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Lake Pleasant Striped Bass

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Arizona Game and Fish Department Mission

To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations.

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INTRODUCTION

Lake Pleasant has historically been regarded as one of the premier largemouth bass *(Micropteus salmoides)* fisheries in Arizona. However, the quality of the largemouth bass fishery has decreased, resulting in low angler satisfaction and a general concern for the health of the fishery (Bryan and Kohagen 2003). The leading hypothesis for the cause of this decline is the recent invasion of striped bass *(Morone saxatilis)*, which may be responsible, in part, for the shift in largemouth bass size structure through competition for resources and predation.

Striped bass initially entered the Central Arizona Project (CAP) canal system as eggs or larvae, entrained in Colorado River water pumped from Lake Havasu. Results from a four-year canal study in the late 1980's indicated a growing population of adult striped bass and the potential for their reproduction in the canal would increase as favorable hydraulic operations evolved (Mueller 1989). Striped bass reproduction was expected to be limited due to heat induced stress and subsequent mortality. Nevertheless, striped bass quickly found their way into Lake Pleasant soon after it was connected to the canal system in 1992. Striped bass presumably entered Lake Pleasant as eggs or larvae through the Waddell Dam forebay. Preliminary results of an evaluation of the Lake Pleasant fishery indicated striped bass abundance was increasing; however, it was unknown if the canal continued to act as the sole source of recruitment or whether striped bass were successfully reproducing within the reservoir (Bryan and Kohagen 2003).

Lake Pleasant anglers and fishery managers are concerned the striped bass population has become established, and will eventually out compete the favored largemouth bass and white bass *(Morone chrysops)* fisheries by effectively eliminating the primary prey source, threadfin shad *(Dorosoma petenense)*. Although studies in some reservoirs have confirmed these fears (Hart 1978; Allen and Roden 1978; Baker and Paulson 1983), others have shown these predators can co-exist if properly managed (Combs 1982). If reproduction is occurring within the lake, extirpation of striped bass from the system is unlikely, and lake managers will need to develop a plan that allows for the continued prosperity of the largemouth and white bass fisheries, while developing and promoting a valuable striped bass fishery.

To make the proper decisions for management of the reservoir, the current status of the striped bass population must be properly researched. We addressed the following objectives with a 3-year evaluation of the striped bass fishery in Lake Pleasant:

i) Determine energetic requirements of striped bass and other pelagic predators in Lake Pleasant to predict the impact on prey resources and to predict the potential for striped bass population growth in the future.

ii) Determine seasonal spawning movements, habitat preferences and reproductive success and recruitment of striped bass in Lake Pleasant.

Study Area

Lake Pleasant is a water storage reservoir located approximately 50 km northwest of Phoenix (Figure 1). The original dam was built in 1927 for the purpose of irrigation and water storage for Maricopa Water District. Increasing demands prompted the United States Congress to authorize the Bureau of Reclamation (USBR) to construct the Central Arizona Project (CAP) in 1968 for the purpose of transporting water from the Colorado River to Central Arizona to meet these increasing water demands. Lake Pleasant was the logical location for water storage due to its proximity to the Phoenix metropolitan area, the greatest concentration for water demand in the state. Since the storage capacity of Lake Pleasant was not enough to meet CAP needs, USBR proposed the construction of the New Waddell Dam, which commenced in 1985 and was completed in 1992. After the old dam was breached, surface area of Lake Pleasant nearly tripled from 3,760 acres to 9,970 acres, and storage capacity increased from 157, 000 to more than 1.1 million acre-feet.

Water is pumped into and out of the reservoir

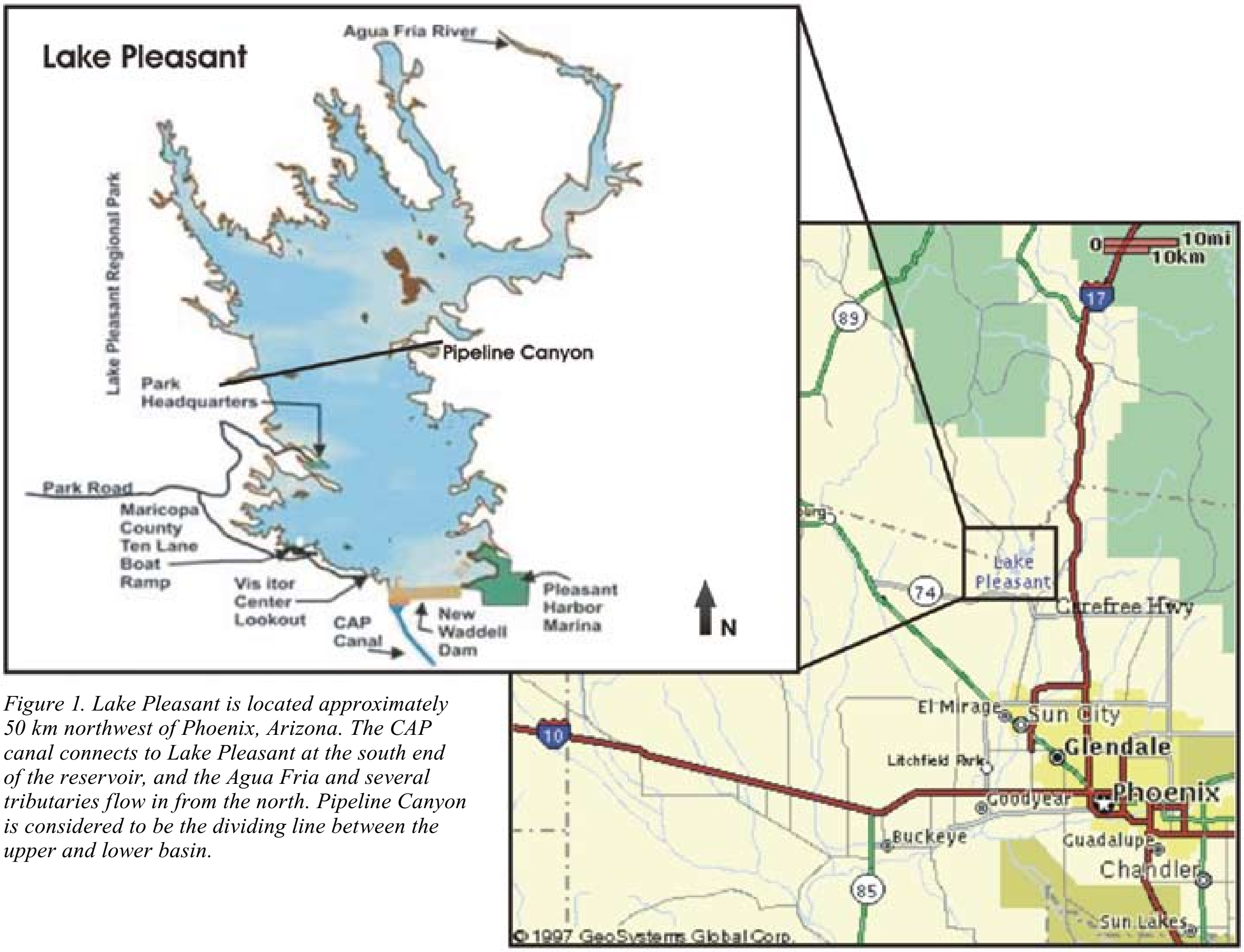

Figure 1. Lake Pleasant is located approximately 50 km northwest of Phoenix, Arizona. The CAP canal connects to Lake Pleasant at the south end of the reservoir, and the Agua Fria and several tributaries flow in from the north. Pipeline Canyon is considered to be the dividing line between the upper and lower basin.

through the same intake structure located at the dam. Water is typically pumped from the canal into the reservoir from November to April. The water elevation is maintained (at least 90% of full pool) until water consumption exceeds what is available through the canal system alone, and then water is pumped out of the reservoir to meet downstream needs (D. Crosby, Personal communication).

High water demand results in a substantial change (up to 40 m.) in reservoir water elevation between summer and fall/spring months. The Agua Fria River and several small tributaries supply seasonal inputs to the upper portion of the reservoir. Because the upper basin is influenced by the Agua Fria River and its various tributaries, it tends to be more productive than the lower basin (Walker 1998). The lower basin is deep and makes up the majority of the reservoir. Various fish surveys since the construction of the new Waddell Dam have identified 21 species (Table 1). A little less than half of the species are sport fish with largemouth and white bass identified as the most sought after species by anglers (Bryan 2005).

METHODS

Telemetry

Transplant Methods

Fifteen CTT 83-3-I (62 mm x 16mm, 22g) (Sonotronics, Inc. Tucson, AZ) temperature sensitive sonic transmitters with a 36-month life, were implanted into 15 striped bass between January 2005 and January 2006. Initial attempts to

Species	Scientific Name
Yellow Bullhead	Ameiurus natalis
Goldfish	Carassius auratus
Sonora Sucker	Catostomus insignis
Common Carp	Cyprinus carpio
Red Shiner	Cyprinus lutrensis
Threadfin Shad	Dorosoma petenense
Mosquitofish	Gambusia affinis
Channel Catfish	Ictalurus punctatus
Green Sunfish	Lepomis cyanellus
Bluegill	Lepomis macrochirus
Redear Sunfish	Lepomis microlophus
Sunfish Hybrid	Lepomis sp.
Inland Silverside	Menidia beryllina
Largemouth Bass	Micropterus salmoides
White Bass	Morone chrysops
Striped Bass	Morone saxatilis
Golden Shiner	Notemigonus crysoleucas
White Crappie	Pomoxis annularis
Black Crappie	Pomoxis nigromaculatus
Flathead Catfish	Pylodictis olivaris
Tilapia	Tilapia sp.

Table 1. List of species that have been identified at Lake Pleasant from 1987-2006. In 2006, a new species to Arizona, inland silverside, was discovered.

implant transmitters took place during early spring 2005. Striped bass were collected by angling and gill netting in January, February and April of 2005, and a total of 8 fish were tagged. Due to Food and Drug Administration requirements regarding the use of certain types of anesthesia on edible fish, an alternative anesthesia was used and consisted of a water bath of sodium bicarbonate at a concentration of 442 - 642 mg/l as described by Brooke et al. (1978). If needed, small amounts of hydrochloric acid were added to the bath to maintain a pH between 6.5 and 7.0.

Tags were surgically implanted in the body cavity of striped bass greater than 770 g to keep tag weights less than 5 percent of the fishes weight using methods described by Hart and Summerfelt (1975). Initial attempts in 2005 resulted in high fish mortality (7 of 8 fish died) post-release due to capture and handling stress. Methods were revised and a second attempt was conducted in January of 2006, whereby all fish were collected via angling. The use of the sodium bicarbonate as an anesthetic was discontinued and fish were released immediately following surgery. A portable surgical station was set up on a pontoon boat and Arizona Game and Fish enlisted the help of public anglers to catch striped bass and quickly transport each fish to the surgical station. The fish were measured (TL mm) and weighed (g) prior to tag implantation and release. In total, 10 striped bass were successfully tagged (one from the first attempt and nine from the second attempt).

Fish Tracking

Surveys were conducted bi-weekly from January-May (spring) and September-December (fall) and monthly from June-August (summer) using an ultrasonic receiver (Sonotronics model USR-96). When a fish location was identified, the date, time, tag number, tag temperature, and global positioning system (GPS) location of each fish was recorded. The varying pulse intervals emitted by the transmitter identified tag temperature; as tag temperature increased, pulse intervals also increased (Sonotronics, Inc. 2006). Mean monthly temperature was calculated for all fish during each survey for use in bioenergetics modeling.

Larval Fish Surveys

Larval surveys were conducted from May 19, 2004 to June 2, 2004 and March 16, 2005 to May 25, 2005 to determine presence/absence of striped bass eggs and larvae. The presence of striped bass eggs and larvae would indicate that striped bass are naturally reproducing within the reservoir.

Larval Light Traps

Larval light traps, similar to the Quatrefoil trap designed by Floyd et al. (1984), were deployed bi-weekly in 2004 (May through June) and 2005 (March through April). The north end of the reservoir including the Agua Fria River was deemed the most suitable habitat for striped bass reproduction. As such, most of the light traps were set in that area. Traps were constructed with 4 clear PVC pipes with a slit cut longitudinally that are glued to a Styrofoam frame (top) and Plexiglas to allow a 4 mm space between the pipes to permit larval fish to swim into the inner chamber. A string of three LED battery powered lights was lowered into the center of the pipes. The light trap was lowered into the water in littoral areas typically less than 2 meters in depth, and anchored to the lake bottom with a weight to prevent it from being washed away. The Styrofoam enabled the traps to float flush with the surface of the water while the PVC tubing was submerged below the water surface. The traps were deployed prior to dusk in clusters of 2-3 and allowed to fish 4 to 7 hours until traps were pulled from the water trapping any fish and zooplankton in a mesh container attached to the bottom of the frame. Samples were preserved in 5% formalin, and, upon return to the laboratory, larval fish were counted, identified to species (if possible), and measured (mm).

Larval Tow Surveys

Bi-weekly larval tows began in mid-March 2005, when surface temperatures reached 16°C, and continued until late May when surface temperatures reached 27°C. Two 1-m diameter conical (3:1 length to diameter ratio) 500µm nets were supported via a modified side-mounted portable push-net apparatus (Tarplee et al. 1979) on a 5.85 m aluminum boat. A General Oceanics Inc. (Model 2030R, Miami, FL) digital-mechanical flow meter installed at the center of the mouth of each net recorded the volume (m^3) of water sampled. Volume was determined using the following calculations:

(1)

$$\text{Volume } (m^3) = [3.14 * (\text{diameter of net})2 * \text{Distance}]/4$$

(2)

$$\text{Distance} = [(\text{stop odometer} - \text{start odometer}) * 26873]/999999$$

Six random transects were sampled each night parallel to the shoreline. Tows lasted between 2 and 6 minutes based on the amount of plankton in the water. Nets were set at a depth of ≈ 0.3 m below water surface. At each run, surface water temperature, start and end GPS coordinates, and sample time were recorded. At the end of each run, samples were preserved in 5% formalin. All 3 basins were sampled over the course of 3 months with each effort occurring between the hours of 15:00 and 20:00 mountain standard time. All samples were sorted in the lab, were counted and identified to family or species if possible. The remaining sample was subsampled in order to estimate zooplankton per cubic meter. Zooplankton density was calculated as follows:

(3)

$$\text{Density } (\#/m^3) = \text{Total Zooplankton/Tow volume } (m^3)$$

Larval fish collected in larval traps and tows were identified according to Preliminary Guide to the Identification of Larval Fishes in the Tennessee River, 1976, and Identification of Larval Fishes of the Great Lakes Basin with Emphasis on the Lake Michigan Drainage, 1982. Once identified, counted to species (if possible), and measured (TL, mm), fish were preserved in 10% ethanol. Moronidae larval fish could not be identified to species, so samples were sent to Colorado State University's Larval Fish Laboratory for taxonomic identification.

Fish Surveys

Gill Netting

Pelagic gill netting surveys were conducted in August (summer), November (fall), and February (spring) beginning August 2004 and ending November 2006. Sites were selected using a stratified random design whereby a 50 x 50 m grid was superimposed on Lake Pleasant (Figure 2) and quadrants were randomly chosen as long as they were determined to be pelagic (greater than 6 meters deep and at least 10 meters from shore). If a quadrant was located in unsuitable waters (i.e., not pelagic), the next randomly chosen site was selected, until a suitable site was found. Nets were 55.38 x 3.08 m experimental monofilament gill nets with 6 panels of varying bar mesh size (12.7, 25.4, 38.1, 50.8, 63.5, and 76.2 mm). Sixteen sites were randomly sampled during the first 3 surveys.

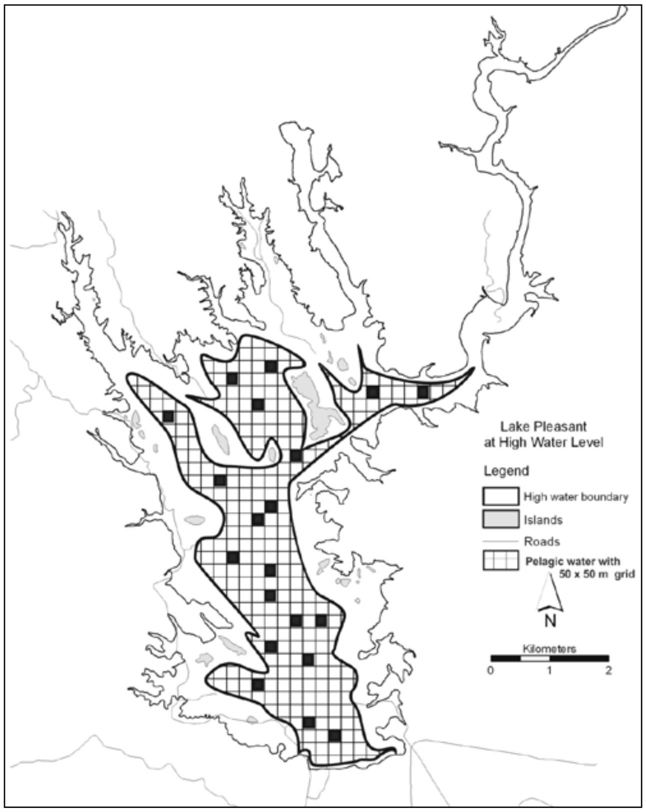

Figure 2. Sample sites (■) were randomly selected within pelagic waters (≥ 6 m deep and ≥ 10 m from shore). Sites were 50 m x 50 m. This illustration is not drawn to scale, and does not accurately represent Lake Pleasant pelagic water or sample quadrant sizes.

The number of random sites was increased to 24 to increase catch for diet analysis. An equal number of surface and bottom nets were set during each survey with the exception of the first survey where nets were also set at the thermocline since literature suggests striped bass school immediately above the thermocline during summer (Matthews et al. 1985). Thermocline nets were eliminated from subsequent summers due to net entanglement upon itself. For each trip, a target sample size of 10 striped bass and white bass per each 50-mm length group was set to obtain an adequate number of diet and aging samples. If this target was not met, additional gill nets were set at locations where the target species were known to be present (i.e., selected sites). Data from the selected net sets were not included in relative abundance estimates. All nets were set in the early evening prior to sunset and retrieved the following morning unless extreme weather conditions or other unforeseen situations arose causing a delay in gill net retrieval.

