Appendix G. USU Fishery Report for Cutler Reservoir (Budy et al. 2007)

An evaluation of the fish community of Cutler Reservoir and the Bear River above the reservoir with consideration of the potential for future fisheries enhancement

by

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EXECUTIVE SUMMARY

This report represents a synthesis of two years (2005 – 2006) of fisheries research in Cutler Reservoir located in northern Utah. We initiated exploratory fisheries research in July 2005, in response to the need to understand the factors determining the diversity, abundance, and distribution of fish in Cutler Reservoir, as identified by the Utah Division of Water Quality (UDEQ). We began with four primary objectives for this research project: (1) data reconnaissance: collect and synthesize all available past data for Cutler Reservoir and Bear River above Cutler Reservoir (Year 1; 2005); (2) determine the species composition and abundance of the fish community in Cutler Reservoir and the Bear River above Cutler Reservoir (2005 – 2006); (3) evaluate factors limiting the distribution and abundance of sport fish in Cutler Reservoir and the Bear River above Cutler Reservoir (2005 – 2006); and (4) evaluate options for enhancing the fishery (Year 2; 2006). In addition, components of this research compose the Master's thesis research for Kirk Dahle, to be completed in spring 2007.

To meet our objectives, Cutler Reservoir was sampled in 2006 during spring (May – June), summer (July), and autumn (October) at five index sites in the reservoir and at two sites in the Bear River: Site 1 = Highway 23, Cache Junction; Site 2 = Clay Slough; Site 3 = Benson Marina; Site 4 = Swift Slough; Site 5 = Southern Tributaries; Site 6 = Bear River above Cutler Reservoir; and Site 7 = Bear River at the Utah-Idaho border. These areas were also sampled in 2005 and were chosen as index sites because they represent a range of abiotic and biotic conditions present in the reservoir, and are associated with long-term water quality monitoring stations of the UDEQ. Here we detail the results from both years to date including information describing key abiotic and biotic factors important for understanding not only fisheries but also water quality, as well as comprehensive information on fish distribution, abundance, growth, size, age, diet, and trophic position. In addition, in this year's report, we have included detailed comparisons of fish growth, condition, and indices of stock density, size structure, and angler preference among fishes from Cutler Reservoir and other systems where the same information was available.

Physically, the reservoir was well mixed and did not stratify, due to the shallow depth overall and large fetch. However, the reservoir does demonstrate a large degree of variability in physical (e.g., dissolved oxygen) and biological (e.g., productivity) conditions. In 2006, seasonal mean reservoir temperature was 18.6 ^{o}C in spring, 26.5 ^{o}C in summer, and 11.4 ^{o}C in autumn with a maximum temperature of 31 ^{o}C. Our sampling indicated that dissolved oxygen (DO) levels were generally suitable (greater than 5 mg/L) for fish at all sites and depths in Cutler Reservoir, but summer readings were as low as 4.6 mg/L at sites 1 (Highway 23), 2 (Clay slough), and 3 (Benson marina). Nitrogen levels varied greatly seasonally across reservoir sites, but at Site 5 (Southern tributaries), nitrate-nitrite concentrations reached nearly double the concentrations observed in summer 2005 and a 2- to 20-fold increase over other sites; this large influx of inorganic nitrogen is common at sample stations downstream of ski resorts or agricultural lands. In contrast, phosphorus levels varied little by site and season; however, TP was highest during summer periods at all sites and phosphorus levels were elevated at Site 3, Benson marina. In 2005, bacteria (as *E. coli*) concentrations were greatest at the riverine site just above the reservoir (Site 6, Bear River above Cutler Reservoir) where concentrations were two- to three-times higher than the other sites on average. The largest degree of temperature and DO variation occurred at Site 5 and was likely due to the influence of nearby multiple stream and spring inflows as well as elevated nutrient inputs.

As with nutrients and physical parameters, primary and secondary productivity is quite variable across space and time in Cutler Reservoir. Chlorophyll *a* levels (an index of primary productivity) varied across sites and ranged from a high of 64.8 μg/L ($\pm$ 1 SE = 1.7) at Site 4 (Swift slough) in summer 2006 to 2.1 μg/L ($\pm$ 0.04) at Site 4 in spring 2006. Based on general classification standards and our August sampling, Cutler Reservoir would be classified as eutrophic according to chlorophyll *a* levels and mesotrophic according to total nitrogen concentrations. Phytoplankton growth is likely phosphorous limited as indicated by the high N:P ratio (greater than 400:1). In terms of secondary production, eight different genuses of cladocerans and several taxanomic groups of copepods were captured in the reservoir. Zooplankton density varied greatly by site and season, ranging from 0 zooplankters/L at Site 5 in autumn 2006 to 5 zooplankters/L at Site 5 in summer 2006. Zooplankton biomass ranged from 0 mg/L at Site 5 in autumn 2006 to 23.8 mg/L at Site 3 during summer 2006. Interestingly, whereas *Daphnia* dominated the summer zooplankton biomass in summer 2005, moinids (e.g., *Moina* and *Moinadaphnia*) dominated (90%) the biomass in summer 2006 . Moinids may be aquatic health bioindicators and appear in high concentrations in pools, ponds, lakes, ditches, slow-moving streams and swamps where organic material is decomposing; they are generally quite tolerant of poor water quality, living in water where DO-levels vary from almost zero to supersaturation. Despite the generalities provided here, owing to the multiple, diverse input sources and reservoir morphology, Cutler Reservoir is a very heterogeneous environment in terms of primary and secondary productivity.

The fish community of Cutler Reservoir and the Bear River above Cutler Reservoir is abundant, diverse, and demonstrates a high, overall biomass of fish. In comparison to limited data from past fish surveys, in Cutler Reservoir, we were able to quantify or provide indices of abundance and other metrics for all fish species. Across the two years of the study, we captured 14 different species of fish including centrarchids, catfish, percids, minnows, suckers, salmonids, and whitefish. While carp made up the greatest proportion of the total biomass in both years (62.9 – 69.5% of biomass), walleye (5.1 - 14.8%) and catfish (11.7 – 19.2%) also comprised a considerable proportion of the biomass and were present at most sites. Of the 14 fish captured in 2006, four (29%) species are classified as Intolerant or Moderately Intolerant and ten (71%) are classified as Moderately Tolerant or Tolerant to degradation of water quality. According to this criteria applied to Cutler Reservoir, smallmouth bass and walleye may be valuable indicator species regarding toxicity of water.

In addition to this high abundance and diversity of fish, we also observed relatively high growth rates and a substantial number of large-sized sport fish with potential for providing a warmwater trophy fishery in Cutler Reservoir. Captured walleye were as large as 800 mm (5 kg) and channel catfish were as large as 795 mm. Walleye grew rapidly to large sizes, and growth was generally greater compared to other systems. Growth rates of channel catfish bserved in Cutler Reservoir are moderate but typical of other reservoirs with similar growing seasons, while crappie growth rates, like walleye, were in the mid to upper range of growth rates observed for other populations across their distribution. In addition, despite some variability across species and sites, fish condition was generally at or above average with K-values greater than 1 and relative weight (W_r) values above the national standard (100). In contrast, although most age and size classes were present, both length-frequency assessment and proportional stock density values indicate that recruitment was poor for walleye and green sunfish; the walleye, channel catfish, black crappie, and common carp populations were all dominated by large fish, while the largemouth bass, smallmouth bass, bluegill, green sunfish, and bullhead populations were dominated by small fish. In terms of age and origin of walleye, otoliths from a subsample of walleye were aged and checked for otolith dye (oxytetracyclene) marks by Idaho Department of Fish and Game (IDFG); of the 73 otoliths checked, seven (or ~ 10%) were dye marked indicating they originated in Idaho and moved down to Cutler Reservoir. This downstream movement of walleye into Cutler Reservoir, in addition to the rapid growth rates (reaching large sizes in their first year) we observed, aide in explaining why we see limited evidence of walleye recruitment in Cutler Reservoir.

Carp and catfish comprised an important diet item for the predominant piscivores in Cutler Reservoir, but aquatic insects, zooplankton, and vegetation also made up a large proportion of the diet, and catfish were observed to be eating mice. Walleye appeared to shift prey based on relative abundance, and switched from carp and catfish to minnows based on availability. Stable isotope ratios of ^{15}N generally corroborated diet information and were the highest in walleye, large-sized (> 150 mm TL) crappie, and largemouth bass muscle tissue indicating consumption at a higher trophic level, as compared to other fish ratios of ^{15}N in small crappie, bullhead, catfish, and carp muscle tissue, indicating consumption at an intermediate trophic level. Fishing pressure on Cutler reservoir is low to moderate and is concentrated around road access points (bridges). Boat angling is negligible, and most bank anglers are bait fishing for channel catfish and black bullhead as their primary target species. Nationally and on Cutler Reservoir, more sportsmen appear to view carp less exclusively as “trash fish”, but also as an exciting species to hunt.

Lastly, in 2006, we initiated preliminary exploratory analyses of statistical models that would best describe the relative distribution and abundance of the dominant fishes of Cutler Reservoir. Walleye abundance (CPUE) was highly correlated with chlorophyll *a*, TKN, conductivity, and abundance indices (CPUE) of prey (catfish, crappie, and minnow), but surprisingly showed little correlation to carp CPUE. Crappie abundance (as indicated by CPUE) was highly correlated with NH_4, pH, and walleye CPUE. As predicted, carp were strongly and positively correlated with many abiotic and biotic variables demonstrating their wide tolerance to a range of conditions. Future analyses will include the identification of the most parsimonious regression model describing walleye and crappie abundance and distribution with detailed consideration of autocorrelation and interactions among response variables. In addition, the pending Master’s thesis of Kirk Dahle will include a spatially explicit quantification of the bioenergetics-based growth potential of the primary sport fishes of Cutler Reservoir. Completion of these final analyses, in combination with discussion with Utah Division of Wildlife Resources (UDWR) and UDWQ regarding fishery goals, will lead to the conclusion of our final objective, consideration of options for enhancing the fishery of Cutler Reservoir in the future.

INTRODUCTION

Reservoir fisheries are shaped by both biotic and abiotic factors, and identifying these factors and understanding their relative importance is a major goal in fisheries research today (Presson 1995; Jackson et al. 2001; Quist 2005). In the broadest sense, physical variables such as temperature and water chemistry determine which species of fish can successfully inhabit a water body (Tonn et al. 1990). In natural systems, a series of hierarchical filters "screen" the global fish community beginning with broad geographic filters and ending with species specific physiological tolerances, and ultimately this screening process determines the community structure within a particular water body (Tonn and Magnuson 1982). Anthropogenic influences remove much of the geographic filter through the transportation and introduction of fish species; however, at other levels, the structure of these altered communities is determined by much the same screening process. In addition to physical screens, the role of biological interactions, particularly predation, can influence the presence or absence of fish species within a system (Tonn et al. 1990).

One measure of the suitability of a water body for a particular fish species is growth potential (Brandt 1993). Temperature and food availability act in combination with species specific physiological processes to directly influence the observed growth rate (Kitchell 1977). Slight temperature deviations above or below the physiological thermal optima of a species can result in increased metabolic demands, increased physiological stress, and a subsequent reduction in individual growth rate (Jackson et al. 2001). In addition, in order for an individual to achieve its maximum growth rate, optimum thermal conditions must be coupled with food resources sufficient to meet the consumption demands of the fish (Hansen et al. 1993). Further, both the amount and type of food resources required may change across life stages of a fish as many fishes undergo ontogenetic shifts (Post 2003). High growth rates that result in large body size positively influence the reproductive success (Helfman et al. 1999) and probability of survival of fishes. As such, achieving high individual growth rates can determine a fish species likelihood of persistence in a specific water body. Additionally growth potential provides a surrogate for habitat suitability, as positive fish growth only occurs in habitats that meet or exceed the minimum requirements of the species (Boisclair 2001).

Bioenergetics modeling uses the inputs of thermal history, growth, diet, and a balanced energy budget to predict the consumption and growth potential of an individual fish (Hanson et al. 1997). Bioenergetics modeling has diverse ecological, and management applications which include, for example, estimating the impacts of introduced predators on prey populations (Ruzycki et al. 2003), estimating appropriate stocking rates of predatory game fish (Liao et al. 2004), and estimating the growth potential of fish populations (Brandt et al. 1992). Bioenergetics modeling incorporates physical and biological factors that affect fish growth and in doing so provides a tool to link the habitat conditions of a system mechanistically to the growth potential of fish inhabiting that system (Brandt and Kirsch 1993). As such, in systems where little is known about factors regulating the fisheries, a bioenergetics modeling framework can provide a rich data set for investigating community composition, trophic status, and potential predator-prey interactions. While bioenergetics studies are traditionally undertaken on systems for which considerable data are already available, their application as an exploratory tool provides investigators with robust quantitative estimates of predator-prey relationships and growth potential that are useful for understanding dynamic aquatic ecosystems (Ney 1993; Vatland et al., *in press*).

A common limitation in most fisheries studies in large reservoirs has been a lack of spatial resolution, a distinct limitation in large heterogeneous systems. As the control of metabolic rate in ectotherms, temperature plays the most influential role in regulating the growth potential of fishes. Traditionally, temperature data have been measured at a few discrete index sites and then extrapolated to the entire area. Homogenizing thermal conditions in this manner underestimates the heterogeneity of complex aquatic systems and reduces the accuracy of bioenergetics modeling (Brandt et al. 1992; Brandt and Kirsch 1993; Ney 1993). Increasingly, the importance of spatially delineating the heterogeneity of aquatic habitats is being recognized as an essential step in quantifying the nonlinear relationships present in the fish growth potential of a system (Brandt 1992). Brandt and Kirsch (1993) showed that averaging thermal gradients within Chesapeake Bay gave bioenergetics outputs that bore little resemblance to their spatially explicit data set for the same area and time period. After taking thermal stratification and water quality parameters into account, areas that provided positive growth potential of striped bass (*Morone saxatilis*) were restricted to a small portion of the metalimnion, indicating that suitable habitat was actually limited.

Remote sensing techniques have transformed data collection in terrestrial environments through their ability to collect data as a continuous variable across landscapes (Roughgarden 1991). However, remote sensing data collection in aquatic habitats has been slower to develop due to detection issues associated with the complex underwater environment (i.e., deep water or three dimensional space; Steele 1978). In aquatic systems that do not display thermal stratification, such as streams, the use of remote sensing techniques has proven useful. Shallow lentic systems, such as Cutler Reservoir, which demonstrate little stratification also make likely candidates for remote data capture of thermal conditions. As growth potential provides a surrogate for habitat suitability (Boisclair 2001), this process can provide a quantitative measure of the amount of suitable habitat present within the system, as well as a means of estimating the total growth potential for species of interest or concern.

While temperature and diet are the primary determinates for estimating growth potential, other water quality parameters such as dissolved oxygen, water clarity, and biotoxin levels can also affect the growth potential experienced by a fish in a specific habitat (Rajotte 2002; Sherwood et al. 2000, 2001). Fish tolerance to low dissolved oxygen levels differs by species, and in extreme cases, low dissolved oxygen can limit the amount of suitable habitat available. In addition, water clarity can also affect the foraging success of a predator (Werner and Hall 1988; Koski 2002) and therefore influence the growth potential of a habitat. Further, Rajotte (2002) found that lakes containing high heavy metal concentrations had lower growth potential for native yellow perch (*Perca flavescens*) populations; the reduction in growth potential came as a consequence of higher metabolic demands caused by the stress of exposure to toxic heavy metals. Finally, biotic interactions have also been shown to affect the growth potential of individual fish species. For example, Werner and Hall (1988) showed that juvenile bluegill sunfish (*Lepomis macrochirus*) were faced with a feeding-rate-predation -rate tradeoff that resulted in use of littoral habitats by juvenile fish, even though pelagic habitats provided greater growth rates. This reduction in realized growth is an example of an indirect affect of predation.

Introduced species and habitat alterations, common in impoundments, can affect the dynamics of aquatic communities. In particular, reservoirs in the western United States create lacustrine conditions for which native riverine fish species are ill adapted. As a result, piscivorous game fish, and prey species to provide suitable forage for these game fish, are commonly introduced to establish popular sport fisheries. Many of these reservoirs are trophically simple (e.g., Wydoski and Bennett 1981), and fish production is primarily sustained by pelagic food webs (O'Brien et al. 1990; Jones et al. 1994). However, the outcome of fish introductions varies greatly due to the complexity and alternative routes of energy (Vander Zanden and Vadeboncoeur 2002) and considerable spatial heterogeneity typically associated with large lentic systems (e.g., Hall and Van Den Avyle 1986).

Key species can greatly drive the dynamics and composition of aquatic communities. The term ecosystem engineer was coined by Jones et al. (1994) to describe the role that some organisms play in the direct or indirect control of resource availability within a system. In a review of the topic, Cooks (2002) included the common carp *Cyprinus carpio* as a common ecosystem engineer in North American aquatic systems. Carp can reduce the presence of submerged aquatic vegetation resulting in increased turbidity and nutrient levels (Miller and Crowl 2006). Further, increased turbidity and nutrient levels created by foraging carp can alter primary productivity rates and subsequently influence zooplankton community structure (Lougheed et al. 1997). Since the fish community of Cutler Reservoir is dominated by carp, this species likely plays an important role in structuring the aquatic community of the system.

We had four primary objectives for this research project: (1) data reconnaissance: collect and synthesize all available past data for Cutler Reservoir and Bear River above Cutler Reservoir (Year 1; 2005); (2) determine the species composition and abundance of the fish community in Cutler Reservoir and the Bear River above Cutler Reservoir (2005-2006); (3) evaluate factors limiting the distribution and abundance of sport fish in Cutler Reservoir and the Bear above Cutler Reservoir (2005-2006); and (4) evaluate options for enhancing the fishery (Year 2; 2006).

SUMMARY of PAST FISHERIES SURVEYS

Past fisheries surveys on the Bear River and Cutler Reservoir were infrequent, non-quantitative, and sporadic. The best compilation of fisheries data on the system was reported by Ecosystems Research Institute under contract to the Bear River Resource Conservation and Development Council (ERI 1995). That report relies heavily on earlier reports (Bangerter 1965; PEO 1991), personal communications, and unpublished data; and in this summary, we draw directly from that report.

Sampling by the Utah Division of Wildlife Resources in the 1960s detected Utah sucker (*Catostomus ardens*), green sunfish (*Lepomis cyanellus*), black crappie (*Pomoxis nigromaculatus*), and walleye (*Sander vitreus*) both above and below the reservoir. Brown trout (*Salmo trutta*), channel catfish (*Ictalurus punctatus*), and largemouth bass (*Micropterus salmoides*) were only found below the reservoir, whereas albino rainbow trout (*Oncorhynchus mykiss*), carp (*Cyprinus carpio*), and yellow perch (*Perca flavescens*) were only found above the reservoir.   During that time period, channel catfish were stocked every other year. In the 1960s, Cutler Reservoir was dominated by carp (Bangerter 1965); however, in the 1970s, numbers of largemouth bass and black bullhead (*Ameiurus melas*) increased, and fathead minnows (*Pimephales promelas*) were first detected (*see* ERI 1995).   From 1965 to 1990, species richness greatly increased (*see* ERI 1995). In the spring 1990, carp dominated catches throughout the reservoir, and high numbers of fathead minnows and green sunfish, and few catfish were captured. In summer 1990, carp dominated, and high abundances of black crappie, largemouth bass, and smallmouth bass (*M. dolomieu*) were observed. In 1990, bluehead suckers (*Catostomus discobolus*) were also captured.

STUDY SITE

The study area is a privately-owned reservoir located in the Newton Quad in Cache Valley (Box Elder and Cache counties; 41°50' N 112°02' W), Utah. Cutler Dam, built by Utah Power and Light (now owned by Pacific Corp) in 1927, is located in a gorge about 13 miles northwest of Logan, Utah in the Wellsville mountains separating Cache and Great Salt Lake valleys. The dam is a concrete gravity arch 545 feet wide and 112 feet high with an irrigation canal intake structure in each abutment and a spillway section. Spillway capacity is 22,000 cfs (ASDSO 1989). The postulated probable maximum flood inflow is 195,500 cubic feet per second (cfs), and the outflow of record was 12,700 cfs in 1986.

Cutler Dam impounds the waters of the Bear, Logan, and Little Bear rivers as well as Spring Creek and many, other small drainages. The Bear River enters the reservoir from southeast (Figure 1). Cutler Reservoir is approximately 19 km long with a maximum capacity of 23,802 acre-feet. At elevation of 1343.6 m ("normal") above sea level, the surface area of Cutler Reservoir is 9,601,200 m^2 or about 9.6 km^2. However, backup from the dam has produced open water and associated wetlands and uplands (referred to as the Cutler Marsh Wetlands Maze) encompassing over 4,000 hectares (10,000 - 15,000 acres; BAS 2004).

Pacific Corp Utah Power currently operates the Cutler Dam Hydroelectric Project under authorization granted by the Federal Power Act, and under the jurisdiction of the Federal Energy Regulatory Commission (FERC No. 2420). The primary obligation of the Cutler Dam Project is to provide water for agricultural use. Power generation is a secondary obligation. The marsh and surrounding lands (Cutler Marsh Wetlands Maze) are managed by Utah Power to protect and enhance flora and fauna, and their habitat. The company also provides recreation opportunities (e.g., canoeing, hunting, fishing, and bird watching) and traditional agricultural land uses such as grazing and irrigation storage (BAS 2004).

Urban development comprises less than 1.5% of the total area in the lower Bear River basin. Most of this urban development in the lower basin occurs within Utah. Confined animal feeding operations (CAFOs) are typically clustered along waterways in the valleys of the basin. Over 200 CAFOs, averaging about 65 animals per operation, are identified in the portion of the project area above Cutler Dam. About 16% of the total watershed drains to the Bear River before it crosses the Utah-Idaho border. Approximately half of the total watershed (890,000 acres) drains to the Bear River as it moves through Cache Valley from the Utah-Idaho border to Cutler Dam. Almost two-thirds of this land is National Forest, and about 22% is in identified agricultural uses. About 543,000 acres drain to the Bear River below Cutler dam, most of which enters through the Malad River drainage. The corridor of the mainstem Bear River passes through broad floodplains dominated by grazing, pasture lands, and dairy operations. About 50% of the land is in agricultural use, of which two-thirds are irrigated (UDEQ 2004). Throughout the entire reach, irrigation return flows drain back to the river. Point sources along the mainstem Bear River include seasonal effluent from a cannery just north of the Utah-Idaho border, and effluent from Logan's wastewater treatment facility, which discharges into a slough upstream of Cutler Reservoir. The towns of Logan, Smithfield, Hyde Park, North Logan, Providence, and River Heights send sewage to this facility, representing 70% of the population in the valley. In addition, all septic tanks in the county are hauled to the lagoons. Current capacity is expected to handle demands until approximately 2007 according to the Logan City Engineering Office.

Cutler Reservoir and the associated wetland contains a varied fish community: largemouth bass, smallmouth bass, black crappie, green sunfish, bluegill sunfish (*Lepomis macrochirus*), channel catfish, walleye, black bullhead, common carp, fathead minnow, Utah sucker, cutthroat trout (*Oncorhynchus clarkii*), and brown trout. Yellow perch and bluehead suckers were captured in historical accounts, but have not been detected in our recent sampling. The Utah state record black bullhead (16 inch; 406 mm; 3 lb 4 oz; 1.47 kg) was caught in Cutler Reservoir in 1999 (UDWR 2006).

A small sample of walleye and channel catfish tested from Cutler Reservoir in 2003 contained elevated levels of PCBs, dioxin/furans, pesticides, and mercury; however, consumption of fish from Cutler Reservoir is considered only an indeterminate health hazard (Scholl 2005).

In 2006, Cutler Reservoir was sampled in spring (May – June), summer (July), and autumn (October) at five index sites in the reservoir and at two sites in the Bear River: Site 1 = Highway 23, Cache Junction; Site 2 = Clay Slough; Site 3 = Benson Marina; Site 4 = Swift Slough; Site 5 = Southern Tributaries; Site 6 = Bear River above Cutler Reservoir; Site 7 = Bear River at the Utah-Idaho border (Figure 1). These areas were also sampled in 2005 and were chosen as index sites because they represent a range of abiotic and biotic conditions present in the reservoir, and are associated with long-term water quality monitoring stations of the UDEQ.

METHODS

Limnological sampling

We measured and recorded water temperature (^{o}C), conductivity (μS/cm), total dissolved solids (TDS), pH, salinity (% solution), turbidity, and dissolved oxygen (DO; mg/L) levels at seven index sites seasonally in 2006. Water clarity (m, secchi depth) and epilimnetic (0.5 m) chlorophyll *a* were used as an index of reservoir primary productivity.

In the field, we sampled pelagic zooplankton seasonally at each index site at the same time that water chemistry samples were taken. We collected triplicate zooplankton samples from each index site using a 1.5-m integrated tube sampler with a 7.5-cm inside diameter (6.5-L total volume; Rabeni 1996). We sampled and filtered 13 L of water with each replicate, depending on depth. We sieved samples through both 500- and 80-μm mesh zooplankton nets, preserved them in a Lugol's solution, and brought samples back to the laboratory for identification, enumeration, and measurement.

In the laboratory, we subsampled (if necessary, into aliquots [mL] using a Henson-Stimpler pipette) and enumerated zooplankton samples. We measured individual zooplankters using an ocular micrometer under a microscope, and identified zooplankton to a minimum of genus level. We grouped rotifers (all species combined) and measured a subsample. We also grouped calanoid and cyclopoid nauplii and measured a subsample. For cladocerans, we measured length from the tip of the rostrum to the end of the body, excluding spines. For copepods, we measured length from the tip of the head to the insertion of the caudal ramus. We determined zooplankton density (number/L) for each species, and estimated biomass (μg/L) based on established length-to-weight relationships (Dumont et al. 1975; McCauley 1984; Pauli 1989).

Fish Sampling

During 2006, we sampled fish at seven sites on three separate occasions; (1) in late May and early June representing spring season, (2) in July representing summer season, and (3) in October representing autumn season. In this type of fixed-station sampling, specific index sites were selected to be representative sites of the overall reservoir and are associated with long-term water quality monitoring stations of the UDEQ.

Fish sampling gear was chosen based on study objectives to determine the species composition, distribution, and abundance using a combination of active (e.g., electrofishing, beach seining) and passive (e.g., gill nets, trap nets) gears suitable for Cutler Reservoir (*see* Murphy and Willis1996). All gears have inherent selectiveness, biases, and shortcomings; therefore, gear type, gear quantity, and set duration were optimized to reduce bias as much as possible. Gill nets are used to sample fish in a wide variety of habitats and are especially selective for species that move substantial distances in their daily movements (e.g., walleye). Trap nets (modified fyke nets) are used to efficiently sample cover-seeking, mobile species (e.g., crappies), and species that tend to follow shorelines. Electrofishing at various pulse rates is effective for capturing fishes such as percids, centrarchids, ictalurids, and cyprinids, basically all species found in Cutler Reservoir. Seining is efficient in capturing littoral (i.e., shoreline) zone species associated with cover (e.g., minnows, juvenile carp, small sunfish).

We set three gill nets (various-mesh “experimental” monofilament gill nets; 1.8 m X 40 m; 8 panels containing 19 - 64 mm bar mesh in 6-mm intervals) and modified trap nets in the evening and pulled gear the following morning, spanning two crepuscular periods. We placed gear in areas and at depths where fish were found to be most abundant, generally set just off shore.

Seining was conducted using a 1.22 x 4.6, or 1.22 x 9.15 meter seine constructed with 3.2 mm mesh. We measured seine haul horizontal distance (length) and average depth at center of haul.

