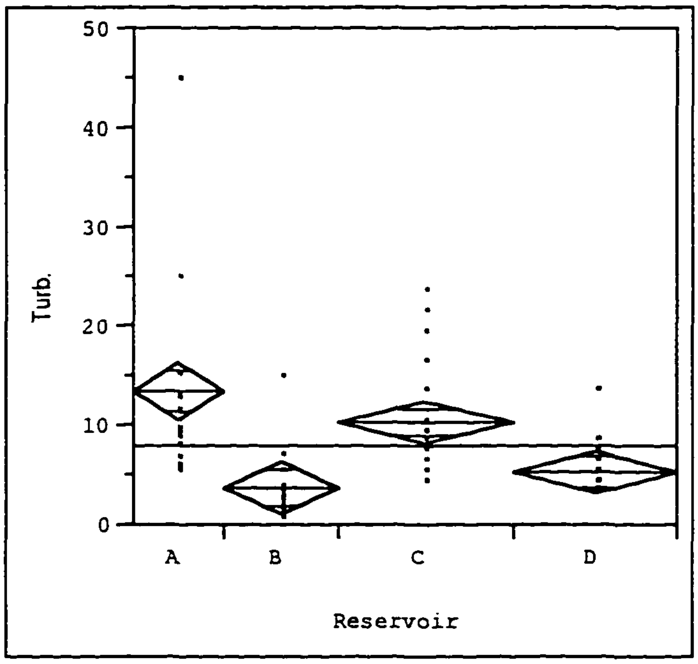

Figure 16. Fall turbidity levels in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

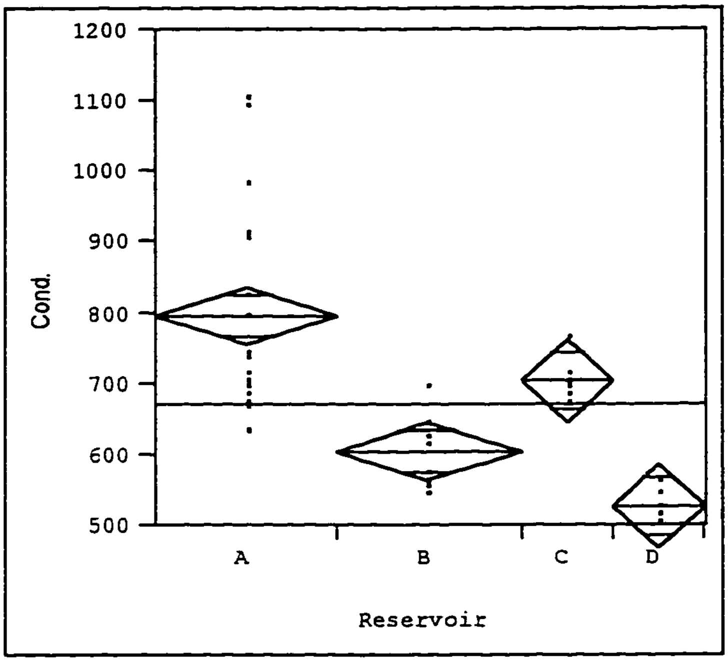

Figure 17. Spring conductivity levels in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents the 95% confidence interval. Each dot is a sample mean.

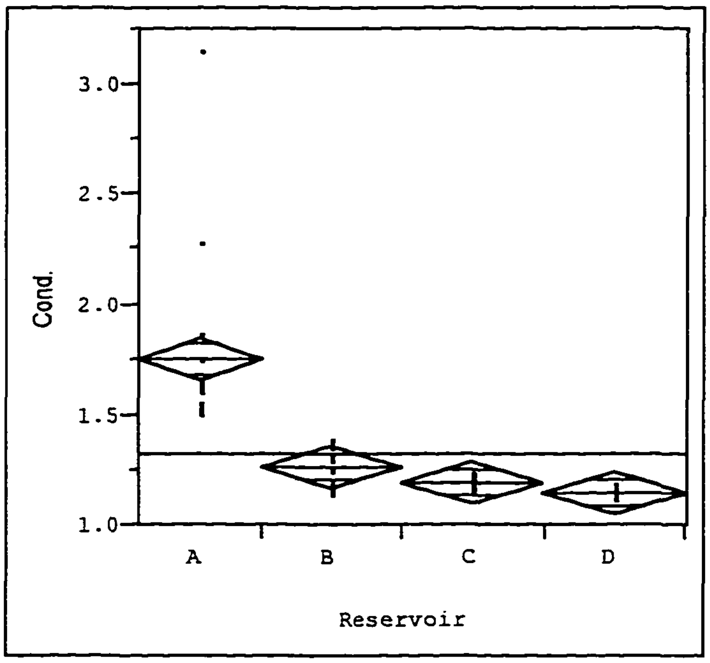

Figure 18. Summer conductivity levels in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