Due to the littoral nature of largemouth bass, very few were captured in the pelagic gill nets. Hence, largemouth bass diet and age samples were collected during electrofishing surveys conducted the week following each gill netting survey with a target of 10 largemouth bass per each 50-mm length group.

All captured fish were identified to species, measured (TL mm), weighed (g.), and, if needed, scales, sagittal otoliths, and stomach samples were removed. Fish not needed for age and diet samples were measured, weighed, and released. Several randomly selected nets that were run over by boaters or badly tangled in debris during spring flooding were not used for fish abundance and population estimates. Extreme flooding in spring 2005 resulted in extreme amounts of debris becoming entangled in the nets. Consequently data from only 11-gill net sets was suitable for abundance estimates. Data from thermocline sets during the first survey were also not included in abundance estimates.

Fish Community Composition and Size Structure

Mean length and weight were calculated for each species for each survey. Species composition and catch-per-unit-effort (CPUE) were calculated for each survey.

CPUE and percent composition are calculated for each fish species as:

(4)

$$CPUE = \frac{1}{n} * \sum_{i=1}^{n} \left(\frac{C_i}{H_i} \right) !$$

where C_i = catch in the ith net, H_i = length the ith net was fished (hours), and n = number of nets.

(5)

$$\%comp = \frac{1}{n} * \sum_{i=1}^{n} \left(\frac{CPUE_{si}}{CPUE_{ti}} \right)$$

where $CPUE_{si}$ = CPUE of species in ith net, $CPUE_{ti}$ = total CPUE in ith net, and n = number of nets.

In addition, size structures of individual species were evaluated using Proportional Stock Densities (PSD; Anderson 1978) and Relative Stock Density (RSD; Gablehouse 1984).

PSD and RSD are calculated as follows:

(6)

$$PSD = \frac{\text{No. of fish} \geq \text{quality length}}{\text{No. of fish} \geq \text{stock length}} \times 100$$

and,

(7)

$$RSD = \frac{\text{No. of fish within size category}}{\text{No. of fish} \geq \text{stock length}} \times 100$$

Relative weight (W_r, Wege and Anderson 1978) was calculated for all species during each survey to evaluate fish condition.

(8)

$$W_r = \frac{\text{Weight of fish}}{W_s} \times 100$$

Where W_s is the length-specific standard weight for individual species (Anderson and Neuman 1996, and Bister et al. 2000). ANOVA and Tukey's multiple comparison tests were used to compare W_r in striped, white, and largemouth bass among surveys, seasons, and years.

Growth

Length-frequency histograms for white and striped bass were created for each of the 8 gill netting surveys and used to estimate growth by following changes in modal length for an age group through time. Mean lengths for age-0, age-1, and age-2+ were calculated based on modal distribution; however, all age-2+ fish were grouped together because of the difficulty of separating older age groups. A weight-length power regression was used to calculate weight from length frequencies for each age group.

(9)

$$W = aLb$$

W = weight (g), L = length (mm), a = 1.42 x 10^{-5} and b = 2.97 for white bass, and a = 1.23 x 10^{-5} and b = 2.99 for striped bass. Growth was then measured in weight difference of each age group from one survey to the next.

Due to small sample size of many of the cohorts, growth for bioenergetic modeling was used from November 2004 to November 2005 and from November 2005 to November 2006. These 2 time spans were significant in that 2004 to 2005 found very high production in the reservoir whereas 2005 to 2006 had very low production.

Aging

Sagittal otoliths and scales (just below the anterior portion of the dorsal fin) were removed from striped, white, and largemouth bass in the field and placed in scale envelopes. Scales were rinsed and mounted between 2 75mm x 25mm slides. Otoliths were placed in glycerol for up to 10 days, washed with water, dried and placed in vials. Small otoliths (usually YOY) were read in whole view, but most otoliths were sectioned on a transverse plane, mounted in Thermoplastic Quartz Cement (Hugh Courtright & Co. Ltd. Monee, IL) on a microscope slide, and read with an Olympus Bx40 microscope (Center Valley, PA) at magnification 4x/0.10. Two independent readers viewed the otoliths and estimated fish age; age discrepancies were re-examined and a consensus was reached. A third reader was used if consensus was not attained. Otoliths were digitized using a Leica S8APO microscope (Bannockburn, IL) mounted with an Olympus Q-Color-3 digital camera (Phoenix, AZ) with QcapturePro software (QImaging, Inc. Surry, BC Canada). Sectioned otoliths were viewed at a 1.6 magnification and whole otoliths were viewed at 1.0 magnification. Measurements for back calculations were made in pixels (converted to millimeters) from the nucleus of the otolith to each annulus and to the edge (Figure 3). Fish length-at-age was back calculated and ages were assigned according to DeVries and Frie (1996).

White Bass *Largemouth Bass* *Striped Bass*

Figure 3. Cross sections of sagittal otoliths from white bass (age 6), largemouth bass (age 4), and striped bass (age 6).

Diet

Striped, white, and largemouth bass stomachs were collected during gill netting and electrofishing surveys to determine predator diet and consumption. Upon removal from the fish, each stomach was punctured to evacuate digestive enzymes, placed in a labeled Whirl-Pak, stored in an ice-filled cooler, and frozen upon return to the lab until subsequent analysis.

In the laboratory, several guides were used to identify stomach contents to species if possible (Auer 1982, Hogue et al. 1976, Sublette et al. 1990). Prey items were counted, weighed (g) by species, and volumetric displacement (ml) was determined for each prey species. Vertebrae count, otoliths, or other distinguishing features were used for positive identification of partially digested fish species. Spine length (atlas to last vertebrae before caudal fin) of all prey fish was measured (mm). If spines were not whole and no other distinguishing features could be identified, fish were deemed as unknown. All contents were stored in 70% isopropyl alcohol following analysis.

Frequency of occurrence by species was used to quantitatively measure prey presence and is calculated as follows:

(10)

$$Frequency\ of\ occurence = \frac{number\ of\ stomach\ with\ prey\ item}{total\ number\ of\ stomachs}$$

Percent composition by number is a measure of the number prey items in the stomach of each predator at time of collection. Percent composition by number and percent composition by weight were calculated for each prey species:

(11)

$$C = 100 * \left(\sum_{i=1}^{n} \frac{p_i}{t_i} \right) \Big/ n$$

where C is the percent composition by number for each prey species, n is the number of fish stomachs with at least one prey item, p_i is the count of an individual species of prey in the ith stomach and t_i is the total number of prey in the ith stomach

and

(12)

$$W = 100 * \left(\sum_{i=1}^{n} \frac{w_i}{tw_i} \right) \Big/ n$$

where W is percent composition by weight, w_i is the total weight of a particular prey species in the ith stomach and tw_i is the total weight of all species in the ith stomach.

Prey items were grouped into 4 categories; threadfin shad, invertebrates, crayfish, and other fish. Threadfin shad, crayfish, and dipterans were the only individual prey items that made up more than 5% frequency of occurrence. As such, threadfin shad and crayfish were each grouped into their own category for bioenergetics analysis. Dipterans, however, were put into the invertebrate category because all other invertebrates were very infrequent. All fish species in the "other fish" category had less than 5% frequency of occurrence. Percent composition by weight was then calculated for each of the 4 categories. Unidentifiable fish species were partitioned into either the categories of threadfin shad or other fish based on the proportion of known threadfin shad to other fish for each trip.

Diet overlap was calculated between striped and white bass (SB/WB), striped and largemouth bass (SB/LB), and white and largemouth bass (WB/LB) according to Schoener (1970) where:

(13)

$$a = 1 - 0.5\left(\sum_{i=1}^{n}\left|p_{xi} - p_{yi}\right|\right)$$

n = number of food categories;
P_{xi} = proportion of food i in diet of species x;
P_{yi} = proportion of food i in diet of species y;

Diet overlap indices are on a scale from 0 (no overlap) to 1 (complete overlap).

Prey Energy Densities

A literature search was conducted to find energy densities of species in each of the 4 prey categories. Mean energy densities were calculated if multiple values were reported or if prey categories were composed of more than 1 species (invertebrates and other fish).

Water Quality

Water Quality Profiles

Monthly water quality parameters were collected at 4 sites in Lake Pleasant: Waddell Dam (WD), Max's Point (MP), Aqua Fria Mouth (AF), and Aqua Fria River (RV) (Figure 4). These sites were in the inundated Agua Fria river channel and were chosen because striped bass are often associated with areas of inflow (Lewis 1985). A YSI 6920 Sonde and YSI 610 Display/Logger (YSI Yellow Springs, OH) was used to measure and record depth, temperature (ºC), specific conductance ($\mu S \cdot cm^{-1}$), dissolved oxygen ($mg \cdot l^{-1}$), and pH at 1-meter intervals at each site. Thermocline depth was plotted monthly from April to October for both 2005 and 2006.

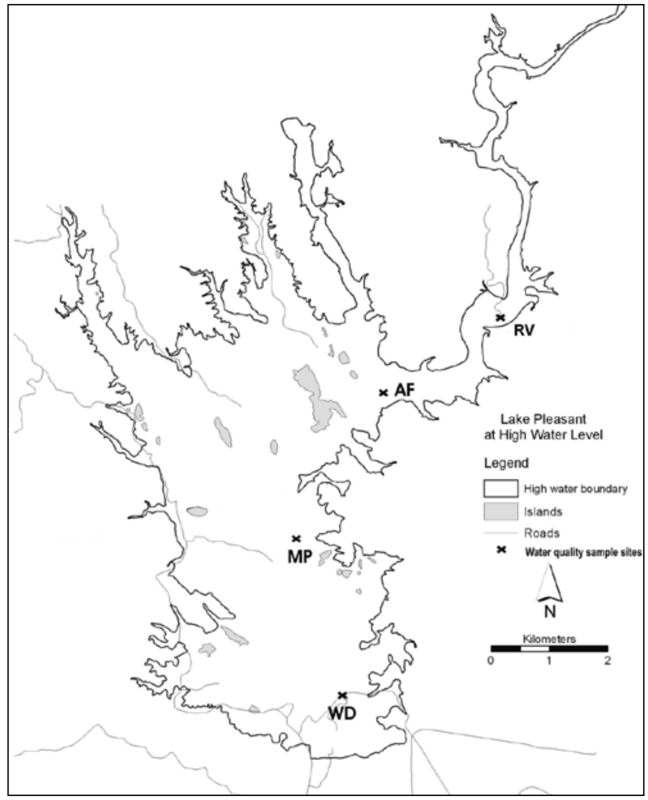

Figure 4. Four water quality sites: Waddell Dam (WD), Max's Point (MP), Agua Fria mouth (AF), and Agua Fria River (RV).

Additional water quality measurements were taken following fish gill netting and electrofishing surveys. These measurements included light penetration via secchi depth (m), turbidity (NTU), and chlorophyll–a ($\mu g \cdot l^{-1}$). Turbidity was measured using a HACH 2100P Turbidimeter (HACH Loveland, CO) and chlorophyll-a samples were collected within 1 m of the surface and filtered in the field through a Whatman GF/F glass fiber filter (0.7 µm Whatman Florham Park, NJ). Filters were wrapped in foil, placed on ice, and transported to the lab where chlorophyll-*a* concentrations were measured with a Perkin Elmer UV/VIS spectrometer Lambda 2 (PerkenElmer Waltham, MA) following extraction into acetone (detection level of 0.005 mg/l) and corrected for phaeo-pigments.

ANOVA was used to compare mean differences among years, seasons, and surveys for both turbidity and chlorophyll-a samples. Lake elevation and daily precipitation data were gathered from monthly CAP reports. Agua Fria River discharge

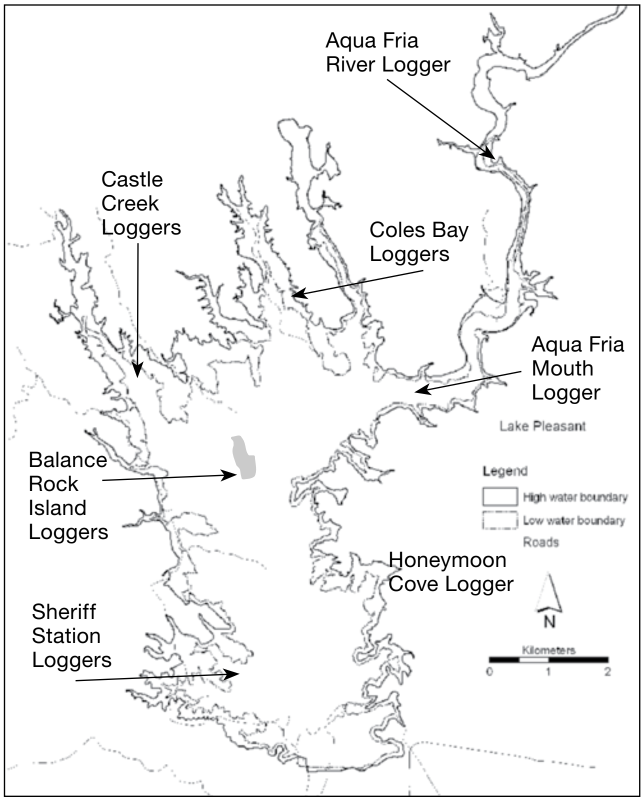

Figure 5. From March 2005 to September 2005, 11 temperature loggers were set at 7 locations throughout the reservoir.

data was gathered from the USGS gauging station (station number 09512800) near Rock Springs, Arizona.

Temperature

Temperature sensitive transmitters were implanted in to striped bass to accurately determine preferred striped bass water temperature (see telemetry methods). Tracking began in February 2005 and continued through January 2007. Fish were located bi-weekly from January-May and September-December and monthly from June-August. Mean monthly water temperature where tagged fish were found was calculated. Due to the lack of tagging success during the first year of this study, temperatures from 2006 were also used for 2005 for the bioenergetics modeling.

Additional water temperature data were collected using temperature loggers deployed at 7 sites throughout the reservoir from March 29, 2005 to September 1, 2006 (Figure 5). One site had a bottom temperature logger, 2 sites had a surface temperature logger, and 4 sites had both a bottom and surface temperature logger. Surface loggers were suspended 2 meters from the surface of the water and bottom loggers were suspended 3 meters from the lake bottom. Two types of loggers were used: Optic StowAway Temperature loggers and Hobo Temperature loggers, both produced by Onset Computer Corporation (Bourne, MA). StowAway loggers recorded temperatures every hour and Hobo loggers recorded temperatures every 2.5 hours due to limited battery life. Initially, 8 StowAway and 4 Hobo loggers were deployed. Several of the loggers died or were damaged by wave action and were refurbished and redeployed and one of the Hobo loggers flooded before the initial download and was not refurbished resulting in no surface data for that site.

Hydroacoustics

Field Surveys

Hydroacoustic surveys were conducted during February 2005 and February 2006 using a 200kHz split beam DTX echosounding system from BioSonics Inc. (Seattle, WA). Transects were run in a zigzag design from a randomly selected start point for time efficiency and ease of running the surveys. Transects were identified with the intent of getting the highest coverage possible. A total of 15 transects in February 2005 and 33 transects in February 2006 were surveyed (Figures 6 and 7). Transects were run at a boat speed of approximately 4 to 6 mph and a ping rate of 5 pings per second. The face of the vertical transducer was submerged approximately 15 centimeters below the surface of the water. The horizontal transducer was mounted above the vertical transducer and tilted such that the top edge of the sound wave was parallel to the surface of the water. Day and night time surveys were conducted to capture diurnal changes in fish behavior. The same transects were run during day and night. Night surveys began after full dark. Hydroacoustics data were analyzed in Echoview 3.0 (Echoview Hobart TAS, Australia). Lake bottom was identified manually and fish target (filtered at threshold of –55dB) densities (#/m^3) were calculated at 100 ping intervals, surface to

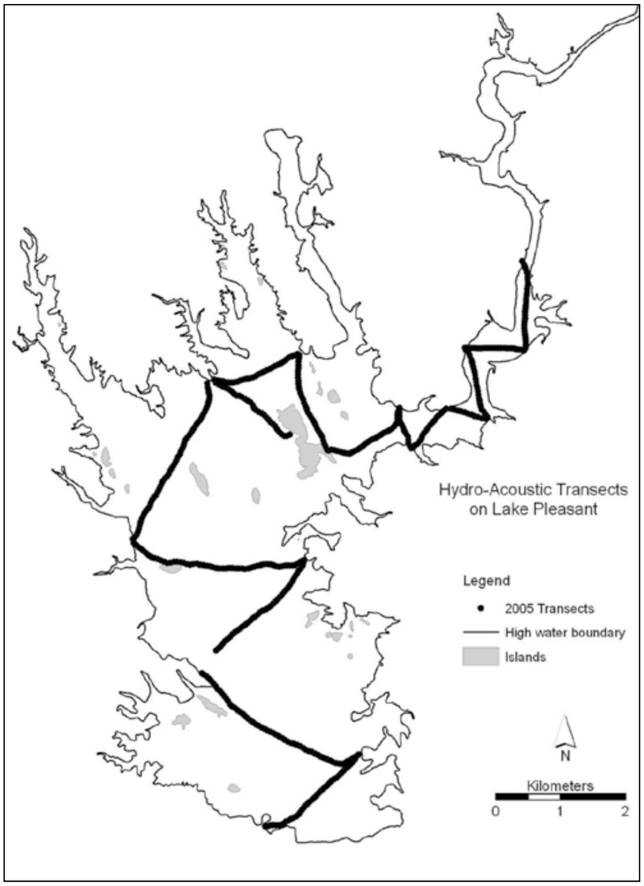

Figure 6. Hydroacoustic transects from February 2005. Conducted at night using a 200Hz split beam DTX echosounder.

