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Age, Growth, and Simulation Modeling to Characterize Fish Populations at Two Reservoirs in South-Central Kansas

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AGE, GROWTH, AND SIMULATION MODELING TO CHARACTERIZE FISH POPULATIONS AT TWO RESERVOIRS IN SOUTH-CENTRAL KANSAS

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ABSTRACT

Several fish populations in Kansas are heavily exploited. To obtain insight into the response of fish populations to management actions, fisheries biologists must obtain as much information as possible with limited resources. To address these challenges, biologists often use age and growth information to understand the age structure of the populations, estimate recruitment and mortality, and gain insight into environmental and genetic factors influencing growth. In addition, age and growth data are used to generate yield-per-recruit models, which allow biologists to extrapolate population trends and make broad predictions about population responses to different management actions.

Cheney and El Dorado reservoirs are in south-central Kansas near urban areas and receive heavy use by anglers. Additionally, both reservoirs contain invasive White Perch *Morone americana* and Zebra Mussels *Dreissena polymorpha*, which adds incentive to provide the most informed decisions that minimize the impact of the invasive species but maintain user enjoyment. This study was conducted to provide age and growth information to assess the status of current fish populations and to model potential outcomes from management decisions by using Beverton-Holt yield-per-recruit models.

I collected age and growth data from populations of Blue Catfish *Ictalurus furcatus*, Flathead Catfish *Pylodictis olivaris*, Gizzard Shad *Dorosoma cepedianum*, Largemouth Bass *Micropterus salmoides*, Walleye *Sander vitreus*, White Bass *Morone chrysops*, White Crappie *Pomoxis annularis*, White Perch, and palmetto bass (female Striped Bass *Morone saxatilis* × male White Bass *M. chrysops*) at both Cheney and El Dorado reservoirs from May 23 to November 15, 2013. These data were analyzed and used to create inputs for yield-per-recruit models in Fisheries Analysis and Modeling Simulator (FAMS). Results suggested that more restrictive length limits could be justified for Walleye at both reservoirs and palmetto bass at Cheney Reservoir; however, unless certain populations aid in the control of invasive species, current restrictions on other fish populations were acceptable.

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PREFACE

This thesis is written in the style of the North American Journal of Fisheries Management.

During this project, all fish were collected and handled in accordance with American Veterinary Medical Association guidelines. These methods were approved by the Institutional Animal Care and Use Committee of Fort Hays State University (IACUC 13-0014).

INTRODUCTION

Recreational fishing provides revenue, jobs, and psychological, social, and health benefits to a large portion of the American population (Fedler and Ditton 1994; Schneidewind 1999). In 2011, more than 33 million individuals 16 years of age and older participated in recreational fishing in the United States (USFWS 2012a). These individuals spent $41.8 billion pursuing these activities. In Kansas alone, an estimated 400,000 anglers spent over $200 million on fishing licenses, equipment, and other related expenses in 2011 (USFWS 2012b). A portion of these funds is collected indirectly through an excise tax on fishing equipment through the Dingell-Johnson Act of 1950 and supports federal aid programs, such as the Sportfish Restoration Program (Ballweber and Schramm 2010). These funds are indirectly available to state agencies to enhance and restore fisheries according to federal guidelines. Another portion of these funds is directly available to state natural resource agencies through license sales. These monetary resources support fish propagation in hatcheries, stocking programs, habitat enhancement, educational programs, research, and the Fish Impoundments and Stream Habitats (F.I.S.H.) program.

By participating in these programs, Kansas Department of Wildlife, Parks and Tourism (KDWPT) fisheries biologists seek to provide quality fisheries to promote the conservation, use, and appreciation of natural resources. They do this by assessing fish populations, recommending regulations, making management decisions, and aiding and educating the public. These biologists are responsible for managing fish populations at 24 federal reservoirs, 40 state lakes, and 235 community lakes, as well as assisting with thousands of privately-owned ponds and streams across the state (B. Sowards, KDWPT Fisheries Program Specialist, personal communication). While many of the impoundments in the state were built for flood control and municipal water supplies, they also provide benefits to farmers, hunters, anglers, and other outdoor enthusiasts (deNoyelles and Jakubauskas 2008) and can be the focus of recreational partnerships between the state agency and the public.

To properly manage waters for anglers, biologists must understand fish populations, fish habitat, and anglers (Willis and Murphy 1996). Biologists regularly sample fish populations by using a variety of techniques to characterize fish populations based on catch rates, growth rates, mortality, recruitment, condition, and age and size structures (Ricker 1975; Willis and Murphy 1996). By characterizing populations, biologists can assess changes over time and adjust management strategies, if necessary (Allen and Hightower 2010).

Growth information is especially important to biologists and offers an index of environmental and genetic factors that affect populations (Wootton 1990; Devries and Frie 1996). The environmental factors include prey availability, water temperature, and environmental pollutants (Fry 1971; Quist et al. 2003; Helfman et al. 2009; Quist et al. 2012). For example, Quist et al. (2003) determined that abundance of Gizzard Shad *Dorosoma cepedianum* had the greatest impact on growth of age-0 and age-1 Walleye *Sander vitreus* in Kansas. Shoup et al. (2007) determined that growth of small Bluegills *Lepomis macrochirus* was most influenced by littoral habitat and pH. Additionally, Fishback et al. (2002) concluded that heritability estimates had high genetic correlations when predicting growth and condition for Rainbow Trout *Oncorhynchus mykiss*. Growth information also can be valuable in assessing previous management decisions, mortality rates, year-class strength, and recruitment variability (Quist et al. 2012).

Age and growth of fishes are generally estimated by counting rings on calcified hard structures when a direct age assessment (e.g., known ages from marking studies) cannot be made (Casselman 1987; Chambers and Miller 1995; Devries and Frie 1996; Campana 2001; Buckmeier et al. 2002). Some hard structures include scales (Cross et al. 1959; Pierce et al. 1996; Johnson 2004), otoliths (Clayton and Maceina 1999; Holley 2009; Fleming 2012), and pectoral spines (Mayhew 1969; Gray and Collins 1970; Goeckler et al. 2003). Otoliths are calcareous structures within the inner ear chambers of fish that facilitate hearing and balance, and grow as the fish grows. Though some studies have indicated that hard structures do not always grow proportionally with the fish, they are still considered to provide valuable growth information and are widely used by biologists (Campana 1990; Casselman 1990).

In all of these hard structures, seasonal bands (annuli) result from differential accumulations of bone or calcium carbonate throughout a growing season and are visible as alternating light and dark bands that correspond to different growth rates (Chambers and Miller 1995; Helfman et al. 2009; Quist et al. 2012). Because fish exhibit indeterminate growth, it is theoretically possible to observe a complete growth history of a fish based on these structures. Though annuli are generally considered to form yearly in North America due to seasonal variations in growing conditions, any factor that decreases growth (e.g., spawning conditions) can result in what appears to be an annular mark

(Helfman et al. 2009). As a result, validation studies have been conducted to determine whether marks are truly annular, or at least whether the marks consistently appear due to some seasonal change (Erickson 1983; Hales and Belk 1992; Campana 2001; Buckmeier et al. 2002). Though some validation discrepancies occur, most biologists commonly use and accept age and growth data determined through use of these hard structures (Quist et al. 2012).