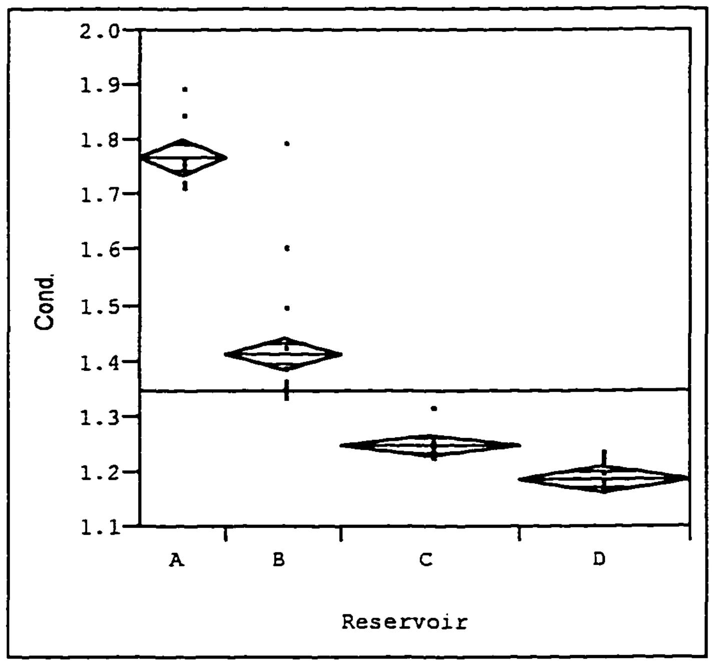

Figure 19. Fall conductivity levels in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represent 95% confidence interval. Each dot is a sample mean.

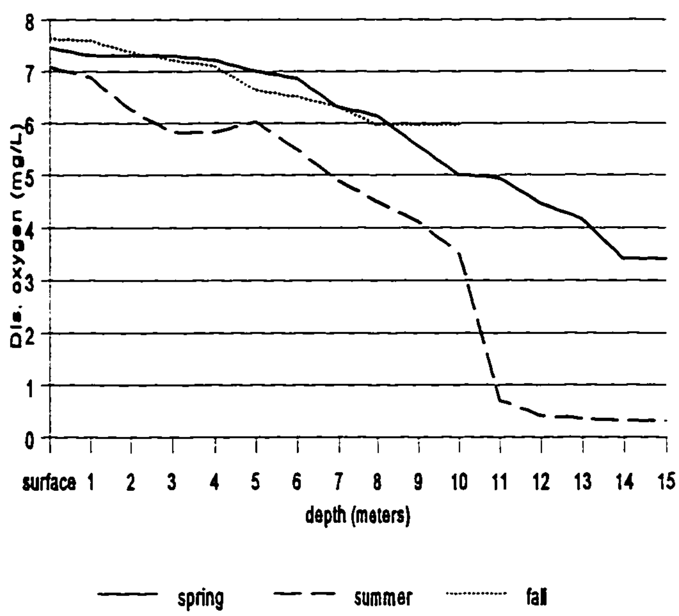

Figure 20. Seasonal dissolved oxygen levels (1996) in Roosevelt Reservoir.

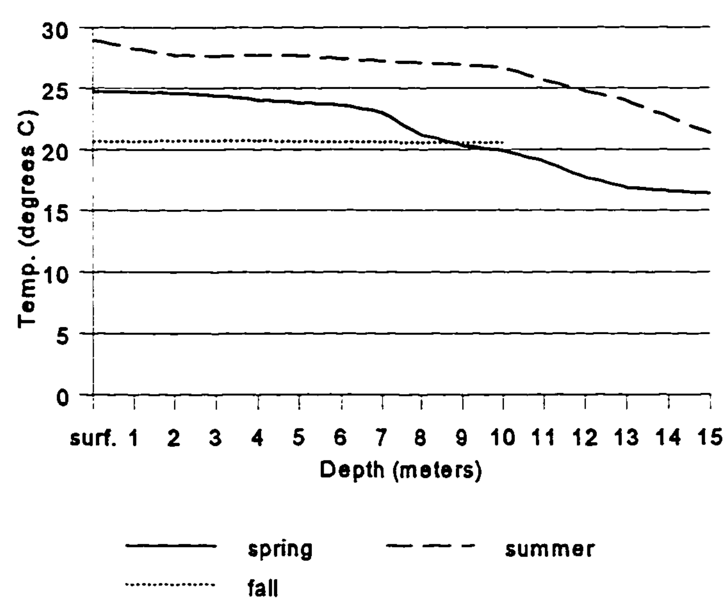

Figure 21. Seasonal temperature levels (1996) in Roosevelt Reservoir.