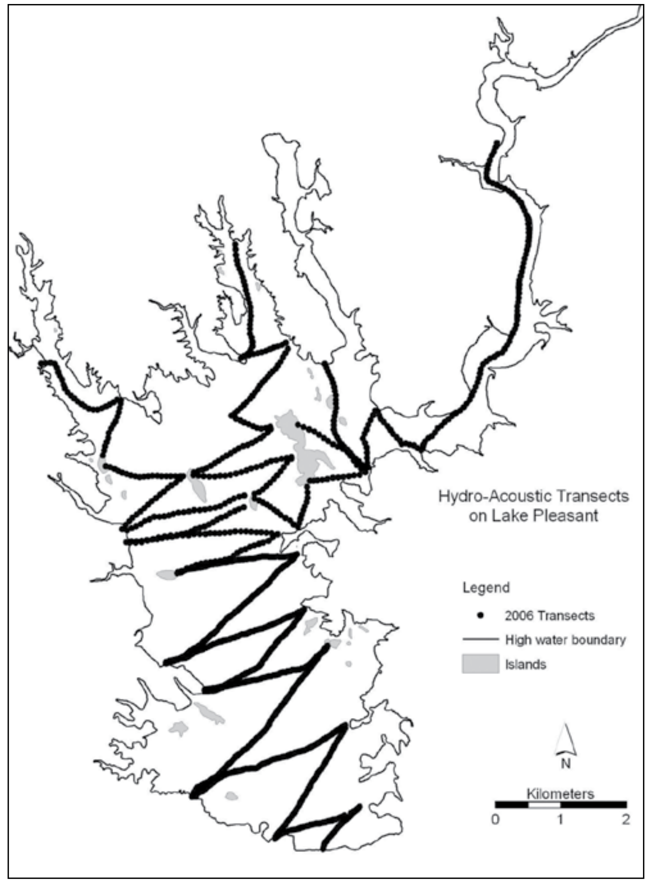

Figure 7. Hydroacoustic transects from February 2006. Conducted at night using a 200Hz split beam DTX echosounder.

bottom. Individual fish tracks were identified and mean target strength (dB) was calculated.

Data Analysis

Analysis regions were defined by the morphometry and productivity of the reservoir. The South Basin is deep and oligotrophic. The North Basin is shallow, but has higher nutrient concentrations. The Agua Fria is riverine habitat, and has higher productivity and a different temperature regime. Transects collected in each region were imported in to Echoview, cleaned, and analyzed by region.

The August 2006 survey was cancelled following completion of the 2005 August survey because stratification of the reservoir causing fish to be compressed into the transition zone at the thermocline. This resulted in a high density of fish such that individual fish targets could not be identified, and therefore fish tracks could not be detected.

The following equation was used to estimate fish number throughout the entire reservoir for both February 2005 and February 2006 surveys:

(14)

$$Fish\ Number = Lake\ Volume * Fish\ Density$$

Lake volume data was acquired from monthly CAP reports (B. Henning, Personal communication) at the time of each survey.

Love's equation (Love 1977) was used calculate the relationship between target strength and fish length:

(15)

$$TS = 19.1 * \log \log_{10}(L_m) + 0.9 * \log_{10}(\lambda) - 23.9$$

where TS (-dB) is target strength, L_m is fish length in meters, and λ (m) is acoustic wavelength. Fish less than 125 mm TL and 150 mm TL were determined not to be pelagic predators based on the maximum sized threadfin shad collected during gill netting surveys February 2005 and February 2006 respectively. Percent composition of white and striped bass from gill netting surveys were used to estimate the total number of those species in February 2005 and February 2006.

Bioenergetics

To determine the energetic demands of pelagic predatory fish at Lake Pleasant, the Wisconsin bioenergetics model (Hanson et al. 1997) was used to estimate striped and white bass daily consumption from November 2004 to November 2006. The Bioenergetics model is a mass balance equation that assumes:

$$\text{Energy consumed} = \text{Respiration} + \text{Waste} + \text{Growth} \quad (16)$$

where energy consumed is the maximum daily consumption rate (g of prey per g body mass per day), respiration is the amount of energy used by the fish for metabolism, which is dependent on fish size, water temperature and activity, waste is computed as a function of consumption, and growth is in grams per unit time.

The Wisconsin bioenergetics model estimates the energy consumption of an average fish using 4 basic input parameters: water temperature (°C), diet proportion, prey energy densities (J/g), and fish growth (g). Laboratory data (thermal preference, size dependence, assimilation efficiency, etc) from age-1, age-2, and adult striped bass (Hartman and Brandt 1995) were used for physiological parameters required by the model. Since these physiological parameters are not available for white bass, striped bass parameters were used for white bass because the 2 species are closely related.

Daily growth, total daily energy consumed, and average daily diet consumption for each of the 4 prey categories was modeled for white and striped bass. Simulations were run for YOY fish from November 2004 to November 2005 and YOY fish from November 2005 to November 2006.

RESULTS

Telemetry

Tracking

A total of 10 striped bass were implanted with transmitters (Table 2). Tagged fish were originally captured in the Agua Fria River approximately 5 miles upstream from the mouth. One month after tags were implanted, 2 fish moved out of the Agua Fria River into the main reservoir and, by July, all tagged fish moved out of the Agua Fria River. While in the Agua Fria River, striped bass were observed moving throughout the entire river, however the area across from Tule Cove (~7.25 km upstream from mouth) is likely a preferable

Fish Number	Date Tagged	Length (mm)	Weight (g)	Months Tracked
69	1/25/06	406	780	10
71	1/12/06	565	1800	13
72	1/25/06	445	1000	13
74	1/12/06	460	970	13
76	1/24/06	453	1040	5
77	1/25/06	680	3080	6
78	1/25/06	615	2100	13
79	2/26/05	477	1140	25
81	1/25/06	491	1280	1
83	1/25/06	580	1680	7

Table 2. Fish ID, date tagged, fish length, fish weight, and months tracked for 10 striped bass tracking with sonic telemetry.

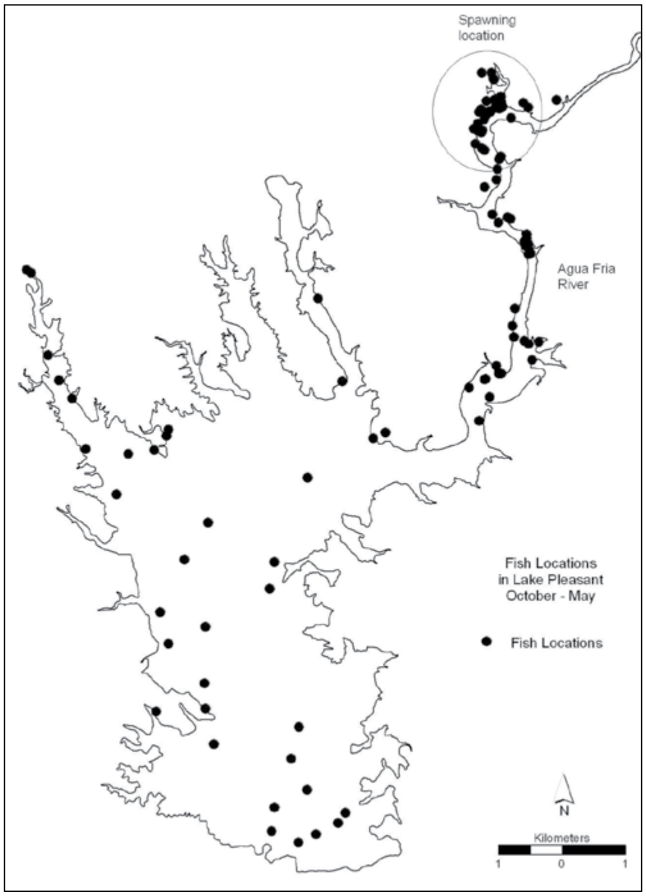

Figure 8. Locations of tagged striped bass during spring (January-May) and fall (October-December) 2006. The high frequency of striped bass at the upper end of the Agua Fria River suggests a spawning location.

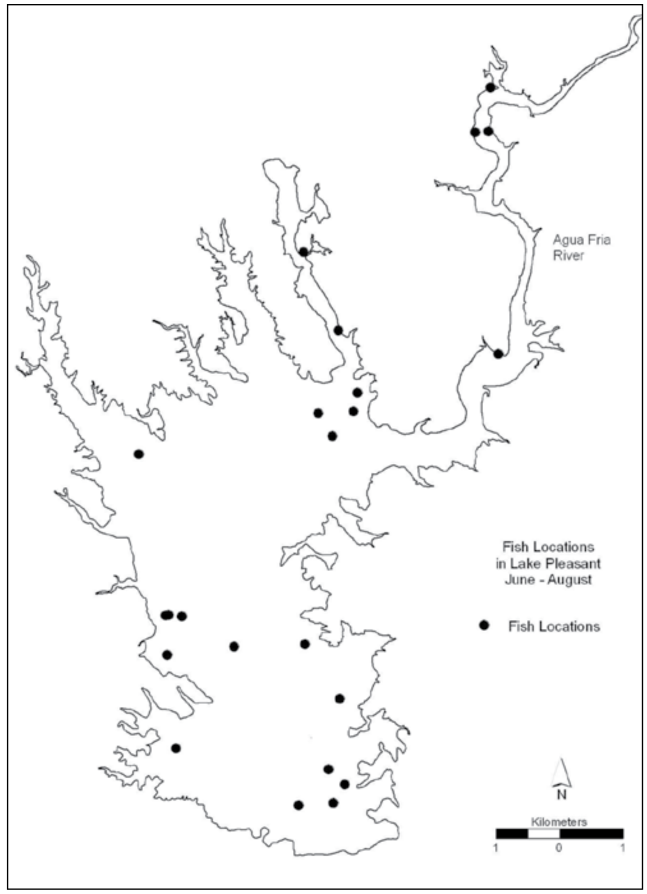

Figure 9. Locations of tagged striped bass during summer (June-September 2006). Only 4 times was a fish found in the Agua Fria River during this period. Fish were "squeezed" out of the Agua Fria River during the summer months due to high water temperatures and low dissolved oxygen levels.

spawning habitat of striped bass as indicated by their frequency of occurrence.

Six months following tagging, 3 fish were lost: 1 to mortality, 1 to angling, and 1 for unknown reasons. By January 2007, an additional 2 striped bass were lost for unknown reasons.

Figures 8 and 9 are maps of locations for all 10 tagged striped bass. Figure 8 shows the various locations of the striped bass during fall and spring months (October through May) when most tagged fish were observed in the Agua Fria River. Figure 9 shows locations of the tagged striped bass during summer months (June through August) when tagged fish moved out of the Agua Fria River.

Temperature Transmitters

Despite overall temperatures rising throughout the reservoir during summer months, there was a leveling off of water temperature occupied by striped bass in June when striped bass moved from the Agua Fria River to the main reservoir where temperatures were cooler and dissolved oxygen levels were higher. As surface lake temperatures began to drop in August, mean temperatures occupied by striped bass increased slightly in September as the bass began moving back into the Agua Fria River where water temperatures were warmer (Figure 10).

Larval Fish Surveys

A total of 36 sites were sampled from March 16, 2005 to May 25, 2005: 11 sites sampled in basin 1 (upper reservoir), 5 sites in basin 2 (lower

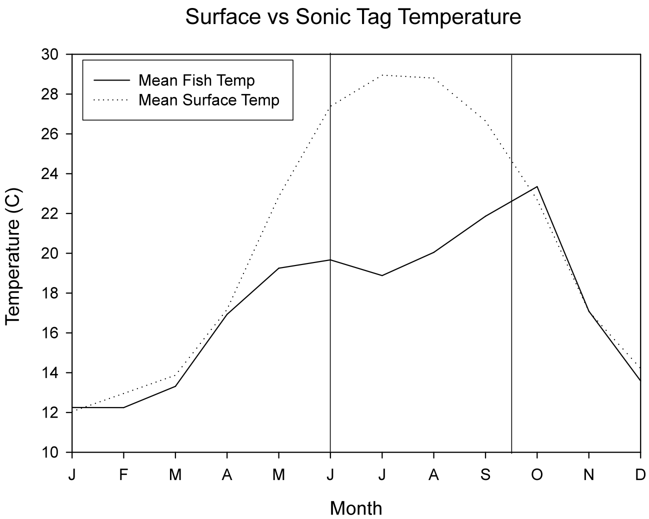

Figure 10. Mean surface temperature of 4 water quality sites versus mean temperature of tagged fish by month. Striped bass movement out of the Agua Fria River occurred in June (first vertical line) and back into the River occurred in mid-September (second vertical line).

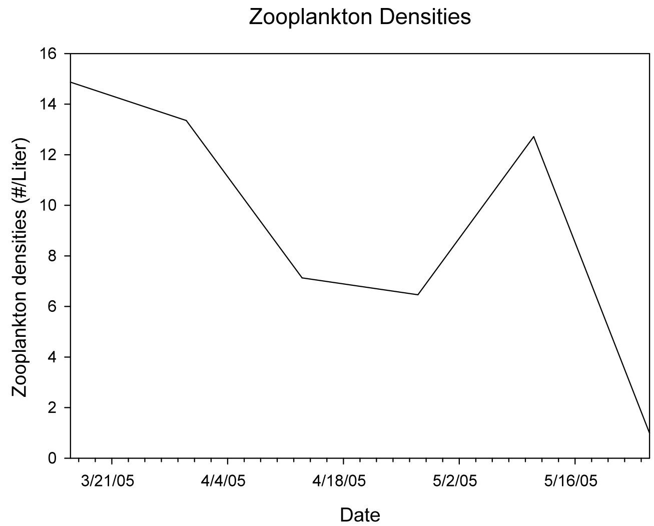

Figure 11. Zooplankton densities from March 16, 2005 to May 25, 2005.

reservoir), and 20 sites in basin 3 (Agua Fria River). The total volume of water sampled was 5,551 m^3. Six different larval fish were identified: common carp *(Cyprinus carpio)*, threadfin shad, largemouth bass, *Morone spp.* (white bass or striped bass), *Lepomis spp.*(bluegill, green sunfish, or redear sunfish) , and *Pomoxis spp.* (black crappie or white crappie) Threadfin shad were most abundant (0.62 fish/m^3) followed by *Lepomis spp.* (0.28 fish/m^3) and *Morone spp.* (0.06 fish/m^3). Differentiating between larval *Morone* species is extremely difficult and as such 13 *Morone* larval samples from varying sizes and locations within the reservoir were sent to Coloarado State University Larval Fish Laboratory for analysis. Two were positively identified as *Morone chropysis* and the other 11 were indistinguishable.

Zooplankton densities peaked at just under 15,000/m^3 in March when surveys first began. During the last survey in May 2005 zooplankton numbers dropped considerably to about 1,000/m^3 (Figure 11).

Fish Population Dynamics

Species Composition

Nine fish species were caught in pelagic nets during the course of the study. Striped bass (n = 230) and white bass (n = 250) numbers were substantially greater in the November 2005 survey than any other survey (Table 3). Threadfin shad generally comprised the greatest composition of the catch. Threadfin shad composition was lowest in the summer (24%) and highest in fall (65%). White bass composition was highest in the summer (43%) and relatively low the rest of the year, in most cases less than 15%. Striped bass composition remained consistent at approximately 15% of the catch and did not vary seasonally (Figure 12).

CPUE

Total CPUE of species collected in gill nets was greatest during November 2006 survey. CPUE for white and striped bass was greatest during fall surveys, and in fall 2005 was nearly double that of any other survey with 0.641 fish/hour (SE = 0.473) and 0.562 fish per hour (SE = 0.169), respectively (Figure 13). White bass CPUE was greater than striped bass in all surveys with the exception of February 2005 and November 2006. The November 2006 survey was the only survey where striped bass CPUE (0.321 fish/hour) was significantly higher (t-test; $p < 0.05$) than white bass (0.043 fish/hour). Appendix 1a shows CPUE of the most caught species for each trip.

		Aug 2004		Nov 2004		Feb 2005		Aug 2005	
		N	Mean (SE)	N	Mean (SE)	N	Mean (SE)	N	Mean (SE)
Common Carp	Length	7	608 (24)	33	539 (17)	69	540 (6)	3	604 (10)
	Weight	7	3064 (373)	33	2245 (203)	69	2071 (67)	3	3070 (257)
Threadfin Shad	Length	12	102 (2)	94	104 (1)	57	103 (1)	65	106 (1)
	Weight	12	10 (0)	94	14 (1)	57	10 (0)	65	10 (0)
Channel Catfish	Length	5	371 (83)	29	388 (18)	8	356 (40)	18	322 (23)
	Weight	5	738 (313)	29	652 (97)	8	523 (191)	18	387 (122)
Bluegill	Length	-	----	1	152	-	----	-	----
	Weight	-	----	1	60	-	----	-	----
Largemouth Bass	Length	1	366	49	333 (10)	41	314 (10)	43	295 (13)
	Weight	1	720	49	556 (44)	41	426 (44)	43	454 (53)
White Bass	Length	41	384 (6)	179	315 (5)	18	356 (15)	174	217 (5)
	Weight	41	726 (37)	179	434 (17)	18	550 (52)	174	186 (16)
Striped Bass	Length	13	476 (49)	53	492 (20)	41	470 (18)	11	292 (30)
	Weight	13	1345 (328)	53	1334 (126)	41	1169 (100)	11	333(68)
Black Crappie	Length	-	----	-	----	4	171 (45)	38	205 (9)
	Weight	-	----	-	----	4	115 (61)	38	162 (18)
Flathead Catfish	Length	-	----	6	599 (36)	-	----	-	----
	Weight	-	----	6	2812 (550)	-	----	-	----

		Nov 2005		Feb 2006		Aug 2006		Nov 2006	
		N	Mean (SE)	N	Mean (SE)	N	Mean (SE)	N	Mean (SE)
Common Carp	Length	27	460 (25)	11	463 (47)	22	560 (14)	19	527 (19)
	Weight	27	1549 (235)	11	1941 (468)	22	2382 (202)	19	2130 (205)
Threadfin Shad	Length	70	101 (1)	98	102 (1)	76	99 (1)	53	109 (3)
	Weight	70	10 (0)	98	10 (0)	76	10 (0)	53	70 (6)
Channel Catfish	Length	20	484 (27)	2	441 (104)	33	445 (19)	14	446 (24)
	Weight	20	1420 (256)	2	1000 (700)	33	976 (161)	14	881 (182)
Bluegill	Length	-	----	-	----	-	----	-	----
	Weight	-	----	-	----	-	----	-	----
Largemouth Bass	Length	83	284 (10)	56	360 (15)	60	269 (12)	104	279 (7)
	Weight	83	401 (41)	56	861 (114)	60	352 (54)	104	330 (39)
White Bass	Length	250	285 (5)	77	324 (8)	101	334 (5)	37	332 (7)
	Weight	250	370 (20)	77	515 (39)	101	442 (18)	37	423 (30)
Striped Bass	Length	230	323 (7)	69	354 (15)	63	352 (14)	192	366 (3)
	Weight	230	470 (34)	69	607 (72)	63	511 (83)	192	454 (15)
Black Crappie	Length	14	266 (14)	2	267 (39)	-	----	2	226 (59)
	Weight	14	320 (47)	2	315 (145)	-	----	2	220 (170)
Flathead Catfish	Length	3	632 (77)	-	----	-	----	2	562 (29)
	Weight	3	3233 (1230)	-	----	-	----	2	1860 (230)

Table 3. Mean total length (mm), mean weight (g) and number of each species caught for each of the 8 gill netting and 7 electrofishing surveys from 2004 to 2006.