Electrofishing was conducted using a boat-mounted electrofisher. We attempted to keep all electrofisher settings the same between sites and sample periods. During reservoir electroshocking, three to six 100-m transects were selected at random, measured (horizontal shoreline distance and elapsed time to complete transect), and electrofished after sundown at each sample site during each sample period (spring, summer, and autumn). At Bear River sites (6 and 7), four 100-m transects were electroshocked at each sampling location during spring, summer, and autumn. Again, we measured transect length and the duration spent electrofishing.

We used fish catch data from all gear types to evaluate temporal and spatial distribution and abundance of fishes and to evaluate temperatures experienced by the fish.   We calculated catch-per-unit-effort for gill-net, trap-net, and electrofishing catches at each sample site for each species of fish.   We determined density (fish per m^2) of fishes captured during seining.

Fish demographics

We weighed (nearest g) and measured (nearest mm TL) all captured fish. We calculated length-weight relationships, and computed condition of all fish using two indices: Fulton's K (K_{TL}) and relative weight (W_r)

$$\text{Fulton's } K_{TL} = W / L^3 \times 100{,}000$$

$$W_r = 100 \times (W / W_s)$$

We then compared these calculations seasonally and temporally when sample sizes were adequate.   Equations and values for W_s were obtained from the literature (Anderson and Neumann 1996; Bister et al. 2000). A W_r of 100 is generally accepted as the "national standard". Calculations of W_r exclude young-of-year fishes.

Fish ageing and growth

We inferred fish growth from analysis of length-frequency trends, and removed and prepared a subset of scales and otoliths for microscopy. Walleye otoliths were aged and checked for origin by Idaho Department of Fish and Game.   Black crappie scales were aged at the Fish Ecology Lab at USU.

Fish stock density indices

We determined the proportional stock density (PSD) for each warmwater fish species following procedures outlined in Anderson and Neumann (1996). We calculated PSD as

$$\text{PSD} = \frac{\text{number of fish} \geq \text{minimum quality length}}{\text{number of fish} \geq \text{minimum stock length}} \times 100.$$

Values of PSD range from 1 to 100, and PSD is a numerical descriptor of length-frequency data and can provide insight into population dynamics. For most fish, 30 - 60 or 40 - 70 are typical objective ranges for "balanced" populations. Values less than the objective range indicate a population dominated by small fish, while values greater than the objective range indicate a population comprised mainly of large fish.

Stock and quality lengths, which vary by species, are based on percentages of world-record lengths (Gabelhouse 1984). Stock length (20 - 26% of world-record length) refers to the minimum size fish with recreational value, whereas quality length (36 - 41% of world-record length) refers to the minimum size fish most anglers like to catch.

Table 1. Length categories (in inches and millimeters) proposed for various fish species (Gablehouse 1984). Measurements are minimum total lengths.

	Category									
	Stock		Quality		Preferred		Memorable		Trophy	
Species	in	mm	in	mm	in	mm	in	mm	in	mm
Walleye	10	250	15	380	20	510	25	630	30	760
Channel catfish	11	280	16	410	24	610	28	710	36	910
Black crappie	5	130	8	200	10	250	12	300	15	380
Largemouth bass	8	20	12	300	15	380	20	510	25	630
Smallmouth bass	7	180	11	280	14	350	17	430	20	510
Bluegill	3	80	6	150	8	200	10	250	12	300
Green sunfish	3	80	6	150	8	200	10	250	12	300
Black bullhead	6	150	9	230	12	300	15	380	18	460
Common carp	11	280	16	410	21	530	26	660	33	840

We evaluated the relative stock density (RSD) using the five-cell model proposed by Gabelhouse (1984; Table 1). Preferred length (45 - 55% of world-record length) refers to the minimum size fish anglers would prefer to catch when given a choice. Memorable length (59 - 64% of world-record length) refers to the minimum size fish most anglers remember catching, whereas trophy length (74 - 80% of world record length) refers to the minimum size fish considered worthy of acknowledgment . Like PSD, RSD can provide useful information regarding population dynamics, but is more sensitive to changes in year-class strength. We calculated RSD as

$$\text{RSD} = \frac{\text{number of fish} \geq \text{specified length}}{\text{number of fish} \geq \text{minimum stock length}} \times 100.$$

For example, RSD-Preferred (P) was the percentage of stock length fish that were also longer than preferred length, RSD-Memorable (M), the percentage of stock length fish that were also longer than memorable length, and RSD-Trophy (T) as the percentage of stock-length fish that were also longer than trophy length.

Stomach diet analysis

Fish stomach, excluding intestine, contents were identified to species of prey fish (when possible) and zooplankton, whereas terrestrial invertebrates and organic matter were classified explicitly. Aquatic invertebrates were identified to order. Prey fish were identified to species, counted, and weighed (blot-dry wet weights to nearest 0.001 g), while invertebrate prey were weighed *en masse* by classification. Intact prey fish were measured to the nearest mm (total, standard, or backbone length).

Stable isotope analysis

In addition to examining a predator diets short term based on stomach contents, we quantified the longer-term dietary habits of a subset walleye (n = 16), crappie (n = 31), largemouth bass (n = 8), catfish (n = 22), bullhead (n = 20), carp (n = 20), and brown trout (n = 1) using stable isotope analysis. Specifically, we assessed fish trophic position and dietary carbon source based on the respective ^{15}N and ^{13}C levels (relative to their respective lighter isotopes, ^{14}N and ^{12}C) of dorsal muscle tissue (Post 2002). Stable isotope makeup was also quantified for zooplankton (n = 17), and phytoplankton (n = 9). To do this, we dried tissue for 24 - 48 h at 60°C, ground it to a powder, and shipped encapsulated samples to the University of California-Davis Stable Isotope Facility for a mass spectrometry-based determination of isotopic signatures. Ratios (^{15}N:^{14}N and ^{13}C:^{12}C) were evaluated and are expressed as $\delta^{13}C$ and $\delta^{15}N$, per mille (‰) values relative to the ratios of the standards Pee Dee Belemnite and atmospheric N_2, respectively.

Statistical correlations

We initiated preliminary exploratory analyses of statistical models that would best describe the relative distribution and abundance of the dominant fishes of Cutler Reservoir. We were especially interested in the variables that best explained the distribution and abundance of walleye and crappie, the dominant sport fishes thought to be most sensitive to water quality. We started first with a simple correlation matrix among abiotic (e.g., temperature, nutrients), biotic, and fish response variables using correlation coefficient (r) of > 0.5 as an arbitrary cut off for correlations likely to be biologically meaningful, and including all available data across both years and sites.

RESULTS and DISCUSSION

Limnological sampling

Temperature and dissolved oxygen

Owing to the shallow depths in Cutler Reservoir, no thermocline was apparent.   Late summer temperature varied by site and depth, ranging from nearly 31 ^{o}C at the surface at Site 3 to 23 ^{o}C at the bottom (2.0 m) at Site 5 (Figure 2).   In 2006, seasonal mean reservoir temperature was 18.6 ^{o}C in spring, 26.5 ^{o}C in summer, and 11.4 ^{o}C in autumn (Figure 3). Our sampling indicated that dissolved oxygen (DO) levels were generally suitable (> 5 mg/L) for fish at all sites and depths in Cutler Reservoir; however, summer readings were as low as 4.6 mg/L at sites 1, 2, and 3. Dissolved oxygen generally declined with depth, ranging from a high of 19.4 mg/L at 0.5 m at Site 4 in autumn 2006 to 4.6 mg/L at Site 3 in summer 2006.   In 2006, seasonal mean reservoir DO was 7.6 mg/L in spring, 7.5 mg/L in summer, and 13.4 mg/L in autumn (Figure 4). The largest degree of temperature and DO variation occurred at Site 5 and was likely due to the influence of multiple stream inflows nearby.

Water clarity and turbidity

Water transparency, measured as Secchi depth within Cutler Reservoir, varied seasonally by site, ranging from a high of 0.9 m at Site 4 in autumn 2006 to 0.22 at Site 5 in summer 2006 (Figure 5).   In 2006 among reservoir sites, Secchi depth was generally deepest at Site 4, Swift slough, and turbidity was lowest at Site 4 (Figure 5).

Salinity and pH

Trends in pH were similar in Cutler Reservoir during the summers 2005 and 2006; pH was highest at Site 4 and lowest at Site 5 (Figure 6).   During all sample periods in the reservoir, salinity was lowest at Site 4 and highest at Site 2, Clay slough (Figure 6). Salinity was always higher at Bear River sites versus reservoir sites (Figure 6)

Nutrients

In general, phosphorus levels varied little by site and season; however, TP was highest during summer periods at all sites, and phosphorus levels were elevated at Site 3, Benson marina (Figure 7) . Nitrogen levels, nevertheless, varied greatly seasonally across reservoir sites. At Site 5 (Southern tributaries), nitrate-nitrite concentrations reached 2100 ppb in autumn 2006; almost double the concentrations observed in summer 2005 and a 2- to 20-fold increase over other sites (Figures 3 and 4). This large influx of inorganic nitrogen is common at sample stations downstream of ski resorts or agricultural lands (M. Palmer, High Sierra Water Labs, *personal communication*). Further, as in 2005, Site 5 had the lowest TKN, (134 ppb in autumn) , at least one-half or one-tenth the TKN concentrations at other reservoir sites (Figure 7). Within the reservoir proper, TN (sum of NO_3, NO_2, and TKN) ranged from 403 ppb at Site 4 (Swift slough) in spring 2006 to 2574 ppb at Site 5 in summer 2006 (Figure 7). As with temperature and DO, the largest degree of nutrient variation occurred at Site 5 (likely due to the influence of nearby multiple stream inflows) and in the Bear River at Site 6 (Figure 7).

Primary productivity

Chlorophyll *a* levels (an index of algal biomass and primary productivity) varied across sites and was the inverse of trends in TKN. Within the reservoir chlorophyll *a* concentrations ranged from a high of 64.8 μg/L (± 1 SE = 1.7) at Site 4 (Swift slough) in summer 2006 to 2.1 μg/L (± 0.04) at Site 4 in spring 2006 (Figure 9).

Based on general classification standards (Wetzel 2001) and our August sampling, Cutler Reservoir would be classified as eutrophic according to chlorophyll *a* levels and mesotrophic according to total nitrogen concentrations; phytoplankton growth is likely phosphorous limited as indicated by the high N:P ratio (greater than 400:1). However, owing to the multiple, diverse input sources, Cutler Reservoir is a very heterogeneous environment.

Zooplankton

Eight different genuses of cladocerans were captured in the reservoir including *Daphnia, Bosmina, Ceriodaphnia, Moinadaphnia*, *Moina*, *Diaphanasoma*, *Scapholebris,* and *Alona.* Copepods included cyclopoids, calanoids, nauplii, and on one occasion, harpactacoids. Several different orders of rotifers and protozoa were also sampled as in 2005 (Budy et al. 2006).

Zooplankton density varied greatly by site and season, ranging from 0 zooplankters/L at Site 5 in autumn 2006 to 5 zooplankters/L at Site 5 in summer 2006 (Figure 10). Zooplankton biomass ranged from 0 mg/L at Site 5 in autumn 2006 to 23.8 mg/L at Site 3 during summer 2006 (Figure 11). In 2006, copepods represented 0 - 44% of zooplankton biomass. Whereas *Daphnia* dominated the summer zooplankton biomass in summer 2005, moinids dominated the biomass in summer 2006 (90%; Figure 11). However, moinids were replaced by *Daphnia* by autumn 2006 (Figures 10 and 11).

As in 2005 samples, mionids (including *Moina* and *Moinadaphnia* spp.) were abundant in the zooplankton (Figure 10); however, moinids increased up to 2-fold in numbers and 9-fold in biomass from summer 2005 to summer 2006 (Figures 10 and 11). Moinids may be aquatic health bioindicators for many different reasons. *Moina* appear in high concentrations in pools, ponds, lakes, ditches, slow-moving streams and swamps where organic material is decomposing; and are generally quite tolerant of poor water quality, living in water where DO-levels vary from almost zero to supersaturation. *Moina* are particularly resistant to changes in the DO concentration and often reproduce in large quantities in water bodies strongly polluted with sewage, and species of *Moina* have been reported to play an important role in the stabilization of sewage in oxidation lagoons. The ability to survive in oxygen-poor environments is due to their capacity to synthesize hemoglobin. Hemoglobin formation is dependent on the level of DO in the water. *Moina* feed on various groups of bacteria, yeast, phytoplankton and detritus (decaying organic matter); bacterial and fungal cells rank high in food value, and *Moina* are one of the few zooplankton which can utilize the blue-green algae *Microcystis aeruginosa* (Rottman et al. 2003). Further, as prey, *Miona* provide a higher protein content versus *Daphnia* (Alam 1992).

Fish Sampling

Fish catch

A great diversity of fish were captured in Culter Reservoir. In 2006, we captured 14 different species of fish including centrarchids, catfish, percids, suckers, salmonids, minnows, and whitefish. In 2006, we captured two mountain whitefish (*Prosopium williamsoni*) and one brown trout, both riverine fishes, at Site 5 (southern tributary inflows). Of the 14 fish captured in 2006, four (29%) species are classified as Intolerant or Moderately Intolerant and ten (71%) are classified as Moderately Tolerant or Tolerant (Table 2; Jester et al. 1992). According to this criteria applied to Cutler Reservoir, smallmouth bass may be a valuable indicator species regarding toxicity of water, followed by walleye. While there are other more intolerant species in Cutler Reservoir, those highly intolerant species are rarely detected in the reservoir. Conversely, smallmouth bass were found at three sites in the reservoir and at both river sites, and walleye currently occur at all five reservoir sites.

As in 2005, catch biomass was dominated by carp (62.9 – 69.5% of biomass) with walleye (5.1 - 14.8%) and catfish (11.7 – 19.2%) representing substantial proportions (Figure 12). Hundreds of fishes were captured at all sites within the reservoir with the lowest catches at Site 1, near Highway 23 and closest to the dam in spring and autumn 2006; and the highest catch biomasses at Swift slough (Site 4) in summer 2006 (Figure 13). Although carp dominated the catch at nearly all sites during all seasons in Cutler Reservoir, walleye dominated the catch at Site 1 in autumn 2006 and channel catfish dominated the catch in autumn at Site 3 (Figure 13). In general, large, "memorable" sport fish were abundant in the reservoir.

Gill nets were very effective for sampling fish, especially carp, channel catfish, black bullheads, and walleye (Figure 14). Summer catch rates (as CPUE) in gill nets generally remained similar between years; however, CPUE declined for some species at some sites, while increasing at other sites (Figure 15).

Most black crappie were captured in trap nets. Catch-per-unit-effort for crappie remained high from spring (CPUE = 0.15 fish/trap/hour) through autumn 2006 (CPUE = 0.09; Figure 16). Trap-net CPUE for bluegill increased from 0.02 in spring 2006 to 0.06 in autumn 2006 (Figure 16).

Fathead minnows dominated electrofishing catch in spring 2005, while bluegill dominated electrofishing catches in summer and autumn. One fathead minnow was captured per minute of electrofishing in spring, and CPUE of bluegill was over 1.3 fish/minute in autumn (Figure 17). Electrofishing also allowed us to encounter species (both in terms of numbers and types) that were not effectively sampled with other gears including largemouth bass, smallmouth bass, green sunfish, and whitefish (Figure 17). Surprisingly, electrofishing was not effective for sampling walleye.

Beach seining was effective in sampling small fish (< 80 mm) and detecting recruitment, especially fathead minnows, young-of-year bullhead, green sunfish, and small carp. Shoreline, littoral catches of fathead minnows ranged from a high of 93 per 100 $m^{2\ in}$ spring 2006 to a low of 10 per m^2 in autumn 2006 (Figure 18). Black bullhead densities reached a high of 198 per m^2 in summer, all captured in one seine haul at Site 1 (Figure 18).

Table 2. Fishes found in Cutler Reservoir, and classification in terms of tolerance of degradation of water quality (from Jester et al. 1992). List is in sequential order from most intolerant (top) to most tolerant (bottom). Notation for water quality tolerance designations: T = tolerant (score = 4.0), MT = moderately tolerant (score = 2.6 – 3.3), MI = moderately intolerant (score = 1.8 – 2.5), I = intolerant (score = 1.0 – 1.7).

Species	Water quality tolerance	Numerical tolerance score (± SD)	Occurrence in Cutler Reservoir in 2006
Cutthroat trout	I[a]	1.2 (0.05)[a]	Absent
Mountain whitefish	I[a]	1.2 (0.05)[a]	Few at Site 5
Brown trout	I	*Not quantified*	Few at Site 1
Smallmouth bass	I	1.5 (0.55)	Few at 3 of 5 sites
Utah sucker	MI[b]	1.8 (0.45)[b]	Few at all sites
Walleye	MT	2.8 (0.96)	Occur at all sites
Bluegill	MT	3.2 (0.41)	Many at all sites
Black crappie	MT	3.2 (0.45)	Many at all sites
Channel catfish	MT	3.2 (0.55)	Many at all sites
Largemouth bass	MT	3.2 (0.98)	Occur at all sites
Yellow perch	T	3.7 (0.58)	Absent
Fathead minnow	T	3.7 (0.52)	Many at all sites
Common carp	T	4.0 (0.0)	Many at all sites
Green sunfish	T	4.0 (0.0)	Many at all sites
Black bullhead	T	4.0 (0.0)	Many at all sites

a. Value for rainbow trout, *Oncorhynchus mykiss*
b. Value for white sucker, *Catostomus commersoni*

Fish demographics

Using length-frequency analysis, we were able to infer size-class (i.e., age class) for many species of fish. We were also able to estimate sizes attained (i.e., growth) for many species. Captured walleye (2005-2006 data) appeared to represent at least 5 age classes ranging from 160 to almost 800 mm (Figure 19), but see *Fish Ageing and Growth* section. Captured channel catfish ranged in size from 25 to 795 mm, representing up to 8 age classes; further, age-0 catfish potentially grew up to 180 mm by October (Figure 20). Channel catfish growth rates are highly variable across their North American range of distribution. The growth rates observed in Cutler Reservoir are moderate but typical of other reservoirs with similar growing seasons.

Black crappie exhibited at least 5 age classes. Based on length-frequency analysis it appears that age-0 crappie reached a modal length of 60 mm and age-1 crappie reached a modal length of 120 mm by October (Figure 21), but see *Fish Ageing and Growth* section. Observed growth rates for black crappie in Cutler Reservoir are in the mid to upper range of growth rates for black crappie populations across their distribution, and are typical of black crappie populations that are not "stunted" by high population densities (Galinat and Willis 2002). Seining was very effective at collecting young-of-year (age-0) crappie and detecting recruitment in summer; however, in general, trap netting and electrofishing allowed us to track crappie demographics the remainder of the year (Figure 22).

Largemouth bass potentially represented 4 age classes, and it appears that age-0 largemouth bass were able to reach 110 mm by the end of their first summer of growth (Figure 23), growth typical for this species. Captured bluegill conceivably represented 4 separate age classes, with age-0 recruits in some cases reaching 75 mm in their first growing season (Figure 24). As with crappie recruitment, seining was effective at capturing young-of-year bluegill in summer (Figure 24).

Black bullhead demonstrated at least 4 age classes with age-0 bullheads attaining lengths up to 80 mm by September (Figure 25). Bullheads typically spawn between May and July. As with crappie and bluegill, seining was effective at capturing young-of-year bullheads in summer (Figure 25). The autumn length-frequency histogram is puzzling (with the length distribution of nearly all bullheads amassed between 125 – 275 mm TL) and leads to several theories; age-0 bullhead evaded our sampling gears, age-0 bullhead were severely predated by autumn, or age-0 bullhead grew rapidly and attained first-growing-season lengths of > 125 mm (Figure 25). Size at maturity for black bullhead ranges from 170 – 250 mm (Carlander 1969); therefore reaching 125 mm in the first summer of growth seems improbable.

Carp represented at least 4 age classes, and age-0 carp could attain nearly 150 mm by October (Figure 26). The reservoir supports vast numbers of carp in the 350 – 550 mm (14 – 22 inch) size range (Figure 26). Most carp mature at ages 2 to 5 in temperate climates (Carlander 1969), roughly > 225 mm TL. Patterns of carp growth in Cutler Reservoir, show similar patterns to other reservoirs in North America (Sigler and Sigler 1996).

Fish condition

Condition indices provide an index of robustness, nutritional status, and the seasonal and long-term nutritional trends of fish. The condition of an individual may reflect environmental conditions for feeding and growth, and thus both density dependent and independent factors (Murphy et al 1991; Anderson and Neumann 1996; Hansen and Nate 2005).

Fulton's index.—In simple terms, undernourished or thin fish have a condition factor (K) of less than 1, while adequately fed or fat fish have a K greater than 1. Walleye condition fluctuated seasonally by site, ranging from 0.92 (±1 SE = 0.02) in summer at Site 1 to 1.11 (± 0.04) in autumn at Site 3 (Figure 27). With perhaps the exception of walleye captured (at low sample sizes) at Site 5 , condition was lowest in summer (Figure 27). Condition of channel catfish within the reservoir was highest at Site 2 (Clay slough) during spring (1.04 ± 0.06) and lowest during autumn at Site 1, Highway 23 (0.80 ± 0.02; Figure 28). Overall across sites and seasons, catfish condition was highest at Site 4, Swift slough (Figure 28). Black crappie condition was generally high (> 1.15), except at the Bear River site just above Cutler Reservoir where condition was as low as 0.91 ± 0.08 (Figure 29). Similarly, condition of bluegill sunfish was generally high (> 1.8), with lowest values still greater than 1.4 (Figure 30). As with crappie, condition of bluegill was lowest at Site 6, the Bear River site (Figure 30).

Relative weight.—Condition measured as relative weight (W_r) for walleye in Cutler Reservoir was close to the national average (Figure 31), and seasonal trends in Wr were not apparent (Figure 32). In many systems, W_r varies seasonally, with highest W_r-values occurring from October through May (Quist et al. 2002; Hansen and Nate 2005). In general, channel catfish W_r was at or just below the national standard of 100; however, W_r-values were quite high for catfish between 70 – 200 mm TL (Figure 31). As with walleye, seasonal patterns in W_r were not evident (Figure 32). Over 96% of the carp from Cutler Reservoir exhibited W_r-values below the national standard (Figure 31). Smallmouth bass W_r-values were mostly above the national standard, and largemouth bass W_r were always above 100; however, sample sizes for both species were low (Figure 33).

Relative weight for black crappie was commonly above 100 for crappie < 250 mm; yet, for larger crappie, W_r-values hovered around the national standard (Figure 33). This change may correspond to and ontogenetic diet shift to include more fish prey in diets of large-sized crappie (Budy et al. 2005). As with walleye and catfish, seasonal differences in W_r were not noticeable (Figure 32). Bluegill exhibited high W_r (76 – 152), which was revealed also by high Fulton's K (1.8 – 2.4; Figure 34). Green sunfish in Cutler Reservoir demonstrated wide-ranging Wr-values between 46 and 140, and black bullhead W_r-values were predominantly (98%) below the national standard (Figure 34).

The justification for using W_r is to provide a convenient, integrated measure of physiological status for fish populations, assuming the plumpness of an individual fish reflects its physiology (Murphy et al. 1990). A W_r range of 90 - 100 is a typical objective for most fish species. When mean W_r values are well below 100 for a size group, problems may exist in food and feeding relationships. When mean W_r values are well above 100 for a size group, fish may not be making the best use of available prey. Low values of W_r (i.e., low energy reserves; fat and protein) may be related to high rates of mortality (Newsome and Leduc 1975). Murphy et al. (1991) suggested that targets for W_r should be dictated by management objectives for a particular water body (*see* Table 3 for examples).

Table 3. Targets for relative weight (W_r) based on various management objectives.

Species	W_r target	Management objective or goal	Source
Largemouth bass	95 - 100	Suitable or optimal W_r	*Wege & Anderson (1978)*
Bluegill	95 - 100	Suitable or optimal W_r	*Wege & Anderson (1978)*
Largemouth bass	95 - 105	Balanced population	*Anderson (1980)*
Largemouth bass	85 - 95	Crowded population	*Anderson (1980)*
Largemouth bass	85 - 95	Maximal production of large bluegill	*Gablehouse (1987)*
Bluegill	105 - 115	Maximal production of large bluegill	*Gablehouse (1987)*
Walleye	95 - 100	National standard, balanced population	*Murphy et al. (1990)*
Walleye	86 - 92	Objective range for upper Midwest region fisheries	*Hansen & Nate (2005)*

<u>Fish ageing and growth</u>

Otoliths from 73 walleye were aged and checked for otolith dye (oxytetracyclene) marks by Idaho Department of Fish and Game (IDFG). In spring (March to May) 1997, 1998, 1999, 2000, 2001, and 2005, IDFG stocked 500,000 fingerling (~ 75 mm TL) walleye into Oneida Reservoir, Idaho; therefore, walleye captured in Cutler Reservoir with marks verify that the walleye originated in Idaho. However, it is important to note that not all IDFG-stocked walleye were dye marked. Of the 73 otoliths checked, seven (or ~ 10%) were dye marked. These Idaho-origin walleye ranged from age-1 to age-3 and demonstrated good growth rates (Table 4). Reservoir-wide otolith-aged walleye ranged in age from age-0 to age-13 (Table 5; Figure 35). Walleye grew rapidly to large sizes, and growth was generally greater compared to other systems (Table 6).

Table 4. Catch information on otolith-aged, dye-marked walleye released in Idaho and recaptured in Cutler Reservoir, 2005 and 2006.

Age (yr)	Length (mm)	Weight (g)	Capture location	Capture period
1	312	283.0	Site 1, Hwy 23	Summer 2005
2	460	1050.0	Site 4, Swift slough	Spring 2006
2	495	1159.0	Site 1, Hwy 23	Summer 2006
3	442	793.8	Site 3, Benson marina	Summer 2006
3	480	1133.0	Site 1, Hwy 23	Autumn 2006
3	505	1241.9	Site 2, Clay slough	Summer 2006
3	505	1293.5	Site 2, Clay slough	Autumn 2006

Table 5. Average size-at-age and growth for walleye captured in Cutler Reservoir, 2005-2006). “—“ means growth was negative or not determinable.

Age group	Sample size	Average total length (mm ± 1 SD)	Annual length gain (mm)	Average weight (g ± 1 SD)	Annual weight gain
0	1	160.0	188	33.6	228.1
1	6	348.0 (50.9)	105.7	371.7 (186.0)	561.1
2	19	453.7 (34.3)	36.1	932.9 (236.9)	255.5
3	26	489.8 (38.8)	65.7	1188.3 (287.2)	709.4
4	10	555.5 (41.3)	4.8	1897.9 (508.1)	—
5	3	560.3 (35.5)	52.7	1655.5 (628.6)	819.5
6	1	613	—	2475	204.8
7	2	613 (89.1)	107	2679.8 (806.4)	1310.2
8	1	720	—	3990	—
10	4	621.2 (57.4)	—	2613 (890.7)	—
13	1	789	—	4850	—

Table 6. Comparisons of annual growth (mass, g) of walleye based on mean total weight-at-age information from Cutler Reservoir (this study), Utah Lake (Radant and Sakaguchi 1980), Glen Elder Reservoir (Quist et al. 2002), Lake Oahe (Bryan 1995), and Lake Huron (MDNR 2001). "—" signifies missing data.

Walleye age (yr)	Cutler Reservoir	Utah Lake, Utah	Glen Elder Reservoir, Kansas	Lake Huron, Michigan	Lake Oahe, South Dakota
0	228.1	—	—	—	—
1	561.1	159	375.4	—	145.4
2	255.5	278	208.3	270	234.5
3	709.4	96	791.5	330	327.1
4	—	390	604	320	417.2
5	819.5	370	—	360	500.7
6	204.8	450	—	360	575.6
7	1310.2	420	—	330	—
8	—	320	—	280	—
9	—	570	—	220	—

Twenty-eight black crappie, ranging in age from age-2 to age-8, were aged using scales (Figure 36). Mean length-at-age and growth for black crappie from Cutler Reservoir was comparable to other systems (Table 7).