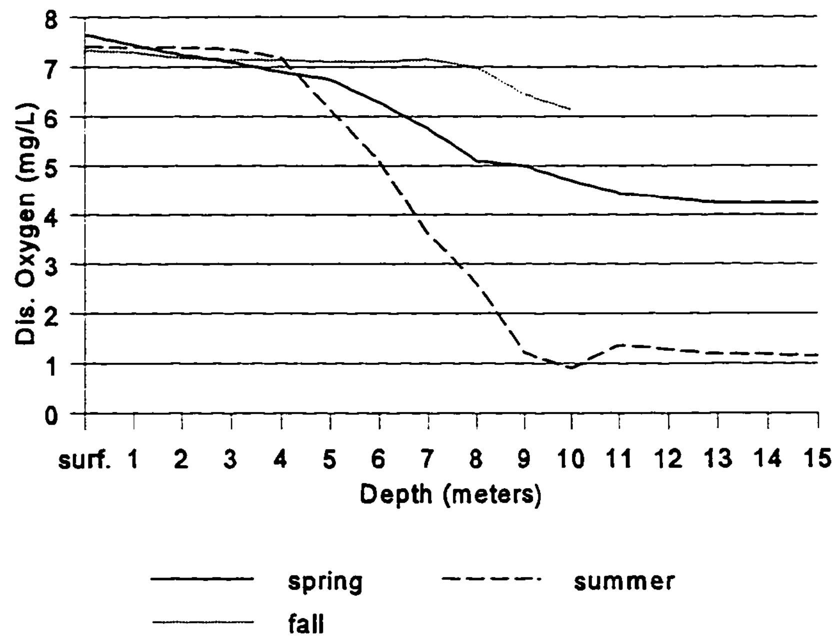

Figure 22. Seasonal dissolved oxygen levels (1996) in Apache Reservoir

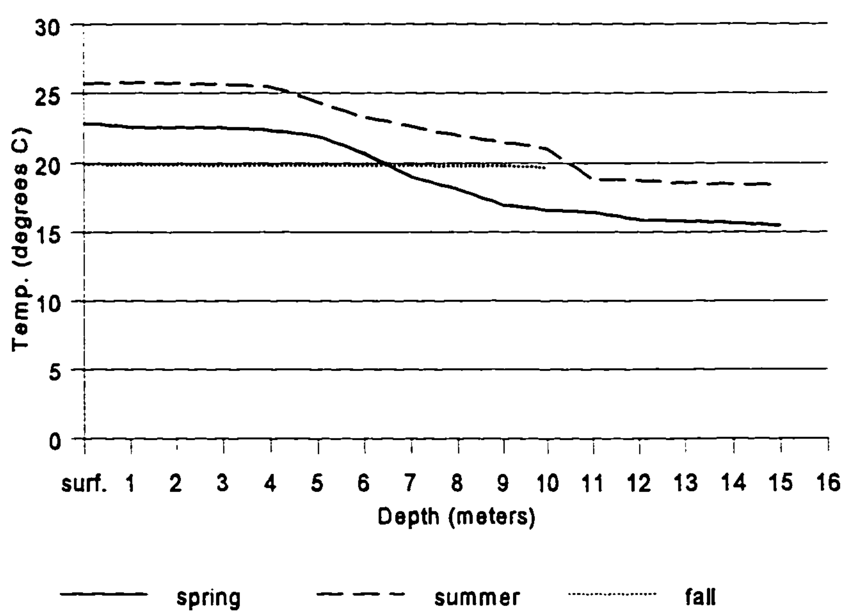

Figure 23. Seasonal temperature levels (1996) in Apache Reservoir.

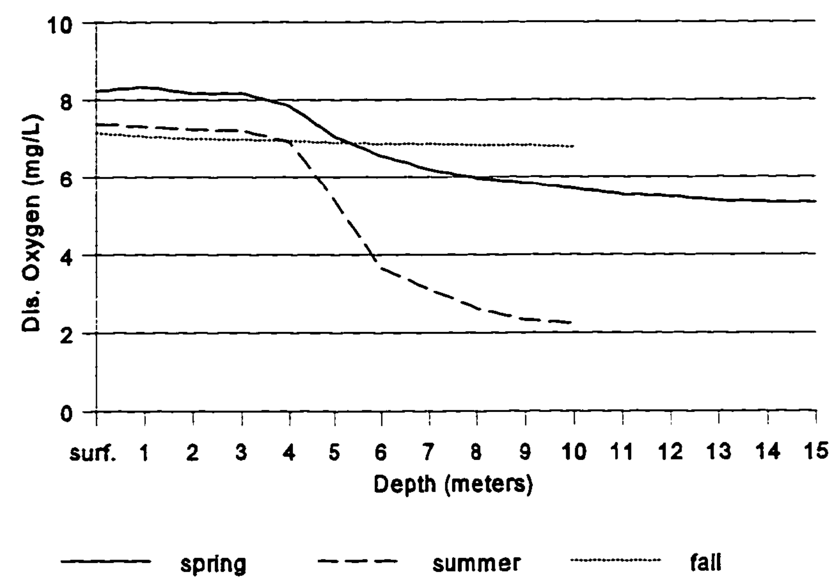

Figure 24. Seasonal dissolved oxygen levels (1996) in Canyon Reservoir.

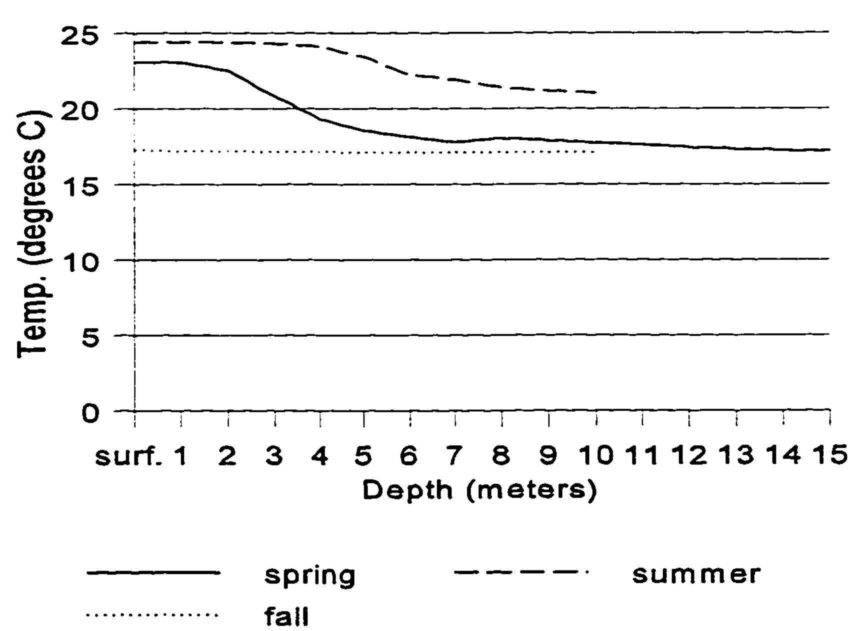

Figure 25. Seasonal temperature levels (1996) in Canyon Reservoir.