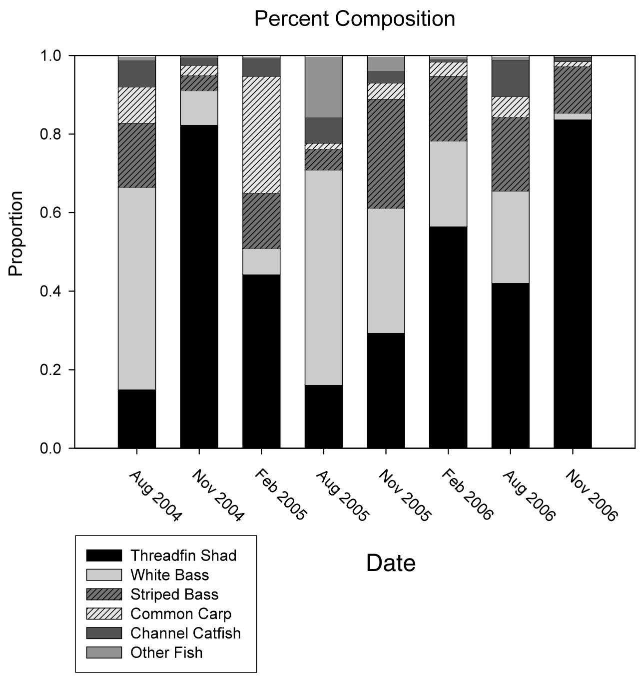

Figure 12. Percent composition of fish caught during gill netting surveys from August 2004 to November 2006. Other fish include crappie, sunfish, largemouth bass, and flathead catfish.

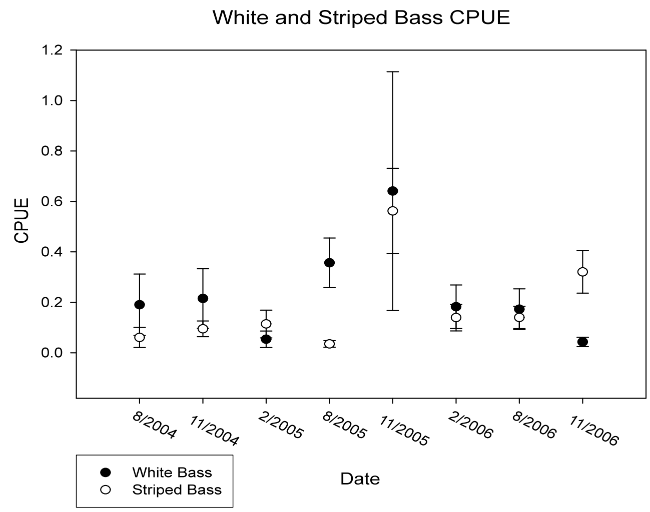

Figure 13. CPUE comparison between white and striped bass with error bars from August 2004 to November 2006.

Species		Aug-04			Nov-04			Feb-05			Aug-05	
		Mean (SE)	N		Mean (SE)	N		Mean (SE)	N		Mean (SE)	N
Common Carp		96(2)	7		93(2)	33		92(1)	69		100(4)	3
Channel Catfish		93(3)	4		97(3)	28		93(6)	8		88(3)	18
White Bass		91(2)	39		87(1)	176		84(3)	18		102(1)	172
Striped Bass		76(4)	13		79(2)	52		80(1)	41		95(9)	11
Black Crappie								99(8)	4		103(2)	38
Flathead Catfish					100(5)	6						
Largemouth Bass					88(2)	39		81(2)	38		93(1)	37

Species		Nov-05			Feb-06			Aug-06			Nov-06	
		Mean (SE)	N		Mean (SE)	N		Mean (SE)	N		Mean (SE)	N
Common Carp		90(1)	27		103(5)	11		93(2)	22		97(2)	19
Channel Catfish		96(4)	20		97(8)	2		89(3)	33		87(4)	14
White Bass		93(1)	249		92(1)	77		82(1)	101		80(2)	37
Striped Bass		78(1)	229		78(1)	69		73(1)	63		72	192
Black Crappie		92(3)	14		92(1)	2					88(12)	2
Flathead Catfish		93(2)	3								85(3)	2
Largemouth Bass		88(1)	71		89(1)	55		87(2)	57		83(2)	102

Table 4. Relative weight with standard error and number of fish (n) for all species.

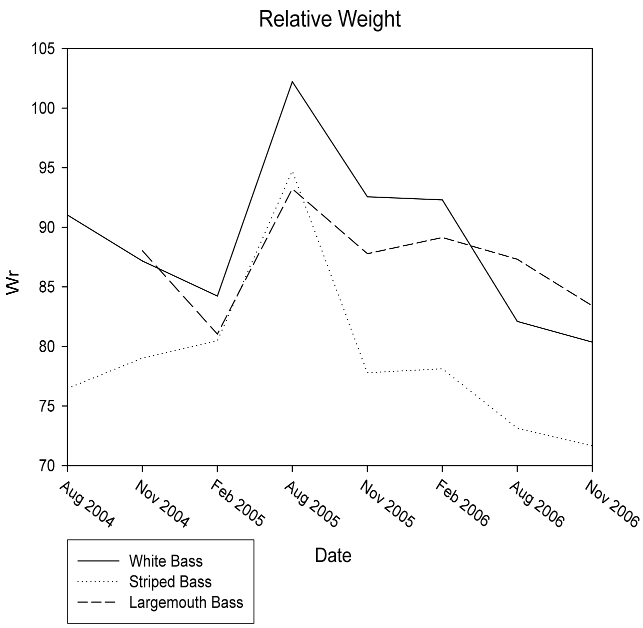

Figure 14. Relative weight of white bass, striped bass, and largemouth bass from August 2004 to November 2006.

Species	Aug 2004	Nov 2004	Feb 2005	Aug 2005
Common Carp	100 + I	94 + I	99 + I	100 + I
Channel Catfish	75 + I	52 + 16	50 + I	40 + I
Largemouth Bass		86 + 10	53 + 12	61 + 13
White Bass	100 + I	80 + I	89 + I	19 + I
Striped Bass	55 + I	40 + 11	29 + 12	0 + I
Black Crappie			100 + I	76 + 12
Flathead Catfish		100 + I		

Species	Nov 2005	Feb 2006	Aug 2006	Nov 2006
Common Carp	56 + 16	78 + I	100 + I	89 + I
Channel Catfish	68 + 17	50 + I	73 + 13	50 + 22
Largemouth Bass	61 + 10	84 + 8	42 + 11	23 + 6
White Bass	69 + I	91 + 5	100 + I	100 + I
Striped Bass	17 + 6	26 + 13	19 + 10	3 + I
Black Crappie	93 + I	100 + I		50 + I
Flathead Catfish	100 + I			100 + I

Table 5. Proportional stock density (PSD) of fish collected using electrofishing and gill netting in Lake Pleasant, 2004-2006. Confidence intervals (80%) are also presented (Gustafson 1988); an "I" indicates that sample size was too small to determine the 80% confidence interval.

Relative Weight

With the exception of channel catfish *(Ictalurus punctatus)* and common carp, W_r was greatest for all species in the August 2005 survey (Table 4). White, striped, and largemouth bass showed similar trends throughout the study (Figure 14). In 2006, striped bass W_r was significantly lower than 2004 and 2005. White bass W_r was significantly higher in 2005 than any other year during the study (ANOVA; P<0.05). Largemouth bass W_r did not differ significantly from year to year. Largemouth and white bass had the greatest W_r in the summer, while striped bass did not show a statistical significant difference between seasons. Striped bass and white bass W_r was significantly higher (ANOVA; P<0.05) in August 2005 than any other survey. Largemouth bass W_r was also highest during this survey, but not statistically significant.

Proportional and Relative Stock Densities

PSD varied among species (Table 5). PSD for white and striped bass were lowest in August 2005. White bass had a higher PSD than striped bass for each survey. Striped bass PSD was less than 50 for all surveys except August 2004. Memorable to trophy relative stock density values were greatest in most survey for white bass and common carp. Appendix 1b shows RSD for the most caught species for each trip.

Age and Growth

A total of 118 striped bass, 61 white bass and 100 largemouth bass were aged. The maximum age of striped bass was 8 years, white bass 7 years and largemouth 8 years (Table 6). Backcalculated growth for white and largemouth bass was similar. Striped bass growth, however, was greater, especially during the first year (Figure 15). Mean backcalculated growth to year 1 for striped bass was 328 mm compared to 198 mm and 215 mm for largemouth and white bass, respectively. Year 2 striped bass continue to have greater growth than white bass and largemouth bass and, by year 3, annual growth rates start to look similar (Table 7).

Striped Bass			**Age**									
Length (mm)	**n**	**Number (age) in sample**	0	1	2	3	4	5	6	7	8	**Totals**
0-100	0											
101-150	1	1(0)	1									1
151-200	2	2(0)	2									2
201-250	9	6(0), 3(1)	6	3								9
251-300	11	5(0), 6(1)	5	6								11
301-350	13	12(1), 1(2)		12	1							13
351-400	10	10(1)		10								10
401-450	13	10(1), 3(2)		10	3							13
451-500	10	8(1), 2(2)		8	2							10
501-550	10	1(1), 9(2)		1	9							10
551-600	12	7(2), 4(3), 1(5)			7	4		1				12
601-650	11	1(2), 2(3), 7(4), 1(7)			1	2	7			1		11
651-700	11	1(2), 4(3), 3(4), 1(5), 1(7), 1(8)			1	4	3	1		1	1	11
701-750	3	2(5), 1(6)						2	1			3
751-800	2	1(4), 1(5)					1	1				2
All	118		14	50	24	10	11	5	1	2	1	118

White Bass			**Age**									
Length (mm)	**n**	**Number (age) in sample**	0	1	2	3	4	5	6	7	8	**Totals**
0-100	0											0
101-150	0											0
151-200	7	7(0)	7									7
201-250	7	6(0), 1(1)	6	1								7
251-300	10	7(0), 3(1)	7	3								10
301-350	10	4(1), 6(2)		4	6							10
351-400	13	1(1), 9(2), 1(4), 1(6), 1(7)		1	9		1		1	1		13
401-450	13	1(3), 5(4), 4(5), 3(6),				1	5	4	3			13
451-500	1	1(5)						1				1
501-550	0											
All	61		20	9	15	1	6	5	4	1	0	61

Largemouth Bass			**Age**									
Length (mm)	**n**	**Number (age) in sample**	0	1	2	3	4	5	6	7	8	**Totals**
0-100	5	5(0)	5									5
101-150	9	9(0)	9									9
151-200	13	7(0), 6(1)	7	6								13
201-250	10	3(0), 6(1), 1(2)	3	6	1							10
251-300	10	3(1), 7(2)		3	7							10
301-350	10	3(1), 6(2), 1(3)		3	6	1						10
351-400	14	6(2), 4(3), 2(4), 2(6)			6	4	2		2			14
401-450	11	3(2), 4(3), 4(4)			3	4	4					11
451-500	10	2(3), 2(4), 4(5), 1(6), 1(7)				2	2	4	1	1		10
501-550	4	1(4), 1(6), 1(7), 1(8)					1		1	1	1	4
551-600	4	3(7), 1(8)								3	1	4
601-650	0											0
												0
All	100		24	18	23	11	9	4	4	5	2	100

Table 6. Age/length frequencies for striped, white, and largemouth bass for each 50mm length category. n is the number of otoliths read.

Annual growth of both striped and white bass varied from 2004 to 2006 (Table 8). The mean weight of young-of-year striped bass in November 2004 was 149 g. This year class grew to a mean weight of 1059 g one year later. During the same time span, young-of-year white bass grew from 111 g to 541 g. The 2005 young-of-year class did not see such growth. The mean weight of young-of-year striped bass in November 2005 was 171 g and grew to 503 g by November 2006, half the size of the young-of-year class of 2004. White bass had similar growth. In November 2005, the average young-of-year white bass weighed 168 g and was 300 g by November 2006 (Figure 16).

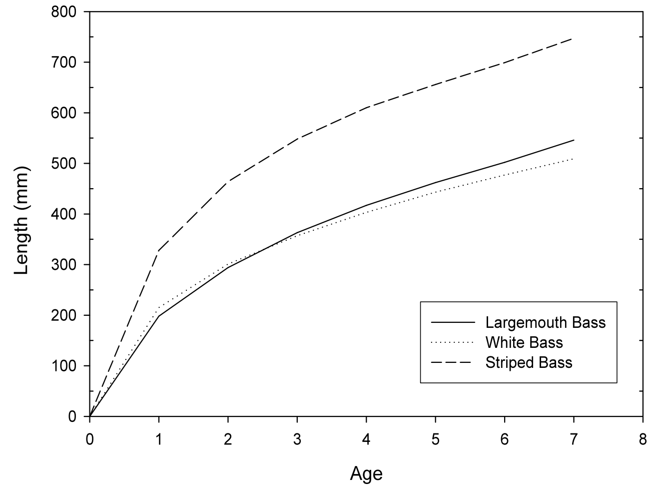

Figure 15. Largemouth, white, and striped bass backcalculated growth.

Diet

Frequency of Occurrence

Stomach contents were examined from 329 largemouth bass (mean TL = 305 ± 5), 326 white bass (mean TL = 327 ± 4), and 292 striped bass (mean TL = 410 ± 8). A total of 30 prey items were identified in 942 stomachs from the 3 predatory species (Appendix 2a). Empty stomachs were found in 23% of largemouth bass, 40% of white bass and 36% of striped bass (Appendix 2b).

	Largemouth Bass		White Bass		Striped Bass	
Age	Growth (mm)	N	Growth (mm)	N	Growth (mm)	N
1	198(7)	72	215(7)	41	328(6)	92
2	96(4)	44	86(4)	27	136(5)	44
3	69(3)	28	56(3)	17	84(5)	25
4	54(2)	22	46(1)	16	62(3)	18
5	45(2)	14	40(2)	10	46(5)	5
6	40(2)	8	34(2)	5	43(2)	4
7	44(1)	2	32	1	48	1

Table 7. Mean backcalculated growth (mm) and number of largemouth, white, and striped bass. Standard error in parentheses.

Percent Composition by Weight/Number

Diets were divided into 4 categories: threadfin shad, crayfish, other fish, and invertebrates. Threadfin shad consumption was greatest in striped bass (74.40%) followed by white bass (43.77%), and largemouth bass (9.69%). Invertebrates consumption were the next highest consumed item by striped bass (19.81%). Invertebrates made up the greatest proportion in largemouth bass (48.07%) and the second greatest in white bass (33.55%). Crayfish consumption was substantial for largemouth (27.64%) and white bass (19.95%), but was low for striped bass (1.28%). Largemouth bass also had a considerable proportion of other fish in their diet (14.79%), while striped (4.52%) and white bass (2.73%) had relatively low proportions (Figures 17 and 18). There appeared to be a seasonal difference in largemouth bass diets. Proportions of invertebrates in their diet were only 7.04% in summer compared to 54.02% in fall and 80.21% in spring.

Diet Overlap

Diet overlap index ranges from 0 (no overlap) to 1 (complete overlap). Diet overlap between striped bass (SB), white bass (WB), and largemouth bass (LB) varied throughout the study. SB/WB had the greatest overall diet overlap (0.68) while SB/LB had the lowest overall diet overlap (0.35). In 2004 and 2005 SB/WB overlap was 0.60 and 0.85, respectively. In 2006, SB/WB overlap reduced to slightly more than half that of 2005 (0.38). SB/LB overlap remained consistently less than 0.40 each year (Figure 19). While SB/WB overlap decrease in 2006 compared to prior years, WB/LB increased. The overlap index was 0.22 in 2004, 0.50 in 2005, and 0.71 in 2006 (Table 9).

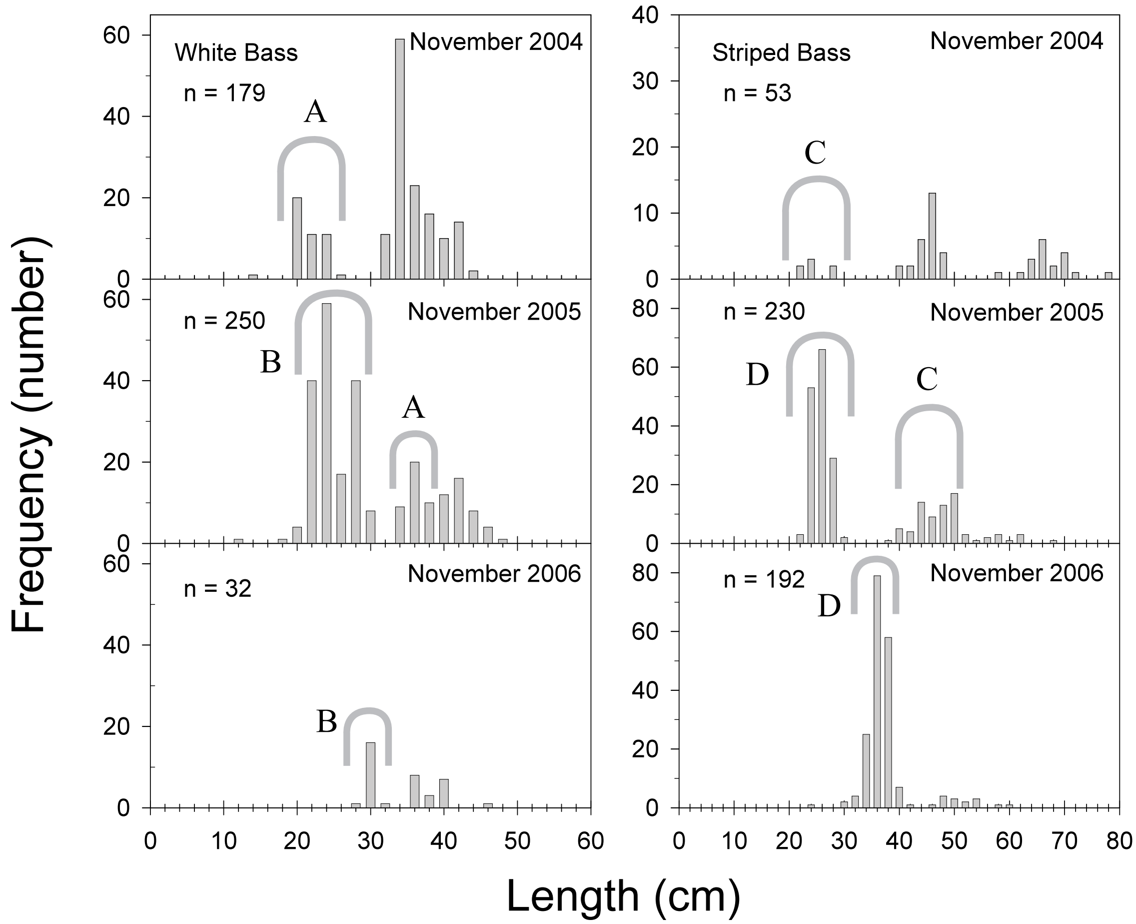

Figure 16. Growth of young-of-year white and striped bass across years. Growth of young-of-year white bass indicated by A for November 2004 to November 2005 and B for November 2005 to November 2006. Growth of young-of-year striped bass indicated by C for November 2004 to November 2005 and D for November 2005 to November 2006.