Age and growth information is used to calculate population characteristics, such as growth rate, mortality rate, age distribution, and productivity; therefore, managers consider it highly valuable in determining management actions (Ricker 1975; Devries and Frie 1996; Campana 2001; Koch and Quist 2007; Barada et al. 2011; Schultz et al. 2012). Accordingly, numerous studies also have evaluated the most accurate and precise aging methods (Erickson 1983; Campana 2001; Buckmeier et al. 2002; Isermann et al. 2003; Barada 2011; Fleming 2012). Scales have historically been used to estimate age, because they do not require euthanizing fish and are simple to remove; however, annular marks in otoliths are less ambiguous and are generally more accurate and precise (Erickson 1983; Maceina and Sammons 2006; Fleming 2012; Quist et al. 2012). Thin-sections of otoliths often have higher clarity and aging precision than whole-view otoliths, making them preferable to use in age and growth studies (Clayton and Maceina 1999; Fleming 2012; Quist et al. 2012).

To obtain growth information from hard structures, biologists measure the distance from the center of the structure (i.e., focus, core, nucleus) to the outer edge of each annulus in a straight line (Devries and Frie 1996; Quist et al. 2012). The distances can then be used to back-calculate length-at-age by using a variety of techniques, including the Dahl-Lea or Fraser-Lee methods. The Dahl-Lea back-calculation method (also known as the direct-proportion method) determines length-at-age of fish based on a linear relationship between body length and hard-structure radius, where the y-intercept is at zero (Devries and Frie 1996). Thus, by knowing the length of fish at capture as well as the radii of the hard structures, lengths-at-age of fish can be proportionally determined by measuring the distance from the origin of the hard structure to each annulus. These "back-calculated" lengths are averaged for all ages and provide useful estimates of lengths-at-age for a population (Devries and Frie 1996). The Fraser-Lee back-calculation method is similar to the Dahl-Lea method; however, the y-intercept value is based on either a standard intercept or a biologically determined intercept (Devries and Frie 1996).

Once back-calculations are complete, these data are used in models that describe fish growth in the population as related to length (Allen and Hightower 2010; Quist et al. 2012). The most common growth model currently used is the von Bertalanffy growth model. This model describes the growth of a fish as related to age and assumes that growth slows as fish age. The von Bertalanffy growth model is useful for fisheries managers who want to assess growth within a population, compare growth between populations, or assess the vulnerability of populations to overfishing (Helfman et al. 2009; Quist et al. 2012).

Estimating exploitation and recruitment of fish populations is important in fisheries management, and can be estimated from age and growth data. Exploitation is the number of fish removed from a population due to human activity (e.g., fishing) (Pope et al. 2010; Pine et al. 2012) and is influenced by restrictions, such as length limits and creel limits, established by biologists. Recruitment is the number of fish that survive to reach a specific size or age, and is usually related to gear selectivity, reproductive age, or harvestable size (Willis and Murphy 1996). In the context of fisheries management, recruitment generally refers to the number of fish that survive to reach the harvestable population (Allen and Hightower 2010). Fisheries managers can then incorporate mortality rates, recruitment, and values from the von Bertalanffy growth equation into yield-per-recruit models, such as the Beverton-Holt model, which simulate how the yield of a fish population will change in response to regulations and exploitation. Yield-per-recruit models thus describe the potential biomass of a cohort by calculating approximately how many fish will recruit and how much those fish weigh on average (Allen and Hightower 2010). Yield-per-recruit models contrast with other population models (e.g., catch-at-age models), which focus on how population numbers and structures will vary in response to harvest rates and require estimates of population size. Yield-per-recruit models, thus, illustrate trends in estimated yield for each length limit in response to varying exploitation and natural mortality rates.

Often yield-per-recruit models are used to determine the likelihood of overfishing (Allen and Hightower 2010; Quist et al. 2010). Overfishing occurs when too many fish are removed from a population, reducing spawning success (i.e., recruitment overfishing) or when too many small fish are removed prior to reaching full or optimal growth potential (i.e., growth overfishing) (Maceina et al. 1998; Radomski et al. 2001). While overfishing in Kansas occurs even in rural reservoirs (Quist et al. 2010), the likelihood that a fishery will be overexploited is related to the distance that a fishery is from a large population center (Post et al. 2002, 2008). As the distance from a fishery to an urban area decreases, the amount of angling pressure likely increases. This increase in angling pressure often leads to overexploitation and lower catch-rates, population conditions that decrease angler satisfaction, or both (Post et al. 2008). Despite the drop in angler satisfaction, the fishery will continue to be exploited due to its proximity to the urban area (Post et al. 2008). As such, management in these areas is especially difficult, and an understanding of how each fishery will respond to changes associated with regulations and angling effort is essential.

Another issue that biologists encounter, that relates to human activity, is the management, control, and prevention of aquatic invasive species (Johnson et al. 2001; Vander Zanden and Olden 2008; Kolar et al. 2010). An invasive species is defined as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" by United States Executive Order 13112 (Kolar et al. 2010). One such invasive species that has spread across regions of the United States, including the Midwest, is the White Perch *Morone americana*. This species has been introduced both intentionally and unintentionally, and is highly prolific (Hergenrader and Bliss 1971; Hergenrader 1980; Prout et al. 1990). In order to reduce densities of invasive White Perch, biologists sometimes use biological control techniques, such as adding a new predator to a system or protecting an existing predator from harvest (Gosch 2008; Kolar et al. 2010). This technique was implemented by KDWPT after White Perch were introduced into several impoundments in Kansas (J. Koch, KDWPT District Fisheries Biologist, personal communication).

Cheney Reservoir and El Dorado Reservoir are both near urban communities in south-central Kansas and are heavily used by anglers and recreationists. Both bodies of water contain popular sportfish such as Walleye, palmetto bass (female Striped Bass *Morone saxatilis* × male White Bass *M. chrysops*), Largemouth Bass *Micropterus salmoides*, and Flathead Catfish *Pylodictis olivaris*. Additionally, both reservoirs are designated as Aquatic Nuisance Species Waters (ANS) by KDWPT due to the presence of White Perch and Zebra Mussels *Dreissena polymorpha*. In an attempt to biologically control these species, both reservoirs have high stocking rates of large piscivores and special regulations that limit the harvest of these predators in an attempt to maximize predation on nuisance species. The intensive public use and special fishery regulations mean that these systems need to be well understood so careful and appropriate management decisions can be made regarding restrictive regulations and biological control mechanisms.

In summary, both Cheney and El Dorado reservoirs are heavily exploited and contain ANS species. Additionally, they have special regulations to control White Perch. This study was part of a larger fish characterization project conducted to gain insight into target fish populations and potential regulations. The intent of this study was to obtain growth information for populations of potential prey species, including Gizzard Shad and the invasive White Perch, as well as to characterize, model, and recommend management decisions based on growth parameters and yield-per-recruit models for piscivorous sport fish that potentially act as biological controls (Blue Catfish *Ictalurus furcatus*, Flathead Catfish, Largemouth Bass, Walleye, White Bass, White Crappie *Pomoxis annularis*, and palmetto bass). The objectives of this study were to: (1) provide baseline age, growth, and size structure information for target species by using otoliths and pectoral spines; (2) calculate growth parameters necessary for Beverton-Holt yield-per-recruit models for all target species; (3) model and analyze fish populations to evaluate the effectiveness of current and potential regulations on yield; and (4) recommend management decisions that will maximize yield of predatory sport fish.