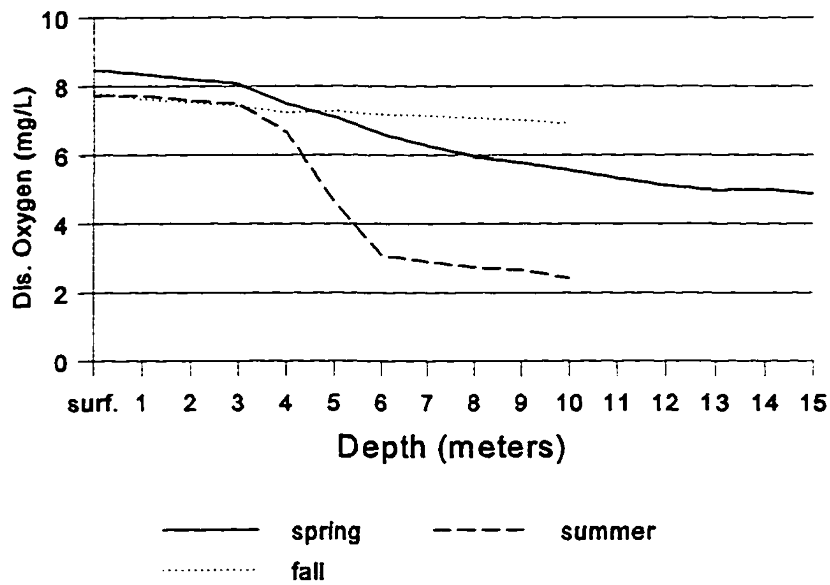

Figure 26. Seasonal dissolved oxygen levels (1996) in Saguaro Reservoir

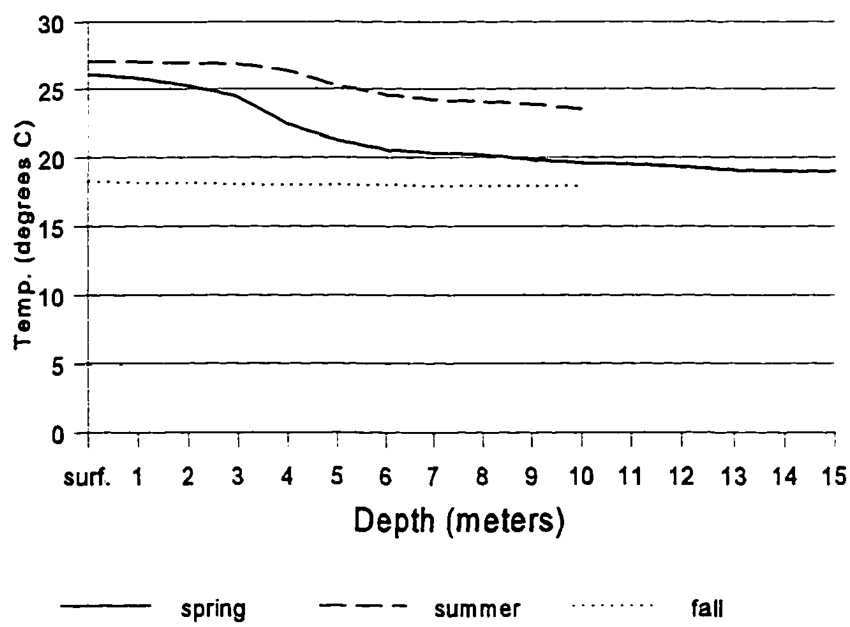

Figure 27. Seasonal temperature levels (1996) in Saguaro Reservoir.

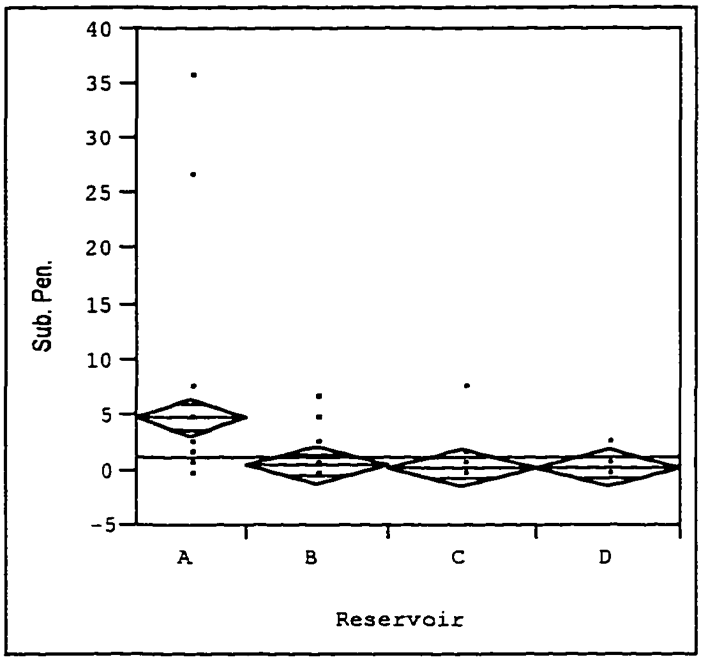

Figure 28. Substrate penetration in 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