Energy Densities

Mean energy densities taken from literature were calculated for each of the 4 prey categories (Table 10). Threadfin shad had the highest energy density (5,450 J/g) and the invertebrates category had the lowest (2,944 J/g).

Water Quality

Lake levels are generally highest from January to March and lowest from August to October (Figure 20). Lake Pleasant did not reach full pool in 2004 or 2006. Due to heavy rains in early 2005, however, Lake Pleasant remained at or near full pool until May (Figure 21). In early 2005, substantial rainfall saw flow in the Agua Fria River reach levels of over 481 m^3/sec where historical levels normally remain at 0 m^3/sec and rarely get above 14 m^3/sec (Figure 22).

Temperature

Surface temperatures varied dramatically from fall/spring to summer months. Mean surface temperatures from the 4 water quality sites ranged from 12.04°C in January 2006 to 29.85°C in July 2005 (Table 11). Thermocline in Lake Pleasant would typically develop in April and remain stratified until October. Thermocline depths ranged from 6 m in April 2005 to 16 m in September 2006 (Figure 23).

Conductivity

Surface conductivity ranged from a low of 0.561 $\mu S \cdot cm^{-1}$ in March 2005 to a high of 1.018 $\mu S \cdot cm^{-1}$ in August 2004 (Table 11). In spring 2005, conductivity was lower than all other months during this survey, likely due to heavy precipitation during that time period.

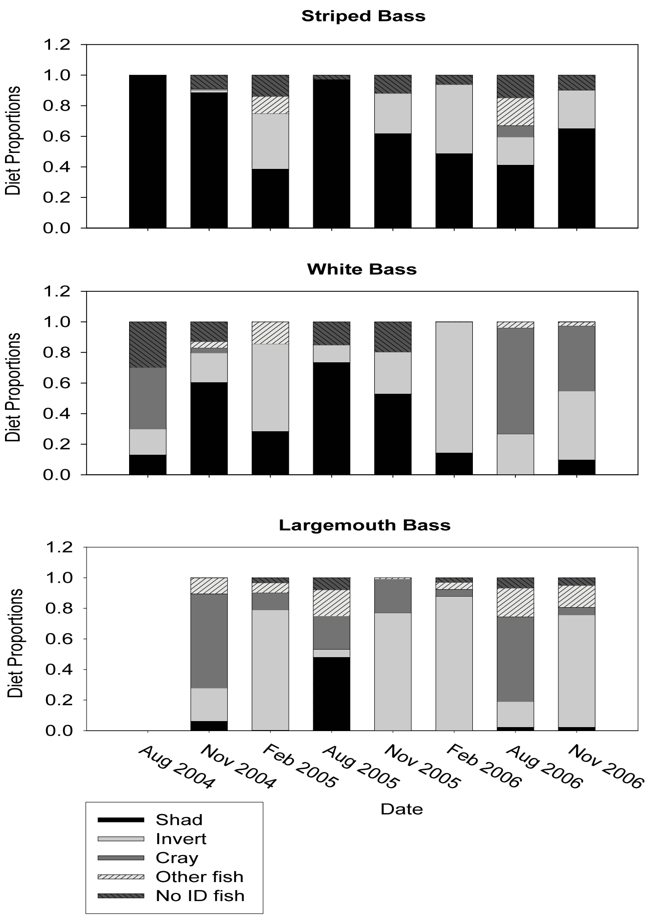

Figure 17. Percent diet composition by number for largemouth, white, and striped bass.

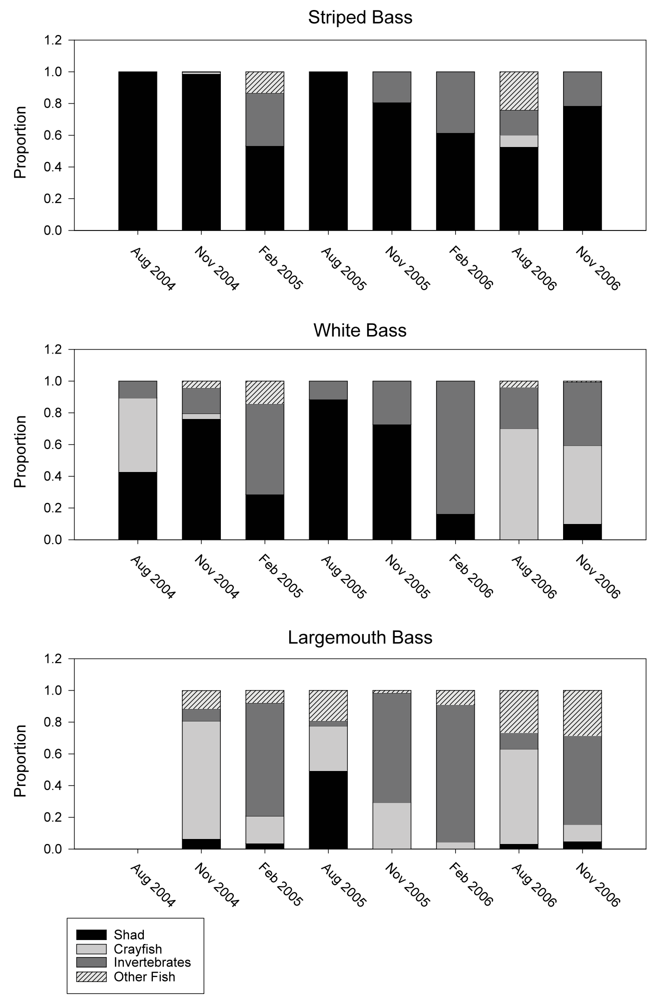

Figure 18. Percent diet composition by weight for largemouth, white, and striped bass.

Dissolved Oxygen

Dissolved oxygen levels at the surface were highest during March in both 2005 and 2006, 11.04 $mg \cdot l^{-1}$ and 12.30 $mg \cdot l^{-1}$ respectively (Table 11). Dissolved oxygen levels were lowest during summer with July 2005 being the lowest at 6.56 $mg \cdot l^{-1}$. Summer mean surface dissolve oxygen levels were significantly lower than fall and spring dissolved oxygen levels (ANOVA; $P < 0.05$). Appendix 3 shows seasonal difference of temperature and dissolved oxygen.

pH

Mean surface pH levels ranged from a minimum of 7.63 in May 2005 to a maximum of 8.80 in March of 2006 (Table 11).

Secchi Depth

Secchi depth ranged from 0.88 m in spring 2005 (Agua Fria River) to 10.50 m (Max's Point) in spring 2004 (Figure 24a). In 2005, secchi depth was lower than that of 2004 and 2006. Mean secchi depth in 2005 was 2.32 m (SE = 0.29) with March 2005 having the lowest secchi depth of 1.38 m (SE = 0.29).

Chlorophyll

Chlorophyll level ranged from 0.70 mg/l (fall 2006, Max's Point) to 13.04 mg/l (spring 2005, Agua Fria River mouth) (Figure 24b). Between years, 2005 mean chlorophyll levels (5.07 mg/l, SE = 0.84) were higher than 2004 (2.12 mg/l, SE = 0.42) and 2006 (1.98 mg/l, SE = 0.41).

Striped Bass						White Bass					
Cohort	**Day**	**Length**	**Weight**	**N**	**SE**	**Cohort**	**Day**	**Length**	**Weight**	**N**	**SE**
2002	1	652	3092	6	26	2002	1	398	775	34	4
2002	105	659	3192	19	10						
2002	198	725	4245	1							
2002	468	678	3475	1							
2003	1	324	383	7	10	2003	1	311	372	7	5
2003	105	440	956	27	5	2003	105	331	446	88	1
2003	198	501	1408	34	11	2003	198	345	506	10	4
2003	468	574	2114	10	8						
2004	105	236	149	7	9	2004	105	208	111	44	3
2004	198	249	175	6	7	2004	198	218	129	2	1
2004	378	344	460	8	17	2004	378	328	436	23	4
2004	468	455	1059	66	4	2004	468	353	541	39	2
2004	554	466	1135	29	8						
2004	742	531	1671	11	17						
2004	833	493	1340	13	8						
2005	378	154	41	3	27	2005	378	188	83	142	1
2005	468	247	171	153	1	2005	468	238	168	170	2
2005	554	252	180	38	3	2005	554	259	215	38	4
2005	742	305	320	51	5	2005	742	283	279	44	2
2005	833	355	503	176	1	2005	833	290	300	18	2
2006	833	236	149	1							

Table 8. Annual growth of striped and white bass. Cohort represents the year class for both striped bass (left) and white bass (right). Day corresponds to the day of the study (day 1 = August 2004). Total length (mm), weight (g), number and standard error (SE) are given for each cohort during corresponding survey.

Turbidity

Turbidity levels ranged from 0.45 NTU in spring 2004 (Waddell Dam) to 7.71 NTU in spring 2005 (Agua Fria River mouth). Turbidity levels in fall 2004 (4.63 NTU, SE = 0.96) and spring 2005 surveys (6.24 NTU, SE = 0.79) were higher than any other survey from August 2004 to November 2006 (Figure 24c).

Striped bass prefer water temperatures less than 25°C and dissolved oxygen levels greater than 2.5 mg/l. At site 4 (Agua Fria River), the number of meters within the water column that met the striped bass preferred water quality dropped considerably in summer with only 7 m of preferred water quality in June, 3 m in July, and 0 m in August. In addition, site 3 (Agua Fria River mouth) had 0 m of preferred water quality in August (Figure 25).

Hydroacoutsics

Hydroacoustic surveys were run in February 2005 and February 2006. Mean target strength in 2005 was -48.63 dB (TL = 64.04 mm), SE = 0.04. Mean target strength in 2006 was –46.04 dB (TL = 87.41 mm) SE = 0.04. Total lake fish density was 4 times greater in 2005 (0.0068 fish/m^3) than in 2006 (0.0017 fish/ m^3; Table 12). In 2005, the greatest

Trip	SB/WB	SB/LB	WB/LB
Aug-04	0.43		
Nov-04	0.78	0.08	0.22
Feb-05	0.75	0.45	0.69
Aug-05	0.88	0.49	0.53
Nov-05	0.92	0.19	0.27
Feb-06	0.55	0.39	0.84
Aug-06	0.27	0.45	0.73
Nov-06	0.32	0.26	0.56
Year			
2004	0.60	0.08	0.22
2005	0.85	0.38	0.50
2006	0.38	0.37	0.71
Total	0.68	0.35	0.66

Table 9. Diet overlap index by survey, year, and total for striped bass and white bass (SB/WB), striped bass and largemouth bass (SB/LB) and white bass and largemouth bass (WB/LB).

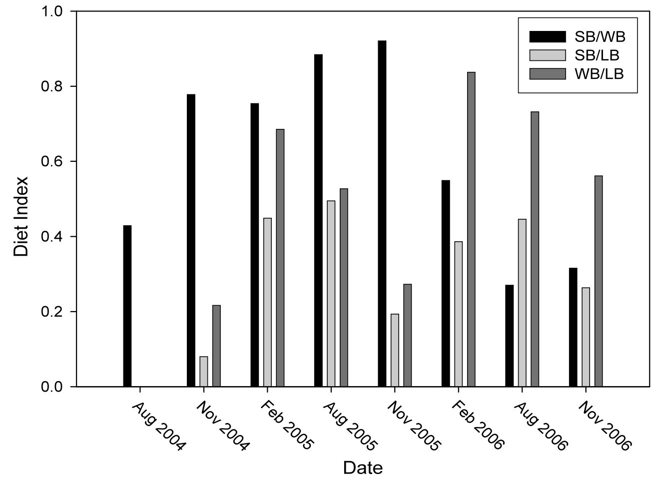

Figure 19. Diet overlap index for each survey for striped bass and white bass (SB/WB), striped bass and largemouth bass (SB/LB), and white bass and largemouth bass (WB/LB).

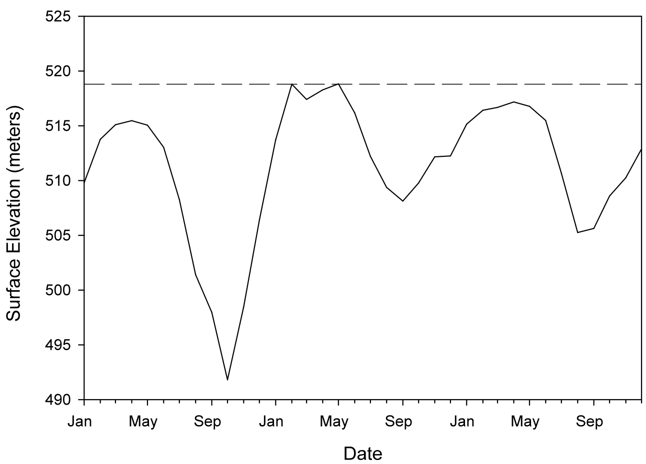

Figure 20. Lake elevation from January 2004 to December 2006. Dashed line across the top indicates full pool.

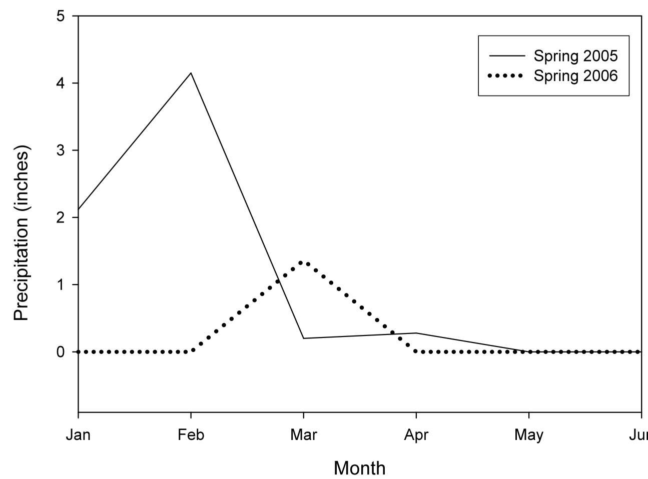

Figure 21. Comparison of spring precipitation from 2005 and 2006.

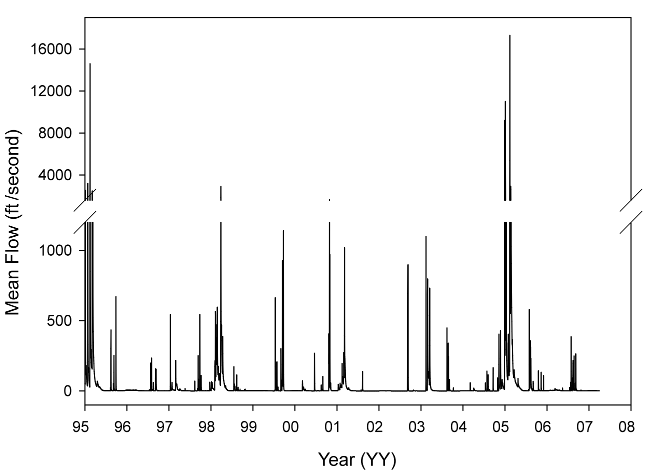

Figure 22. Mean daily Agua Fria River flow from January 2004 to January 2007 at USGS gauging station 09512800.

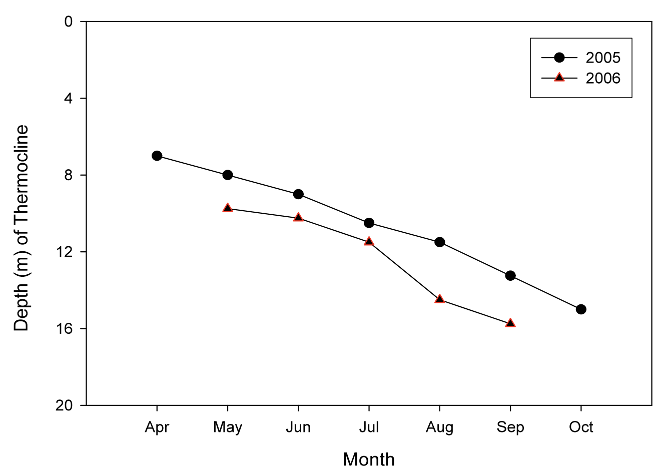

Figure 23. Thermocline depths from April to October in 2005 and 2006.

Prey	Mean Energy Density (J/g)	Source
Threadfin shad	5450	Eggleton and Schramm 2002 (Threadfin shad)
Crayfish	3529	Roell and Orth 1993, Kelso 1973, Eggleton and Schramm 2002
Invertebrates	2944	Cummins and Wuychuck 1971
Other Fish	4766	Miranda & Muncy 1991 and Bryan et al 1996

Table 10. Mean energy densities for threadfin shad, crayfish, invertebrates and other fish from literature.