METHODS

Study sites—Cheney Reservoir impounds the Ninnescah River in south-central Kansas within 56 km (35 mi) of both Hutchinson and Wichita, Kansas. Most of the reservoir is in Reno County, with portions also in Kingman and Sedgwick counties. The watershed is approximately 1,720 km^2 (664 mi^2), and the major land-cover types are cultivated crops and herbaceous rangeland (NLCD Land Cover (2011 Edition), accessed from Kansas Data Access & Support Center, http://kansasgis.org/catalog/index.cfm?data_id=2181 &show_cat=1, accessed September 26, 2014). The reservoir is relatively shallow, windswept, and turbid, and it experiences fluctuating inflows and lake levels, with conservation pool at an elevation of 433 m (1,422 ft). The reservoir has a surface area of 3,865 ha (9,550 acres), a maximum depth of 13 m (42 ft), and a mean depth of 5 m (17 ft) (J. D. Koch, 2009 progress report and management plan for Cheney Reservoir, Kansas Department of Wildlife, Parks and Tourism). White Perch were inadvertently introduced into Cheney Reservoir in 1992, and a management plan was implemented in 2003 (J. Koch, personal communication).

El Dorado Reservoir is in Butler County, in south-central Kansas, on the Walnut River, within 64 km (40 mi) of Wichita and only 4 km (3 mi) from El Dorado, Kansas. The dam for this reservoir was competed in 1981, and two smaller reservoirs were subsequently merged (Kansas Water Office 2012). The reservoir is generally less turbid, with more diverse bottom topography than Cheney Reservoir, but it also experiences fluctuating lake levels, with conservation pool at an elevation of 408 m (1,339 ft) (Army Corps of Engineers, http://www.swt.usace.army.mil/Locations/TulsaDistrictLakes/

Kansas/ElDoradoLake/PertinentData.aspx, accessed September 26, 2014). The watershed is approximately 640 km^2 (247 mi^2), and herbaceous rangeland is the dominant land-cover type for the surrounding area (NLCD Land Cover (2011 Edition), accessed from Kansas Data Access & Support Center, http://kansasgis.org/catalog/index.cfm?data_id=2181&show_cat=1, accessed September 26, 2014). The reservoir has a surface area of 3,237.5 ha (8,000 acres) and a maximum depth of 18 m (59 ft) (Kansas Biological Survey 2012). White Perch were discovered in El Dorado Reservoir in 2009 and the same White Perch management plan that had been implemented at Cheney Reservoir was employed at El Dorado Reservoir in 2010 (C. Johnson, KDWPT District Fisheries Biologist, personal communication).

During this project, all fish were collected and handled in accordance with American Veterinary Medical Association guidelines. These methods were approved by the Institutional Animal Care and Use Committee of Fort Hays State University (IACUC 13-0014).

Sample methods—Fish from target species were collected from May 23 through November 15, 2013. Because this study occurred in coordination with a diet analysis, the majority of fish were collected in core panel gill nets set at eight-minute intervals and retrieved after 30 minutes of being submerged (i.e., short-sets). These net sizes and panel configurations complied with the standard gill nets used by KDWPT (Monofilament, eight panels, 80 ft × 6 ft; mesh bar size: 0.75 in, 1.00 in, 1.25 in, 1.50 in, 1.75 in, 2.00 in, 2.25 in, 2.50 in) for annual fall sampling. Nets were deployed biweekly at each reservoir for a period of five days per sample period as weather permitted. Most nets were deployed at dawn or dusk, with the majority of samples collected in the morning. Sample locations included standardized sampling stations (KDWPT) augmented by a stratified-random set of locations throughout the reservoirs.

In addition to short-set gill nets, supplemental overnight sets also were deployed on six occasions. These sets consisted of one 91.44 m (300 ft), 6.35 cm (2.5 in) multi-filament gill net and the same core-panel gill nets described above. Nets were deployed for 8-10 hours at sites chosen in the same manner as above.

Day and night electrofishing were used as a supplemental sampling method at least once per sample period at each reservoir. Day electrofishing samples were collected prior to 1200 hrs, while night electrofishing was conducted between sunset and 0100 hrs. Sites were selected based on advice from KDWPT biologists, habitat preferences of target fish, and equipment capability. Largemouth Bass, White Crappie, and White Bass were collected by using high-pulse electrofishing (60 or 120 pulses-per-second) at four to six amperes with a Smith-Root Model GPP Electrofisher and a Honda GX160, 5.5 horsepower motor. Catfishes were collected by using low-pulse (7.5 or 15 pps) electrofishing at approximately two amperes with the same equipment. In addition to our standard sampling, we used 26 fish donated by anglers, 78 fish from KDWPT standard fall sampling, and all mortalities that occurred as part of the diet study.

Data collection—Target fish were placed into a 0.3- 0.5% salted live-well until all nets had been inspected. Fishes were then measured to the nearest millimeter total length (TL), and masses were recorded with one of two scales based on the size of the fish. Fish were measured to the nearest gram for fish less than 2,000 g and to the nearest 2 g for fish between 2,000 and 5,000 g. Masses were measured by using A&D Weighing waterproof scales (Models SK-2000WPZ and SK-5000WPZ). For eleven Flathead Catfish and one Blue Catfish over 5,000 g, masses were measured with a Berkley hanging scale with a precision to 250 grams. All data, including temporal lake characteristics, were recorded on datasheets.

Sagittal otoliths were collected from scaled fishes and pectoral spines were collected from catfishes. Pectoral spines were used because they did not require euthanizing the fish, and they were efficiently removed (Devries and Frie 1996; Koch and Quist 2007; Barada et al. 2011). This was preferred at Cheney Reservoir, where catch-rates of catfishes were low and KDWPT biologists were concerned about excessive harvest. Otoliths were extracted from five fish per 10-mm length-group for Gizzard Shad, White Bass, White Crappie, White Perch, and from any mortalities. To minimize mortality, otoliths were extracted from five fish per 20-mm length-group under legal harvest limits and from two fish per 20-mm length-group over the legal harvest limit for Largemouth Bass, Walleye, palmetto bass, and from all mortalities (J. Goeckler, Fisheries Research Biologist, personal communication). Pectoral spines were removed from five fish per 20-mm length-group for both Flathead Catfish and Blue Catfish.

Prior to extracting otoliths, fish were euthanized by having their spinal cord severed with diagonal cutters. Otoliths were then extracted by using the "up through the gills method" (Secor 1991). Pectoral spines were extracted by holding a relaxed spine proximally to the body of the catfish and then twisting downward and in an anterior direction, until the spine was dislocated at the articulating process and removed. Most spines came out cleanly; however, scissors occasionally were needed to sever muscle tissue. At this time, if possible, muscle tissue for the diet analysis was collected from the same wound to reduce the amount of stress inflicted on catfishes. Catfishes were then placed in a 3% to 5% salt bath for 10 seconds before being returned to the reservoir.