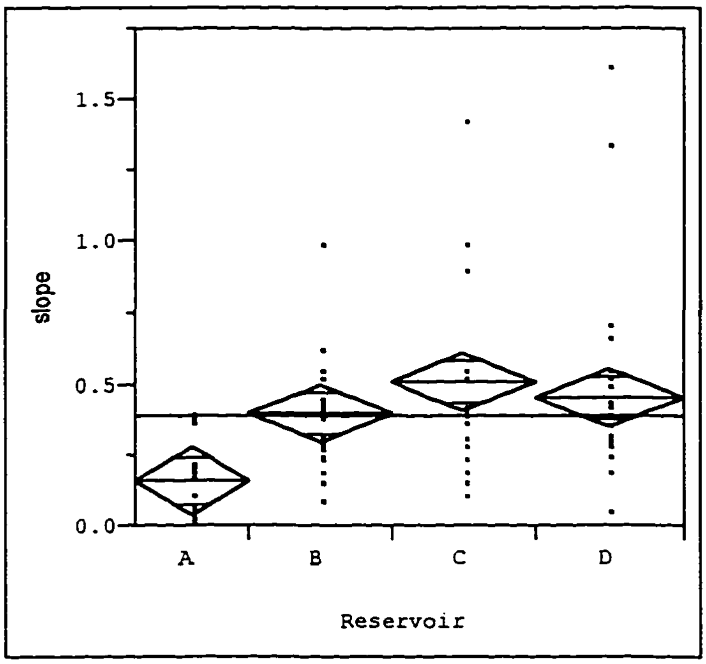

Figure 29. Relative slope of 4 reservoirs (A=Roosevelt, B=Apache, C=Canyon, D=Saguaro) on the Salt River, Arizona. Horizontal bar in center of diamond represents reservoir mean. Height of diamond represents 95% confidence interval. Each dot is a sample mean.

greater than 0.3 (slope = rise/run and therefore is unitless).

More than 59% of the (reservoir) sites sampled had no cover. When cover was available most of it was in the form of boulder piles (41% of the sites on Apache, 30% on Canyon, 24% on Roosevelt, and 19% on Saguaro). Submerged or partially submerged trees formed 11% of the cover in Saguaro and 9.5% of the cover in Roosevelt. There were no submerged trees in Apache or Canyon reservoirs. Saguaro was the only reservoir that had aquatic macrophytes (emergent), 11% of the sites surveyed.

DISCUSSION

The dominance of the age 3 year class and the absence of age 1 black crappie in Roosevelt Reservoir seem to indicate sporadic recruitment. The dominance of large fish may result from gear bias, but gear bias is not likely because age 1 crappie were sampled from Apache Reservoir with similar gear. Early investigators of crappie populations believed that recruitment cycles were the result of intraspecific competition (Swingle and Swingle 1967; Rutledge and Barron 1972). They hypothesized that an abundant year class resulted in competition for food and other resources. Competition in turn caused poor condition, low growth rates, and low reproductive success. A strong year class was followed by a few years of almost no recruitment and thus at least one missing year class. However, it is now believed that intense intra- or even interspecifc competition is not likely in a large impoundment. Instead, several studies indicate that water level fluctuations are responsible for the cyclic nature of crappie populations in reservoirs (Cichra et al. 1981; Mitzner 1981, 1991, 1995; Beam 1983; McDonough and Buchanan

1991; Guy 1993). Periods of high water during the spawning and larval period probably provide additional nest sites, cover, and forage by inundating terrestrial vegetation. Recruitment is high and growth of fish is rapid. Conversely, when water levels are low during spawning and larval periods, adequate cover, nest sites, or forage may be limited. The result is poor recruitment, and a missing year class. The absence of age 1 crappie in Roosevelt Reservoir is probably the result of declining water levels from May 1995 until September 1996. Daily water level fluctuations of 2.4 m in Canyon and Saguaro reservoirs may account for the rarity of crappie there. Crappie that do successfully spawn may be forced from nests when water levels fall (Ginnelly 1971).

A balanced crappie population should have a PSD between 30-60% (Gablehouse 1984a). However, the dominant age 3 year class (almost all fish > 200 mm in length) and absence of smaller fish caused a 93% PSD in Roosevelt Reservoir. The quality of crappie fishing in Roosevelt Reservoir should be high during the next 2 years. However, angler harvest will then decline because of the absence of age 1 and 2 black crappie that would recruit to angler harvest.

The total Wr for all length groups of black crappie in Roosevelt Reservoir fell in the range of 95 - 105 (Neumann and Murphy 1991), indicating satisfactory condition. A satisfactory condition factor suggests that the forage base is not limiting growth of black crappie in Roosevelt Reservoir. If the forage base were limiting, growth rates would be slow and condition factors would fall below the minimum target of 95 Wr.

Zooplankton populations in Apache, Canyon, and Saguaro reservoirs may limit survival of juvenile planktivorous crappie. Reeves (1989) found that stomachs of age-0 white crappie generally contained 43% cladocerans (*Diaphanosoma* spp.) and 27% copepod nauplii. Black crappie generally make the transition from zooplankton to fish when they reach lengths of 150 - 200 mm TL (Ager 1975; Oakey 1986), which for Roosevelt crappie was at about age 2. Therefore, crappie in Apache, Canyon, and Saguaro reservoirs are dependent upon zooplankton for at least 1 and probably 2 years. If zooplankton densities are low during the fall, juvenile crappie in these reservoirs may not be able to store enough energy to overwinter.