Table 7. Comparisons of mean total length-at-age information for black crappie from Cutler Reservoir (this study), Black Lake (Mueller and Downen 2000), and Lake Eufaula (Weathers et al. 2005). "—" signifies no data available.

Crappie age (yr)	Cutler Reservoir	Black Lake, Washington	Lake Eufaula, Alabama
1	—	46.0	—
2	156.7	111.2	215.0
3	219.1	156.7	228.2
4	248.7	183.4	262.6
5	279.4	220.0	275.0
6	296.0	—	310.8
7	312.0	—	367.0
8	333.0	—	325.0
9	—	—	328.7
10	—	—	329.0

Fish stock density indices

High and low PSD and RSD values and wide variation over time are evident in populations with functional problems such as unsatisfactory recruitment, growth, and mortality (Anderson and Neumann 1996). For most fish, 30 - 60 or 40 - 70 are typical objective ranges for “balanced” populations. Values less than the objective range indicate a population dominated by small fish, while values greater than the objective range indicate a population comprised mainly of large fish.

In Cutler Reservoir, both length-frequency assessment and PSD values indicate that recruitment was poor for walleye and green sunfish (Figure 19; Table 8). The walleye, channel catfish, black crappie, and common carp populations were dominated by large fish, while the largemouth bass, smallmouth bass, bluegill, green sunfish, and bullhead populations were dominated by small fish. Black crappie PSD and RSD-P values indicate an unbalanced population, skewed toward large-sized fish (Table 8).

As with the interpretation of condition indices, values of PSD and RSD may not necessarily define the true health of a system. What is defined as “optimal” or “balanced” will vary according to management objectives and environmental limitations; a single definition that covers all management situations does not exist (Murphy et al. 1991). However, PSD and RSD values and comparisons between systems are valuable for initially assessing a fishery and aiding in the determination of management goals.

Table 8. Stock density index ranges for fish in Cutler Reservoir in 2006 compared to "generally accepted" stock density index ranges from the literature (*see* Anderson and Neumann 1996) and reported values from the literature (see footnotes). For most fish, 30 - 60 or 40 - 70 are typical objective ranges for "balanced" populations. Values less than the objective range indicate a population dominated by small fish, while values greater than the objective range indicate a population comprised mainly of large fish. Proportional stock density (PSD), relative stock density of preferred length fish (RSD-P), and RSD of memorable length fish (RSD-M) are given. "—" signifies no data available.

	Cutler Reservoir			Literature values		
Species	PSD	RSD-P	RSD-M	PSD	RSD-P	RSD-M
Walleye	92	24	3	30 - 60, 100[a]	0 - 78[h], 27 - 73[a]	0 - 56[i]
Channel catfish	77	30	6	0 - 100[jb]	0 - 8[j]	—
Black crappie	77	49	6	30 - 60, 100[a]	> 10, 0 - 31[a]	—
Largemouth bass	35	0	0	40 - 70, 57 - 85[a]	0 - 10	0 - 10
Smallmouth bass	29	1	0	35 - 59[bc]	18 - 38[d]	3 - 13[d]
Bluegill	13	0	0	20 - 60, 0 - 2[a]	5 - 20	0 - 10
Green sunfish	3	0	0	9[e]	0[e]	—
Black bullhead	20	3	1	11 - 80[ef]	0[e]	—
Common carp	57	71	20	26 - 95[gjk]	0 - 68[gjk]	—

a. Petersen et al. 2001; b. Tunink 1984; c. Lukens 1986; d. Altena 2004; e. SDDGFP 2005; f. MNDNR 2005; g. Mauldin 2000; h. Zweifel 2006; i. Borkholder and Edwards 2001; j. Pegg et al. 2005; k. Divens and Phillips 2000.

Stomach diet analysis

We evaluated diets from stomach analyses for walleye, channel catfish, black crappie, and one brown trout. Identifiable diet items included carp, catfish, bullhead, fathead minnows, sunfish, crappie, and walleye), aquatic invertebrates (chironomids, coleopterans, plecopterans, dipterans, trichopterans, odonates, ephemeropterans, hemipterans [e.g., corixids], and leeches), zooplankton (copepods and *Daphnia*), mice, and organic matter.

Walleye.—In 2006, we examined 57 stomachs; 44% were empty. Walleye diet information was available from all reservoir sites, but not during all seasons. Carp and catfish were the dominant prey items, and other fish prey included fathead minnow, bullhead, sunfish, and crappie (Figure 37). In 2006, no walleye diets contained aquatic invertebrates. Comparatively, fish comprised 83 - 100% of walleye diets in Lake Powell (Budy et al. 2004). In other systems, prey of walleye was determined by the relative abundance and changes in availability of forage fishes of a preferred size (Parsons 1971; Knight et al. 1984; Hartman 1989). If that is also the case in Cutler Reservoir, it may be inferred that carp, catfishes, and minnows were the most abundant and available prey fish in Cutler Reservoir in 2006.

Black crappie.—We analyzed seasonal diets of 73 black crappie. As in 2005, less than 10% of stomachs were empty. Fish were the dominant prey in summer 2005 (especially carp) and summer 2006 (both carp and minnows), composing almost 70% of diets (Figure 38). In spring and autumn 2006, aquatic invertebrates (predominantly hemipterans – corixids) comprised 60 - 75% of diets (Figure 38). In autumn 2006, corixids dominated diets, and fathead minnows were important fish prey (Figure 38).

Channel catfish.—We processed 76 stomachs; 13.2% were empty. Catfish stomachs contained primarily vegetation and organic matter during all seasons (Figure 39). In 2005, piscivory was detected in 43% of sampled fish that had full stomachs; however, in 2006, only 18% of catfish contained fish prey (Figure 39). These data are similar to Lake Powell catfish diets where vegetation and plant matter dominated diets, with fish representing up to 45% of prey items (Budy et al. 2004). Mice represented a significant proportion of catfish diets in 2005; however, mice only represented a small proportion of autumn catfish diets in 2006 (Figure 39). Mice were found in diets of catfish greater than 410 mm TL.

Stable isotope diet analysis

In conjunction with stomach content diet analysis, we evaluated stable isotope ratios (^{15}N and ^{13}C) to determine trophic position. Stable isotope ratios of ^{15}N were the highest in walleye, large-sized (> 150 mm TL) crappie, and largemouth bass muscle tissue indicating consumption at a higher trophic level, as compared to other fish (Figures 40). Ratios of ^{15}N in small crappie, bullhead, catfish, and carp muscle tissue indicated consumption at an intermediate trophic level (Figure 40). Stable isotope ratios of ^{13}C were similar for walleye, large crappie, largemouth bass, bullhead, and catfish with slightly lower ratios in carp and small crappie muscle tissue (Figure 40). Corroborating stomach diet analysis, stable isotopic analysis also demonstrates the niche shift and differential feeding of black crappie; ^{15}N and ^{13}C signatures are substantially different for small-sized and large-sized crappie (Figure 40).

Statistical correlations

We observed strong correlations among nutrients (e.g., NH_4, TP, TKN) and primary productivity (i.e., chlorophyll *a*), as well as among chlorophyll *a* and indices of secondary productivity (e.g., zooplankton density and biomass; Table 9). Not surprisingly, temperature (both average and maximum) correlated with many variables, abiotic and biotic (Table 9). Walleye abundance (CPUE) was strongly correlated with chlorophyll *a*, TKN, conductivity, and abundance indices (CPUE) of prey (catfish, crappie, and minnow), but surprisingly showed little correlation to carp CPUE (Table 9). Crappie abundance (as indicated by CPUE) was highly correlated with NH_4, pH, and walleye CPUE. Bullhead and bluegill were the only fish species demonstrating correlations with dissolved oxygen. As predicted, carp were strongly and positively correlated with many abiotic and biotic variables demonstrating their wide tolerance to a range of conditions.

Future analyses will include the identification of the most parsimonious regression model describing walleye and crappie abundance and distribution with detailed consideration of autocorrelation and interactions among response variables.

Table 9. Preliminary modeling results suggesting strong negative and positive correlations (r > 0.5) among abiotic, biotic, and fish response variables.

Variable	Explanatory variables
Chlorophyll *a*	Miona density, Copepod density, Total zooplankton density, Moina biomass, Copepod biomass, Total zooplankton biomass, Avg temperature, Max temperature, NH_4, TP, TKN, pH, Conductivity, Walleye CPUE, Catfish CPUE, Carp CPUE
Daphnia density	Total zooplankton density, Total zooplankton biomass, Conductivity, Carp CPUE
Moina density	Chlorophyll *a*, Cladoceran density, Copepod density, Total zooplankton density, Cladoceran biomass, Copepod biomass, Total zooplankton biomass, Avg temperature, Max temperature, Min DO, TKN, Carp CPUE
Cladoceran density	Moina density, Moina biomass
Copepod density	Chlorophyll *a*, Moina density, Total zooplankton density, Moina biomass, Total zooplankton biomass, Avg temperature, Max temperature, TP, TKN, pH, Conductivity, Carp CPUE
Total zooplankton density	Chlorophyll *a*, Daphnia density, Moina density, Copepod density, Daphnia biomass, Moina biomass, Cladoceran biomass, Copepod biomass, Avg temperature, Max temperature, Min DO, TKN, pH, Conductivity, Carp CPUE
Daphnia biomass	Total zooplankton density, Total zooplankton biomass, Conductivity, Carp CPUE
Moina biomass	Chlorophyll *a*, Cladoceran density, Copepod density, Total zooplankton density, Cladoceran biomass, Copepod biomass, Total zooplankton biomass, Avg temperature, Max temperature, Min DO, TKN, Carp CPUE
Cladoceran biomass	Moina density, Total zooplankton density, Moina biomass, Avg DO, Min DO
Copepod biomass	Chlorophyll *a*, Moina density, Total zooplankton density, Moina biomass, Total zooplankton biomass, Avg temperature, Max temperature, TP, TKN, pH, Carp CPUE
Total zooplankton biomass	Chlorophyll *a*, Daphnia density, Moina density, Copepod density, Daphnia biomass, Moina biomass, Copepod biomass, Avg temperature, Max temperature, Avg temperature, Max temperature, Min DO, TKN, pH, Conductivity, Carp CPUE
Average (Avg) Temperature	Chlorophyll *a*, Moina density, Copepod density, Total zooplankton density, Moina biomass, Copepod biomass, Total zooplankton biomass, Max temperature, Min DO, NH_4, TP, TKN, pH, Secchi depth, Catfish CPUE, Carp CPUE
Maximum (Max) Temperature	Chlorophyll *a*, Moina density, Copepod density, Total zooplankton density, Moina biomass, Copepod biomass, Total zooplankton biomass, Avg temperature, Avg DO, Min Do, NH4, TKN, Secchi, Carp

Variable	Explanatory variables
Minimum (Min) dissolved oxygen (DO)	Moina density, Total zooplankton density, Miona biomass, Cladoceran biomass, Total zooplankton biomass, Avg temperature, Max temperature, Avg DO, TP, TKN, Secchi depth, Bullhead CPUE, Bluegill CPUE
Average (Avg) DO	Cladoceran biomass, Max temperature, Min DO, Secchi depth, Bullhead CPUE
NH_4	TP, TKN, Secchi depth, Crappie CPUE
NO_3 - NO_2	SRP, DP, TKN, pH
SRP	DP, TP
DP	TP, Conductivity, Fathead minnow CPUE
TP	TKN, Conductivity, Secchi depth, Catfish CPUE
TKN	pH, Conductivity, Secchi depth, Walleye CPUE, Catfish CPUE, Carp CPUE
pH	Catfish CPUE, Crappie CPUE, Carp CPUE
Conductivity	Walleye CPUE, Catfish CPUE
Secchi depth	Avg Temperature, Max Temperature, Avg DO, Min DO, NH_4, TP, TKN, bullhead CPUE
Walleye CPUE	Chlorophyll a, TKN, Conductivity, Catfish CPUE, Crappie CPUE, Minnow CPUE
Catfish CPUE	Chlorophyll *a*, Avg temperature, TP, TKN, pH, Conductivity, Walleye CPUE
Crappie CPUE	NH_4, pH, Walleye CPUE
Bullhead CPUE	Avg DO, Min DO, Secchi depth
Bluegill CPUE	Min DO
Carp CPUE	Chlorophyll *a*, Daphnia density, Moina density, Copepod density, Total zooplankton density, Daphnia biomass, Moina biomass, Copepod biomass, Total zooplankton biomass, Avg temperature, Max temperature, TKN, pH
Minnow CPUE	DP, Walleye CPUE

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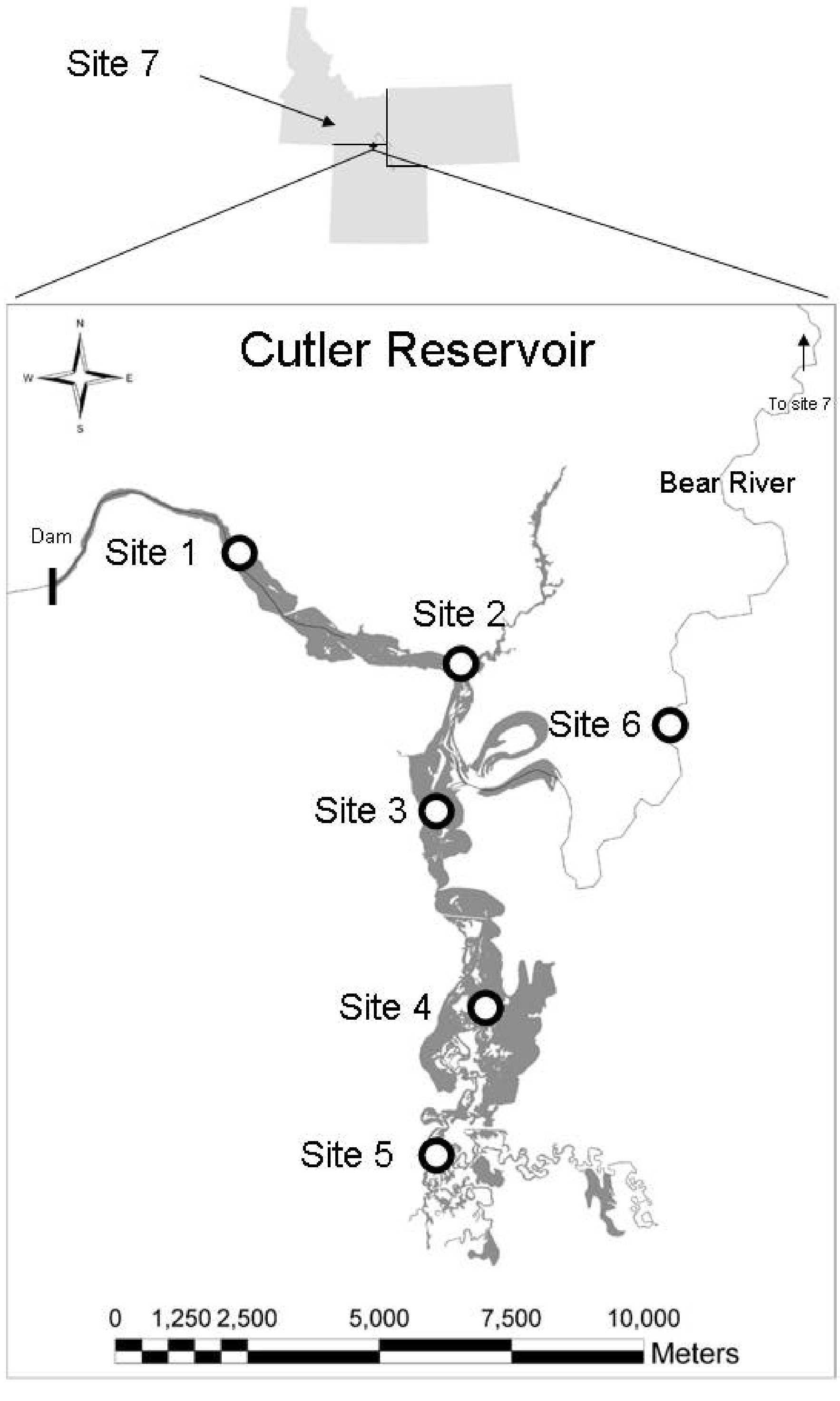

Figure 1. Map of Cutler Reservoir with seven sample locations indicated. Five reservoir index sites were selected for 2005 and 2006 sampling.

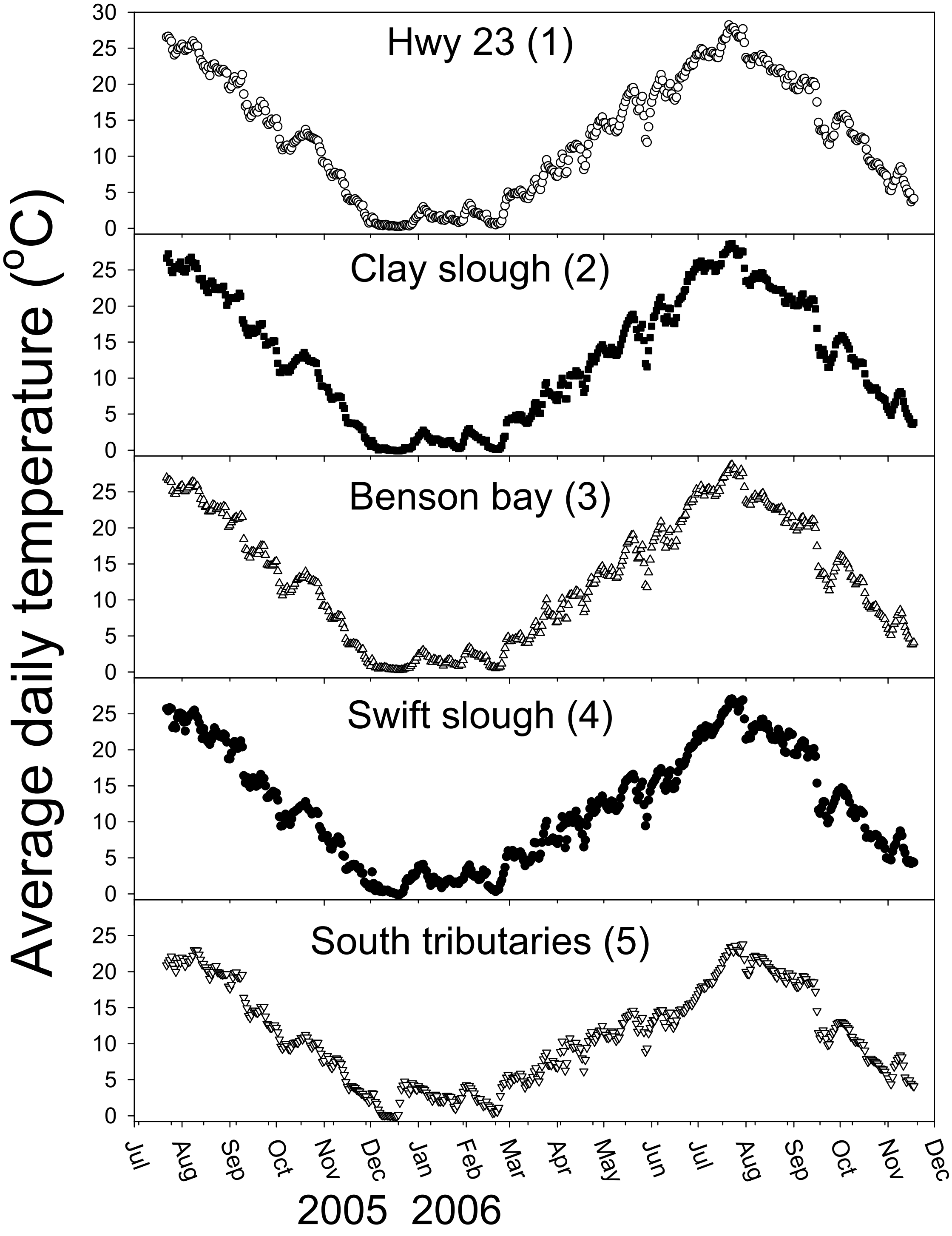

Figure 2. Average daily temperature (°C) at five sites on Cutler Reservoir, July 2005 through November 2006.

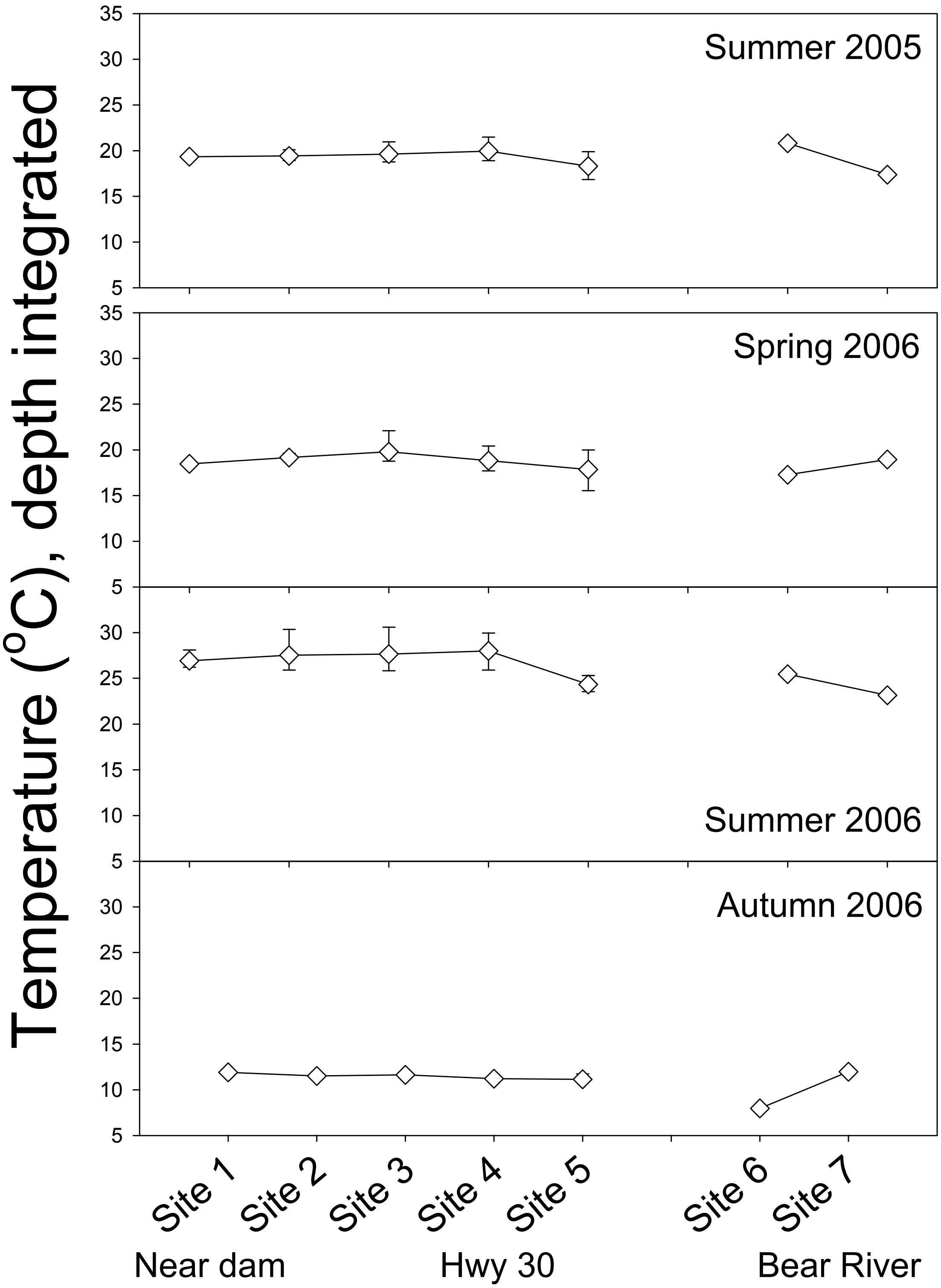

Figure 3. Temperature (°C, mean ± 1 SE) for five sites on Cutler Reservoir and two sites on the Bear River, summer 2005 through autumn 2006.

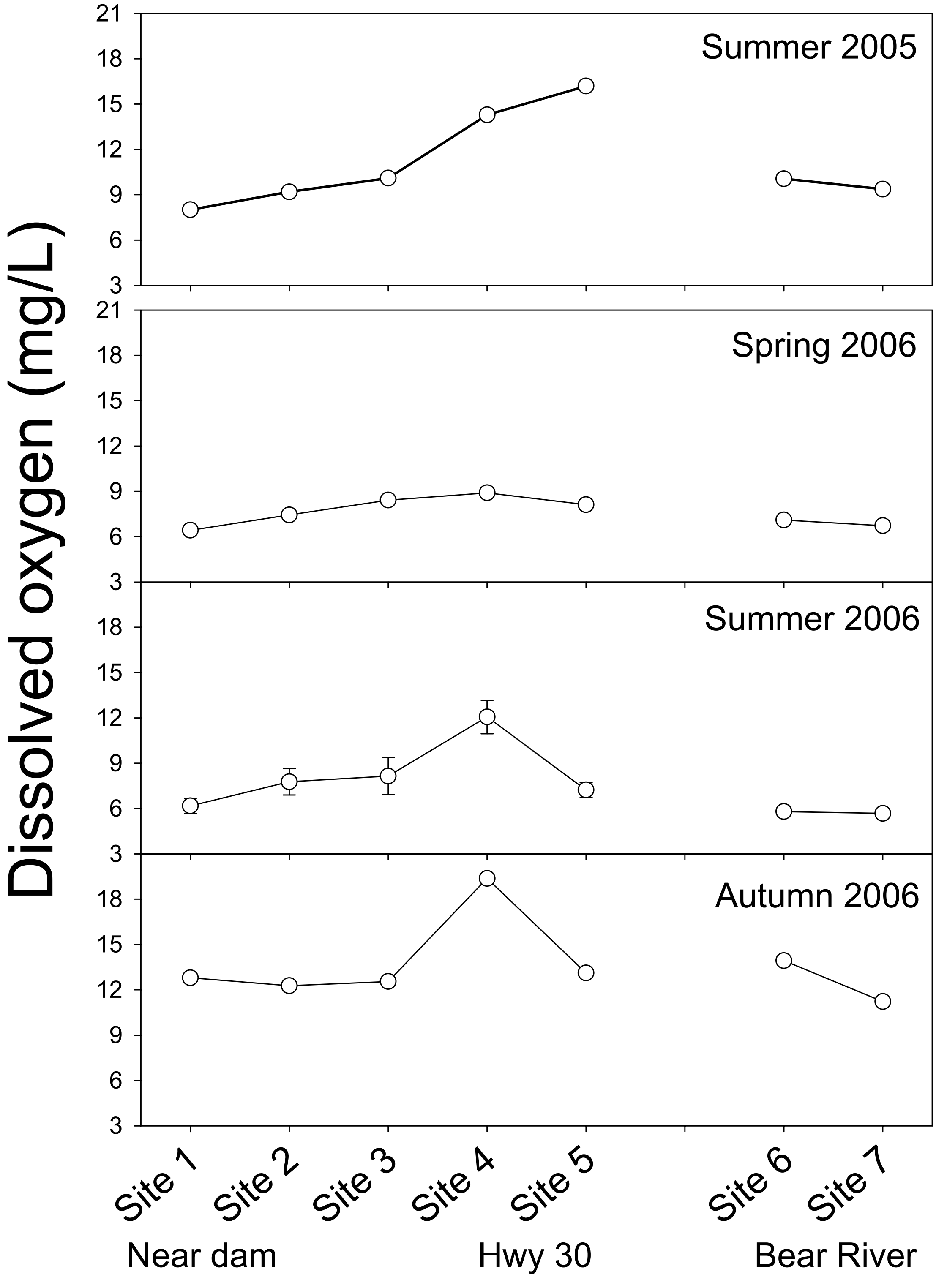

Figure 4. Dissolved oxygen (DO, mean mg/L ± 1 SE) for five sites on Cutler Reservoir and two sites on the Bear River, summer 2005 through autumn 2006.