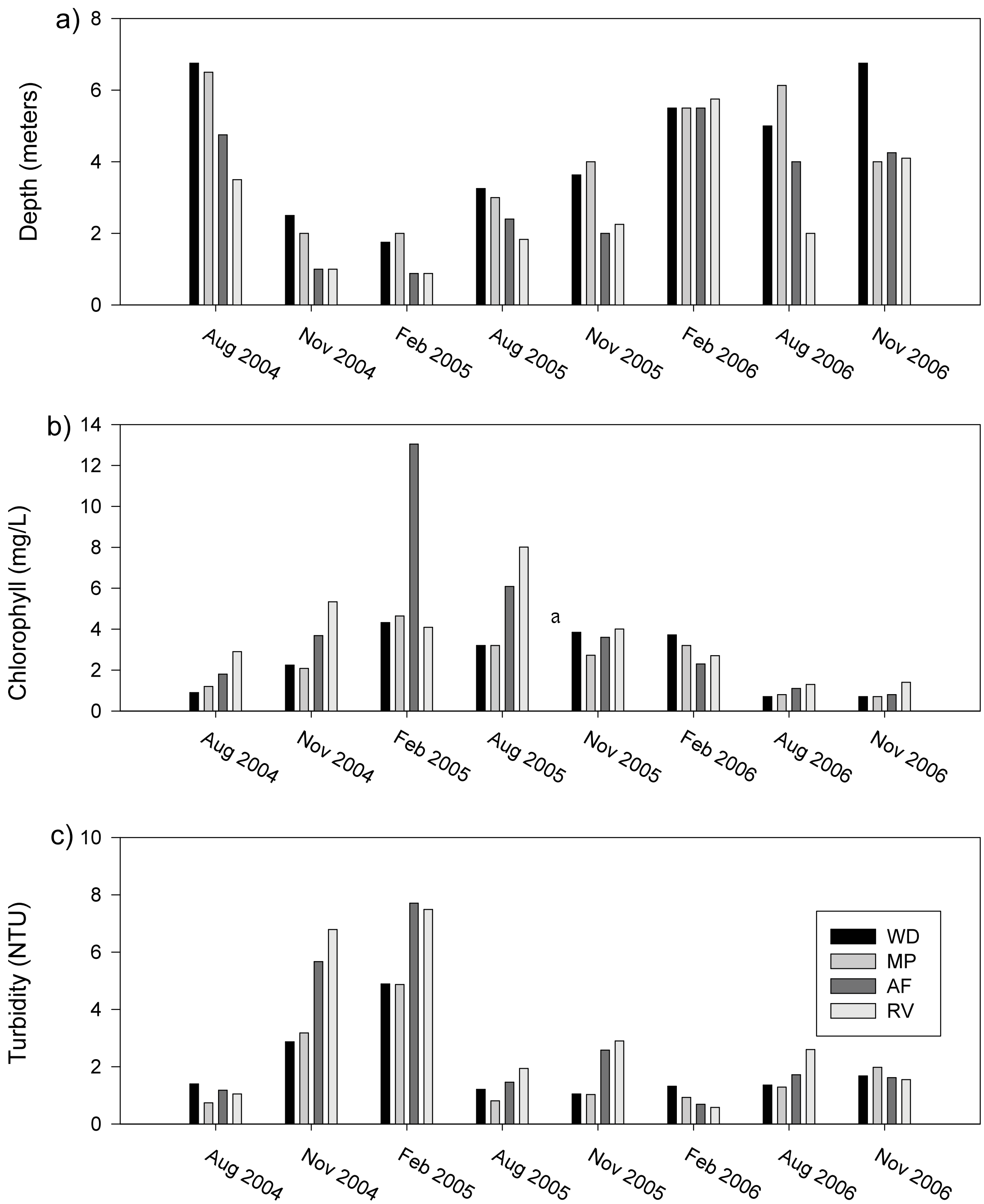

Figure 24. Secchi depth, (a) chlorophyll (b), and turbidity (c) at each water quality site taken following each gill netting survey.

Month	Parameter	2004	2005	2006
January	Temperature (°C)			12.04 (0.02)
	Specific Cond (mS/cm)			0.927 (0.01)
	Dissolved Oxygen (mg/L)			10.79 (0.13)
	PH			8.35 (0.03)
	n			4
February	Temperature (°C)			
	Specific Cond (mS/cm)			
	Dissolved Oxygen (mg/L)			
	PH			
	n			
March	Temperature (°C)		15.08 (0.26)	12.65 (0.26)
	Specific Cond (mS/cm)		0.561 (0.05)	0.923 (0.00)
	Dissolved Oxygen (mg/L)		11.04 (0.36)	12.30 (0.19)
	PH		8.27 (0.12)	8.80 (0.24)
	n		4	4
April	Temperature (°C)	17.23 (0.12)	18.58 0.48)	15.73 (0.43)
	Specific Cond (mS/cm)	0.968 (0.00)	0.714 (0.00)	0.939 (0.01)
	Dissolved Oxygen (mg/L)	10.38 (0.20)	9.18 (0.14)	9.66 (0.94)
	PH	8.67 (0.01)	8.54 (0.23)	8.49 (0.02)
	n	3	4	4
May	Temperature (°C)		22.38 (0.05)	24.84 (0.23)
	Specific Cond (mS/cm)		0.771 (0.00)	0.951 (0.00)
	Dissolved Oxygen (mg/L)		9.26 (0.24)	7.73 (0.05)
	PH		7.63 (0.31)	8.40 (0.00)
	n		4	4
June	Temperature (°C)		27.29 (0.05)	27.47 (0.15)
	Specific Cond (mS/cm)		0.811 (0.00)	0.970 (0.00)
	Dissolved Oxygen (mg/L)		9.23 (0.17)	7.16 (0.05)
	PH		8.42 (0.07)	8.45 (0.00)
	n		4	4
July	Temperature (°C)		29.85 (0.20)	28.05 (0.04)
	Specific Cond (mS/cm)		0.838 (0.00)	0.907 (0.00)
	Dissolved Oxygen (mg/L)		6.56 (0.21)	7.62 (0.12)
	PH		8.54 (0.06)	8.46 (0.01)
	n		4	4
August	Temperature (°C)	29.19 (0.18)	29.02 (0.07)	28.19 (0.15)
	Specific Cond (mS/cm)	1.018 (0.00)	0.836 (0.00)	0.992 (0.00)
	Dissolved Oxygen (mg/L)	8.28 (0.40)	8.47 (0.52)	7.86 (0.31)
	PH	8.41 (0.03)	8.71 (0.12)	8.55 (0.03)
	n	4	4	4
September	Temperature (°C)		28.46 (0.12)	24.83 (0.10)
	Specific Cond (mS/cm)		0.845 (0.01)	0.957 (0.01)
	Dissolved Oxygen (mg/L)		10.87 (0.92)	7.11 (0.47)
	PH		8.44 (0.03)	8.27 (0.07)
	n		4	4
October	Temperature (°C)		25.20 (0.19)	20.17 (0.04)
	Specific Cond (mS/cm)		0.859 (0.00)	0.984 (0.00)
	Dissolved Oxygen (mg/L)		11.02 (0.19)	7.90 (0.26)
	PH		8.36 (0.05)	8.23 (0.06)
	n		4	4
November	Temperature (°C)		17.08 (0.04)	16.47 (0.01)
	Specific Cond (mS/cm)		0.898 (0.00)	1.000 (0.00)
	Dissolved Oxygen (mg/L)		7.74 (0.23)	9.82 (0.20)
	PH		8.48 (0.08)	8.19 (0.03)
	n		4	4
December	Temperature (°C)	15.14 (0.17)	13.30 (0.05)	12.50 (0.05)
	Specific Cond (mS/cm)	1.014 (0.00)	0.920 (0.00)	0.995 (0.00)
	Dissolved Oxygen (mg/L)	9.17 (0.20)	9.82 (0.45)	10.21 (0.28)
	PH	8.00 (0.05)	8.44 (0.01)	8.17 (0.04)
	n	4	4	4

Table 11. Mean monthly surface temperature, specific conductivity, dissolved oxygen, and pH of all 4 water quality sites from April 2004 to December 2006.

		Mean Density			N
Season	**Lake Zone**	**(#/m3)**	**SE**	**SD**	**(100 ping cells)**
Feb-05	Lake	0.0068	0.0005	0.0122	505
	Agua Fria	0.0058	0.0007	0.0077	117
	North Basin	0.0080	0.0011	0.0147	186
	South Basin	0.0063	0.0008	0.0118	202
Feb-06	Lake	0.0017	0.0001	0.0046	1199
	Agua Fria	0.0040	0.0004	0.0046	112
	North Basin	0.0018	0.0001	0.0028	388
	South Basin	0.0013	0.0002	0.0052	699

Table 12. Fish density #/m3 by basin (lake zone)

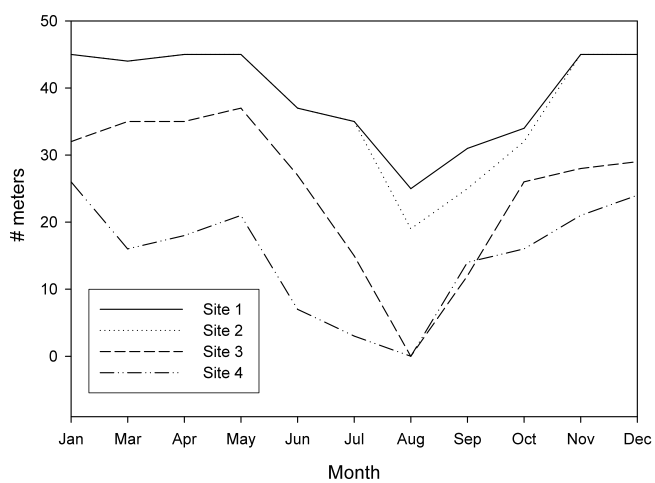

Figure 25. The number of meters within the water column that fit the preferred conditions (water temperature < 25°C. and DO > 2.5 mg/l) for striped bass at each water quality site. Site 1 = Waddell Dam, Site 2 = Max's Point, Site 3 = Agua Fria Mouth, Site 4 = Agua Fria River. No water quality data were taken during the month of February.

fish density (0.0080 fish/m^3) was in the North Basin and the lowest was in the Agua Fria River. Fish density in 2006 was highest in the Agua Fria River (0.0040 fish/m^3) and lowest in the South Basin (0.0013fish/m^3; Figures 26 and 27). Lake volume during the 2005 survey was 1,004 x 106 m^3. Fish abundance was estimated at 6,822,368 ± 501,856 fish. Based on the maximum-sized threadfin shad caught during the February 2005 survey, fish greater than 125 mm were considered potential predators and anything less than 125 mm were considered prey. Only 2.34% (159,734 ± 11,745) of identified fish were estimated as being greater than 125 mm. Percent composition of white bass during the February 2005 gill netting survey was 11.9% for a total of 19,018 ± 1398 fish. Striped bass composition was 25.38% for a total of 40,535 ± 2,980. Lake volume during the February 2006 survey was 9,108 x 10^5 m^3. Fish abundance was lower in 2006 (1,547,782 ± 120,067) than in 2005. The cut-off for what could be considered a predator was estimated at 150 mm TL based on maximum-sized threadfin shad during the February 2006 gill netting survey. Estimates for white bass based on gill net percent composition (white bass = 50.0%, striped bass = 38.2%) was 35,672 ± 2,767. Striped bass abundance was estimated at 27,229 ± 2,112.

Bioenergetics

Growth

Striped and white bass growth was modeled for young-of-year fish from November 2004 to November 2005 and November 2005 to November 2006 (Figures 28 and 29). Both species of fish had a steady decline in daily growth starting in July. Daily growth began to increase in September. During 2004/2005 striped bass growth was lowest in January (min = 1.09 g/day) and greatest in October (max = 5.39 g/day). The following year, striped bass growth was lowest in September (min = -0.2 g/day) and greatest in October (max = 2.11g/day). White bass growth during 2004/2005 was lowest in January (min = 0.52 g/day) and highest in October (max = 2.76 g/day). The following year, white bass growth was lowest in September (min = -0.82 g/day) and highest in November (max = 1.25 g/day).

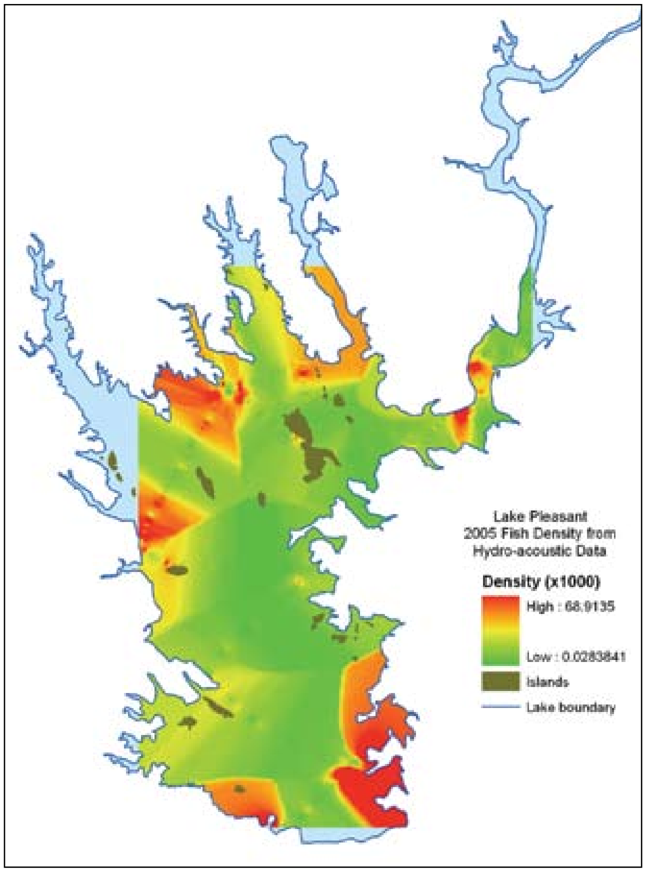

Figure 26. Fish densities map from 2005 hydroacoustic survey.

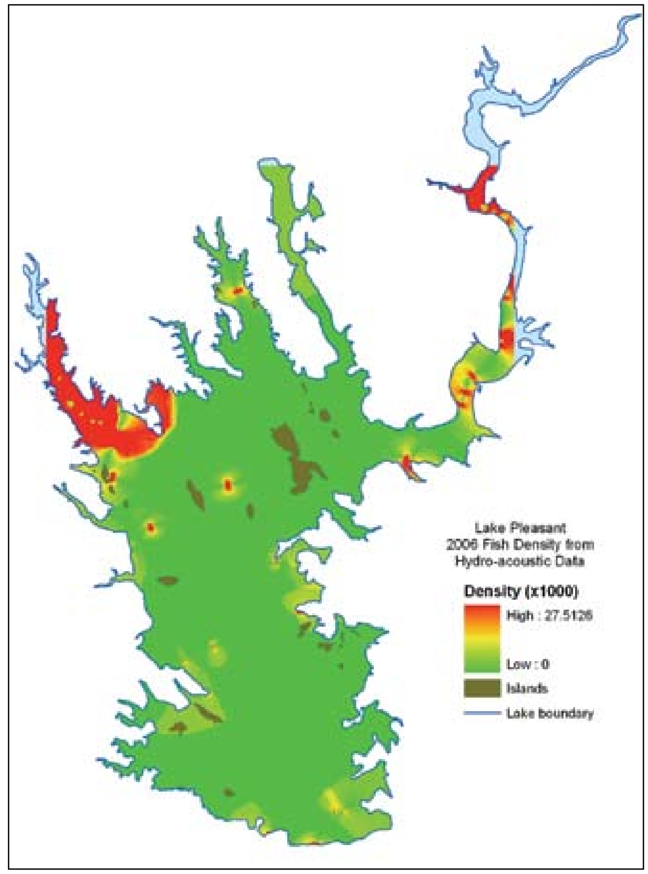

Figure 27. Fish densities map from 2006 hydroacoustic survey.

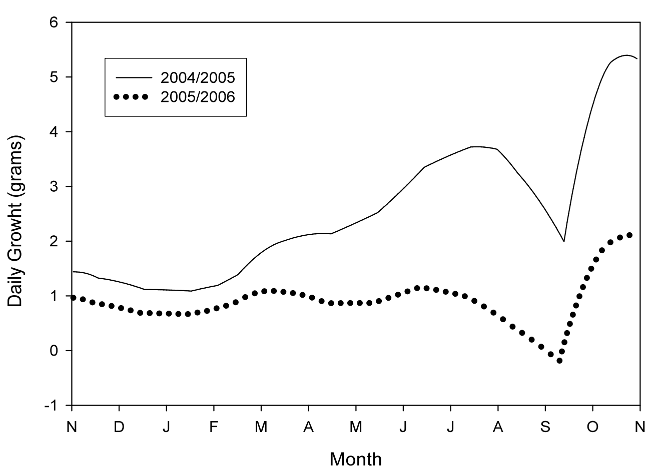

Figure 28. Striped bass daily growth from November 2004 to November 2005 (solid line) and from November 2005 to November 2006 (dashed line) for age 0 fish.

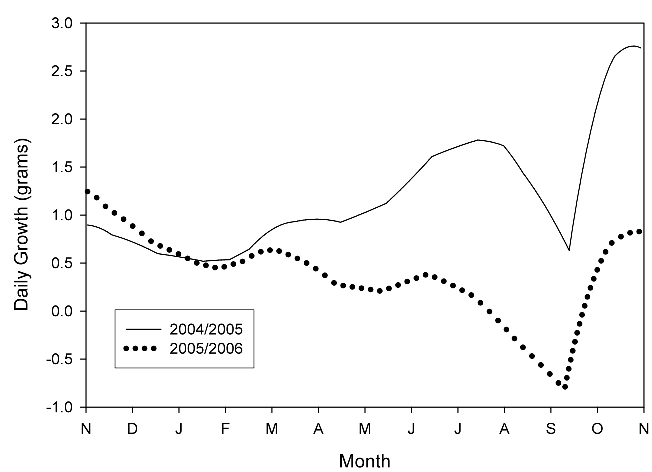

Figure 29. White bass daily growth from November 2004 to November 2005 (solid line) and from November 2005 to November 2006 (dashed line) for age 0 fish.