Although densities of cladocerans were similar in all 4 reservoirs, Roosevelt had higher densities of copepods and nauplii than the other reservoirs. Therefore it seems likely that juvenile crappie in Roosevelt Reservoir have access to more energy from feeding on zooplankton to overwinter.

Whether the exotic cladoceran *D. lumholtzi* has a reduced forage value for larval crappie is unclear. Green (1967) concluded that the helmeted morph was subjected to reduced predation pressure by fishes. In contrast, Havel et al. (1995) stated that this exotic zooplankter had no discernable impact on fish populations in Missouri. In fact, the first record of *D. lumholtzi* in Missouri was from the stomach of a white crappie (Havel et al. 1995).

All 4 reservoirs can be classified as eutrophic (>8 mg/m^3 of chlorophyll a) during spring. However, 1 sample from the confluence of the Salt River and Roosevelt Reservoir was exceptionally high (73 mg/m^3 of chlorophyll a). Samples taken close to the confluence with a major tributary could be high in chlorophyll a because of nutrient input from the watershed. Chlorophyll a levels may be similar among the reservoirs because of the season I sampled. During spring sampling, the reservoirs had begun to stratify. In early spring, the water column generally has a uniform temperature and density. However, as the surface waters begin to warm in mid to late spring (the time of my samples), water near the surface warms faster than water near the bottom. The result is a stratified water column with the upper layer or epilimnion warmer and less dense than the bottom layer or hypolimnion. Between the 2 layers is the metalimnion, a narrow layer where temperature and density change rapidly. The epilimnion and hypolimnion do not mix or readily exchange dissolved ions or molecules due to the different densities. Most of the nutrients (and dead plant and animal matter) are near the bottom of the reservoir. When the reservoir stratifies, nutrients that remain in or fall to the hypolimnion and cannot be used by primary producers such as epilimnetic phytoplankton. However, all 4 reservoirs have a hypolimnetic release, which means that water passing from one reservoir to the next comes from the hypolimnion. Roosevelt receives nutrients from the Salt River and Tonto Creek tributaries, while Apache, Canyon, and Saguaro must depend for nutrients on the hypolimnetic release from the upstream reservoir. The fact that the lower three reservoirs share the same hypolimnetic water may explain the similar chlorophyll values during the spring. Similar chlorophyll values may also have resulted from spring turnover prior to reservoir stratification. Spring turnover would have given all reservoirs access to nutrients from the reservoir bottom.

During the fall, Roosevelt Reservoir had higher chlorophyll a levels than the lower 3 reservoirs. Higher chlorophyll levels may have been due to higher water temperatures in Roosevelt Reservoir. Higher water temperatures would mean that Roosevelt Reservoir probably had a higher rate of photosynthesis than the lower reservoirs. Another possibility is that destratification of Roosevelt during fall resulted in algal blooms due to availability of nutrients once confined to the hypolimnion, and these blooms reduced the nutrient load passed downstream. Roosevelt also received nutrient input from storm runoff during late summer monsoons. The lower 3 reservoirs have much smaller watersheds than Roosevelt Reservoir (excluding the Salt River and Tonto Creek above Roosevelt), and storm runoff would not provide many additional nutrients to these reservoirs. If the lower 3 reservoirs are dependent primarily on hypolimnetic releases from the upstream reservoir for their nutrient supply, then limited amounts nutrients in hypolimnetic releases and little storm runoff would account for the lower productivity of Apache, Canyon, and Saguaro reservoirs during the fall.

Lower productivity may cause the lower reservoirs to provide a limited forage base for planktivorous age-0 black crappie. This conclusion also seems to be supported by the lower densities of zooplankton in Apache, Canyon, and Saguaro reservoirs relative to Roosevelt Reservoir during the fall.

Similar pH values during the summer may result from the lack of storm runoff and nutrient input during arid summers. Lack of rainfall prior to pH sample collection may have allowed the chemical processes that control pH to stabilize. High pH levels in

Roosevelt during fall were probably the result of late summer monsoons. Increased runoff from the Salt River and Tonto Creek probably provided additional nutrients which resulted in increased photosynthesis by phytoplankton. Increased phytoplankton production, in turn, increased the pH. Apache, Canyon, and Saguaro reservoirs tend to be close to the preferred range of ≤ 7.0 pH for black crappie. However, since black crappie are abundant only in Roosevelt, factors other than pH seem to be influencing crappie populations. Mathur et al. (1979) found that annual variations in crappie fecundity were not significantly correlated with variations in pH.

Roosevelt Reservoir was always the most turbid of the 4 reservoirs. High turbidity probably results from sediment input from the Salt River and Tonto Creek. Turbidity was especially high during summer, probably due to decreasing water levels. As water levels decreased, sediments that had once settled out of the water column were resuspended by wave action. Black crappie tend to do well in relatively clear, less turbid waters, while white crappie are adapted to higher turbidity levels. An average turbidity of ≤ 26 NTU's has been shown to have no correlation with catch rates of black crappie (McInerny and Degan 1991), but at higher NTU's catch rates drop off. Turbidity levels in Roosevelt, Apache, Canyon, and Saguaro are well below this range. Thus turbidity probably is not a limiting factor for black crappie in these reservoirs. The higher turbidity of Roosevelt Reservoir may actually benefit black crappie. Turbidity might serve as cover for juveniles.