Age and growth analysis and model development—Otoliths and spines were placed in scale envelopes with a code that corresponded to the information recorded on datasheets. Hard structures were cleaned and prepared in the lab. One otolith from each fish was embedded in Enviro Tex Lite® (Fields Landing, CA) epoxy by using clear-silicone, flat embedding molds (models 70900 and 70901; www.emsdiasum.com). Otoliths were allowed to cure two to five days to allow the epoxy to fully harden. The focus of each embedded otolith was then marked on the epoxy, and transverse cuts were made from the posterior end of the otoliths near the focus (Secor 1991, Fleming 2010) by using a Buehler® Isomet™ (Lake Bluff, IL) low-speed saw. The anterior halves, which included the focus, were then affixed to a labeled, clear, glass slide by using Permatex® (Solon, OH) Adhesive Super Glue. Thin sections (300-500 µm) were cut from the affixed otolith. All remnants of embedded otoliths were returned to their respective coin envelopes. Pectoral spines were sectioned immediately distal to the basal groove (Sneed 1951, Devries and Frie 1996) and at a section width of 550-610µm.

Attempts to section the articulating process were inconsistent and, thus, halted. Pectoral spine sections were glued to labeled slides after sectioning. Larger spines from fish ≥ 205 mm TL, were not embedded in epoxy, because it was more efficient to cut them directly. Spines from catfishes < 205 mm TL were embedded in epoxy in 1.5-mL microcentrifuge tubes following methods similar to Koch and Quist (2007) to increase the strength and stability of the spine during the cutting process.

All slides were viewed under a compound light microscope to determine the quality of the section before photographing. Otolith and spine sections of poor quality were not used in analyses if an unambiguous section could not be cut. Mineral oil was applied to sections to increase clarity and digital photographs were taken through an Olympus BX51 microscope with an Olympus DP71 camera with Microsuite Basic Edition (v2.6 © 2007) software.

Two independent readers estimated the age of each fish by using the same photograph of each sectioned hard structure. When the two primary readers disagreed, the image was examined by a third reader. If the age estimate of the third reader disagreed with those of the initial readers, the fish was removed from analyses; otherwise the age agreed upon by two readers was used. Growth was measured from the focus to the distal edge of each annulus and to the edge of each section by using FishBC 3.0 (v3.0.1 ©2007) (Figure 1).

Age-length keys were created with Microsoft Excel ® and FishBC 3.0. Length-frequency graphs and back-calculations for each species at each reservoir were created with Microsoft Excel ® and Fisheries Analysis and Modeling Simulator (FAMS © v1.0) software. To back-calculate age-at-length, FAMS uses the Dahl-Lea (direct-proportion) method, which uses the following equation:

$$L_i = \frac{S_i}{S_c} L_c$$

where L_i is the back-calculated length of the fish at age i, L_c is the length of the fish at capture, S_c is the radius of the otolith or spine section at capture, and S_i is the radius of the otolith or spine at age i, based on annular marks (Devries and Frie 1996).

Age-at-length and weight data incorporated into FAMS were used to calculate von Bertalanffy growth coefficients, time to recruit to the fishery, and weight-length regressions. FAMS uses the von Bertalanffy growth equation to describe fish growth and estimate associated length-at-age information as follows:

$$L_t = L_\infty \left(1 - e^{-k(t-t_0)}\right)$$

where L_t is the length of the fish at age t, L_∞ is the asymptotic or theoretical maximum length of fish in the population, k is the growth rate or growth coefficient, t is time or age in years, t_0 is the age when the length of the fish would theoretically equal zero, and e is the exponent for natural logarithms (Slipke and Maceina 2010).

Additionally, FAMS calculated instantaneous rates of fishing mortality and natural mortality based on user inputs of conditional fishing mortality (*cf*) and conditional natural mortality (*cm*) by using catch-curve analysis (Slipke and Maceina 2010). Conditional fishing mortality is the theoretical amount of mortality attributed to fishing, if natural mortality did not occur. Similarly, conditional natural mortality is the amount of natural mortality (e.g., disease, old-age, predation) that would occur in a population if fishing did not occur. These inputs were based on exploitation rates of interest (0-90%) and *cm* not exceeding 0.20. Though *cm* might be higher for some species (e.g., approximately 56% for White Bass [Schultz and Robinson 2002]), using levels of 0.20 was sufficient to examine general trends associated with these models. The modeling option was set to "Model by varying Minimum Length" and other user inputs included the number of individuals entering the harvestable population (arbitrarily set at 1,000), maximum age of the population (determined by adding one to three years to the oldest fish age), and potential minimum length limits of interest, which included the current length limit as well as shorter and longer length limits. All of this information was used to run Beverton-Holt yield-per-recruit models in FAMS, which uses the Jones (1957, cited by Slipke and Maceina 2010) modification as follows:

$$Y = \frac{F * N_t * e^{z*r} * W_\infty}{K}[\beta(X, P, Q)] - [\beta(X_1, P, Q)]$$

where Y is the yield-per-recruit, F is the instantaneous rate of fishing mortality, N_t is the number of recruits entering the fishery at time t, Z is the instantaneous rate of total mortality, r is the time in years to recruit to the fishery, W_∞ is the maximum theoretical weight calculated using weight-length regression, K is the growth coefficient from the von Bertalanffy growth equation, β is the incomplete Beta function, X is equal to e^{Kr}, X_1 is equal to $e^{-k(Maxage - t_0)}$ (where Maxage is the estimated maximum age of the population), P is equal to Z/K, and Q is the slope of the weight-length relation plus one (Slipke and Maceina 2010). While FAMS calculated numerous output variables besides yield, the variables of interest were yield and exploitation (u), both of which varied based on *cm* and length limit. These results were graphically displayed with SigmaPlot 9 (© 2004 Systat Software, Inc.).

RESULTS

Total catch—Cheney Reservoir: From June 4 to November 15, 2013, 62 Blue Catfish, 40 Flathead Catfish, 643 Gizzard Shad, 6 Largemouth Bass, 144 Walleye, 155 White Bass, 33 White Crappie, 1,027 White Perch, and 403 palmetto bass were collected. Samples sizes were adequate to generate yield-per-recruit models for Flathead Catfish, Walleye, White Bass, White Crappie, and palmetto bass. No models were developed for Largemouth Bass due to small sample size. Additionally, no models were completed for Blue Catfish because FAMS requires at least four age-classes from a species to complete a model, and only two age-classes were represented in these samples.

El Dorado Reservoir: From May 23 to November 9, 2014, 216 Blue Catfish, 190 Flathead Catfish, 377 Gizzard Shad, 13 Largemouth Bass, 98 Walleye, 95 White Bass, 199 White Crappie, 1,235 White Perch, and 276 palmetto bass were collected. Blue Catfish, Flathead Catfish, Walleye, White Bass, White Crappie, and palmetto bass were used in yield-per-recruit models; however, Largemouth Bass models were not developed due to small sample size.

Size structure and age representation—Cheney Reservoir: Lengths of fish collected at Cheney Reservoir varied from 46 mm TL (White Perch) to 989 mm TL (Flathead Catfish). Gizzard Shad had the most (10-mm) length-groups represented with 29; however, White Perch had the most filled (10-mm) length-groups (five per group) with 22. Largemouth Bass was the most underrepresented species, with three (20-mm) length-groups collected and no length-groups filled. A representative sample for each species by length-group was aged; however, not all length-groups were represented equally (Figures 2-10).