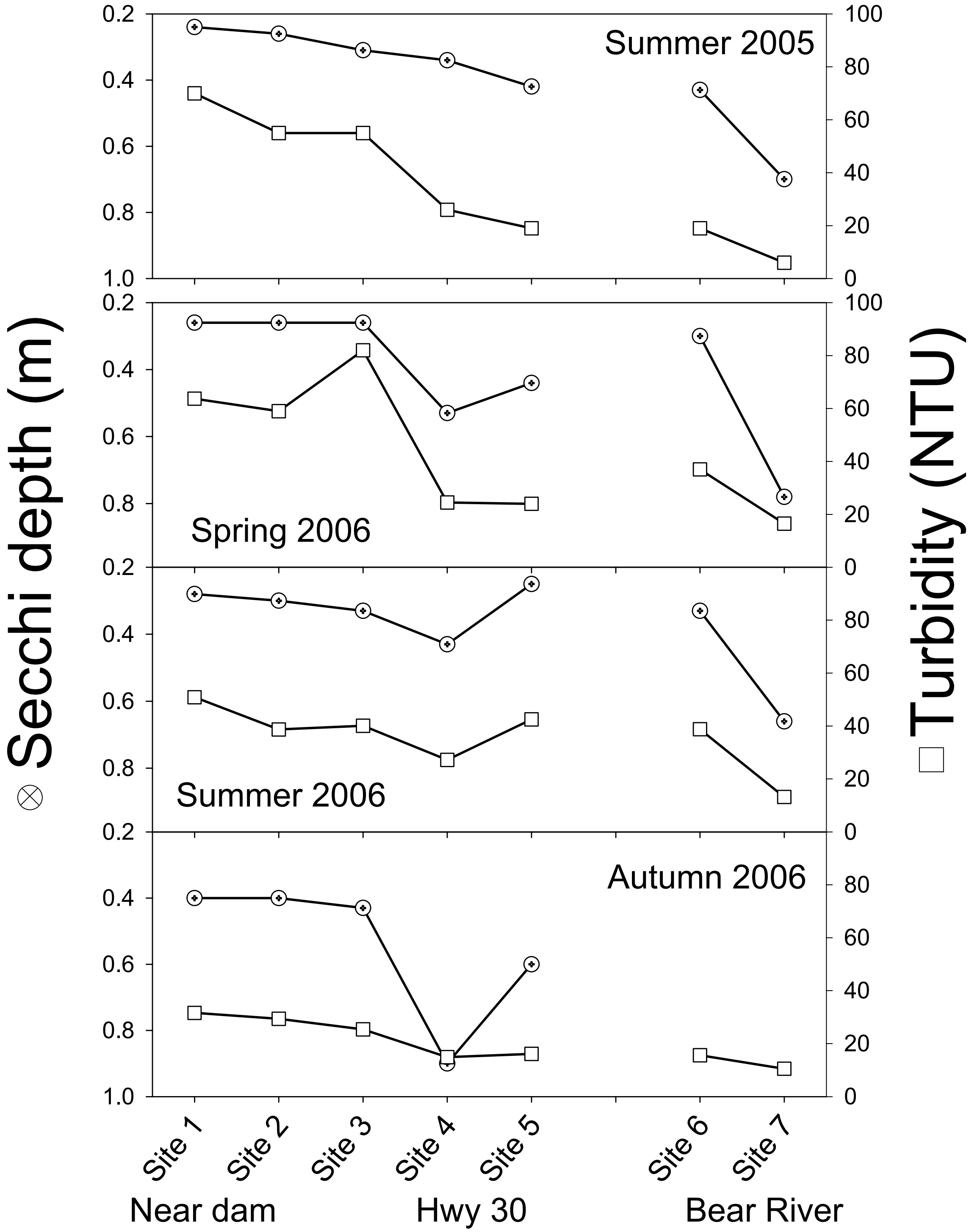

Figure 5. Secchi disk readings and turbidity measured in Cutler Reservoir and two Bear River sites, summer 2005 and seasonally in 2006.

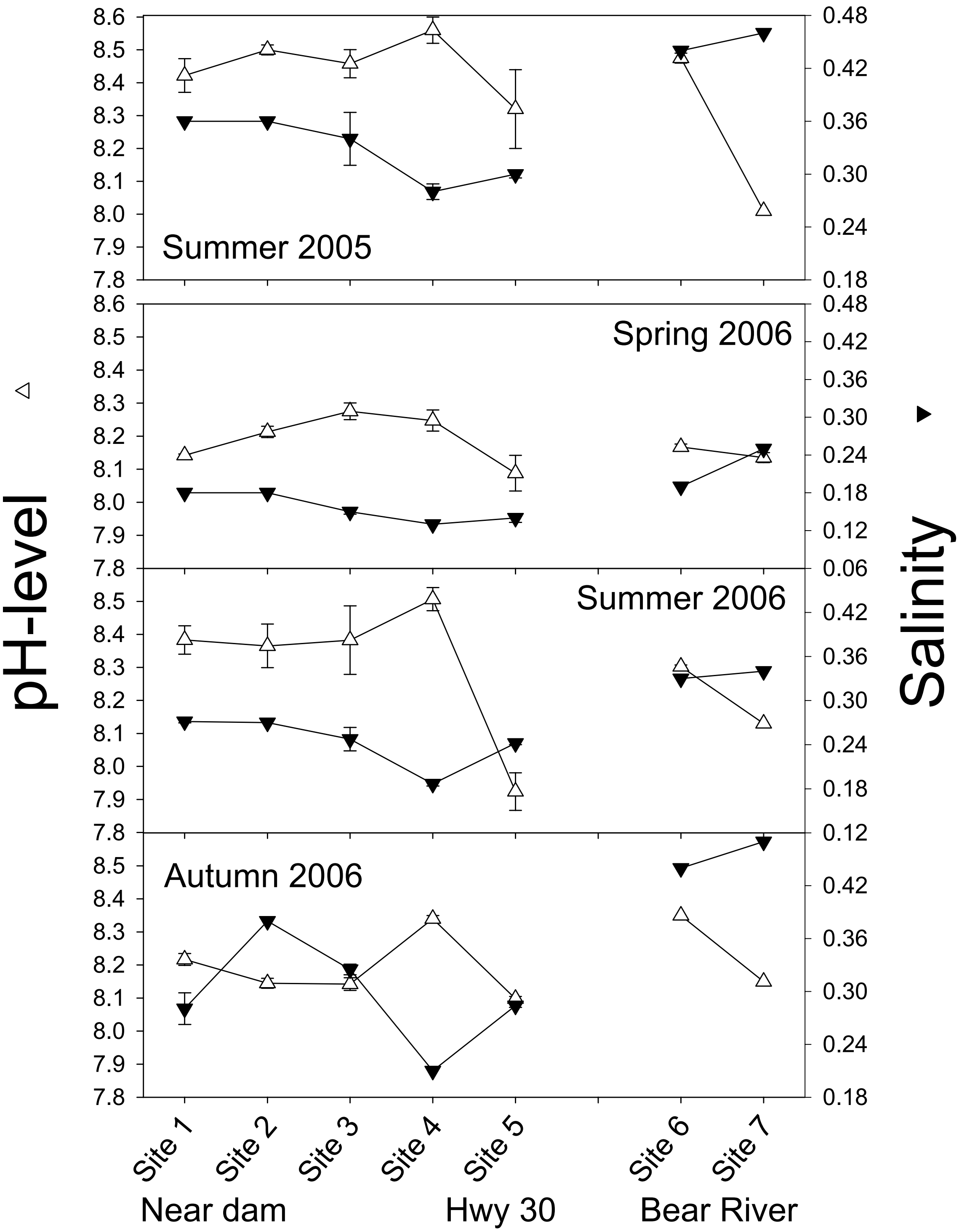

Figure 6. Salinity and pH-level (mean ± 1 SE) measured in Cutler Reservoir and two Bear River sites, summer 2005 and seasonally in 2006.

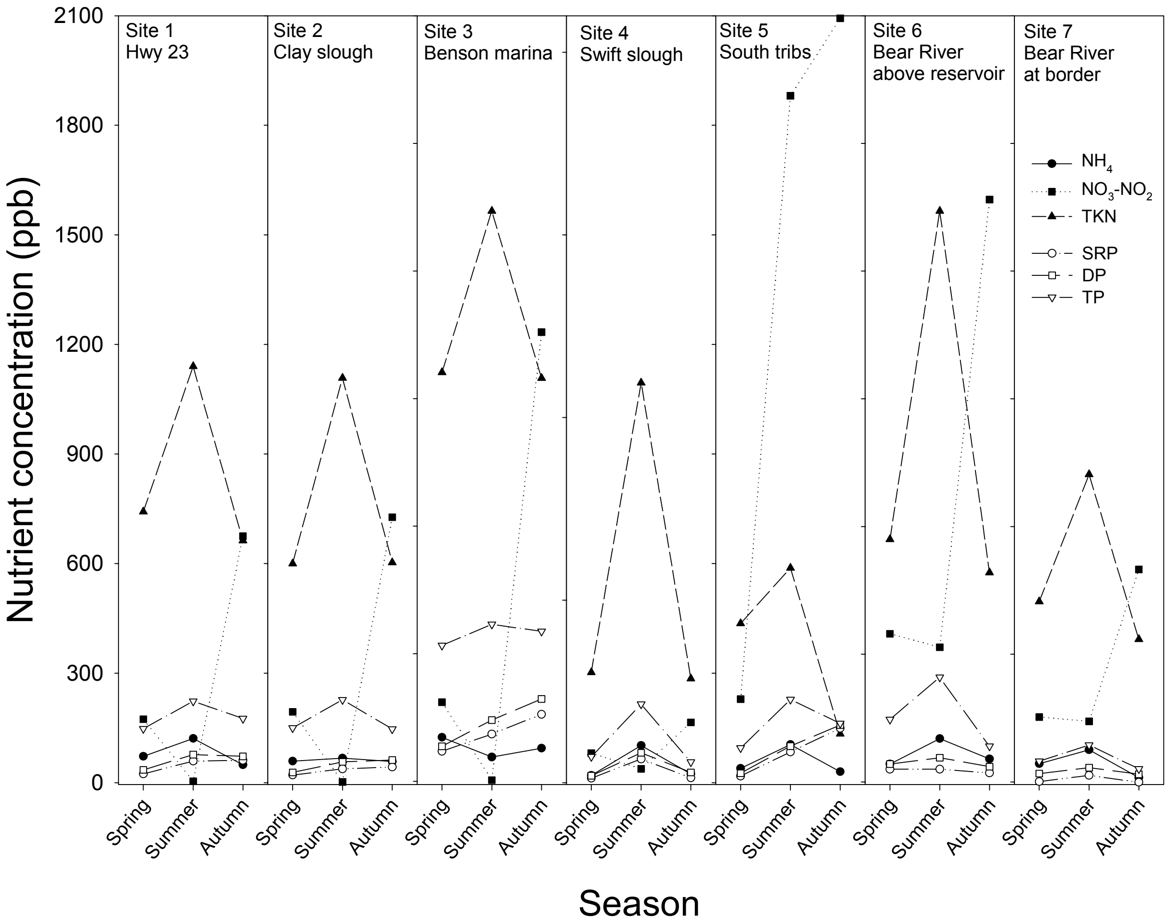

Figure 7. Nitrogen and phosphorus concentrations (parts per billion, ppb) at seven index sites on Cutler Reservoir and the Bear River, 2006. 1000 ppb = 1 mg/L.

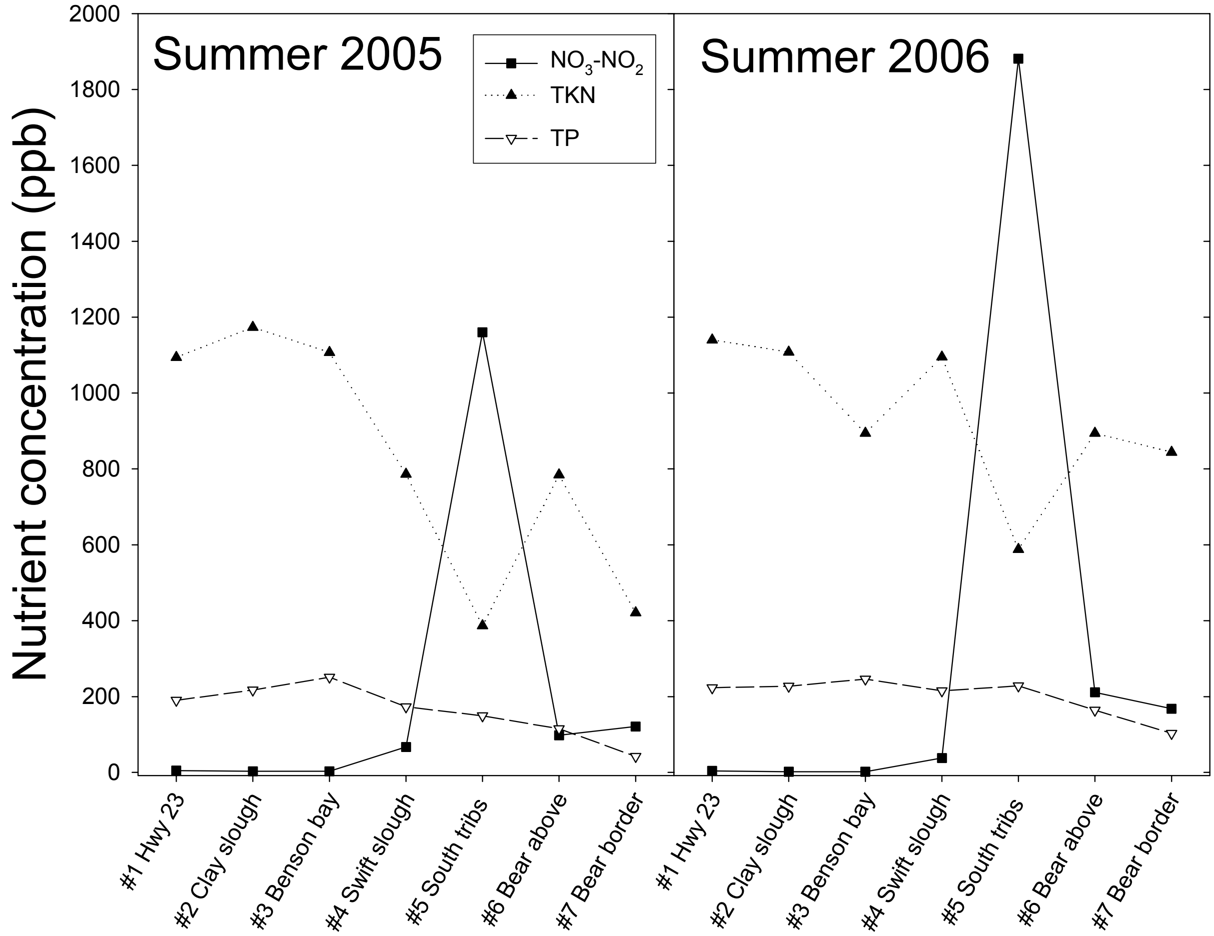

Figure 8. Nitrogen and phosphorus concentrations (parts per billion, ppb) at seven index sites on Cutler Reservoir and the Bear River, summer 2005 and summer 2006. 1000 ppb = 1 mg/L.

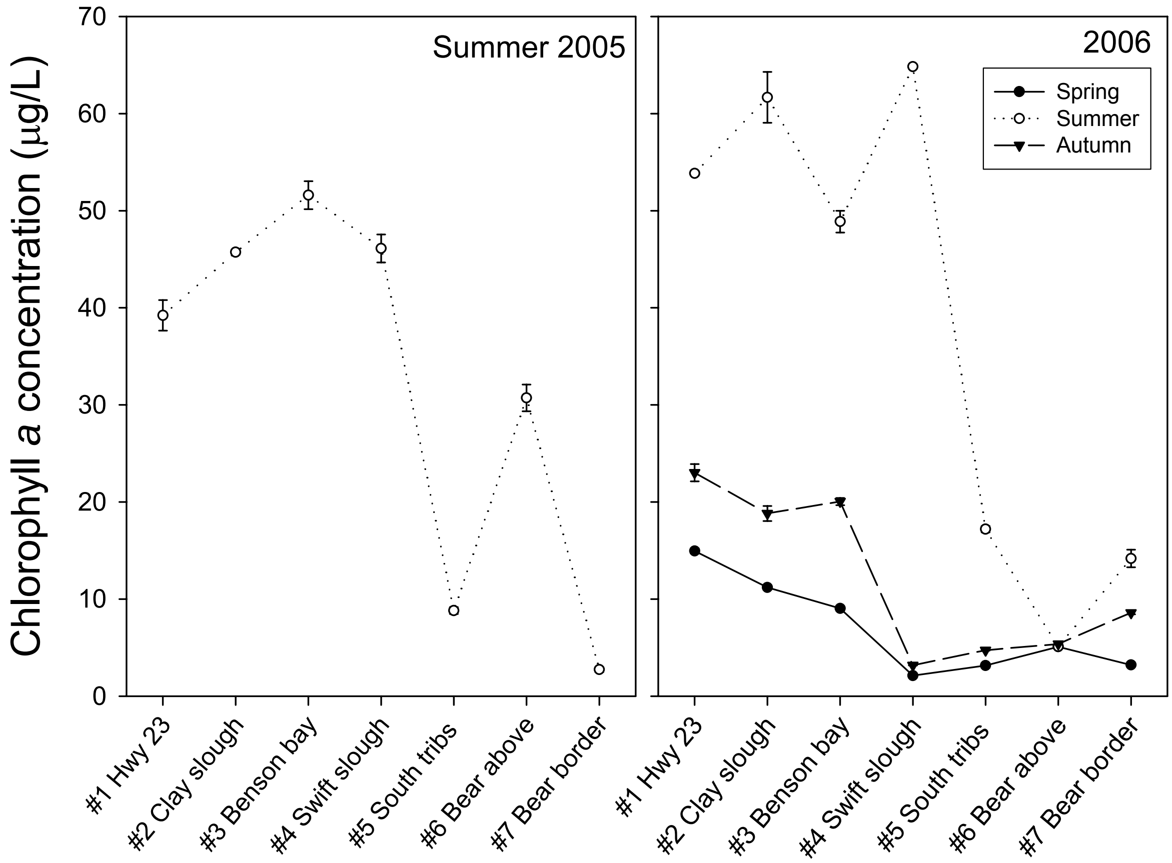

Figure 9. Mean chlorophyll *a* concentrations (mean µg/L ± 1 SE) at five index sites on Cutler Reservoir and two sites on the Bear River (6 and 7), summer 2005 and seasonally in 2006.

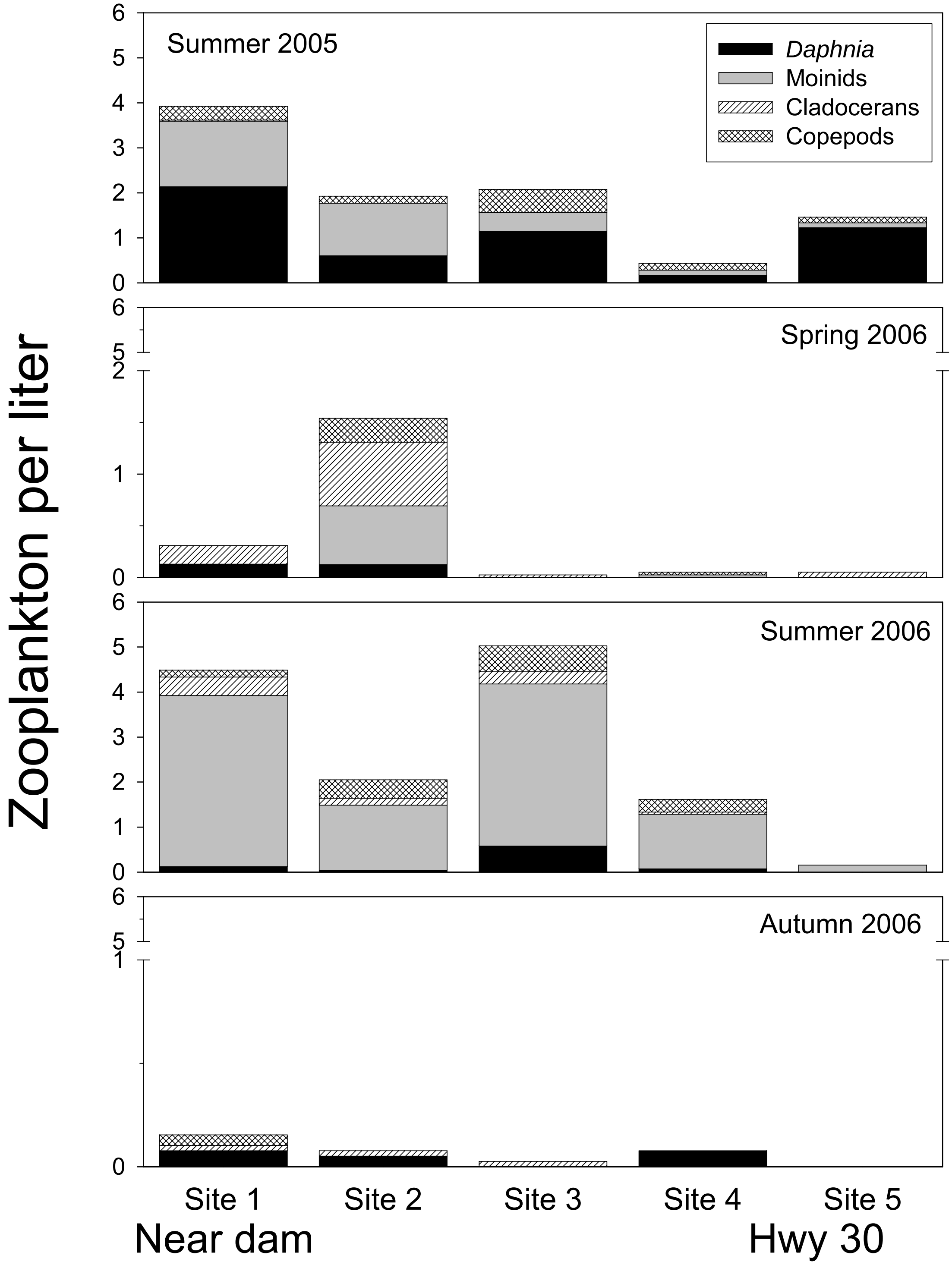

Figure 10. Zooplankton standing density (number/L) at five index sites in Cutler Reservoir, summer 2005 and seasonally in 2006. Cladocerans include *Bosmina, Ceriodaphnia, Diaphanasoma*, *Scapholebris,* and *Alona*. Moinids includes *Moina* and *Moinadaphnia*. Copepods include calanoids and cyclopoids. Note breaks in Spring and Autumn axes.

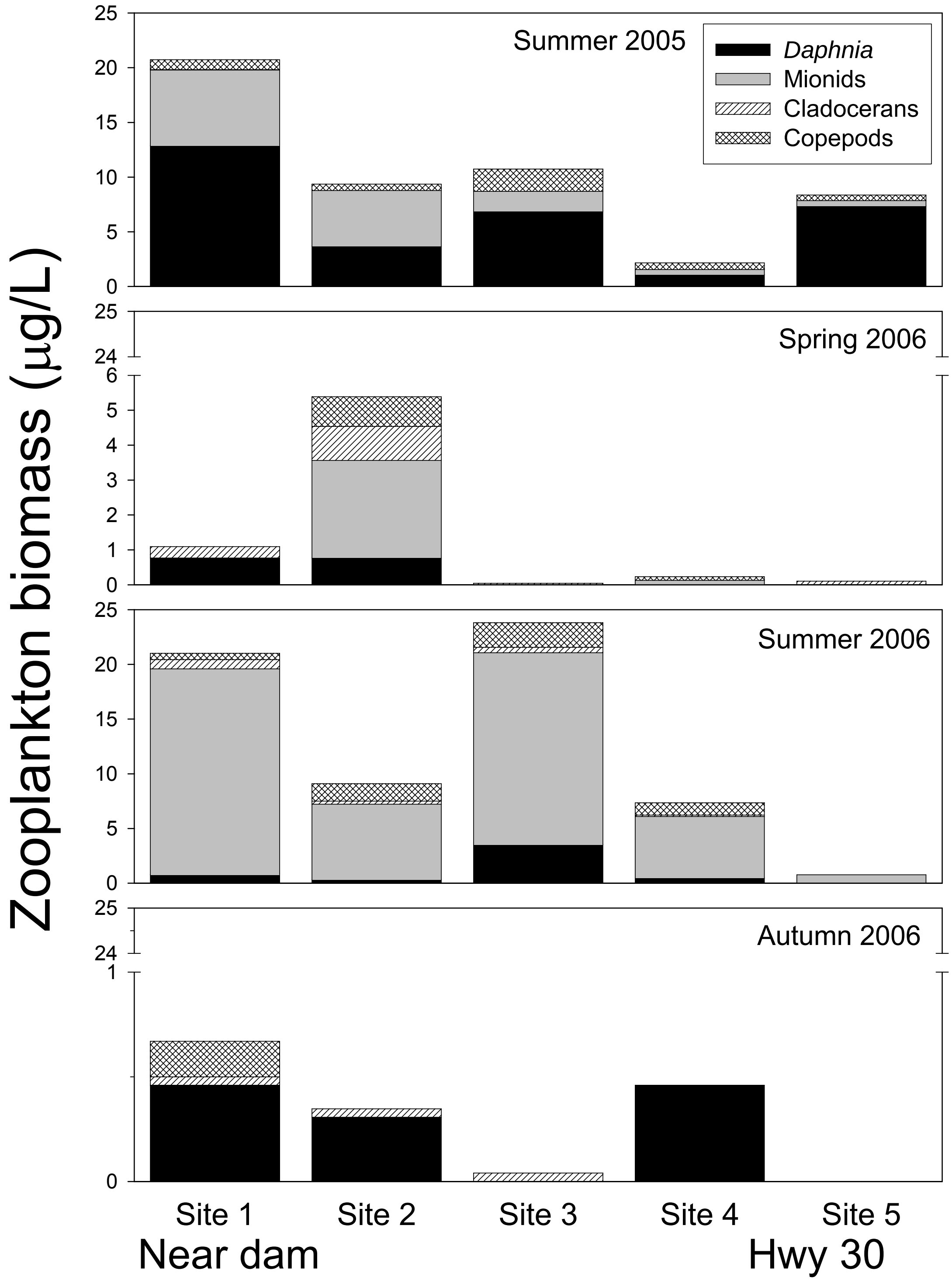

Figure 11. Zooplankton standing biomass (µg/L) at five index sites in Cutler Reservoir, summer 2005 and seasonally in 2006. Cladocerans include *Bosmina, Ceriodaphnia, Diaphanasoma*, *Scapholebris,* and *Alona*. Moinids includes *Moina* and *Moinadaphnia*. Copepods include calanoids and cyclopoids. Note breaks in Spring and Autumn axes.