Roosevelt Reservoir always had the highest conductivity levels of the 4 reservoirs.

High conductivities were likely derived from the load of dissolved solids entering from the two tributaries into Roosevelt Reservoir. The effects of conductivity on crappie populations is not well documented. However, it is unlikely that the higher conductivity in Roosevelt Reservoir are responsible for the higher quality crappie fishery. Mathur et al. (1979) found that annual variations in crappie fecundity were not significantly correlated with variations in conductivity, however they gave no conductivity values in their paper. It is more likely that the factors that cause higher conductivity (primarily runoff from the Salt River and Tonto Creek tributaries) also influence parameters such as productivity and sediments for spawning that are necessary to sustain a crappie fishery in Roosevelt.

Neither dissolved oxygen nor temperature appear to be limiting in any of the reservoirs. Roosevelt and Apache have hypolimnetic dissolved oxygen of < 2 mg/L which could limit crappie nesting, however crappie probably do not nest below the epilimnion in these reservoirs.

Deeper average substrate penetration in Roosevelt Reservoir is likely due to the fine sediments deposited by Tonto Creek and the Salt River. Apache, Canyon, and Saguaro reservoirs all had average substrate penetrations of < 1 cm, indicating hard bottoms of cobble, boulder, or bedrock. Crappie nests consist of shallow depressions in the substrate and black crappie tend to build more definite depressions than white crappie (Hansen 1965). The type of substrate necessary for successful spawning by black crappie appears to be present only in Roosevelt Reservoir. Black crappie select substrates of sand, gravel, and cobble (Breder 1936; Ginnelly 1971) which can be excavated to form nests. Substrates in Apache, Canyon, and Saguaro reservoirs were primarily cobble, boulder, and bedrock. Such substrates do not provide adequate spawning locations for crappie. Without the necessary spawning sites, crappie recruitment is probably severely limited.

I believe I overestimated the amount of cover in all 4 reservoirs. Most of the bottom substrates in these reservoirs were flat or sloping with few obvious objects to provide cover for fish. Any identifiable "bump" on the bottom was designated as a boulder, especially if fish were holding nearby. Roosevelt Reservoir was about 50% full during the last half of my study and I easily viewed tremendous amounts of exposed substrate. I assessed the reliability of my cover estimates by assuming that exposed substrate was similar to substrate still submerged and visually evaluating the amount of cover provided by exposed substrate. There was almost no cover of any kind over most of the exposed bottom. Even where tributaries entered the reservoir there were very few scattered tree remains. Those present had probably washed into the reservoir. Terrestrial plants inundated when the reservoir filled had long since decayed. The lower 3 reservoirs did not fluctuate as much as Roosevelt, so I was unable to assess the reliability of my cover estimates in the lower 3 reservoirs. However, to truly assess the availability of cover, more thorough habitat transects would need to be established and cover type verified by underwater observation.

Cover seems to be a crucial element in the early life history of crappie (Hansen 1965; Goodson 1966; Ginnelly 1971; Beam 1983; Oakey 1986; Robison and Buchanan

1988; Markham et al. 1991), and cover may be more important for black crappie than for white crappie (Neal 1963; Ball and Kilambi 1972; McDonough and Buchanan 1991). Cover is so important to crappie spawning success and juvenile recruitment because it provides protection from predators. Roosevelt Reservoir probably provides more cover than the lower reservoirs because water level fluctuations allow terrestrial vegetation to reestablish. When vegetation is reflooded at periods of higher water, cover is provided. Apache, Canyon, and Saguaro reservoirs all maintain relatively constant water levels which do not allow terrestrial vegetation to reestablish. The result is that the lower reservoirs have practically no cover for crappie.

Roosevelt Reservoir only occasionally provides cover for crappie spawning. Therefore there will only be sporadic crappie recruitment. Recruitment success is dependent on water levels during spawning and nursery periods (Cichra et al. 1981; Beam 1983; McDonough and Buchanan 1991; Mitzner 1995). Additional cover, especially around preferred nesting substrates during periods of low water, would significantly benefit the recruitment of crappie in Roosevelt Lake. Ginnelly (1971) found that in years of higher water levels, crappie spawning in Roosevelt took place at the base of submerged shrubs. He concluded that vegetation alone might be a crucial limiting factor for crappie spawning success in Roosevelt. Since the lower reservoirs do not fluctuate enough to allow for terrestrial plant inundation, they are dependent on the amount of permanent cover (such as boulder piles, submerged trees, and artificial cover) for spawning and nursery sites.

Roosevelt Reservoir has a more gradual slope than the lower reservoirs. Apache, Canyon, and Saguaro reservoirs are held within deep canyons. The basin of Roosevelt Reservoir was characteristic of desert flats just northeast of the Four Peaks mountain range. The shallower slope of Roosevelt means that more of the littoral zone is available for nest sites. Ginnelly (1971) found nests between 2.4 - 3.7 m (8-12 ft). Similarly, Vasey (1972) found white crappie nests were between 0.1 - 6 m in depth. Therefore, Roosevelt has significantly more shallow areas for crappie spawning than the other reservoirs.

All four reservoirs contain largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), and flathead catfish (*Pylodictis olivaris*). The lower reservoirs also contain two additional predators, walleye (*Stizostedion vitreum*) and yellow bass (*Morone mississippiensis*). Each of these species prey on juvenile crappie. In Iowa, Mitzner (1979) found walleye diets consisted of 53% crappie and only 17% gizzard shad (*Dorosoma cepedianum*). In general, biomass proportions of walleye and centrarchids are inversely related (Carline 1986). If yellow bass or walleye are more efficient at capturing juvenile crappie than flathead catfish, largemouth bass, or smallmouth bass, then predation pressure might limit survival of crappie in the lower reservoirs.