El Dorado Reservoir: Fish at El Dorado Reservoir varied from 79 mm TL (White Perch) to 977 mm TL (Flathead Catfish). Flathead catfish had the largest range of lengths represented, with hard structures collected from 35 (20-mm) length-groups. Palmetto bass had the most filled (20-mm) length-groups, with 18. Largemouth Bass was again the most underrepresented species, with seven (20-mm) length-groups represented and only one filled length-group (Figures 2-10).

Age data—Cheney Reservoir: Hard structures were collected from 46 Blue Catfish, 39 Flathead Catfish, 131 Gizzard Shad, 6 Largemouth Bass, 109 Walleye, 111 White Bass, 33 White Crappie, 243 White Perch, and 169 palmetto bass. After removing poor-quality sections or structures that exhibited growth anomalies, 42 Blue Catfish, 36 Flathead Catfish, 105 Gizzard Shad, 5 Largemouth Bass, 101 Walleye, 88 White Bass, 31 White Crappie, 196 White Perch, and 111 palmetto bass were aged by two independent readers. Agreement among age assignments was lowest for Gizzard Shad (67%) and highest for Largemouth Bass (100%). After a third reader assigned ages, overall agreement among age estimates was 97.3% (696 of 715). As a result, 19 fish (13 Gizzard Shad, 1 White Crappie, 2 White Perch, and 3 Flathead Catfish) were excluded from the final analyses (Appendix A). Age-0 individuals were collected from every species except Blue Catfish, Flathead Catfish, and Largemouth Bass. The oldest fish collected was an age-13 White Perch, though age-12 Blue Catfish and Flathead Catfish also were collected. Age-length keys for each species were generated (Appendices B-J).

El Dorado Reservoir: Hard structures were collected from 112 Blue Catfish, 109 Flathead Catfish, 97 Gizzard Shad, 13 Largemouth Bass, 89 Walleye, 81 White Bass, 124 White Crappie, 145 White Perch, and 147 palmetto bass. After removing poor-quality sections or structures that exhibited growth anomalies, 97 Blue Catfish, 90 Flathead Catfish, 77 Gizzard Shad, 12 Largemouth Bass, 81 Walleye, 65 White Bass, 111 White Crappie, 107 White Perch, and 103 palmetto bass were aged by two independent readers. Initial reader agreement was highest for Walleye (100%) and lowest for Flathead Catfish (54%). After a third reader completed age assignments, agreement among readers was 98% (728 of 743). As a result, 15 fish (1 Gizzard Shad, 1 Largemouth Bass, 1 Blue Catfish, and 12 Flathead Catfish) were removed from final analyses (Appendix A). Age-zero individuals were collected for Gizzard Shad, White Bass, and palmetto bass. The oldest fish aged were an age-12 Flathead Catfish and age-10 Largemouth Bass and Gizzard Shad. Age-length keys for each species were generated (Appendices K-S).

Yield-per-recruit models—Length, weight, and age summaries were incorporated into Fisheries Analysis and Modeling Simulator (v1.0) to obtain population characteristics for each species at each reservoir for use in yield-per-recruit models. Growth parameters used in yield-per-recruit models are found in Table 1. Due to small sample sizes, no yield-per-recruit models were created for Largemouth Bass. Yield-per-recruit models also were not created for Blue Catfish from Cheney Reservoir because too few cohorts were sampled. For White Crappie from Cheney Reservoir and palmetto bass from El Dorado Reservoir, all length limits of interest could not be evaluated because the theoretical maximum age did not allow for individuals to reach the desired length.

Maximum yield for each model varied depending on conditional natural mortality (*cm*), harvest restrictions, and amount of exploitation (*u*). Yield always decreased with an increase in *cm* for all length limits. In most cases, the most restrictive length limit maximized yield when coupled with low *cm* and high exploitation. At high natural mortality rates and at lower exploitation, a more moderate length limit often maximized yield. Many simulations exhibited a decrease in yield with an increase in exploitation. This outcome indicates that growth overfishing would occur in those populations.

For Blue Catfish from El Dorado Reservoir, a 907-mm length limit maximized yield at high exploitation rates and low conditional mortality (Figure 11). This effect was decreased as *cm* increased, exploitation rates decreased, or both. The 907-mm length limit was the only option that did not exhibit growth overfishing. Flathead Catfish at both reservoirs exhibited growth overfishing at high exploitation rates regardless of length limit, and the most restrictive length limit greatly increased yield at all exploitation rates and all levels of *cm* (Figure 12).

Walleye at both reservoirs exhibited growth overfishing under all situations except with the most restrictive length limit (606 mm) at El Dorado Reservoir (Figure 13). At high exploitation rates (>80%), the most restrictive length limit produced the highest yield, until *cm* was 0.20 and 0.15 at Cheney and El Dorado reservoirs, respectively. At higher conditional natural mortality rates, the 606-mm and 531-mm length limits produced similar yields at high exploitation rates in Cheney Reservoir, whereas the 531-mm length limit produced higher yields at El Dorado Reservoir under the same conditions.

A similar pattern was described for White Bass at both reservoirs, where the most restrictive length limit (379 mm) produced the highest yields until *cm* exceeded 0.10 (Figure 14). Growth overfishing occurred in most situations for White Bass at both reservoirs.

White Crappie exhibited growth overfishing under all length limits, except for a 354-mm length limit at El Dorado Reservoir; however, this length limit was not able to be assessed at Cheney Reservoir (Figure 15). Most White Crappie yields stabilized at high *cm*.

Palmetto bass exhibited the highest yield under a 606-mm length limit at Cheney Reservoir when high exploitation occurred (Figure 16). At El Dorado Reservoir, a 531-mm length limit maximized yield; however, the 606-mm length limit could not be evaluated due to model constraints. Growth overfishing of palmetto bass occurred at all length limits assessed except for the 606-mm length limit at Cheney Reservoir.

DISCUSSION

Fisheries biologists work to conserve natural resources so the public can enjoy them now and in the future. To accomplish this mission, fisheries biologists must maintain balance among enhancing fish populations, maintaining habitat for fish use, and maintaining a positive public perception (McMullin and Pert 2010). My project was aimed at characterizing target fish populations. One way to characterize fish populations is to use models to simplify relatively complex systems. For this project, I analyzed growth of nine species of fish and created and evaluated 55 yield-per-recruit models. This allowed me to visualize general trends in yield of fish populations due to changes in length limits and mortality rates. The purpose of this information was to recommend management decisions based on the general predictions of the model. This approach was ideal as resources were not available to execute the complex, large-scale population surveys required of other population models.

Total catch, size structure, and age data—As a result of collecting fish over a six-month field season, the size-range for specific ages increased due to growth over the sample period. Despite this, while managers might prefer to have a more precise age-length-key, the age-at-lengths represented by this study were realistic and can be used through the entirety of the year. This assumed that fish are shorter earlier in the year and longer later in the year. This assumption might be unrealistic in some situations. For example, White Perch at Cheney Reservoir showed signs of stunting; thus, larger individuals might be younger and vice versa, but the age-length-keys generated still provided baseline age and growth information.

Additionally, the length-frequencies were based on fish captured with a variety of sampling gears. This should generally be avoided (Quist et al. 2012); however, the intent of my study was to determine age from a standard subset of fish populations, regardless of catch-methods. Despite the use of multiple gear types, length-frequency information for Cheney Reservoir was comparable to data collected by state fisheries biologists in previous years (Koch, progress report and management plan).