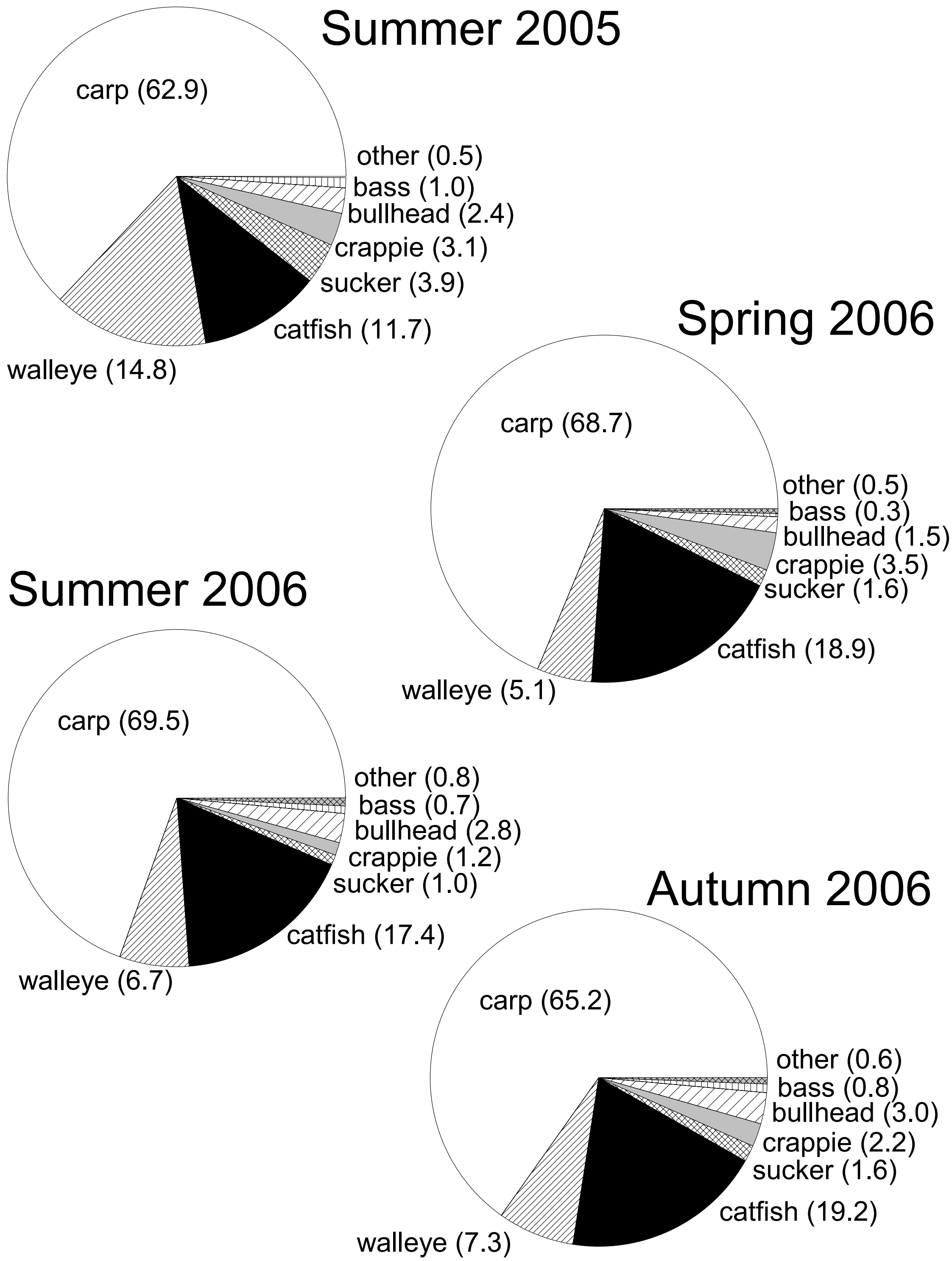

Figure 12. Biomass (as percentage of total kg) of fish by species captured by all sampling methods at all sites on Cutler Reservoir and two sites on the Bear River, summer 2005 and seasonally in 2006. Bass include smallmouth and largemouth. Actual percentages are given in parentheses. Other includes bluegill sunfish, green sunfish, and fathead minnow.

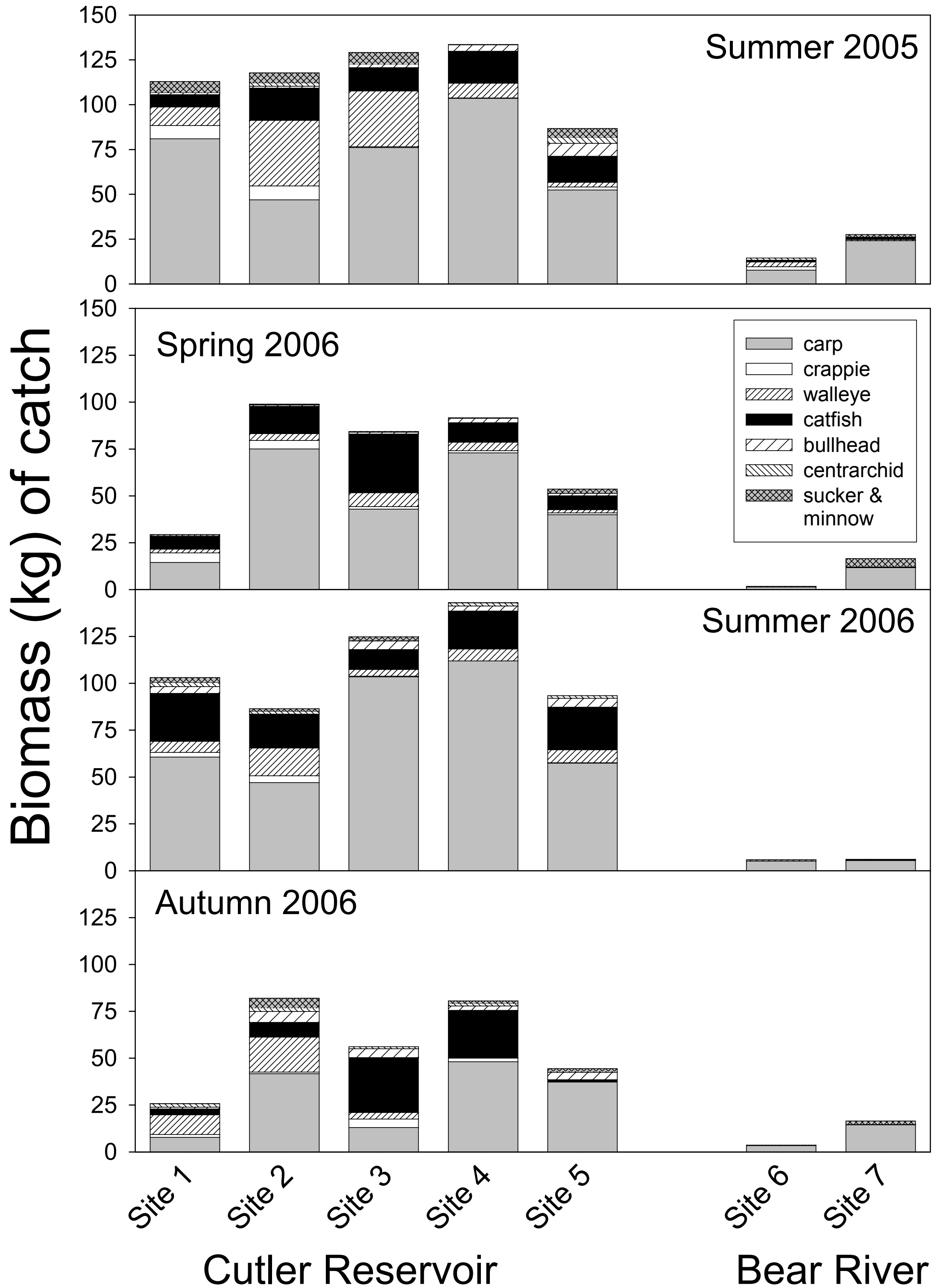

Figure 13. Biomass (kg) of fish by species (or group) captured by all sampling methods at five sample sites on Cutler Reservoir and two sites on the Bear River, summer 2005 and seasonally in 2006. Centrarchid includes bass and sunfish.

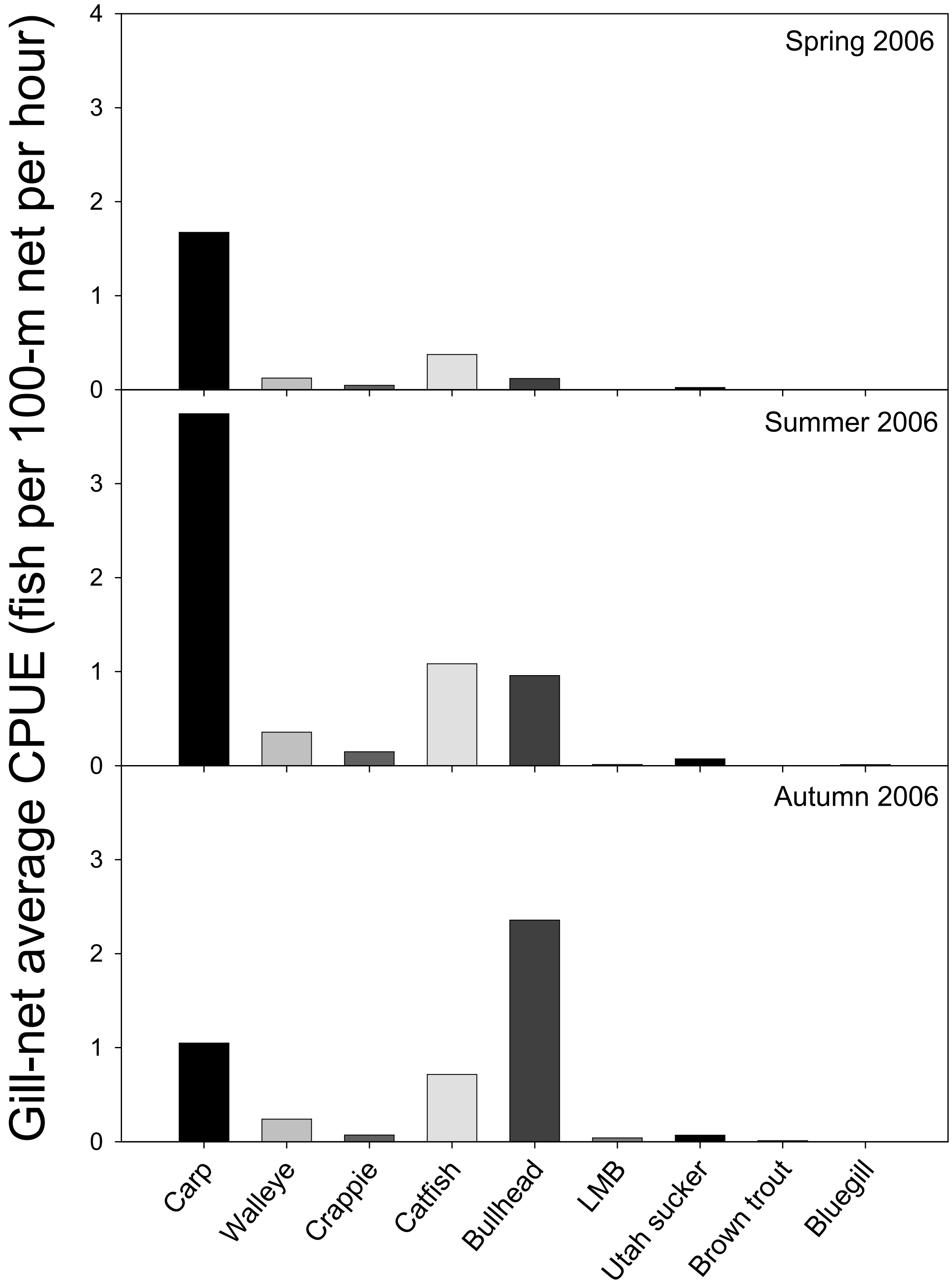

Figure 14. Seasonal catch-per-unit-effort (CPUE; number of fish captured in a 100-m long gill net per hour) for various species captured at five index sites in Cutler Reservoir, 2006. LMB = largemouth bass.

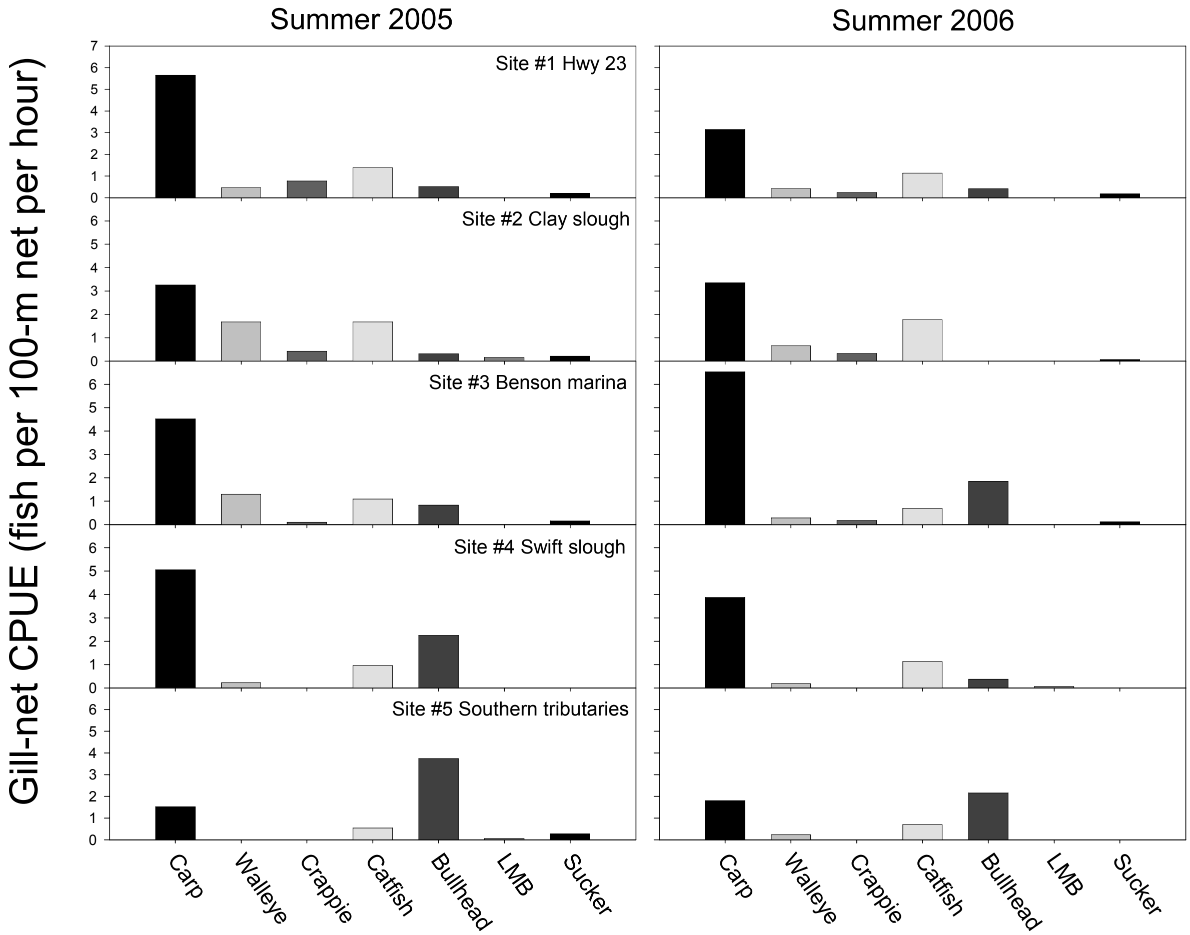

Figure 15. Summer catch-per-unit-effort (CPUE; number of fish captured in a 100-m long gill net per hour) for various species captured at five index sites in Cutler Reservoir, 2005 and 2006. LMB = largemouth bass.

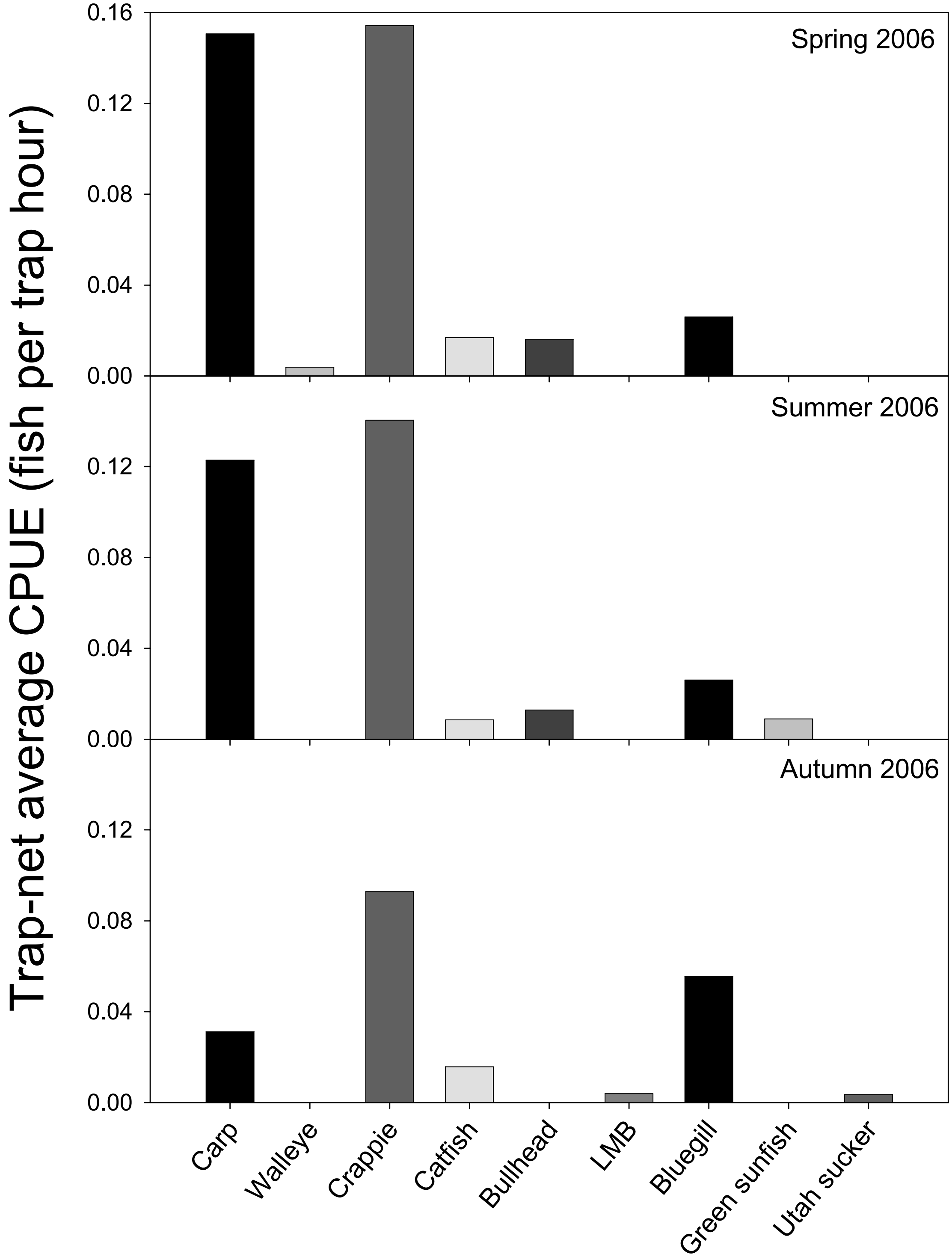

Figure 16. Seasonal catch-per-unit-effort (CPUE; number of fish captured per hour in three trap nets) for various species captured at five index sites in Cutler Reservoir, 2006. LMB = largemouth bass.

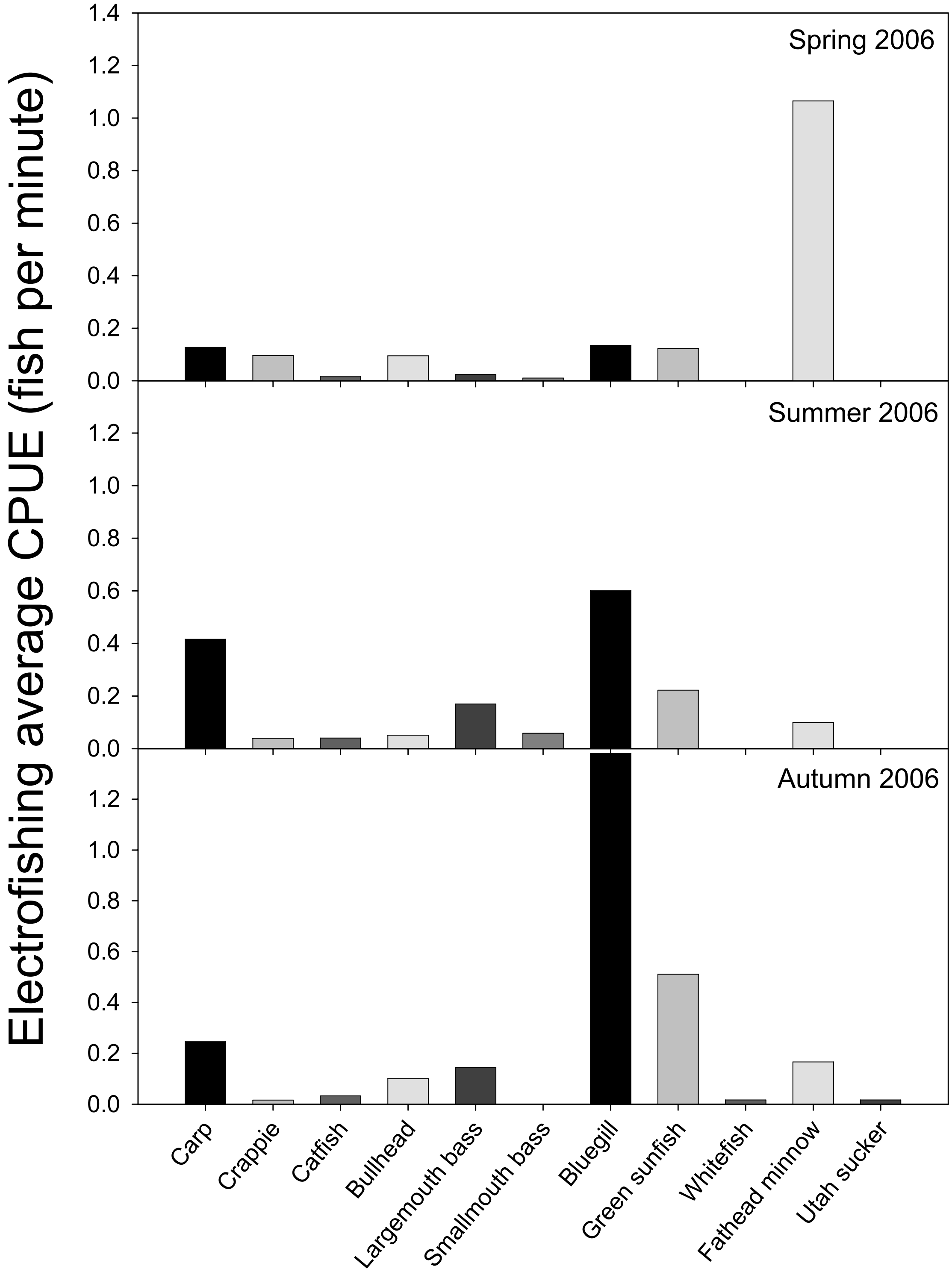

Figure 17. Seasonal catch-per-unit-effort (CPUE; average number of fish captured per minute using electrofishing) for various species captured at five index sites in Cutler Reservoir, 2006.

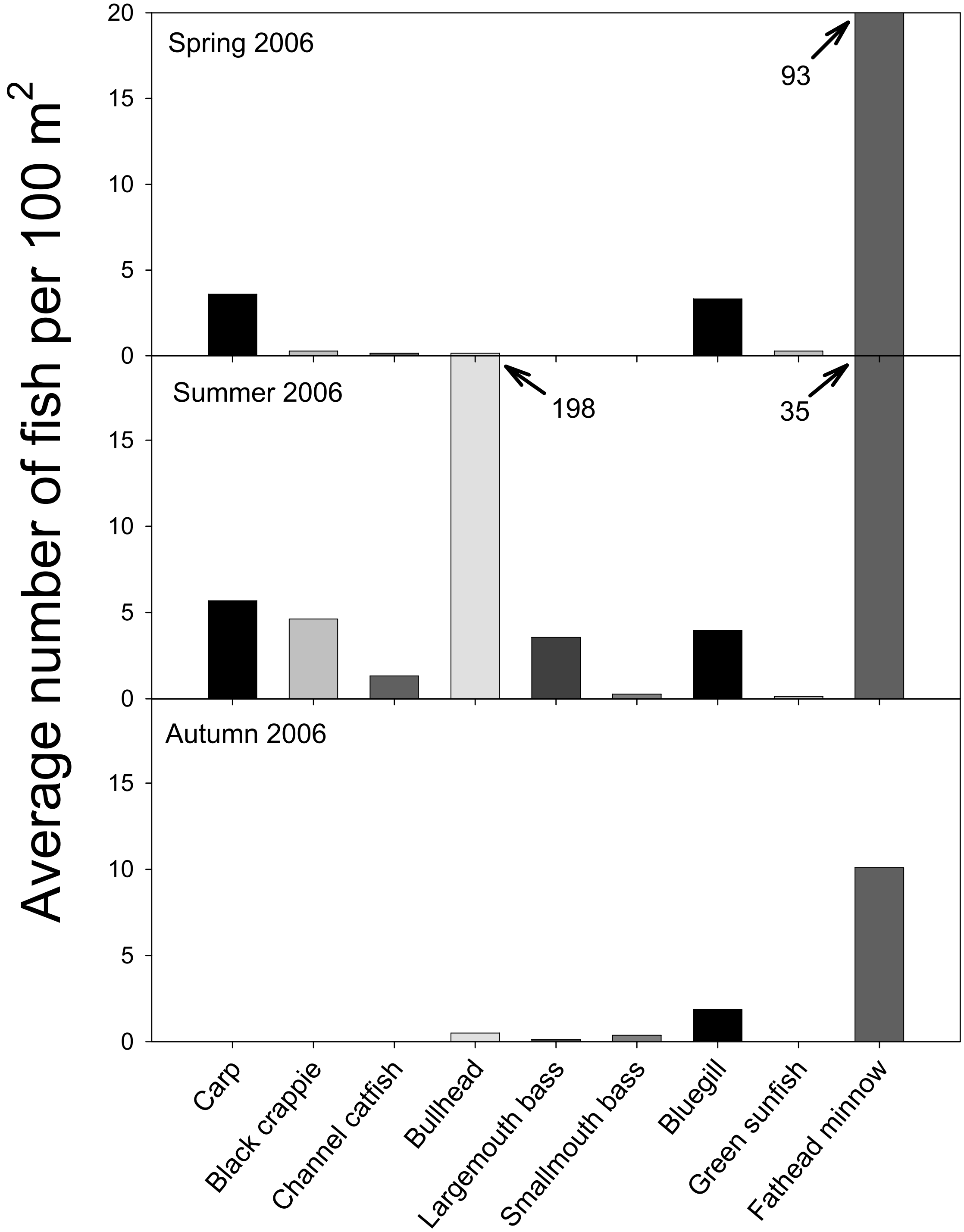

Figure 18. Seasonal density (average number of fish seined per 100-m^2 area) for various species captured at five index sites in Cutler Reservoir, 2006. Numbers and arrows depict high, out-of-range values.