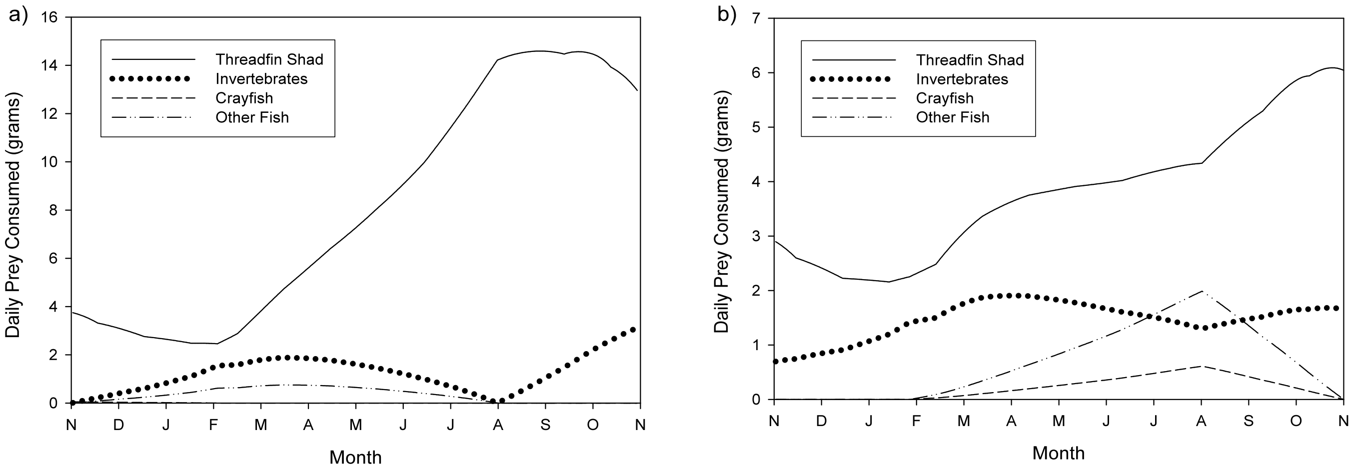

Figure 30. a) Striped bass year 1 daily prey consumption from November 2004 to November 2005. b) Striped bass year 1 daily prey consumption from November 2005 to November 2006.

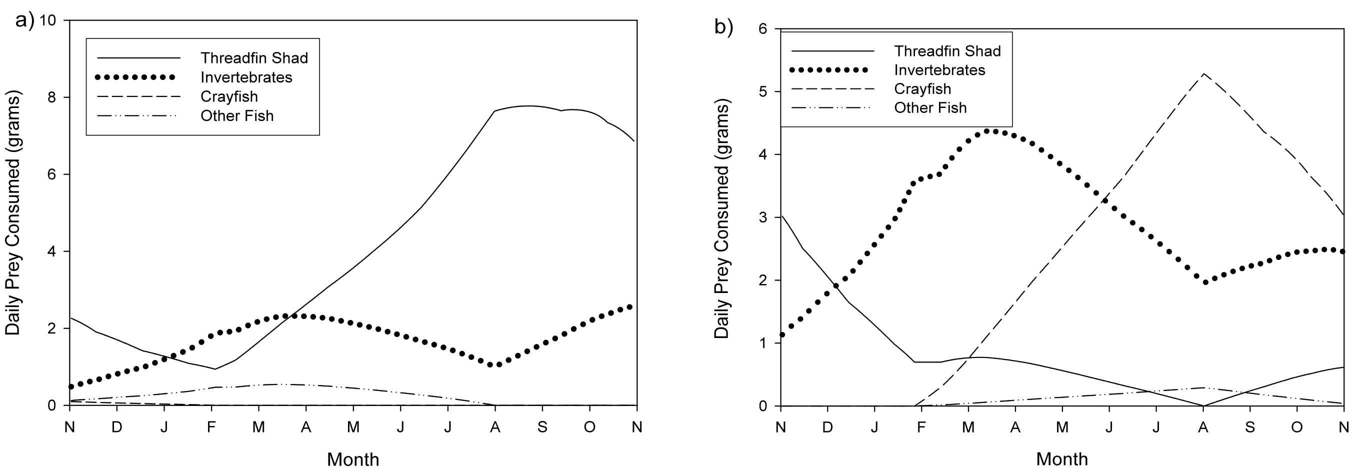

Figure 31. a) White bass year 1 daily prey consumption from November 2004 to November 2005. b) White bass year 1 daily prey consumption from November 2005 to November 2006.

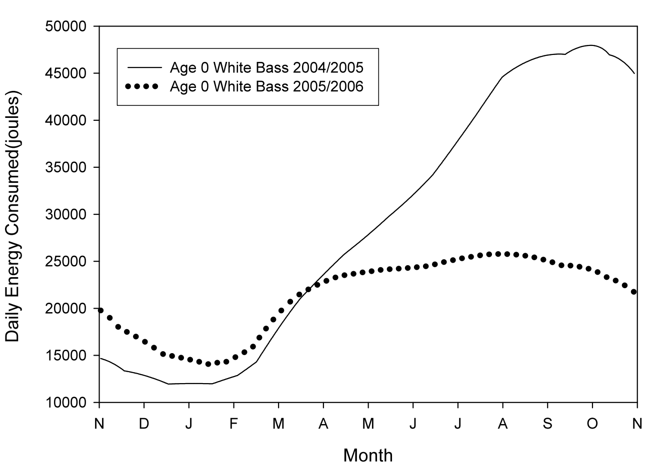

Figure 32. Year 1 white bass daily energy consumption for 2004/2005 and 2005/2006.

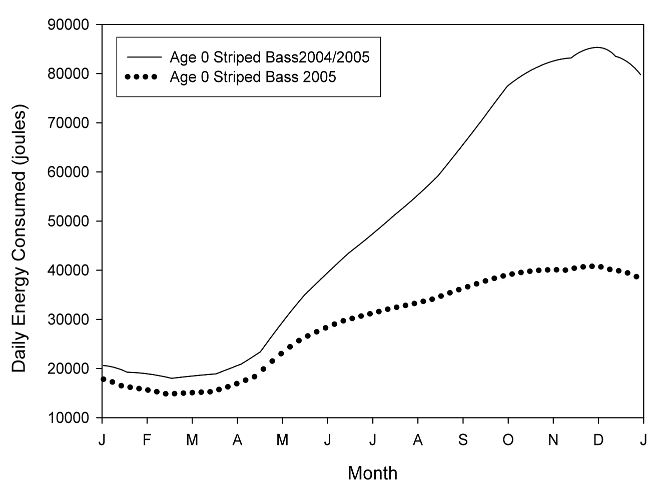

Figure 33. Year 1 striped bass daily energy consumption for 2004/2005 and 2005/2006.

Consumption

Consumption of threadfin shad, invertebrates, crayfish, and other fish was modeled for both years for striped bass (Figures 30a and 30b) and white bass (Figures 31a and 31b). Mean consumption of threadfin shad dropped in half from 2004/2005 (8.06 g shad/day) to 2005/2006 (3.79 g shad/day). White bass shad consumption also dropped from the first year (mean = 4.15 g shad/day) to the second year (mean = 0.76 g shad/day). However, white bass consumption of invertebrates and crayfish increased from year 1 (1.67 g invertebrates/day and 0.01 g crayfish/day) to year 2 (mean = 2.89 g invertebrates/day and 2.33 g crayfish/day). For both white and striped bass total daily energy consumed was lower during 2005/2006 than 2004/2005 (Figures 32 and 33). Mean white bass daily energy consumed decreased by 25.62% from year 1 to year 2. In year 1, white bass daily energy consumption was 28,753 ± 1,398 j/day and decreased to 21,385 ± 416 j/day by year 2. Striped bass energy consumption had an even greater decrease from year 1 to year 2 (40.91%). Year 1 striped bass mean daily energy consumption was 49,091 ± 2,587 j/day and decreased to 29,009 ± 989 j/day by year 2.

DISCUSSION

Telemetry

Adult striped bass do not handle stress well. It was determined that to successfully implant transmitters, the striped bass needed cool water temperatures, minimal handling, and an immediate release back into the water upon completion of the surgery. Other studies used electrofishing as a means to catch striped bass (Hightower et al. 2001). However, Lake Pleasant is a deep reservoir and attempts to electrofish for striped bass were unsuccessful. Although time consuming, angling proved to be the least stressful method of catch. Striped bass were observed using the entire reservoir throughout the course of the year. The majority of the tagged striped bass remained in the Agua Fria River from September to May likely because this area has highest productivity according to the hydroacoustic surveys. The preferred temperature range for striped bass is 18-25 °C (Coutant and Carroll 1980; Crance 1984; Coutant 1985) and according to Crance (1984) striped bass typically select habitats with dissolve oxygen concentrations greater than 2.5 mg/l. During the summer months, the Agua Fria River does not meet the preferred condition for striped bass, which explains why movement out of the river was observed from June to September. Striped bass are able to find refuge outside of the Agua Fria River either near the mouth of the river or at the south end of the reservoir near the Waddell Dam. Despite surface water temperatures in the main reservoir peaking near 30 °C and dissolved oxygen levels dropping to 2.30 mg/l, a thin layer of suitable conditions exists near the thermocline typically 9 to 15 meters deep. As surface water temperatures began to drop (mean 20.14 degrees °C) in September, 5 of the remaining 6 striped bass returned to the Agua Fria River. During this time, dissolved oxygen levels ranged from 2.27 mg/L. to 7.13 mg/L and there were 14 meters of preferred water quality in the Agua Fria River.

Although striped bass were observed moving throughout the entire stretch of the Agua Fria River, the area across from Tule Cove (about 7.25 km upstream from the mouth of the Agua Fria River) is likely preferable spawning habitat for striped bass as indicated by their frequency of occurrence at that location. This area is restricted to many anglers due to an eagle closure that blocks the entrance to this area from mid-December to mid-June. During these months, the only access to this area is along Table Mesa Road, a dirt road not suitable for pulling a trailer. In July 2007, the Maricopa Parks and Recreation Department and the Bureau of Reclamation closed this road indefinitely to motorized vehicles to ensure public safety and protect the natural and cultural resources within the Agua Fria Conservation Area. This leaves no boat access to the Agua Fria River from mid-December to mid-June.

Spawning

Larval tow and light traps surveys were conducted to determine if striped bass were spawning within the reservoir or being fed in through the intake pump at the Waddell Dam. Due to the difficulty of distinguishing between striped bass and white bass at the larval stage, alternative evidence was needed to make a conclusion. In fall 2005, gill nets set in the Agua Fria River, 9 miles from the Waddell Dam, contained over nearly 100 young-of-year striped bass. This was enough evidence to suggest that striped bass were spawning within the reservoir at the upper end of the Agua Fria River. Striped bass broadcast spawn their eggs in waters with considerable current where they will remain suspended such that they do not sink to the bottom and become smothered (Goodson 1966; Barkuloo 1970). The upper reaches of the Agua Fria River run dry most of the year and the lower reach of the river, which is inundated due to the dam, has little to no flow. The exception is during heavy rains such as the case in spring 2005. As a result of the heavy flow in 2005, striped bass had very successful spawn. In contrast, the following spring saw virtually no rain thus no flow and very poor striped bass spawn. Although studies have shown that striped bass are capable of spawning in-reservoir with no flow (Gustaveson et al. 1984), success is still low. The dependence on flow into the Agua Fria River will be a limiting factor for the success of striped bass in this reservoir.

Fish Surveys

Population Dynamics

In 2005, there was a boom in the numbers of white and striped bass at Lake Pleasant. A wet spring provided heavy flows in the Agua Fria River creating suitable conditions for both white and striped bass reproduction. As a result, catch for white bass dramatically increased in August when they were large enough to be captured in gill nets. Then, in November, striped bass catch dramatically increased as they became large enough to be captured in gill nets. The majority of white and striped bass during 2005 were young-of-year fish. As a result, proportional stock densities in the summer and fall surveys were low, indicating a very successful spawn during the spring of 2005. In 2006, striped bass catch was still high, but most of the catch consisted of year 1 fish. No young-of-year white bass and only one young-of year striped bass was captured during the fall 2006 survey suggesting poor reproduction in spring 2006.

White and striped bass share similar life histories. Both are pelagic and rely on threadfin shad as a primary source of food in Lake Pleasant. The strong 2005 striped bass year class appears to have caused a shift between white and striped bass relative abundance. Fall surveys from 2000 to 2004 showed that white bass abundance dominated striped bass abundance (Bryan 2005). The successful spawn of both white and striped bass in 2005 may be a turning point as relative abundance estimates were similar. During the last survey of this study in 2006, white bass abundance was the lowest it had been since 2000 while striped bass abundance was still high. The shift from more white bass to more striped bass suggests that striped bass may be out-competing white bass. This is also suggested by the diet shift of white bass during August and November 2006 following the dry spring. Leading up to those 2 surveys, white and striped bass consumed primarily threadfin shad. While striped bass continued to consume threadfin shad, white bass shad consumption dropped to nearly zero in August and November 2006.

Relative weight for white, striped, and largemouth bass was greatest during the summer following the wet spring in 2005 as lake productivity was high. The following year, when shad forage was low, both white and striped bass relative weights dropped considerably while largemouth bass had a slight drop in relative weight. This suggests that largemouth bass are not as dependent on threadfin shad and remain relatively healthy when shad populations are low.

Age and Growth

White bass and largemouth bass otoliths were much easier to read than striped bass otoliths. Studies suggest the use of scales for aging striped bass (Welch et al. 1993), but readers were more consistent when using otoliths. Backcalculated growth shows that striped bass grow at a much greater rate during their first 2 years compared to white and largemouth bass. White and largemouth bass growth is similar for younger fish, but after about age 3, white bass growth seems to slow compared to largemouth bass. Growth comparisons from 2005 and 2006 are good indicators of growth extremes for young-of-year striped and white bass. Due to the high productivity in spring 2005, growth of young-of-year white and striped bass nearly doubled that of young-of-year growth in 2006. Average growth for young-of-year striped bass falls near the middle of the extreme ranges from 2005 and 2006 as estimated by the mean backcalculated growth for young-of-year striped bass.

Diet

The primary concern for anglers at Lake Pleasant is that striped bass will out-compete other sport fish, specifically largemouth and white bass, for the primary prey source, threadfin shad. Our results show that largemouth bass exhibited an opportunistic feeding behavior, as expected. The majority of their diet was invertebrates, crayfish and other fish (mostly sunfish). Threadfin shad made up very little of their diet. The only survey where largemouth bass diet contained a substantial amount of threadfin shad was following the productive spring of 2005. That summer, all 3 predator species had the highest proportion of shad in their diet than any other time during the course of this study. This suggests that largemouth bass do not depend on threadfin shad, but will take advantage when they are available. Striped bass exhibited a specialist feeding behavior. Their diet consisted mostly of threadfin shad with some minimal seasonal change to invertebrates in the spring. Wilde and Paulson (1989) noted that striped bass in Lake Mead fed primarily on threadfin shad except in spring when seasonal differences in depth and horizontal distribution of striped bass and prey cause spatial separation, causing striped bass to rely on invertebrates. In January 2006, the inland silverside *(Menidia beryllina)*, a new species to Arizona, was discovered. The following summer, inland silversides began showing up in the stomachs of white and largemouth bass, and made up nearly a fifth of the striped bass diet during the August 2006 survey. Striped bass adults generally prefer soft-rayed, schooling species (Setzler et al. 1980), which is likely why inland silversides were so abundant in striped bass stomachs during the summer of 2006 when shad numbers were low. Because of angler concerns that striped bass would eat largemouth bass, it is important to note that not a single largemouth bass was found in the diet of striped bass. There is strong evidence that striped bass are out competing white bass for threadfin shad. At the beginning of this study, white bass diet consisted mostly of threadfin shad with seasonal changes to invertebrates in the spring. In 2006, when striped bass abundance was still high and threadfin shad numbers dropped, there appeared to be a shift in the white bass diet but not in striped bass diet. White bass diet shifted from primarily threadfin shad to primarily crayfish. Competition between striped and white bass is likely the cause for this shift. Schoener's (1970) diet overlap index provides further evidence of a shift in white bass diet. Prior to 2006, the striped bass/white bass index was high indicating similarities in diet. In 2006, however, the striped bass/white bass index dropped and the white bass/largemouth bass index grew. The striped bass/largemouth bass index remained consistently low during the course of this study indicating minimal diet overlap. This suggests that during years of high threadfin shad productivity, competition between striped and white bass are minimal. However, during years of low shad productivity interspecific competition between striped and white bass cause white bass to exhibit feeding behaviors similar to largemouth bass. While striped bass do not directly affect largemouth bass, a year of high striped bass reproduction followed by multiple years of low productivity has potential for interspecific competition between largemouth and white bass for feeding resources.

Water Quality

Precipitation and Flow

Spring of 2005 was one of the wettest on record. The month of February provided nearly half of the mean annual rainfall for Maricopa County.

As a result Lake Pleasant was at full pool for most of spring 2005. In contrast, spring 2006 saw very little precipitation. The months of January, February, and April had no measurable rain. Striped bass require water with a considerable amount of current in order for their eggs to remain suspended during spawning. Such conditions appeared to exist as flows in the Agua Fria River in spring 2005 were the highest they have been since the construction of the New Waddell Dam in the mid 1990s. High flows flushed large amounts of debris into the Agua Fria River and subsequently the rest of the reservoir. This increased chlorophyll levels in the Agua Fria River in summer of 2005, indicating a substantial amount of productivity within this portion of the reservoir. In contrast, the following spring saw very little flow in the Agua Fria due to minimal amounts of rain.

Hydroacoustics

Hydroacoustic surveys run in 2005 showed much more productivity compared to 2006. Estimates in 2005 were more than 4 times that of 2006. There are a couple reasons that could explain such a huge difference in productivity. After the 2005 survey, it was determined that more transects were needed and the number was more than doubled to increase accuracy. Also, extreme rainfall in 2005 flushed large amounts of debris into the reservoir. The combination of fewer transects and extreme amounts of debris may have prevented accurate density estimates in 2005. In addition, many of the gill nets set during February 2005 were damaged due to debris and may have affected the percent composition of white and striped bass captured, which were used to estimate lake-wide fish numbers. In both 2005 and 2006, biomass densities were greatest in the Agua Fria River and North Basin.