Beamish and McFarlane (1983) and Maceina et al. (2007) recommended that validation, as well as reader precision, be analyzed for all age and growth studies. While my study analyzed precision by using multiple readers for verification, no true validation estimates were made, because there were no known-age individuals in these populations. Despite this, there was evidence that supported the assumption that marks were annular for one population studied. Palmetto bass were not stocked in El Dorado Reservoir in 2007 and 2009. Though this information was not known prior to aging fish, no hybrid striped bass were aged from these year-classes. Therefore, while not a true validation study, this supported the annular mark assumption. Precision was estimated through verification between independent readers. Because other studies reported that sectioning is necessary for older fish (Hales and Belk 1992; Clayton and Maceina 1999) and precision is higher in sectioned otoliths (Fleming 2012), these were the hard structures of choice for all fishes except catfishes in my study. Age agreement between readers was lowest for Gizzard Shad and catfishes. This could be due to two potential overlapping issues: reader inexperience (Barada et al. 2011) and lack of clarity and precision (and erosion of the central lumen for pectoral spine sections) (Mayhew 1969; Clayton and

Maceina 1999; Buckmeier et al. 2002). Despite low initial agreements, however, final agreements were not below 86% for these species, which was only slightly lower than agreement for other species in my study. Additionally, some biologists have concerns regarding the true proportionality of otolith growth relative to somatic fish growth (Campana 1990; Casselman 1990); however, for biologists in south-central Kansas, the high accuracy and precision of age estimates is more important than the potential growth estimation bias that might occur (J. Koch, personal communication).

Yield-per-recruit models and management implications—Though public opinion of restrictive length limits is generally negative, at least initially, given time, many anglers accept and even prefer these length limits (Quist et al. 2010; C. Johnson, personal communication). These length limits might be warranted if certain length-groups of fish are providing biological control of invasive species or if fish consumption is not a major goal of anglers compared to the experience of catching large fish. In 2013 and 2014, restrictive length limits of 533-mm (21 inches) were enforced for Walleye and palmetto bass, in addition to an 889-mm (35-inch) length limit for Blue Catfish (KDWPT regulation 115-25-14). My yield-per-recruit models evaluated the current length limit alongside less-restrictive and more-restrictive limits when possible. In 42 of 55 yield-per-recruit models, the most restrictive length limit increased yield compared to the next most restrictive limit. While these models support more restrictive limits they did not incorporate changes in exploitation due to different regulations, fish diet, or angler motives.

At Cheney Reservoir, growth of Blue Catfish appeared rapid compared to that of El Dorado Reservoir; however, catch rates were lower. Because there was such rapid growth and the population was young, the 889-mm length limit should be maintained as long as Blue Catfish maintain a consistent growth rate. Models suggested that a restrictive length limit (~35 inches) at both reservoirs is warranted if exploitation rates are expected to be high; however, at El Dorado Reservoir few fish have reached this limit, and reproduction was high (C. Johnson, personal communication). Therefore, lowering the length limit to 757 mm might be warranted to decrease competition between cohorts and increase growth potential, as long as exploitation rates are not expected to exceed 40% or if large Blue Catfish (e.g., 757-907 mm) are not major predators of White Perch.

Managers do not generally restrict the length of legal Flathead Catfish harvest in Kansas reservoirs. Based on the yield-per-recruit models, if exploitation was high, even under conditional natural mortality rates of 0.20, a length limit might provide much higher yield. At low exploitation rates (< 10%) and $cm \geq 0.15$, a length limit would not be warranted because yields are comparable among all length limits analyzed. To understand this more thoroughly, if Flathead Catfish management is of interest, studies should be conducted to determine fishing and natural mortality rates.

Yield-per-recruit models for Walleye indicated a length limit of 606 mm produced much higher yields at low conditional natural mortality compared to less restrictive length limits. This also was the only option that minimized growth overfishing at both reservoirs in all situations. Quist et al. (2010) estimated that exploitation of

Walleye at Glen Elder Reservoir is 68%, which is likely comparable to other reservoirs in Kansas (J. Koch, personal communication). With such high levels of exploitation, increasing the length limit to 606 mm would provide a higher yield at both reservoirs. An alternative not assessed for this project would be to enforce seasonal length limits, restricting fish harvest more from April to June when exploitation is highest (Quist et al. 2010; J. Koch, personal communication).

Like Flathead Catfish, length of harvestable White Bass is generally not regulated in Kansas. Based on previous studies, natural mortality was most likely higher than the maximum rate analyzed (0.20), while exploitation is likely less than 40% (Schultz and Robinson 2002). With a higher *cm*, it is likely that yield would continue to decrease. Because of this lack of exploitation and yields that equalize with higher *cm*, a length limit is not warranted for White Bass at either reservoir.

Though restrictions on crappies have historically been minimal, using length limits to increase mean size of White Crappie that are not likely to stunt has become more popular in recent decades (Allen and Miranda 1995). Based on high mortality rates and moderate exploitation estimated by Mosher (2009), restricting size of White Crappie harvested at these two reservoirs is probably not justified unless they are aiding in control White Perch.

Length restrictions of palmetto bass and Walleye at both reservoirs increased as part of the implementation of White Perch management plans. Despite these restrictive regulations, exploitation of palmetto bass at these reservoirs is thought to be high (J. Koch, personal communication). Based on yield-per-recruit models, a 606-mm length limit would increase yield at Cheney Reservoir if natural mortality rates are low. Also, this was the only option that minimized growth overfishing. At the highest *cm* modeled, yields were stabilized at high exploitation rates. At El Dorado Reservoir, a 531-mm length limit increased yield at all conditional natural mortality rates, but again, yields stabilized as *cm* increased. Thus, maintaining the current length limit is appropriate.

In summary, this investigation was conducted in conjunction with a diet analysis and in coordination with local biologists in an effort to conserve both human and natural resources. Accordingly, fewer fish were collected than would be expected in separate investigations, which reduced the potential for public discontent. Therefore, even though using fish sampled from a narrow field season is preferred in age and growth studies, it was a necessary compromise to be more efficient and increase public awareness. Despite the compromise, quality data were still obtained.

The main objective of this study was to characterize fish populations in order to recommend management decisions; however, managers also should consider public opinion when making final decisions. In some instances anglers might be opposed to harvest restrictions (Isermann and Paukert 2010), which could alter exploitation rates and cooperation. Alternatively, anglers might have a positive attitude toward length limits and the intent of the agency. Some anglers expressed gratitude while my research was being conducted, stating that they enjoyed the more restrictive length limits because their goals were to catch large fish and enjoy the experience. They stated that consumption of those fish was less important. These positive public interactions strengthen the idea that to make the most appropriate decisions, fisheries biologists must have knowledge of all aspects of fisheries management. The more educated the public is of the goals of the managing agency, the more ability biologists have to make data-driven management decisions that will also satisfy public desires.

Based on model results, lowering the length limit for Blue Catfish at El Dorado Reservoir might be justified, and more restrictive length limits could be justified for Flathead Catfish, Walleye, and palmetto bass in order to increase potential yield. Other models indicated that alternate restrictions were not justified. All of the models represented hypotheses illustrating how a population of fish might respond to varying length limits and mortality rates. While they did not provide exact predictions, they do allow managers to view general trends with regard to yield and susceptibility to overfishing. These data, when coupled with knowledge of the system, can provide valuable information to help managers to assess whether or not to enact length restrictions on the harvest of fish populations.