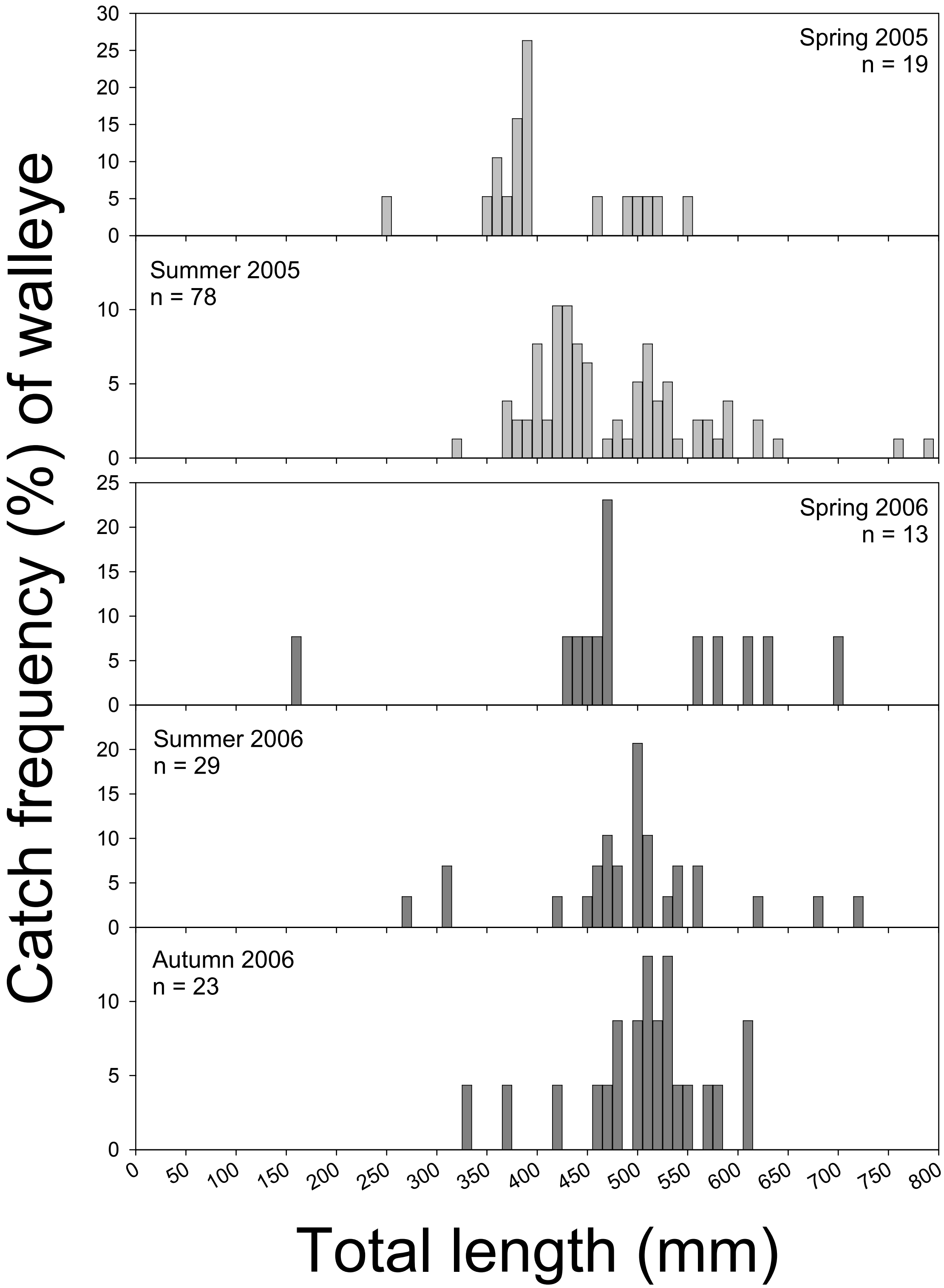

Figure 19. Seasonal length frequency (%) distributions of walleye captured by all sampling methods at five index sites in Cutler Reservoir and two sites on the Bear River, 2005 and 2006. Total numbers captured (n) are given.

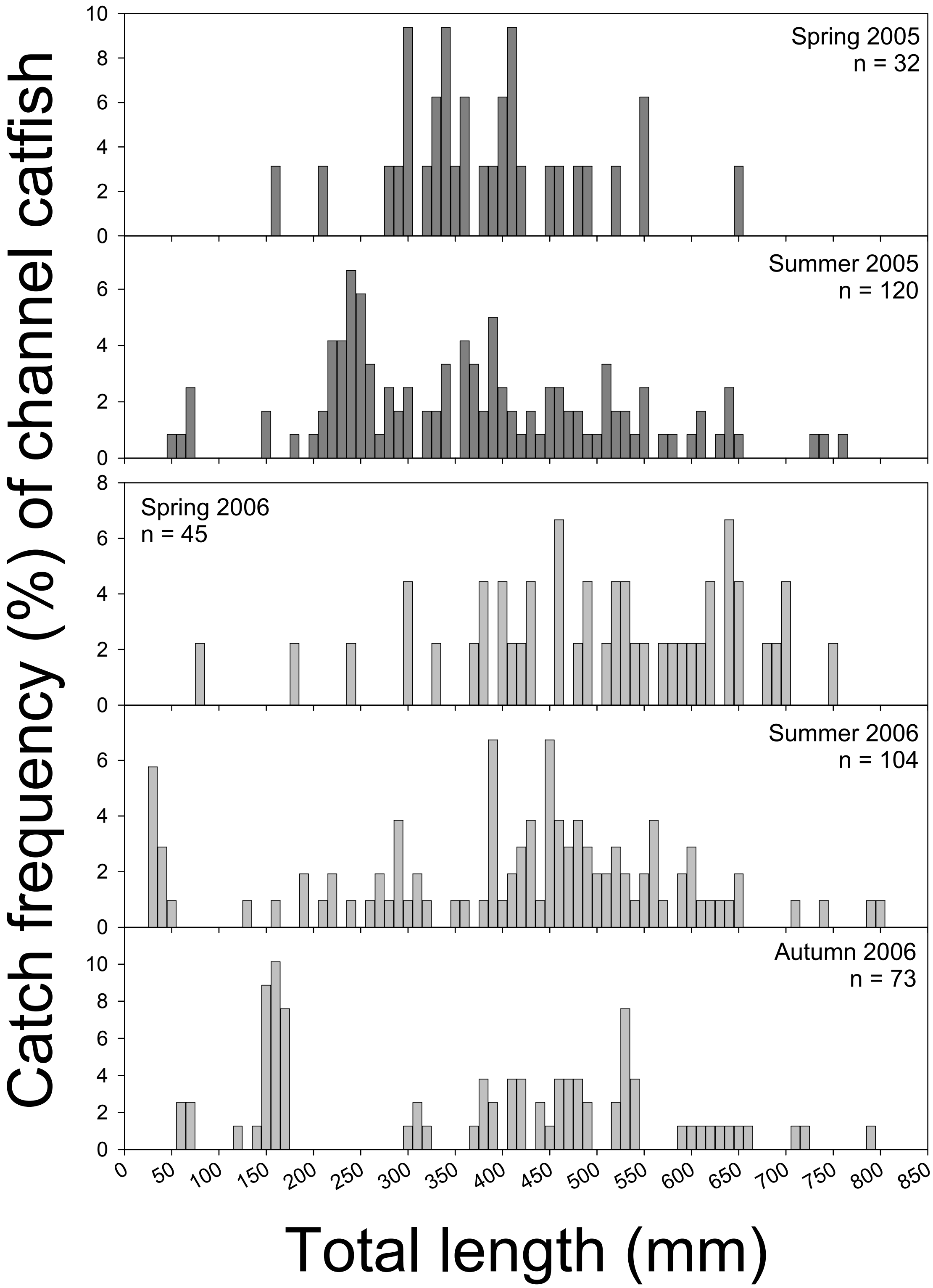

Figure 20. Seasonal length frequency (%) distributions of channel catfish captured by all sampling methods at five index sites in Cutler Reservoir and two sites on the Bear River, 2005 and 2006. Total numbers captured (n) are given.

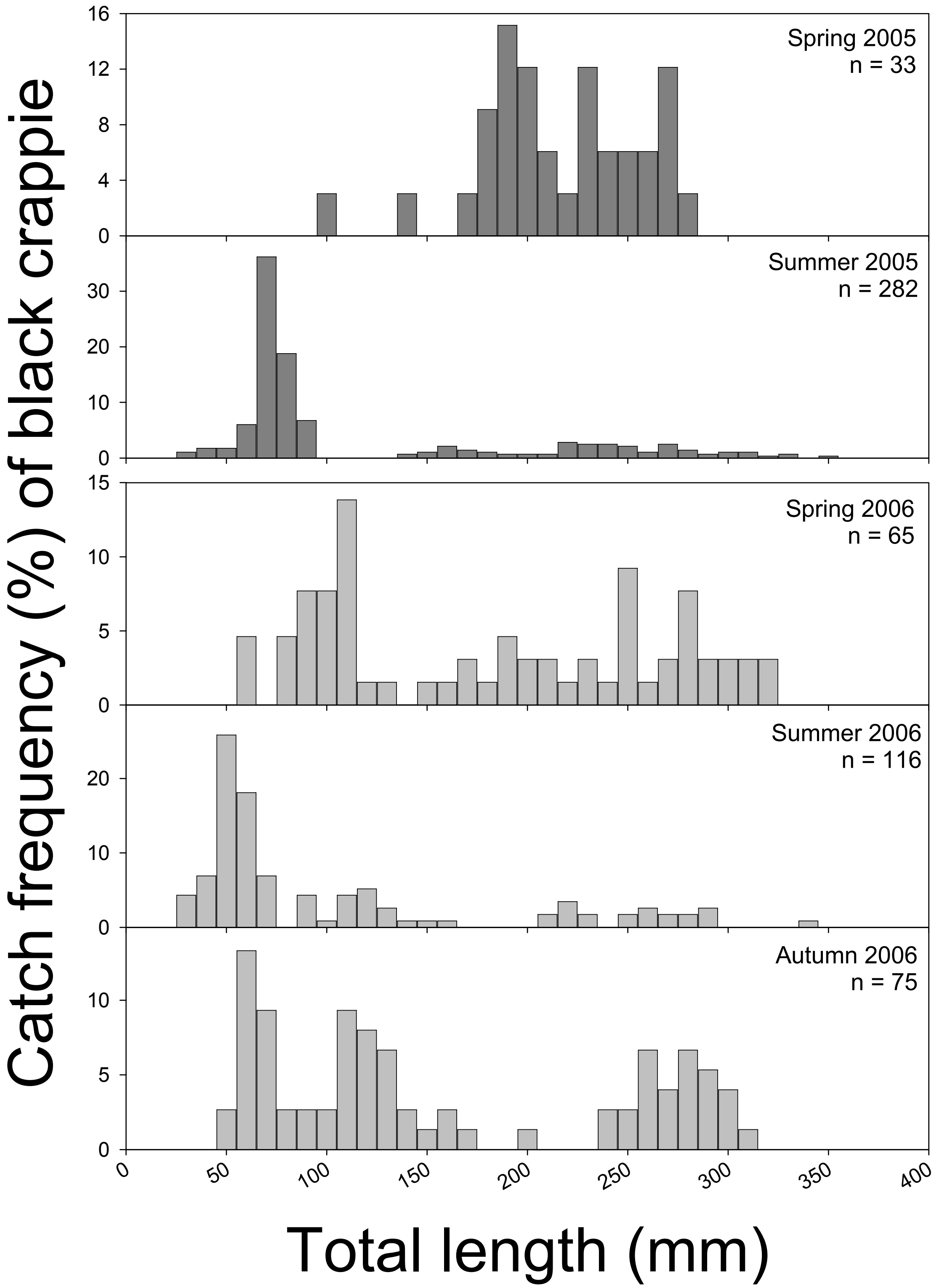

Figure 21. Seasonal length frequency (%) distributions of black crappie captured by all sampling methods at five index sites in Cutler Reservoir and two sites on the Bear River, 2005 and 2006. Total numbers captured (n) are given.

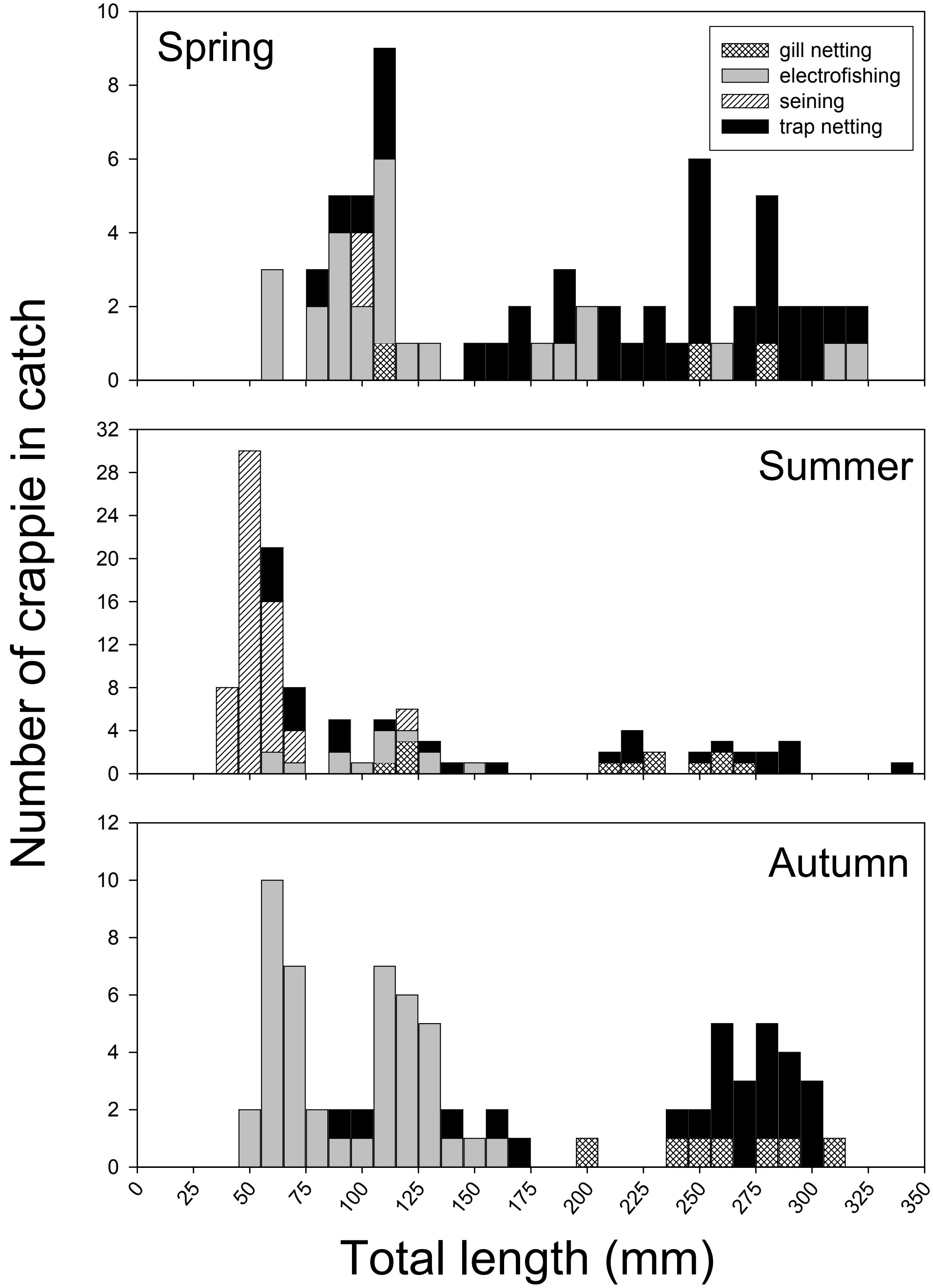

Figure 22. Seasonal length frequency (as number) distributions of black crappie captured by various sampling gears at five index sites in Cutler Reservoir and two sites on the Bear River, 2006.

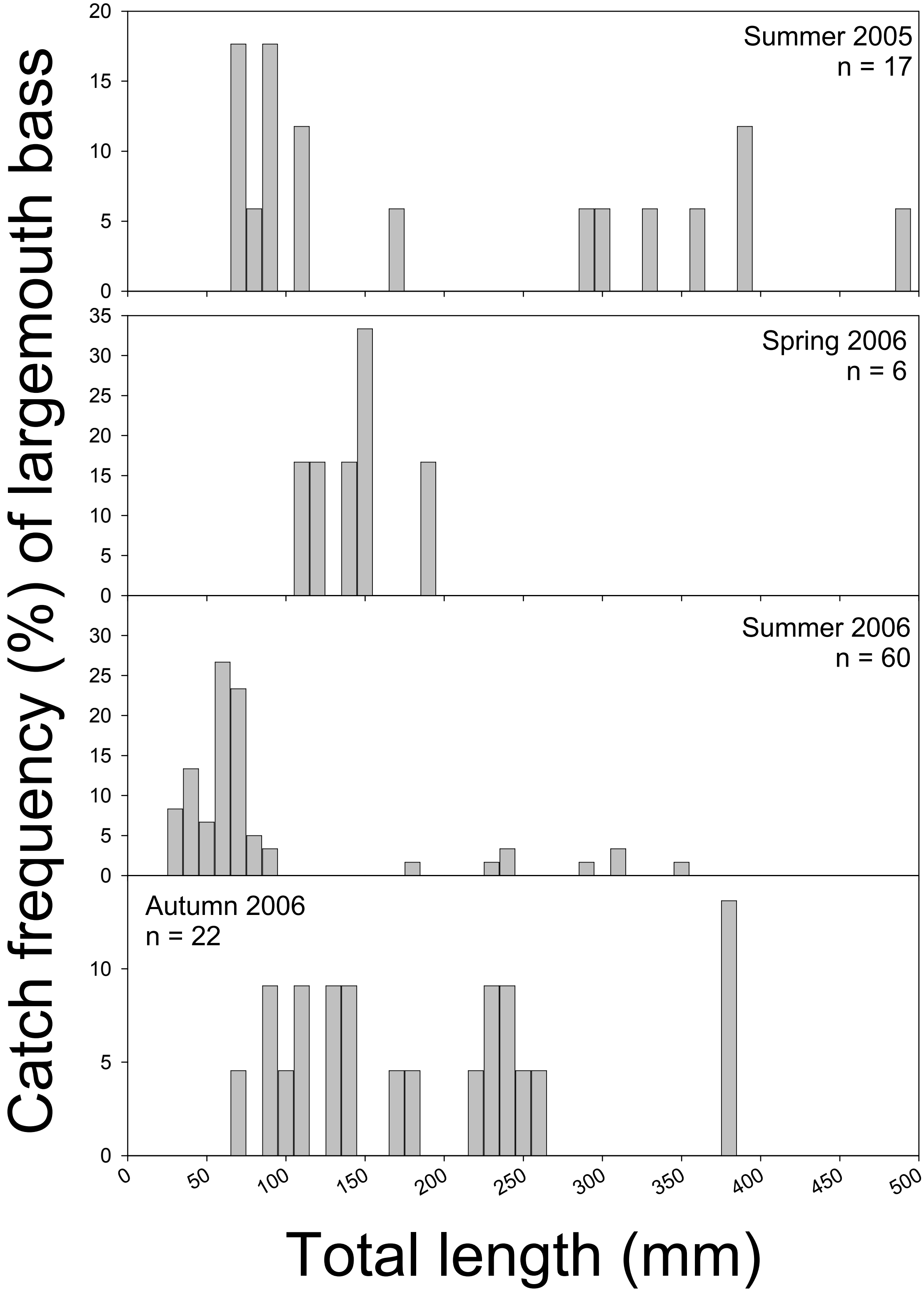

Figure 23. Seasonal length frequency (%) distributions of largemouth bass captured by all sampling methods at five index sites in Cutler Reservoir and two sites on the Bear River, 2005 and 2006. Total numbers captured (n) are given.

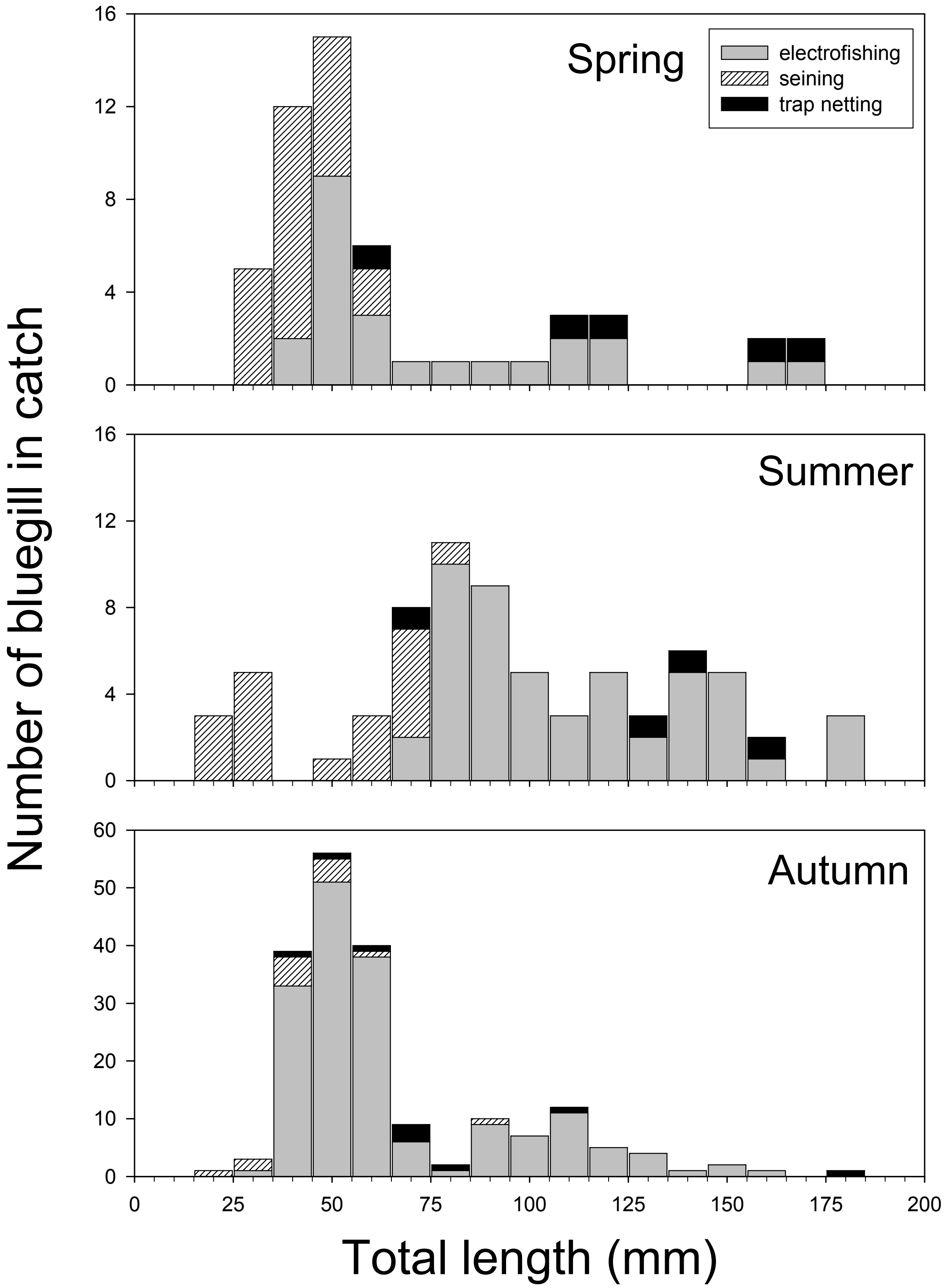

Figure 24. Seasonal length frequency (as number) distributions of bluegill sunfish captured by various sampling gears at five index sites in Cutler Reservoir and two sites on the Bear River, 2006.

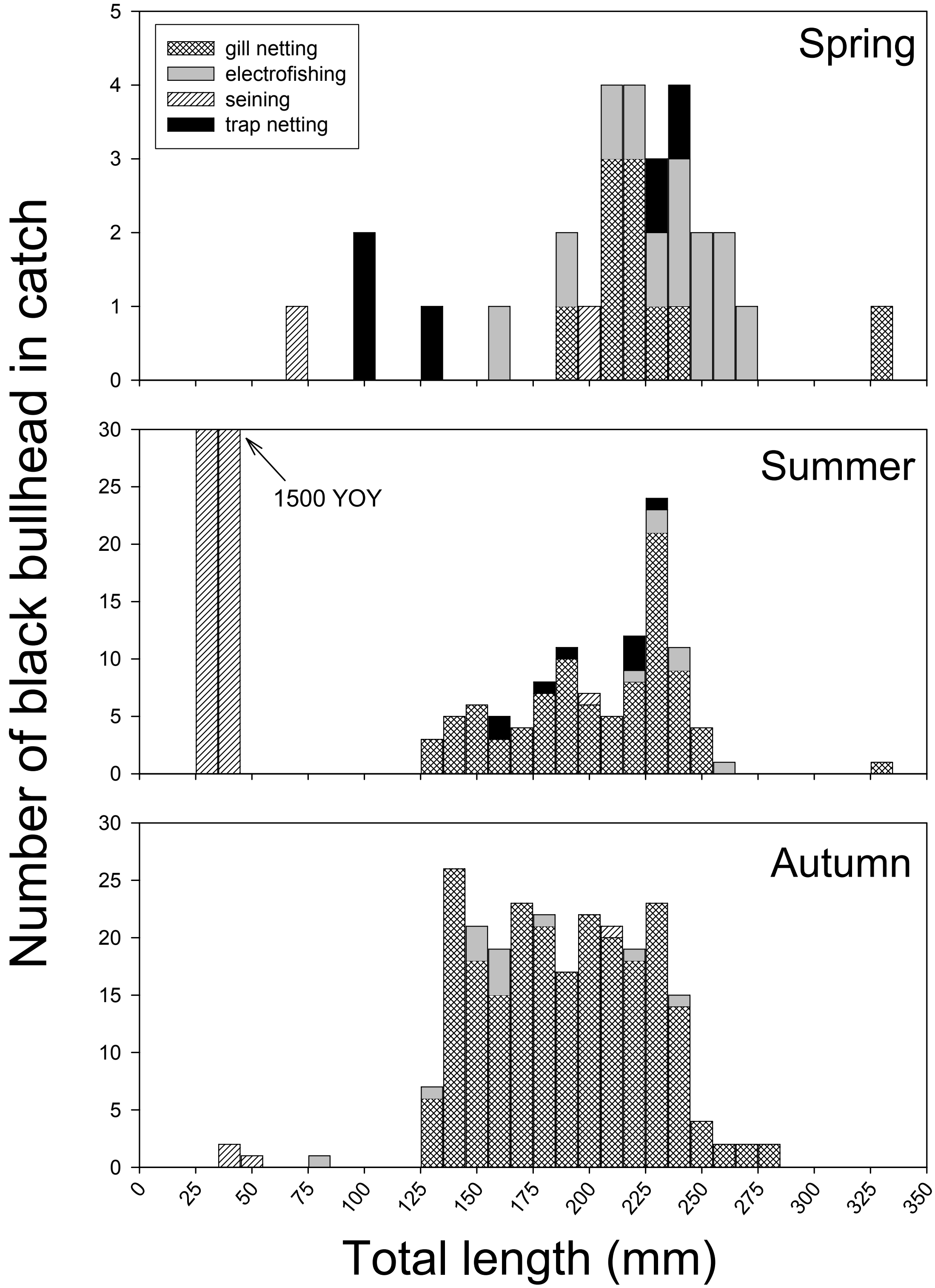

Figure 25. Seasonal length frequency (as number) distributions of black bullhead captured by various sampling gears at five index sites in Cutler Reservoir and two sites on the Bear River, 2006. The arrow and 1500 YOY in the summer panel indicates that 1500 young-of-year bullhead were captured by seine.