SUMMARY

Of the 4 reservoirs, only Roosevelt fits the model for supporting a self-sustaining crappie fishery. However, Roosevelt does not provide sufficient cover during periods of low water. Even if the higher turbidity of Roosevelt acts as a form of cover, overall black crappie recruitment could be increased with additional cover. Apache, Canyon, and

Saguaro reservoirs lack suitable spawning substrate, cover, and possibly a forage base for young crappie in the fall.

MANAGEMENT OPTIONS

Apache - Canyon- Saguaro Reservoirs

If the goal of the Arizona Game and Fish Department is to establish a black crappie fishery in the lower reservoirs of the Salt River, there are several management options that should be considered. These reservoirs lack suitable spawning substrate, adequate cover, and probably an adequate forage base in the fall.

The lack of spawning substrate could be corrected by the placement of suitable substrates such as sand, pebbles, and/or gravel in the shallower ($\leq$ 6 m in depth) areas of the reservoir. Midwater reefs consisting of graveled platforms have successfully provided spawning habitat for centrarchids in other reservoirs (Reeves et al. 1977; Brouha and von Geldern 1979). The advantage of midwater spawning reefs is that they fluctuate with reservoir water levels. Fluctuations with water levels insures that these spawning reefs will not be "silted in" and require replacement.

Providing cover would probably be the simplest and most cost effective way to improve the crappie fishery in these reservoirs. Artificial cover can be purchased from commercial manufacturers as well as constructed from cheap, discarded material such as Christmas trees or brush piles (Warnecke 1986; Wilbur 1978), stake beds (Petit 1972), and tires (Paxton et al. 1979; Prince and Maughan 1979). The advantage of tire reefs and stake beds is that during periods of low water levels, these types of cover will not decay as terrestrial plants do. However, the disadvantage of tire reefs or stake beds is that they are not aesthetically pleasing. Cover constructed from terrestrial vegetation such as Christmas trees and brush piles, when anchored properly, can provide cheap, adequate cover in reservoirs that fluctuate only slightly on an annual basis, such as Apache and especially Canyon and Saguaro reservoirs. However, the addition of cover will only benefit crappie populations if it is placed near suitable spawning areas.

The lack of adequate forage during the fall might be corrected by fertilization. The addition of phosphates, nitrates, and other nutrients have been shown to increase primary phytoplankton productivity. Increased primary productivity increases zooplankton abundance (Kemmerer 1967). There may be concern that fertilizing a multipurpose reservoir will produce unwanted side effects. However, Vaux et al. (1995) found that fertilization of Lake Mead, Nevada-Arizona, did not produce significant negative impacts on water quality from either a public health (drinking water) or environmental perspective.

It might be easier to establish a put-and-take crappie fishery similar to the walleye fishery in Apache, Canyon, and Saguaro reservoirs than to try to correct the several limiting factors in these reservoirs. By stocking sub-adult or adult crappie, the need to establish suitable spawning sites for adults and a forage base and cover for juveniles would be eliminated. To circumvent limited zooplankton forage base during the fall, crappie would need to be stocked at a size large enough to have made the transition from planktivory to piscivory. Crappie tend to make this transition at around 150 to 200 mm TL (Ellison 1984; Oakey 1986), or around 2 years of age. Stocking crappie at this size may not be feasible because of monetary costs or hatchery space. However, stocking crappie may be more economically sound than trying to correct each individual limiting factor.

Roosevelt

Roosevelt has the potential to provide a tremendous crappie fishery for the anglers of Arizona. However, erratic water level fluctuations make it almost impossible to attain consistent recruitment. Water level management to assure high water levels from April through July might increase black crappie recruitment. The reservoir would not have to be brought to conservation pool or above in order to allow good reproductive success of crappie. When Roosevelt is about 50% full there are cockleburr and numerous terrestrial grasses that take root in the exposed substrate. Flooding approximately 20% of this area during critical spawning and nursery periods each year might allow consistent recruitment (Beam 1983). However, management of water levels to this extent is probably impossible given the need for hydroelectric power and water for irrigation.

The addition of cover might also benefit the crappie fishery in Roosevelt Reservoir. Addition of cover would be especially important in areas that are considered good nest sites (Ginnelly 1971). However, cover of terrestrial origin, such as dead trees or shrubs, would decay under the conditions of fluctuating water levels seen in Roosevelt Reservoir. Perhaps placement of artificial cover or reefs at variable depths would be beneficial to crappie. Again, there may be a problem with public concern over aesthetic values when low water levels expose artificial structures. However, Roosevelt is a large reservoir with many areas that can be accessed only by boat. By adding structures to areas of the reservoir that would be less frequented by the non-angling public, conflicts with recreationists other than anglers could be minimized. The exact amount of cover required to benefit the Roosevelt Reservoir crappie population is unknown. Fisher (1995) states that 20% of the total lake or reservoir surface area needs to be covered by aquatic vegetation to provide optimal habitat for balanced fish communities. Adding enough structures to provide cover over 20% of Roosevelt Reservoir's 7,950 hectares would probably not be economically feasible. However, even 5% of additional cover may benefit the crappie population in Roosevelt Reservoir.

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