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Table 1.—Tabulated growth parameters used to create yield-per-recruit models in FAMS for (A) Cheney Reservoir and (B) El Dorado Reservoir. N_0 was the number of initial individuals, b and a were regression coefficients for the weight:length and the von Bertalanffy growth equations, maximum age was the theoretical maximum age of the fish population, L_∞ was the theoretical maximum length of fish in the population, K was the growth rate, t_0 was the theoretical age when fish had a length of 0, and W_∞ was the weight infinity computed by FAMS. Minimum TL (mm) inputs included a start value, end value, and a "step-by" value that was used to model length limits incrementally between the start and end values. Conditional fishing mortality (*cf*) started at 0 and ended at 0.9, stepping by 0.1 for all models. Similarly, conditional natural mortality (*cm*) started at 0 and ended at 0.2 for all models, stepping by 0.05.

A Species	N_0	b	a	Max Age	L_∞ (mm)	K	t_0	W_∞ (g)	Min TL (mm) start	Min TL end	Min TL step by
Flathead Catfish	1000	3.348	-5.884	15	1258.406	0.094	-1.233	16195.523	0	600	200
Walleye	1000	3.318	-5.857	8	850.758	0.138	-2.842	7313.0146	381	610	75
White Bass	1000	2.427	-3.499	7	403.978	0.586	-0.562	670.85733	254	381	25
White Crappie	1000	3.167	-5.276	8	357.364	0.478	-0.922	645.21121	254	330	25
Palmetto bass	1000	3.028	-5.017	8	763.737	0.17	-1.792	5158.8621	381	610	75

B Species	N_0	b	a	Max Age	L_∞ (mm)	K	t_0	W_∞ (g)	Min TL (mm) start	Min TL end	Min TL step by
Blue Catfish	1000	3.305	-5.858	15	1142.479	0.107	-0.364	17708.769	457	907	150
Flathead Catfish	1000	3.147	-5.369	15	2251.403	0.029	-1.636	151764.55	0	600	200
Walleye	1000	3.266	-5.758	8	653.115	0.355	-0.529	2727.4463	381	610	75
White Bass	1000	2.991	-4.926	7	548.298	0.127	-3.552	1846.7105	254	381	25
White Crappie	1000	3.246	-5.468	9	377.838	0.304	-0.614	790.55863	254	354	25
Palmetto bass	1000	2.977	-4.914	8	604.474	0.322	-0.805	2323.5990	381	533	75

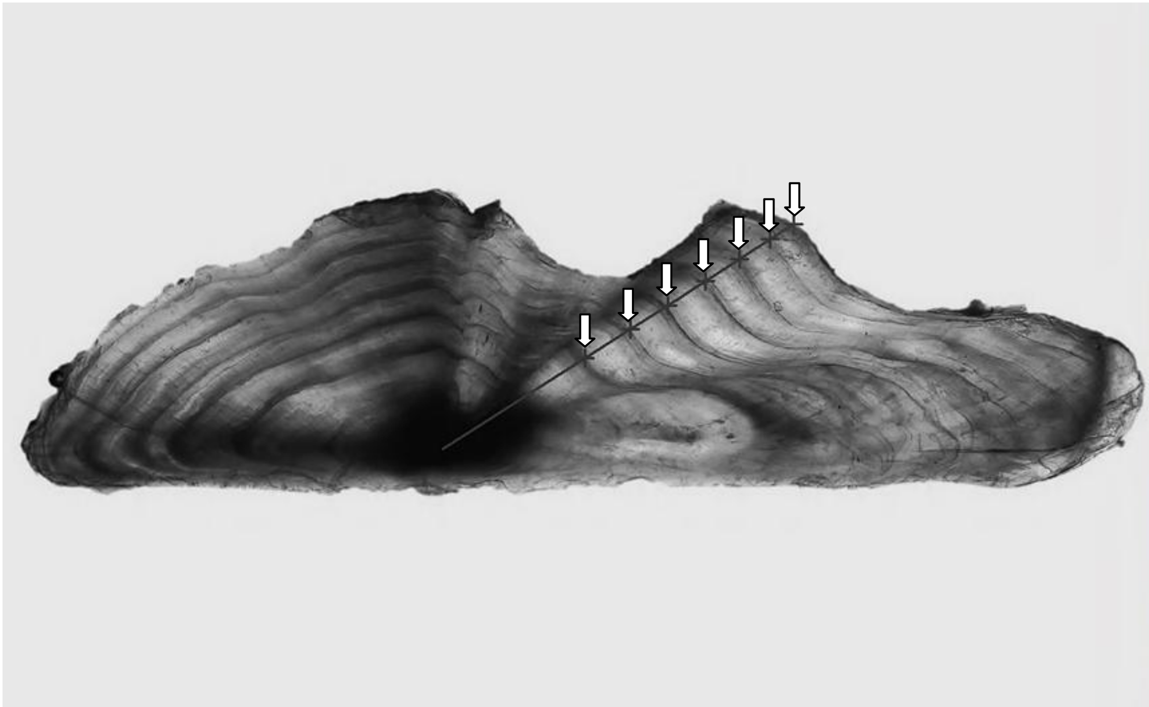


Figure 1.—Image of a transverse section taken from a Walleye otolith with growth measurements marked at the distal edge of each annulus. Because this fish was collected in November, the edge of the section is growth that occurred since the formation of the last annulus, making this fish six years old.