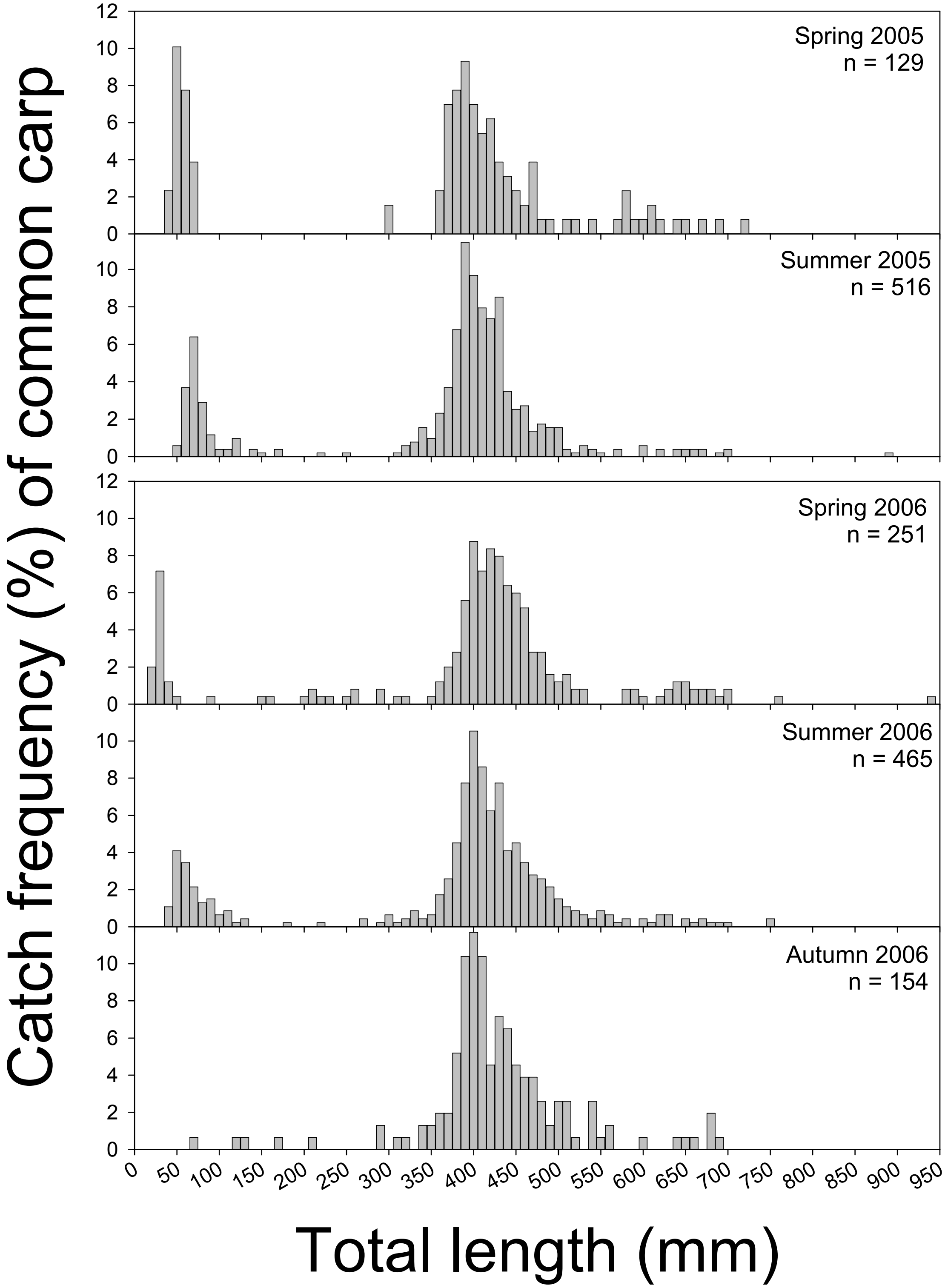

Figure 26. Seasonal length frequency (%) distributions of common carp captured by all sampling methods at five index sites in Cutler Reservoir and two sites on the Bear River, 2005 and 2006. Total numbers captured (n) are given.

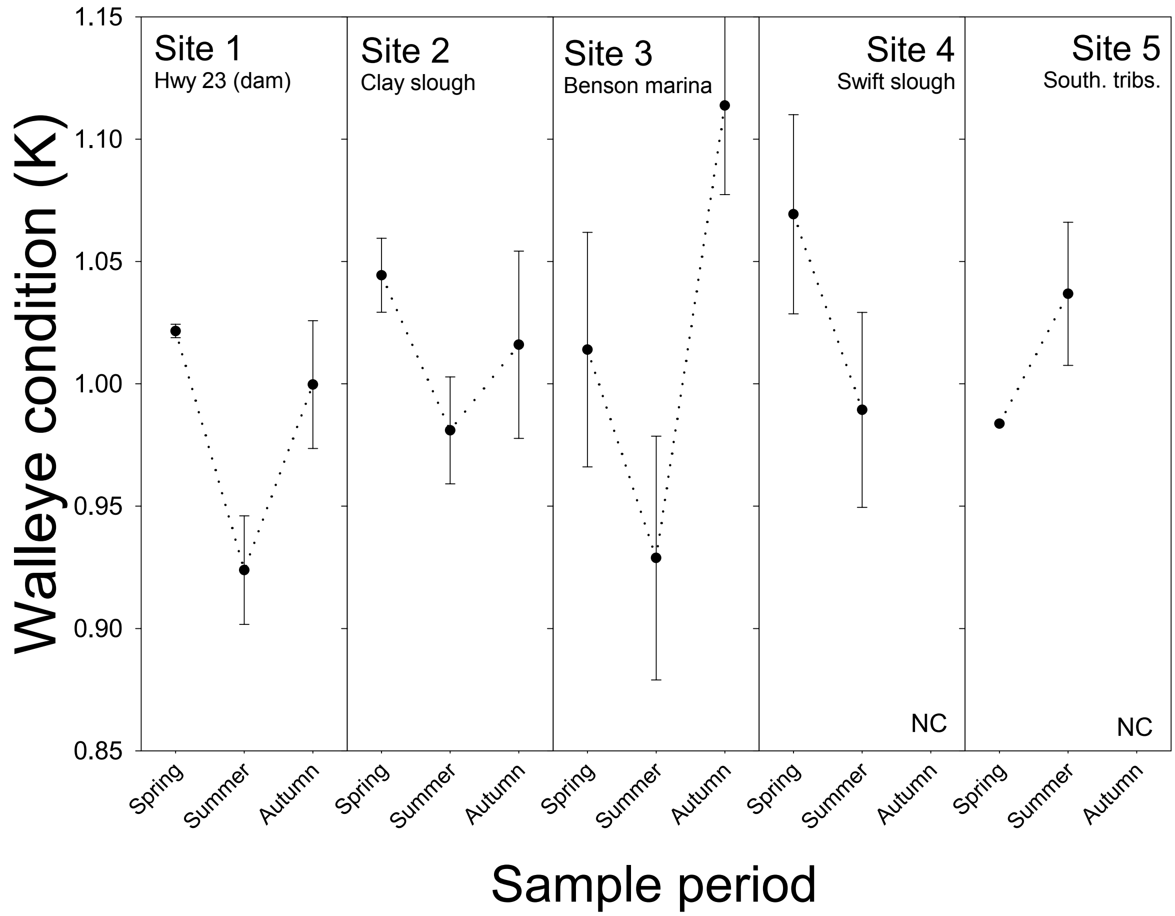

Figure 27. Seasonal condition (mean K $\pm$ 1 SE) of walleye at five index sites in Cutler Reservoir, 2006.

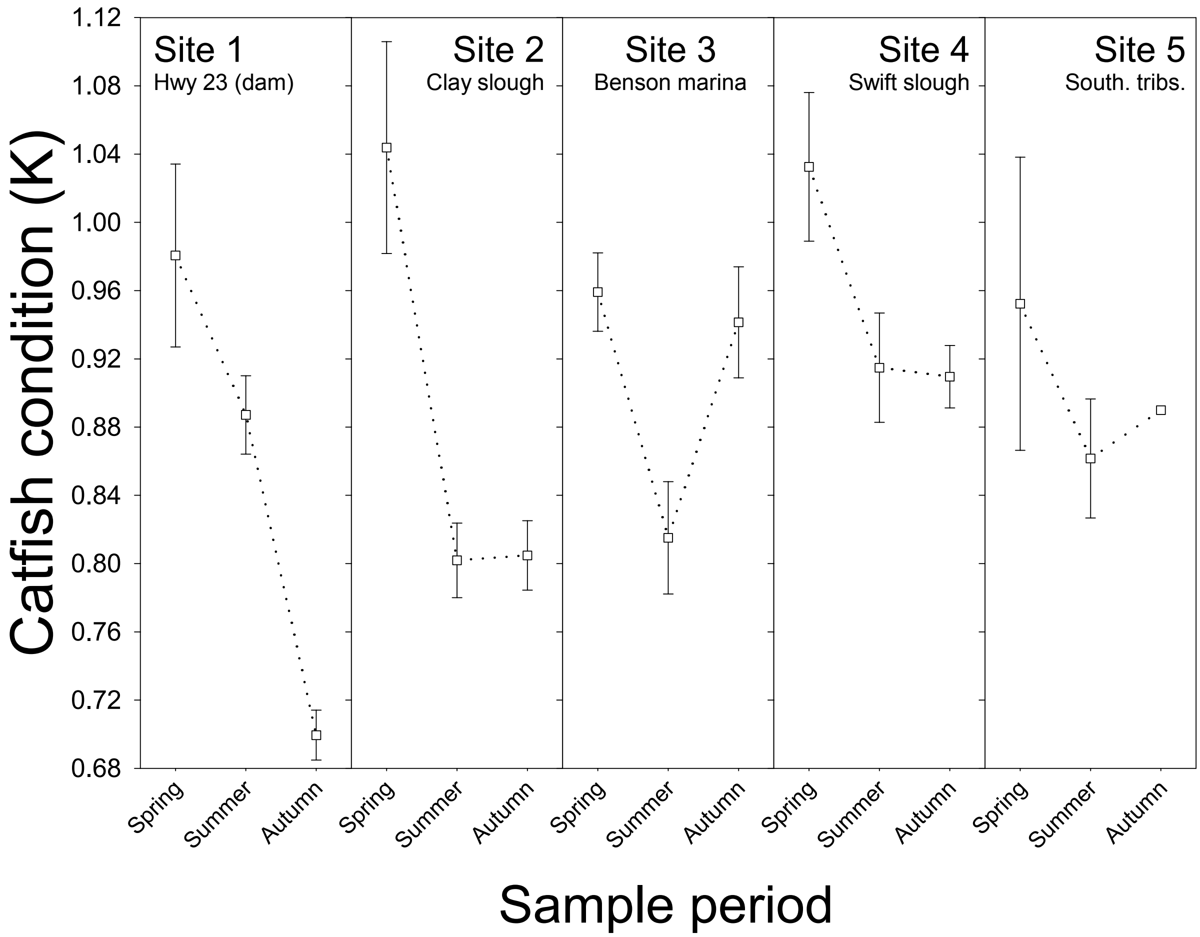

Figure 28. Seasonal condition (mean K $\pm$ 1 SE) of channel catfish at five index sites in Cutler Reservoir, 2006.

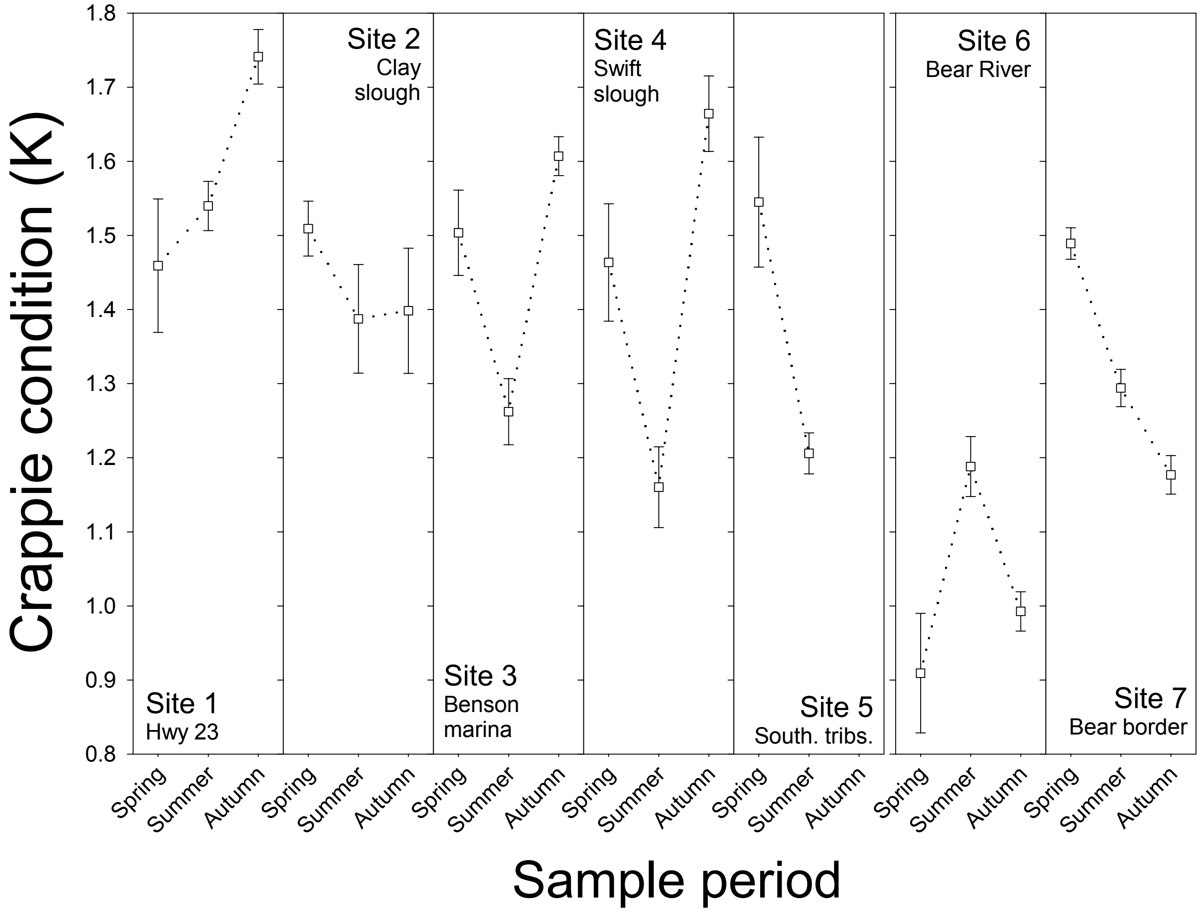

Figure 29. Seasonal condition (mean K $\pm$ 1 SE) of black crappie at five index sites in Cutler Reservoir and two sample sites in the Bear River, 2006.

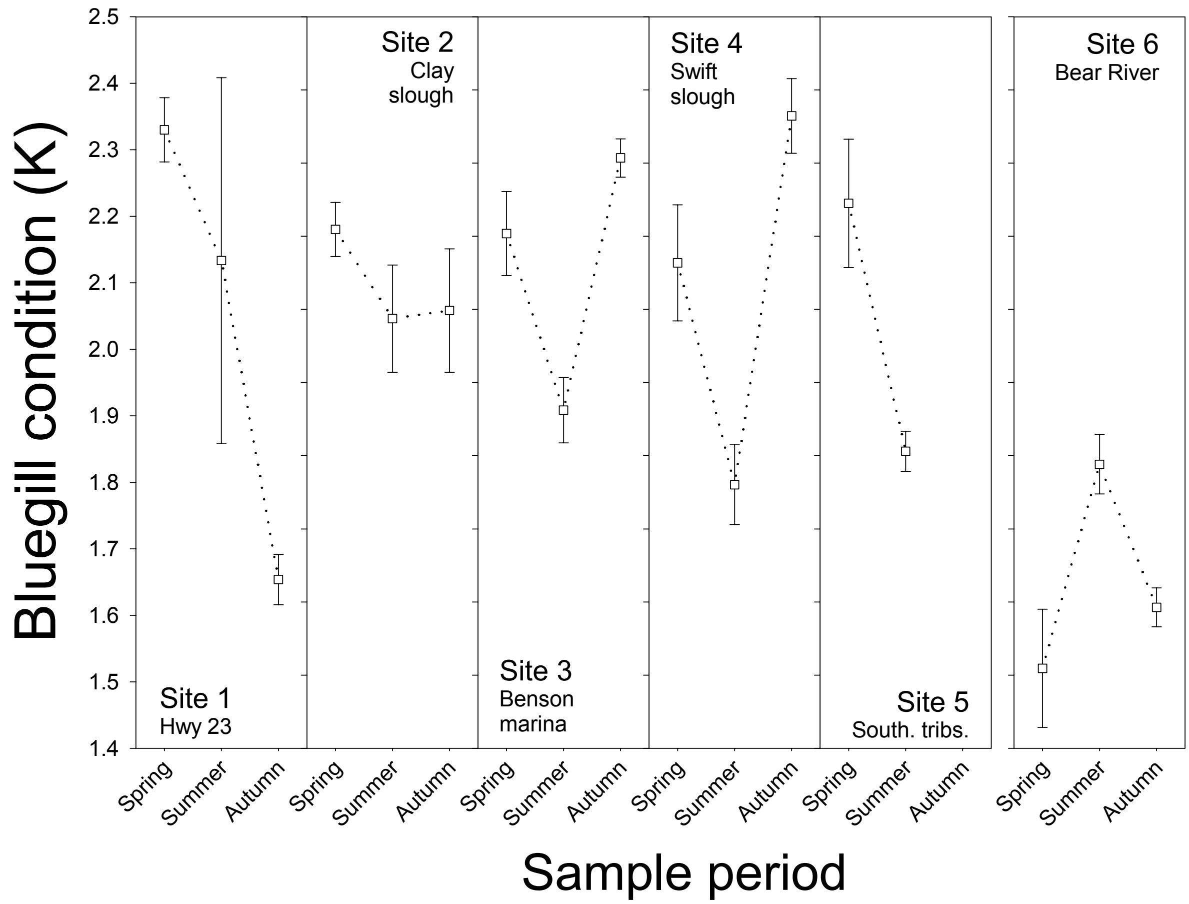

Figure 30. Seasonal condition (mean K $\pm$ 1 SE) of bluegill sunfish at five index sites in Cutler Reservoir and one sample site in the Bear River, 2006.

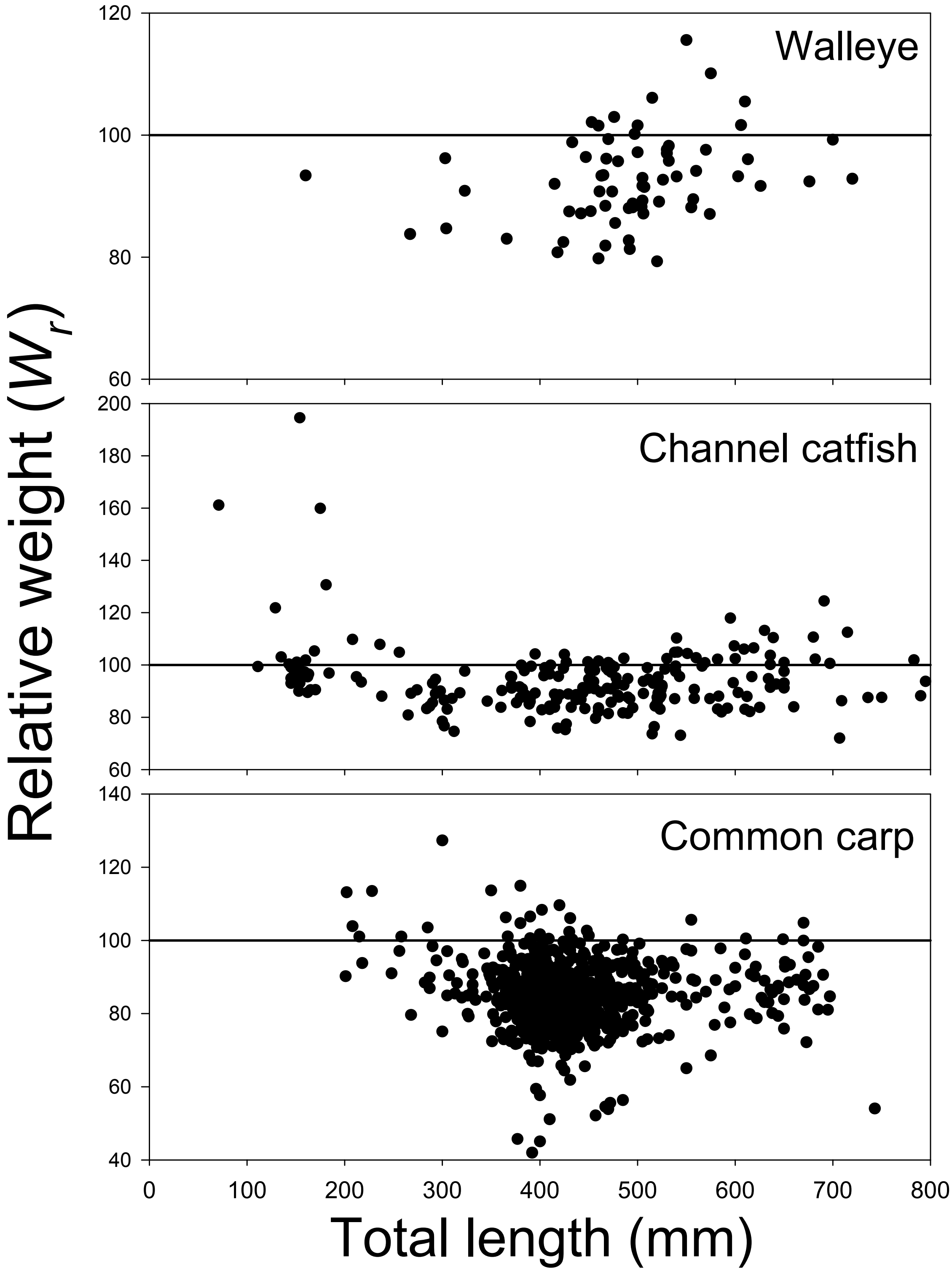

Figure 31. Relationship between total length and relative weight (W_r) of walleye, channel catfish, and common carp from Cutler Reservoir compared to the national standard (reference line at 100).

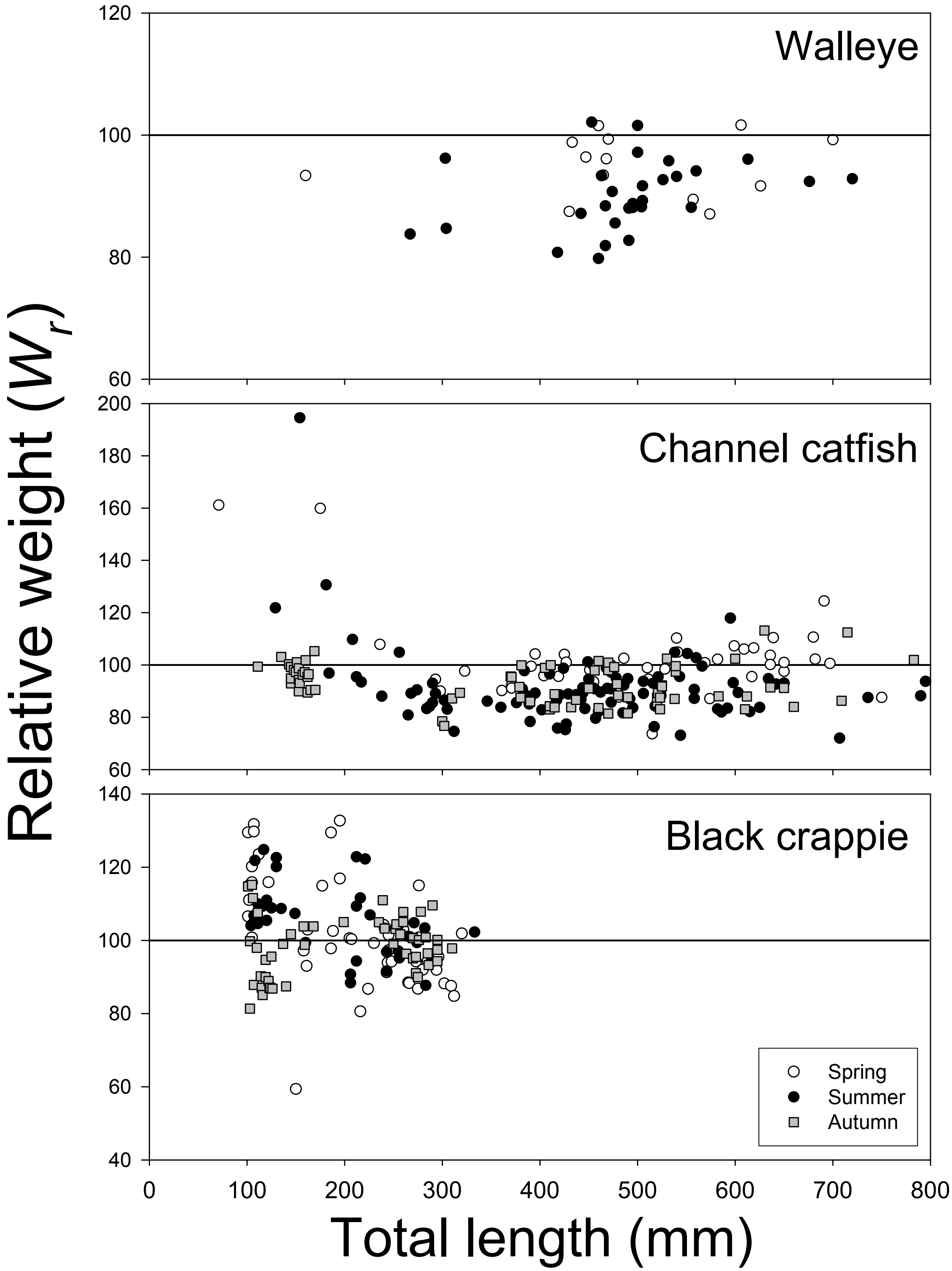

Figure 32. Seasonal relationship between total length and relative weight (W_r) of walleye, channel catfish, and black crappie from Cutler Reservoir compared to the national standard (reference line at 100).

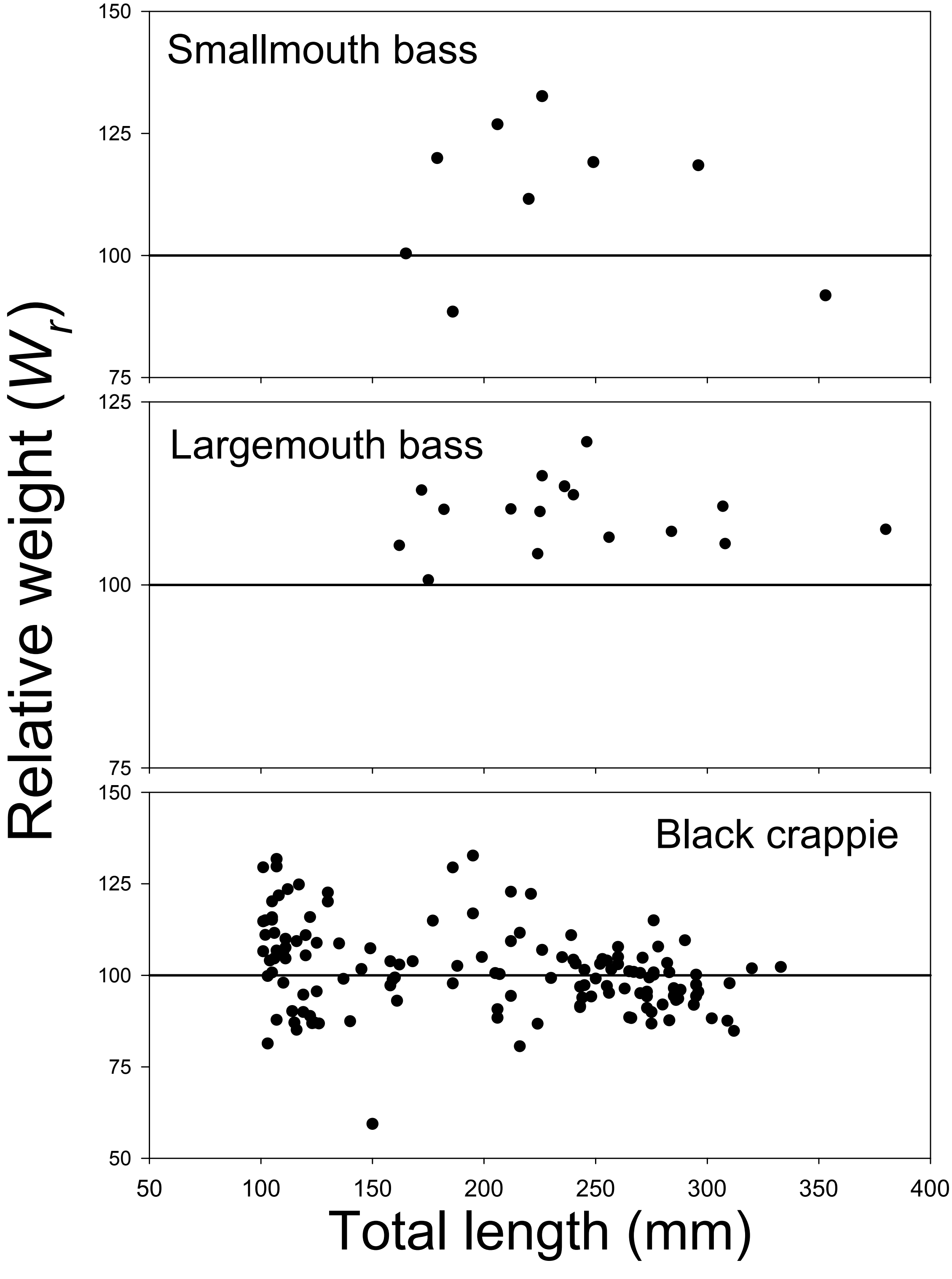

Figure 33. Relationship between total length and relative weight (W_r) of smallmouth bass, largemouth bass, and black crappie from Cutler Reservoir compared to the national standard (reference line at 100).