Bioenergetics

Bioenergetics provides great insight on growth, consumption, and energy demands of predatory species (Hanson et al. 1997). During the course of this study it was likely that 2 growth and consumption extremes were observed. Because young-of-year striped bass were not detected in our gill nets until November, measurements were made in the fall. From fall 2004 to fall 2005, striped and white bass growth was greatest it has been since 2000 (Bryan 2005). The following year from fall 2005 to fall 2006, growth was lower than it has been since 2000. These 2 extremes provide an upper and lower range of energy demands at Lake Pleasant.

In 2005, striped bass growth rates steadily increased leading into the summer months, while rates remained relatively steady in 2006. During both years in mid-summer, striped bass growth slowed substantially and bottomed out in September. Once water temperatures cooled, however, rates increased dramatically. White bass growth had similar patterns to striped bass growth. The only difference is that in 2006, white bass growth rates decreased slightly leading into the summer months. Daily threadfin shad consumption for striped bass was greatest in the early fall during both years. The maximum daily threadfin shad consumption in 2005 was nearly 3 times that of 2006 for year 1 striped bass while consumption of other prey species remained relatively similar. White bass daily consumption of threadfin shad in 2005 was also greatest in early fall. In early fall 2006, white bass theardfin shad consumption was nearly 0. To supplement for the lack of threadfin shad, white bass increased consumption of crayfish. Both striped and white bass total energy consumption decreased from 2005 to 2006. However, the percentage decrease of energy consumed by white bass was less than that of striped bass. Because striped bass are specialists, the dependence on threadfin shad combined with the temperature extremes found at Lake Pleasant will have a much greater effect on striped bass survival. Even though white bass cannot compete with striped bass for threadfin shad, the more generalist white bass feeding strategies will improve their survival.

MANAGEMENT RECOMMENDATIONS

Promote Striped Bass Fishing

2005 produced the greatest class of striped bass since their introduction into Lake Pleasant. Now is an opportunity to take advantage and promote this fishery. According to Bryan (2005), less than 1% of all anglers target striped bass at Lake Pleasant. This same study determined that over a third of anglers are generalists that do not target a specific species of fish. In addition, there are an estimated 150 largemouth bass tournaments per year and not a single striped bass tournament. Lake Pleasant is the only inland lake that provides a white bass fishing opportunity. Also according to Bryan (2005), 10% of anglers target white bass. By increasing fishing pressure on striped bass, this would reduce competition between striped and white bass, allowing for a Lake Pleasant white bass fishery to remain.

Increase Access to Upper Agua Fria River

From December 15th to June 15th, an eagle closure prohibits anglers from reaching the upper end of the Agua Fria River. The area above the closure provides prime spawning grounds for striped bass. As such, striped bass tend to congregate in that area during the time of the closure. In order to help control striped bass populations, maintaining and possibly increasing access (i.e. boat launch) along Table Mesa Road would allow more anglers to fish in these prime striped bass areas.

Continue Monitoring Populations

Data collected towards the end of the study indicated for the first time that striped bass abundance was significantly greater than white bass abundance. Conducting fall surveys with fixed sites in the Agua Fria River as a means to monitor this trend will also provide information about spawning success as young-of-year striped bass typically are too small to be caught in gill nets until the fall.

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APPENDICES

		Aug. 2004		Nov. 2004		Feb. 2005		Aug. 2005
Effort		14.663 (0.259)		18.218 (0.477)		15.924 (0.573)		14.220 (0.192)
Common Carp		0.034 (0.014)		0.063 (0.025)		0.239 (0.073)		0.009 (0.007)
Threadfin Shad		0.056 (0.029)		2.024 (0.957)		0.357 (0.160)		0.105 (0.064)
Channel Catfish		0.025 (0.012)		0.055 (0.024)		0.037 (0.014)		0.043 (0.015)
Largemouth Bass		0.005 (0.005)		0.000 (0.000)		0.000 (0.000)		0.006 (0.004)
White Bass		0.191 (0.122)		0.215 (0.118)		0.054 (0.033)		0.357 (0.098)
Striped Bass		0.061 (0.040)		0.095 (0.031)		0.114 (0.055)		0.035 (0.013)
Crappie		0.000 (0.000)		0.000 (0.000)		0.006 (0.006)		0.096 (0.073)
Flathead Catfish		0.000 (0.000)		0.008 (0.005)		0.000 (0.000)		0.000 (0.000)
Total		0.371 (0.176)		2.460 (1.087)		0.807 (0.230)		0.6521 (0.208)
		Nov. 2005		**Feb. 2006**		**Aug. 2006**		**Nov. 2006**
Effort		18.591 (0.792)		17.820 (0.429)		15.242 (0.135)		16.611 (0.163)
Common Carp		0.083 (0.043)		0.030 (0.013)		0.038 (0.015)		0.034 (0.013)
Threadfin Shad		0.594 (0.339)		0.475 (0.319)		0.312 (0.187)		2.258 (0.652)
Channel Catfish		0.059 (0.025)		0.006 (0.004)		0.069 (0.020)		0.030 (0.010)
Largemouth Bass		0.034 (0.018)		0.003 (0.003)		0.008 (0.004)		0.005 (0.003)
White Bass		0.641 (0.473)		0.183 (0.086)		0.173 (0.081)		0.043 (0.018)
Striped Bass		0.562 (0.169)		0.139 (0.053)		0.140 (0.044)		0.321 (0.084)
Crappie		0.042 (0.025)		0.005 (0.003)		0.000 (0.000)		0.002 (0.002)
Flathead Catfish		0.007 (0.007)		0.000 (0.000)		0.000 (0.000)		0.005 (0.003)
Total		2.021 (0.945)		0.841 (0.404)		0.740 (0.237)		2.698 (0.720)

1a. CPUE by trip of 8 species of fish caught during gill netting surveys from August 2004 to November 2006.

	Aug-04				Nov-04				Feb-05				Aug-05			
	S-Q	Q-P	P-M	M-T	S-Q	Q-P	P-M	M-T	S-Q	Q-P	P-M	M-T	S-Q	Q-P	P-M	M-T
Common Carp	0	14	71	14	6	19	72	3	1	35	62	1	0	0	100	0
Channel Catfish	25	75	0	0	48	52	0	0	50	50	0	0	60	40	0	0
Largemouth Bass	0	0	0	0	14	59	27	0	47	34	18	0	39	36	24	0
White Bass	0	3	38	59	20	4	61	15	11	0	56	33	81	1	16	2
Striped Bass	45	55	0	0	60	38	2	0	71	29	0	0	100	0	0	0
Black Crappie	0	0	0	0	0	0	0	0	0	50	50	0	24	58	18	0
Flathead Catfish	0	0	0	0	0	83	17	0	0	0	0	0	0	0	0	0
	Nov-05				Feb-06				Aug-06				Nov-06			
	S-Q	Q-P	P-M	M-T	S-Q	Q-P	P-M	M-T	S-Q	Q-P	P-M	M-T	S-Q	Q-P	P-M	M-T
Common Carp	44	22	30	4	22	33	44	0	0	32	59	9	11	21	68	0
Channel Catfish	32	53	16	0	50	50	0	0	27	70	3	0	50	43	7	0
Largemouth Bass	39	40	21	0	16	43	27	14	58	31	9	2	77	14	7	2
White Bass	31	37	14	17	9	40	23	27	0	41	38	22	0	46	32	22
Striped Bass	83	17	0	0	74	26	0	0	81	17	2	0	97	3	0	0
Black Crappie	7	36	57	0	0	50	50	0	0	0	0	0	50	0	50	0
Flathead Catfish	0	67	33	0	0	0	0	0	0	0	0	0	0	100	0	0

1b. Relative stock densities for common fish found in Lake Pleasant.

	Largemouth Bass	White Bass	Striped Bass
Fish	n	n	N
Unidentified Fish	24	27	27
Threadfin Shad	25	70	123
Largemouth Bass	3	2	0
Centrarchidae	1	1	0
Common Carp	2	0	0
Green Sunfish	1	1	0
Bluegill	2	0	1
Lepomis	22	1	0
Moronidae	2	0	2
Golden Shiner	2	0	0
Black Crappie	1	0	0
Flathead Catfish	1	0	0
Inland Silverside	2	1	6
Channel Catfish	1	0	0
Invertebrates/Other	n	n	n
Crayfish	80	40	3
Gammarus	8	14	9
Diptera	128	57	32
Coleoptera	1	1	0
Corixidae	3	0	1
Daphnia	21	4	0
Ditritus	4	1	0
Eggs	1	0	0
Ephemeroptera	26	12	5
Hemiptera	1	1	1
Nematode	2	0	1
Odonota	5	0	0
Orthoptera	0	1	0
Ostracod	1	0	0
Zooplankton	8	20	20
Hymenoptera	0	0	1
Arachnid spp.	4	0	0
Empty	75	131	106
Total Stomachs	329	326	292

2a. Prey items found in diet samples for largemouth bass, white bass, and striped bass.

			Aug-04						**Nov-04**			
	Largemouth		**White Bass**		**Striped Bass**		**Largemouth**		**White Bass**		**Striped Bass**	
	Freq	N	Freq	N	Freq	N	Freq	N	Freq	N	Freq	N
Shad	0%	1	9%	32	46%	13	4%	27	37%	57	62%	45
Crayfish	0%	1	31%	32	0%	13	52%	27	2%	57	2%	45
Otherfish	0%	1	0%	32	0%	13	7%	27	4%	57	0%	45
Invertebrates	0%	1	13%	32	0%	13	15%	27	12%	57	2%	45
No ID fish	0%	1	22%	32	0%	13	4%	27	9%	57	9%	45
Empty	100%	1	34%	32	54%	13	41%	27	46%	57	31%	45

			Feb-05						**Aug-05**			
	Largemouth		**White Bass**		**Striped Bass**		**Largemouth**		**White Bass**		**Striped Bass**	
	Freq	N	Freq	N	Freq	N	Freq	N	Freq	N	Freq	N
Shad	3%	39	18%	22	21%	39	45%	44	52%	44	64%	11
Crayfish	15%	39	0%	22	0%	39	27%	44	0%	44	0%	11
Otherfish	8%	39	9%	22	5%	39	16%	44	0%	44	0%	11
Invertebrates	64%	39	36%	22	18%	39	5%	44	11%	44	0%	11
No ID fish	8%	39	0%	22	8%	39	20%	44	16%	44	9%	11
Empty	21%	39	36%	22	54%	39	23%	44	32%	44	36%	11

			Nov-05						**Feb-06**			
	Largemouth		**White Bass**		**Striped Bass**		**Largemouth**		**White Bass**		**Striped Bass**	
	Freq	N	Freq	N	Freq	N	Freq	N	Freq	N	Freq	N
Shad	0%	61	23%	53	38%	55	0%	55	12%	42	48%	44
Crayfish	25%	61	0%	53	0%	55	4%	55	0%	42	0%	44
Otherfish	2%	61	0%	53	0%	55	4%	55	0%	42	0%	44
Invertebrates	56%	61	11%	53	16%	55	71%	55	64%	42	39%	44
No ID fish	0%	61	9%	53	13%	55	4%	55	2%	42	7%	44
Empty	30%	61	58%	53	42%	55	20%	55	26%	42	16%	44

			Aug-06						**Nov-06**			
	Largemouth		**White Bass**		**Striped Bass**		**Largemouth**		**White Bass**		**Striped Bass**	
	Freq	N	Freq	N	Freq	N	Freq	N	Freq	N	Freq	N
Shad	2%	53	0%	44	27%	45	4%	49	6%	32	50%	40
Crayfish	47%	53	43%	44	4%	45	12%	49	31%	32	0%	40
Otherfish	17%	53	2%	44	16%	45	27%	49	3%	32	0%	40
Invertebrates	19%	53	16%	44	13%	45	73%	49	28%	32	18%	40
No ID fish	9%	53	0%	44	11%	45	8%	49	6%	32	10%	40
Empty	25%	53	41%	44	40%	45	6%	49	38%	32	30%	40

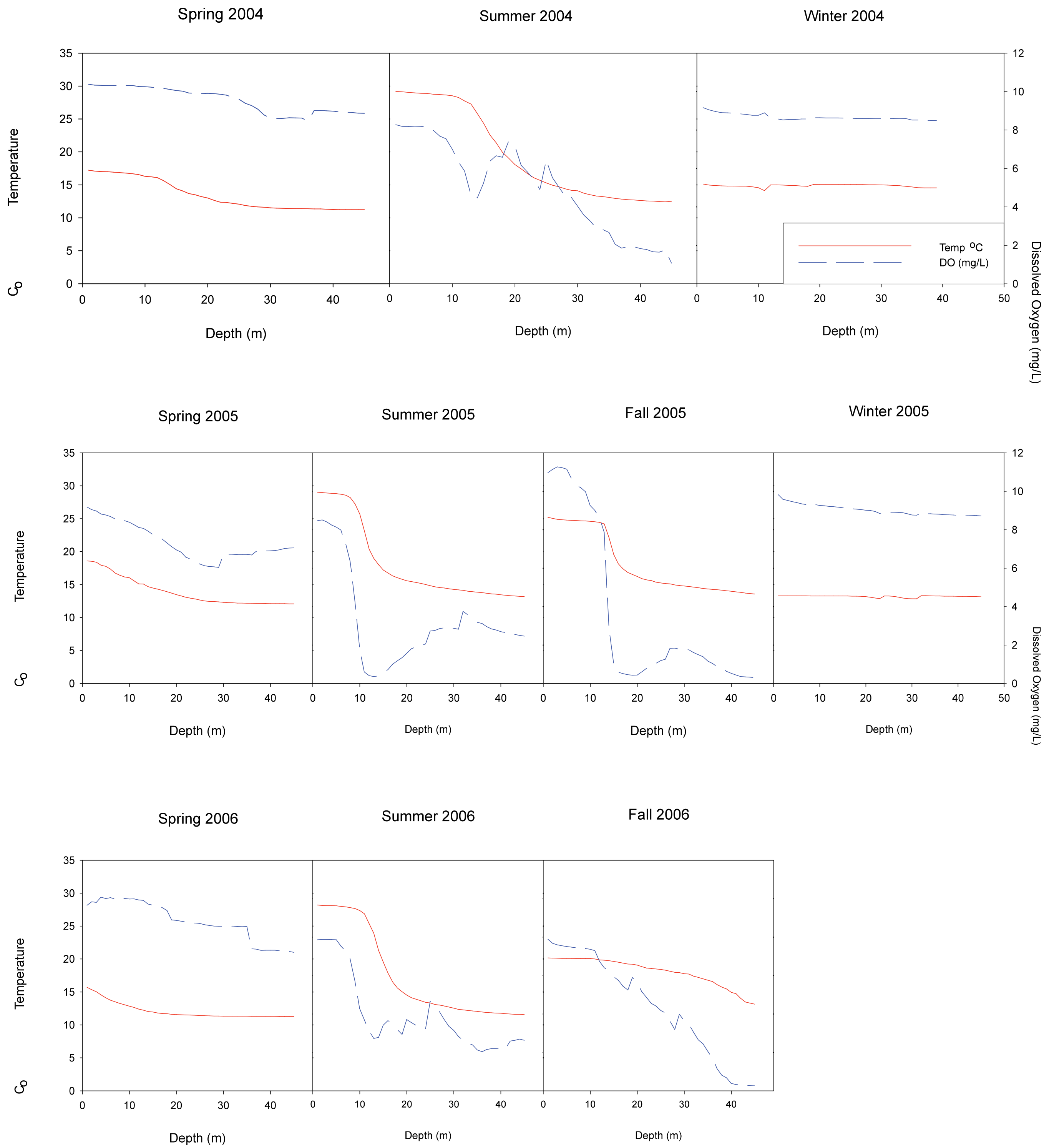
2b. Frequency of occurrence of prey categories for largemouth bass, white bass, and striped bass.

White Bass	Aug-04	Nov-04	Feb-05	Aug-05	Nov-05	Feb-06	Aug-06	Nov-06
Shad	42.86%	76.32%	28.57%	88.40%	72.73%	16.28%	0.00%	10.03%
Crayfish	46.55%	3.23%	0.00%	0.00%	0.00%	0.00%	70.18%	49.38%
Invertebrates	10.59%	16.21%	57.14%	11.60%	27.27%	83.72%	25.97%	39.97%
Other Fish	0.00%	4.23%	14.29%	0.00%	0.00%	0.00%	3.85%	0.61%
Striped Bass	**Aug-04**	**Nov-04**	**Feb-05**	**Aug-05**	**Nov-05**	**Feb-06**	**Aug-06**	**Nov-06**
Shad	100.00%	98.54%	53.18%	100.00%	80.67%	61.40%	52.69%	78.47%
Crayfish	0.00%	1.26%	0.00%	0.00%	0.00%	0.00%	7.41%	0.00%
Invertebrates	0.00%	0.20%	33.47%	0.00%	19.33%	38.60%	15.76%	21.53%
Other Fish	0.00%	0.00%	13.35%	0.00%	0.00%	0.00%	24.15%	0.00%
Largemouth Bass	**Aug-04**	**Nov-04**	**Feb-05**	**Aug-05**	**Nov-05**	**Feb-06**	**Aug-06**	**Nov-06**
Shad		6.47%	3.54%	49.47%	0.00%	0.00%	3.40%	4.78%
Crayfish		74.27%	17.23%	28.16%	29.26%	4.55%	59.70%	10.76%
Invertebrates		7.64%	71.38%	3.24%	69.19%	86.44%	8.99%	55.97%
Other Fish		11.50%	7.86%	19.13%	1.55%	9.02%	26.62%	28.49%

2c. Percent composition by weight for striped, white, and largemouth bass for all surveys.

	Basin 1	Basin 2	Basin 3
Common Carp	8	2	6
Threadfin Shad	138	0	3289
Lepomis	64	1395	114
Largemouth Bass	2	0	2
Moronidae	19	0	335
Pomoxis	108	0	59

4. Number of larval fish collected by basin (basin 1 = upper reservoir, basin 2 = lower reservoir, basin 3 = Agua Fria River).



3. Temperature and dissolved oxygen depth profiles during each season from 2004 to 2006.