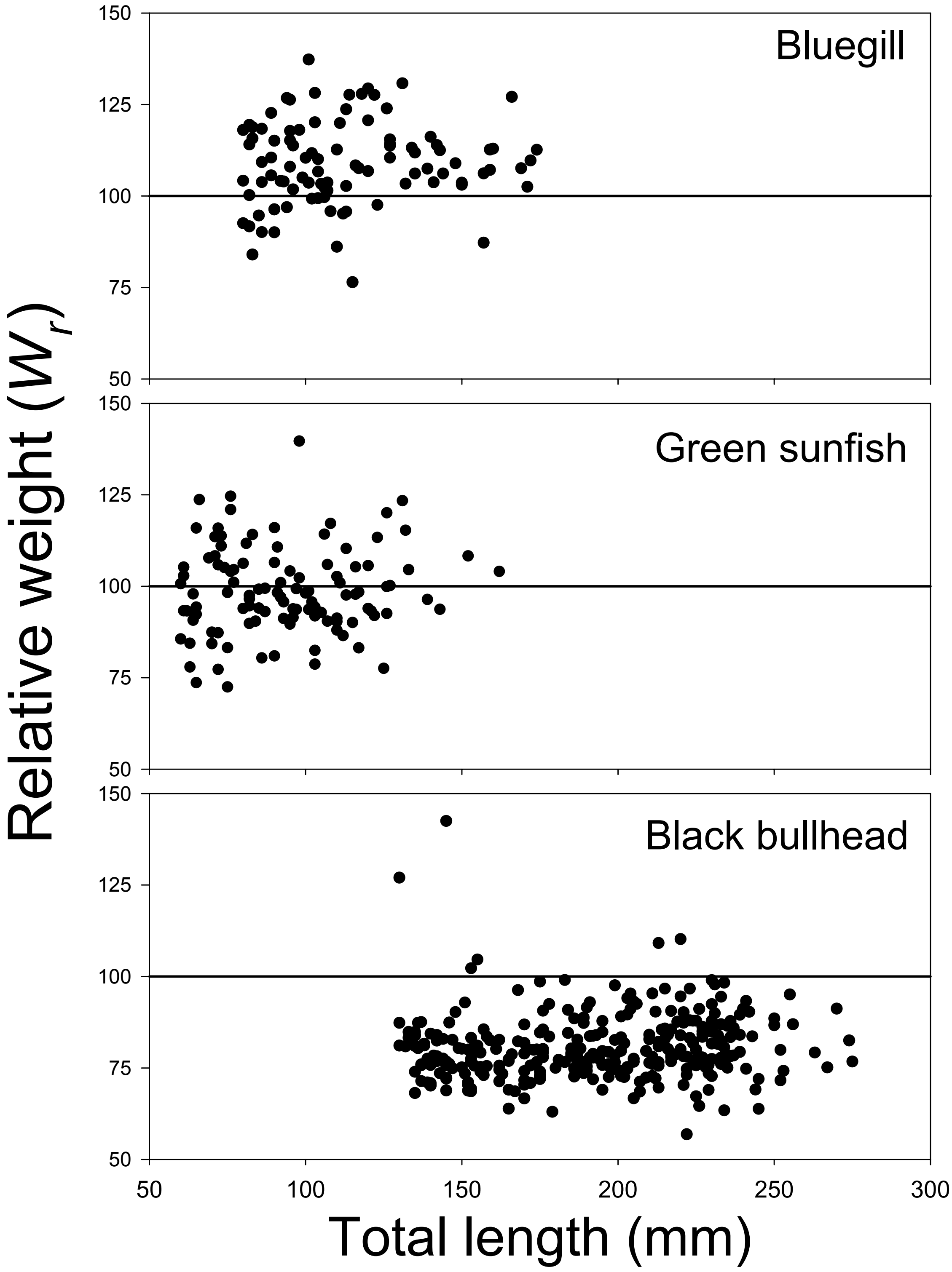

Figure 34. Relationship between total length and relative weight (W_r) of bluegill, green sunfish, and black bullhead from Cutler Reservoir compared to the national standard (reference line at 100).

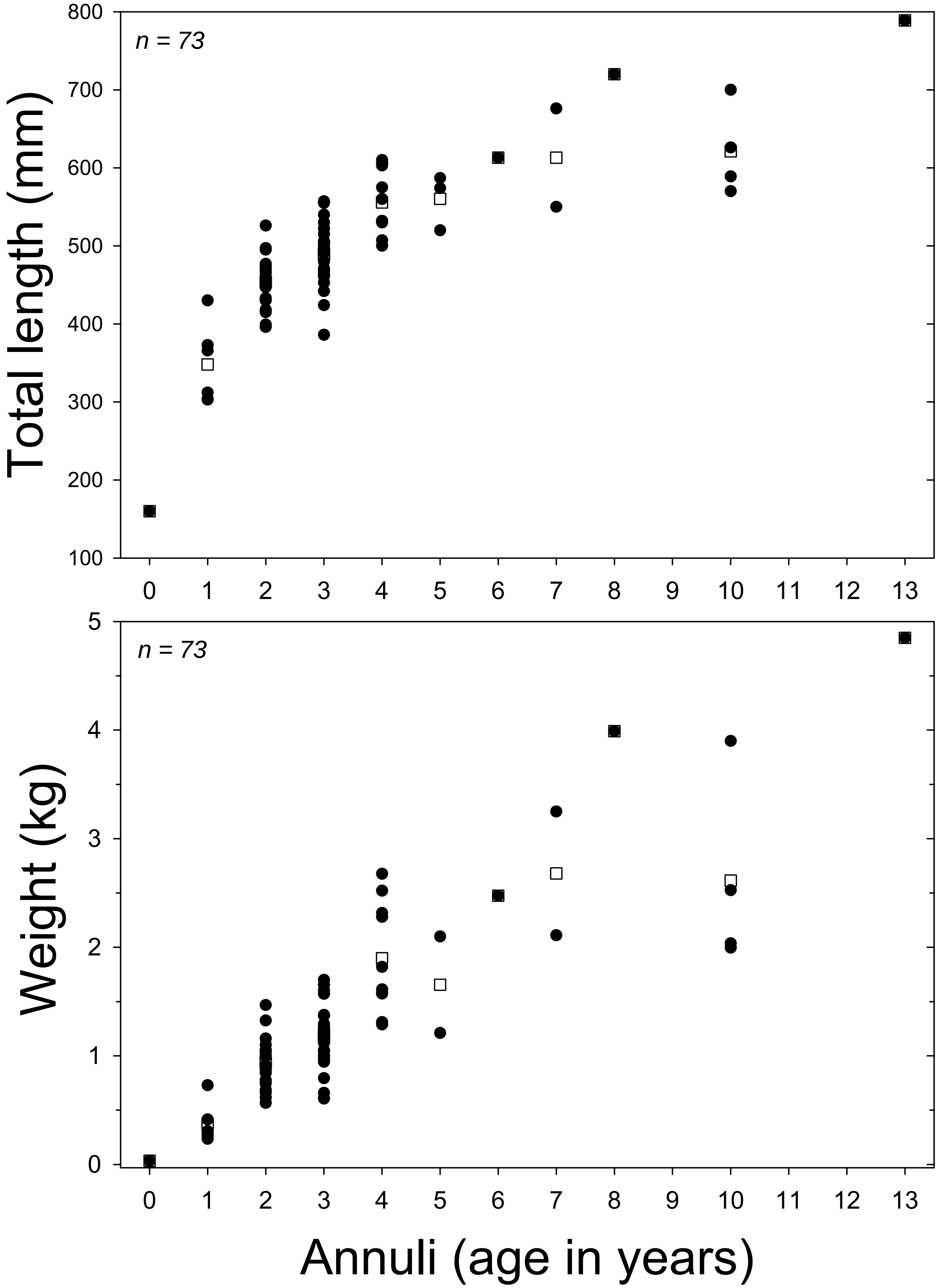

Figure 35. Length-at-age (distribution • and mean □) and weight-at-age (distribution • and mean □) of 73 otolith-aged walleye from Cutler Reservoir, 2005 and 2006.

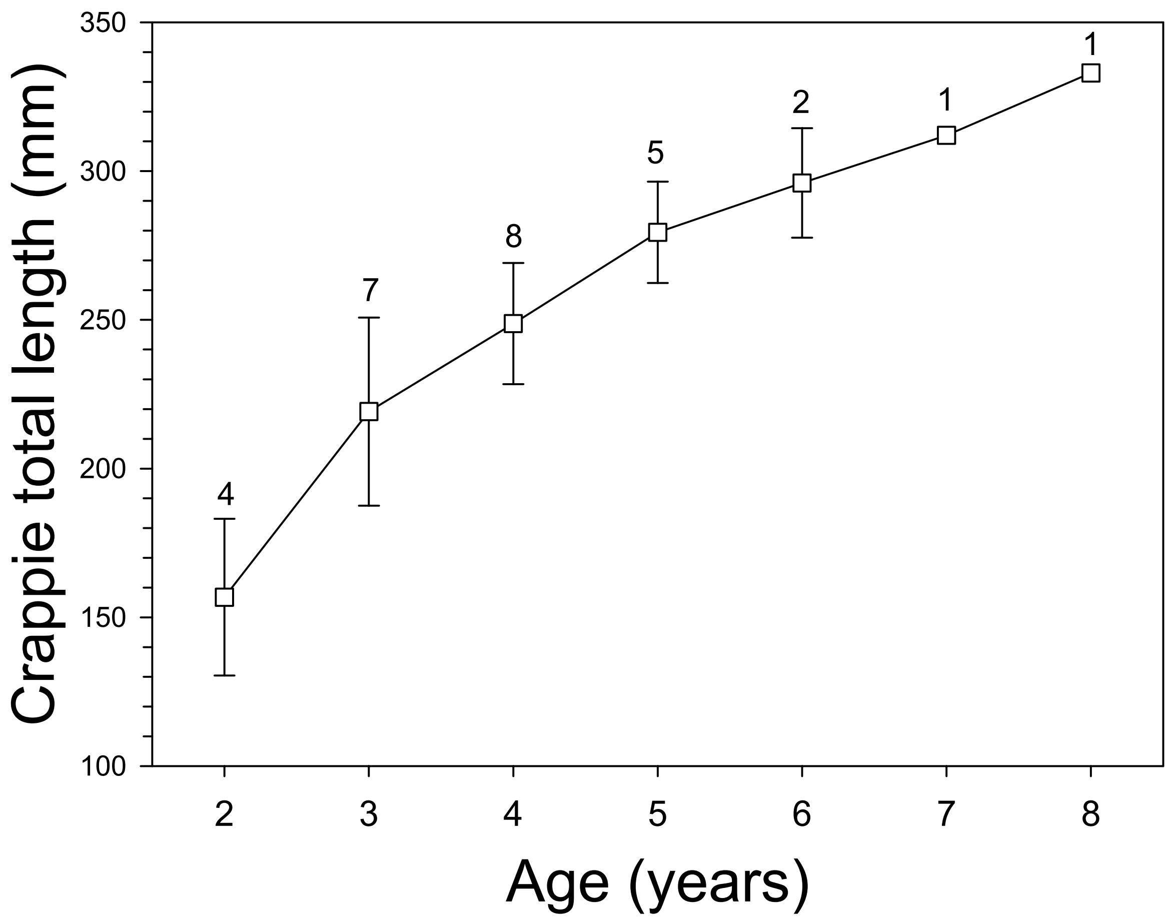

Figure 36. Length-at-age (mean + 1 SE) of scale-aged black crappie from Cutler Reservoir , 2006. Sample size is given above error bars.

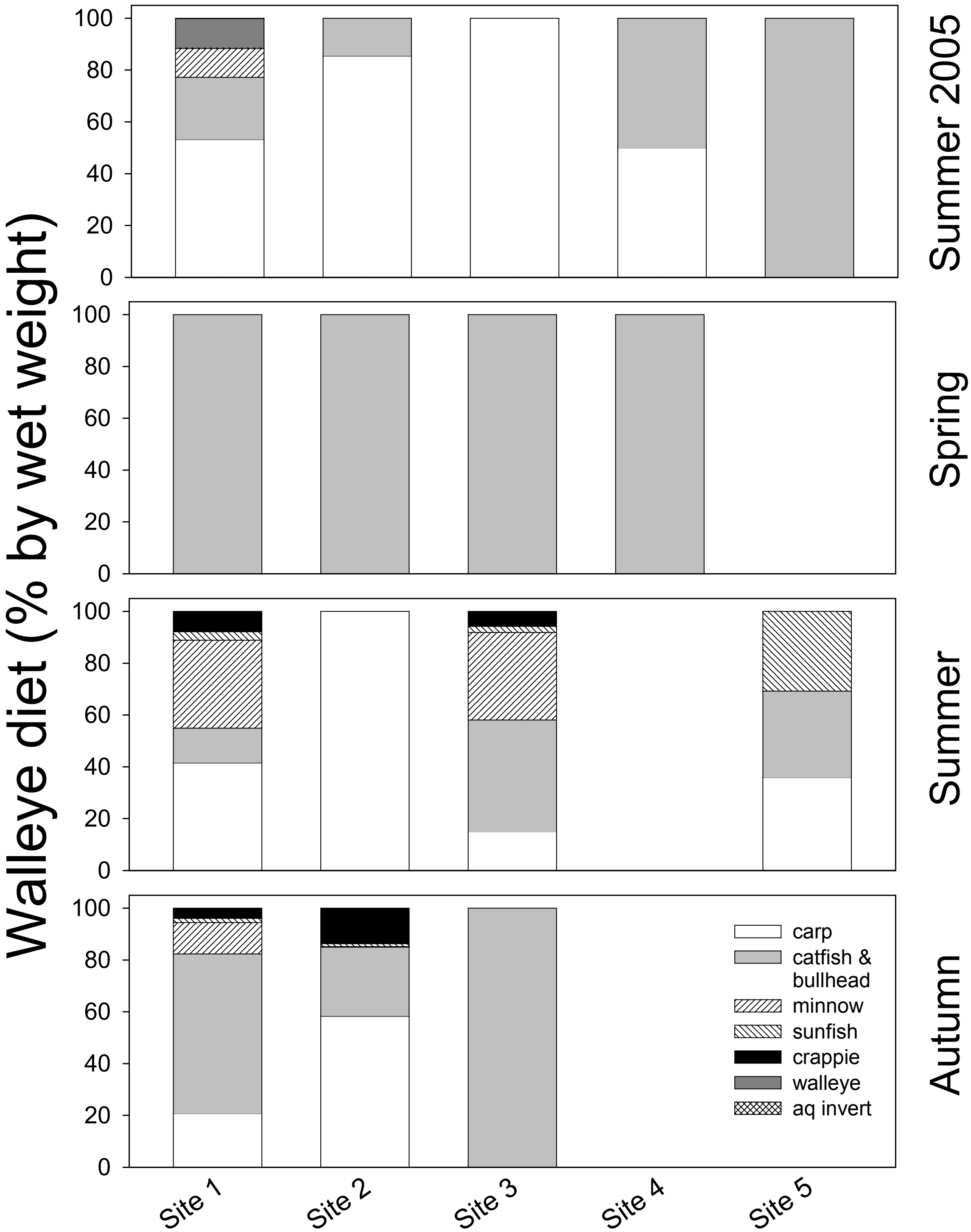

Figure 37. Diet composition (average % by wet weight) of walleye at five index sites in Cutler Reservoir. "aq invert" includes only aquatic invertebrates. Full stomach sample sizes were 27 (summer 2005), 5 (spring 2006), 10 (summer 2006), and 17 (autumn 2006).

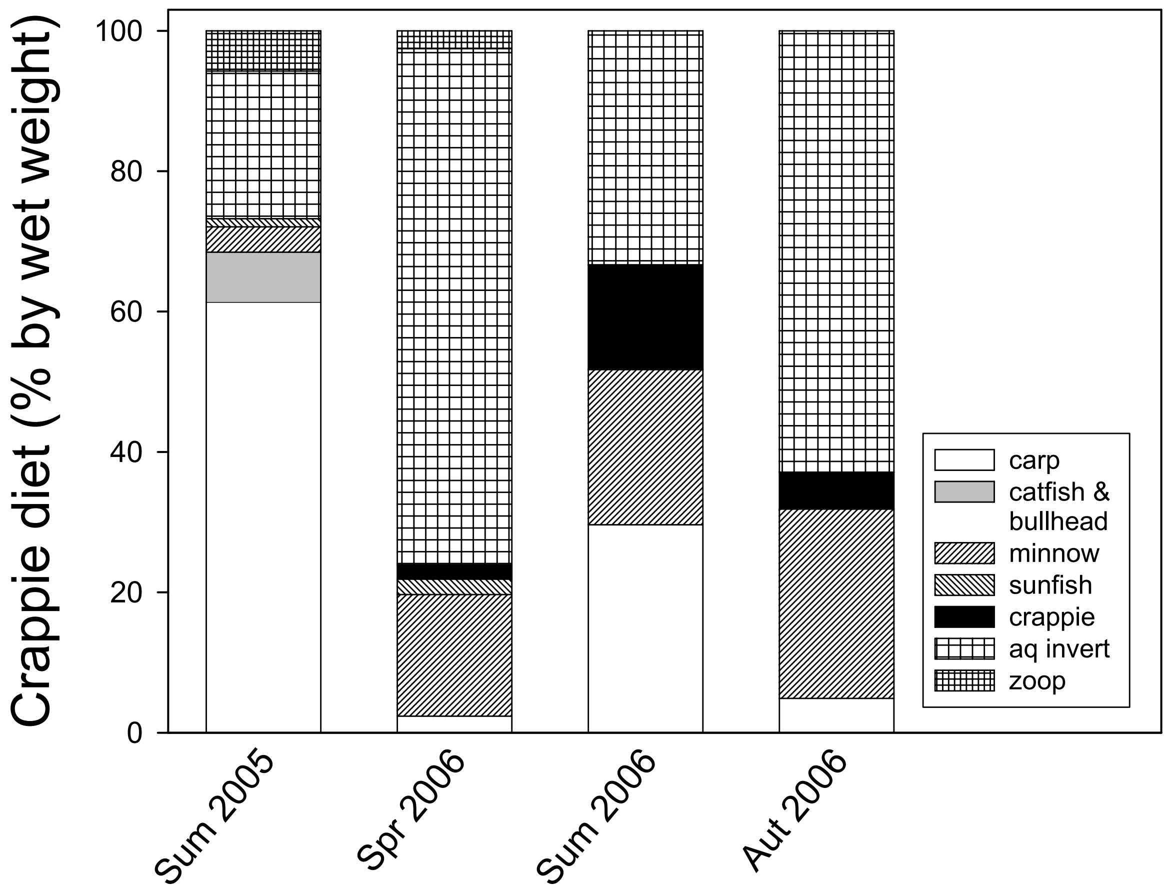

Figure 38. Diet composition (average % by wet weight) of black crappie (> 150 mm TL) at five index sites in Cutler Reservoir, 2005 (*n* = 52) and 2006 (*n* = 73). "aq invert" includes only aquatic invertebrates and “zoop” includes all zooplankton.

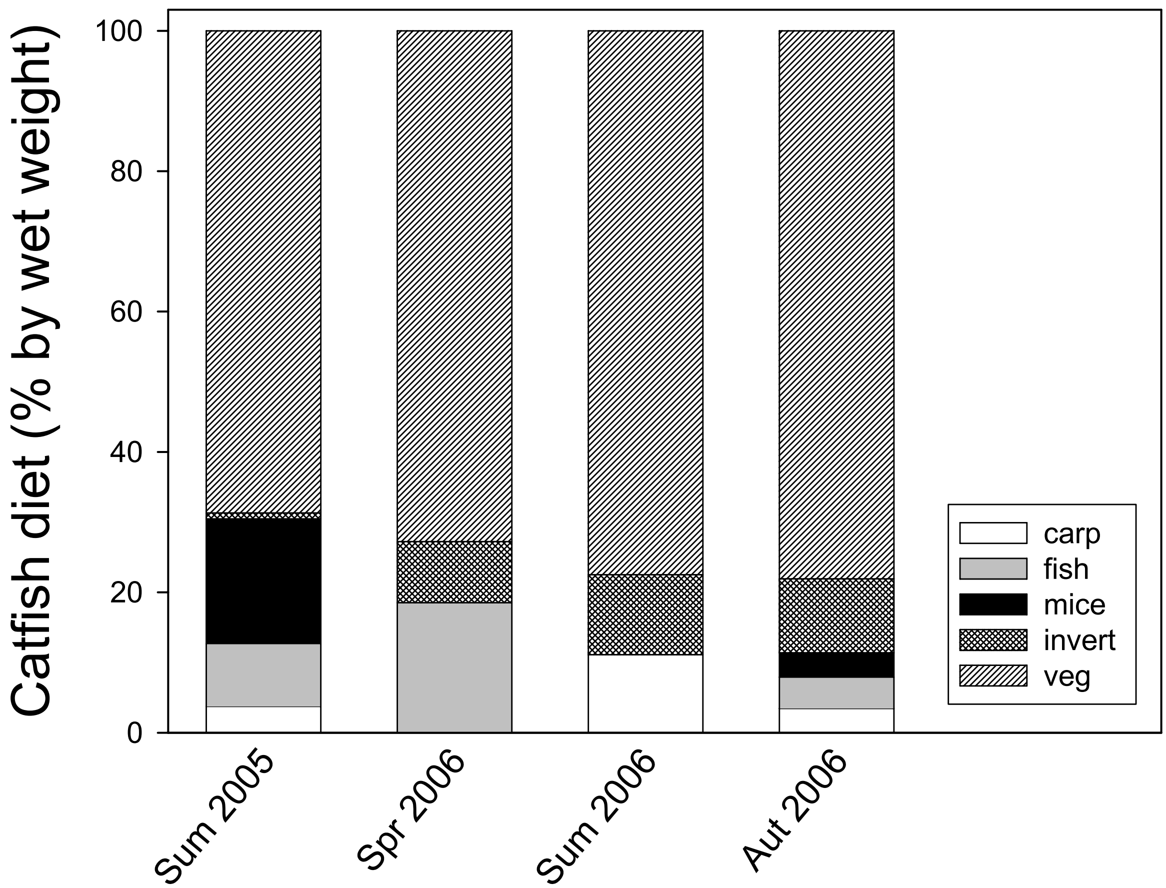

Figure 39. Diet composition (average % by wet weight) of channel catfish at five index sites in Cutler Reservoir. “fish” includes catfishes, fathead minnows, sunfish, largemouth bass, and crappie. "invert" includes only aquatic and terrestrial invertebrates. “veg” includes vegetation and organic matter.

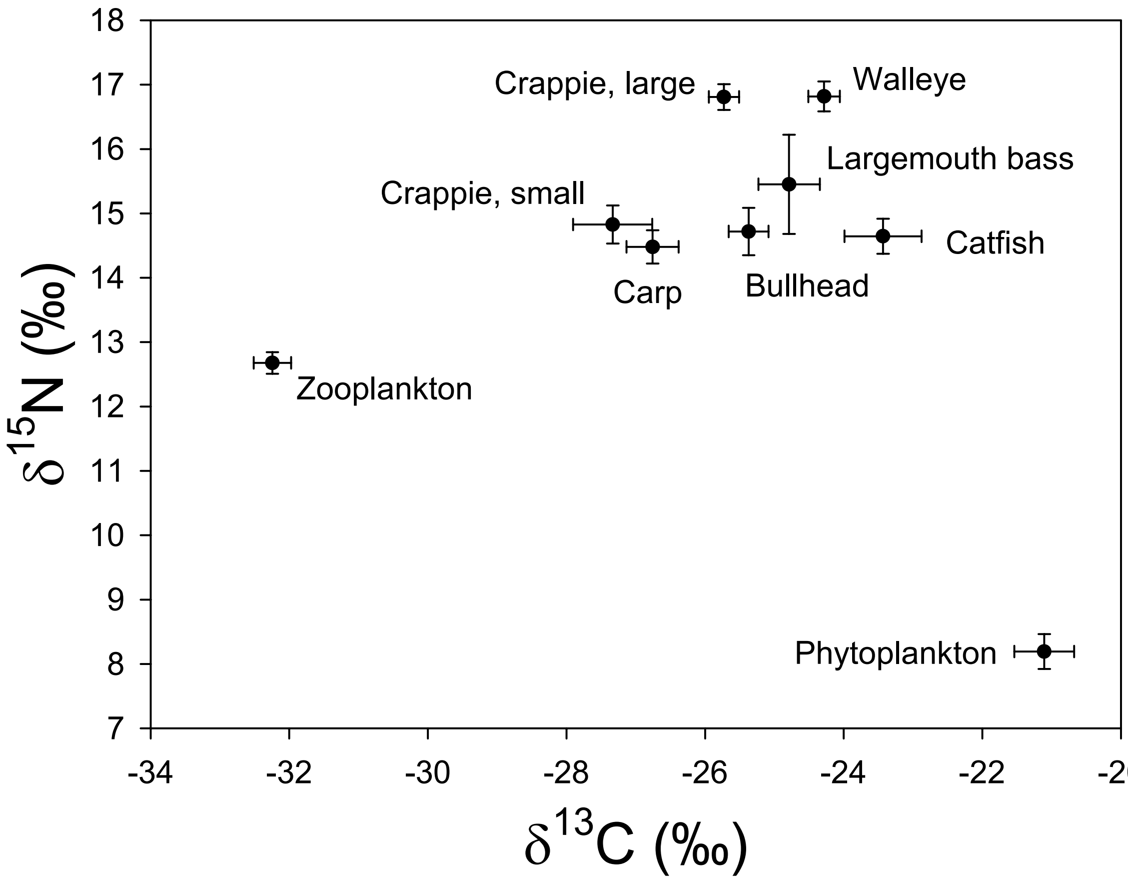

Figure 40. Stable isotope ($\delta^{15}N$ and $\delta^{13}C$, mean ± 1 SE) signatures of fish, zooplankton, and phytoplankton from Cutler Reservoir, summer 2005. Small crappie are ≤ 150 mm total length, while large crappie are > 150 mm.