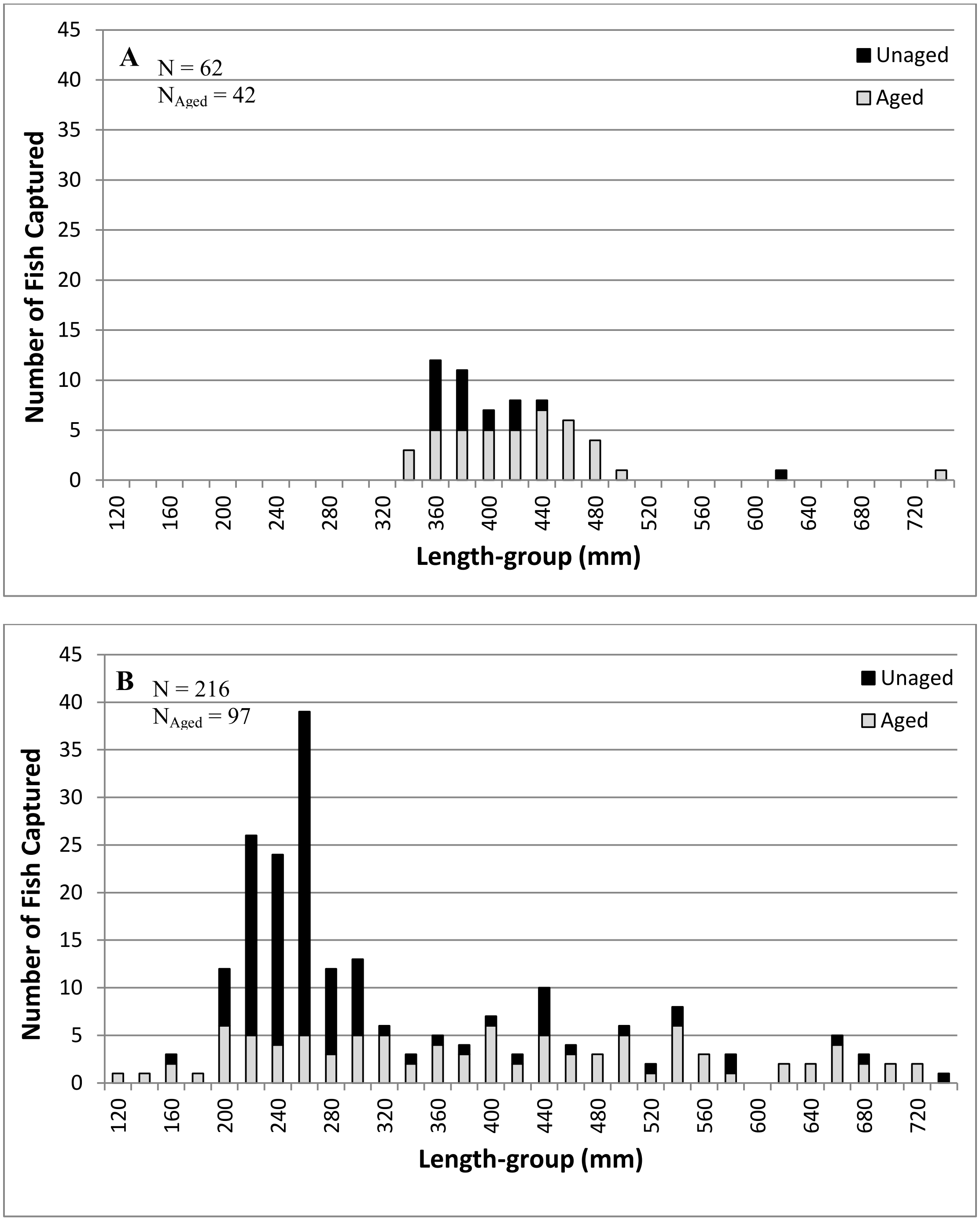
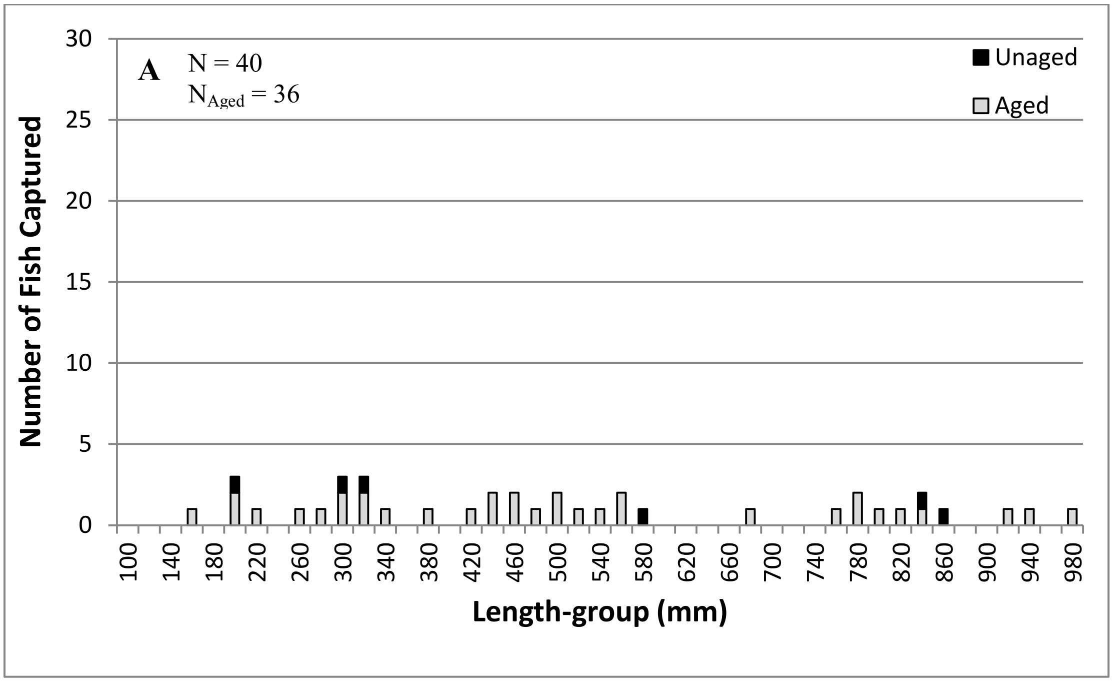


Figure 2.— Length-frequency graphs for Blue Catfish *Ictalurus furcatus* sampled at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas, with aged fish in each 20-mm length-group denoted by the lightly shaded bars and unaged fish in each length-group denoted by black bars. N is the total number of Blue Catfish collected and N_{Aged} is the total number of Blue Catfish aged.



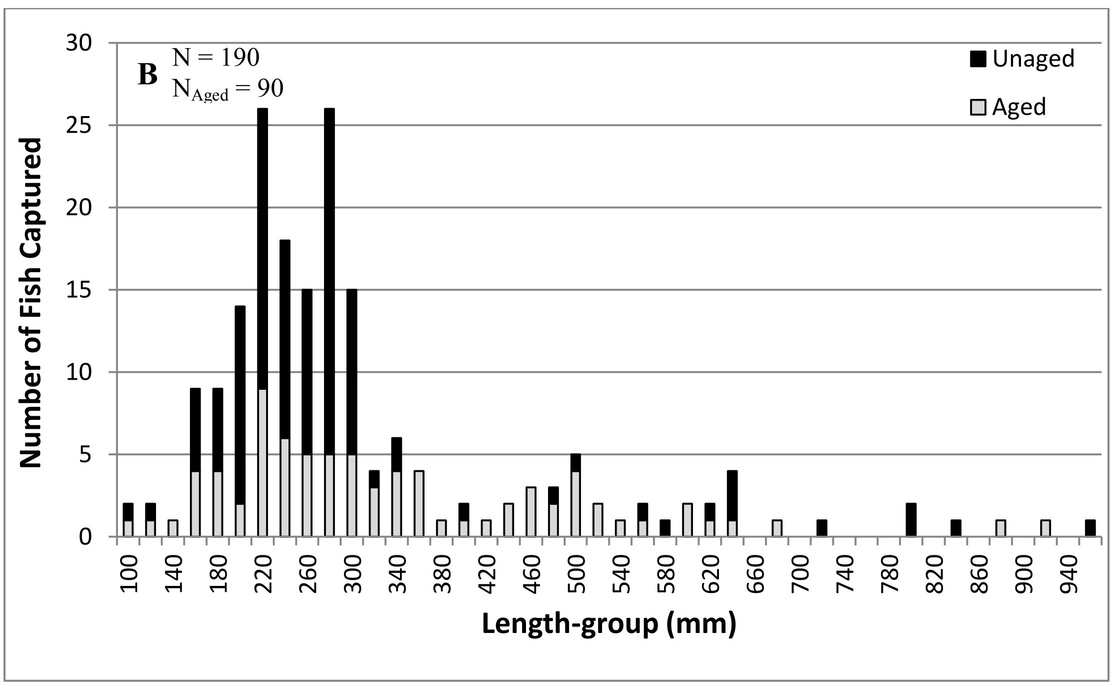
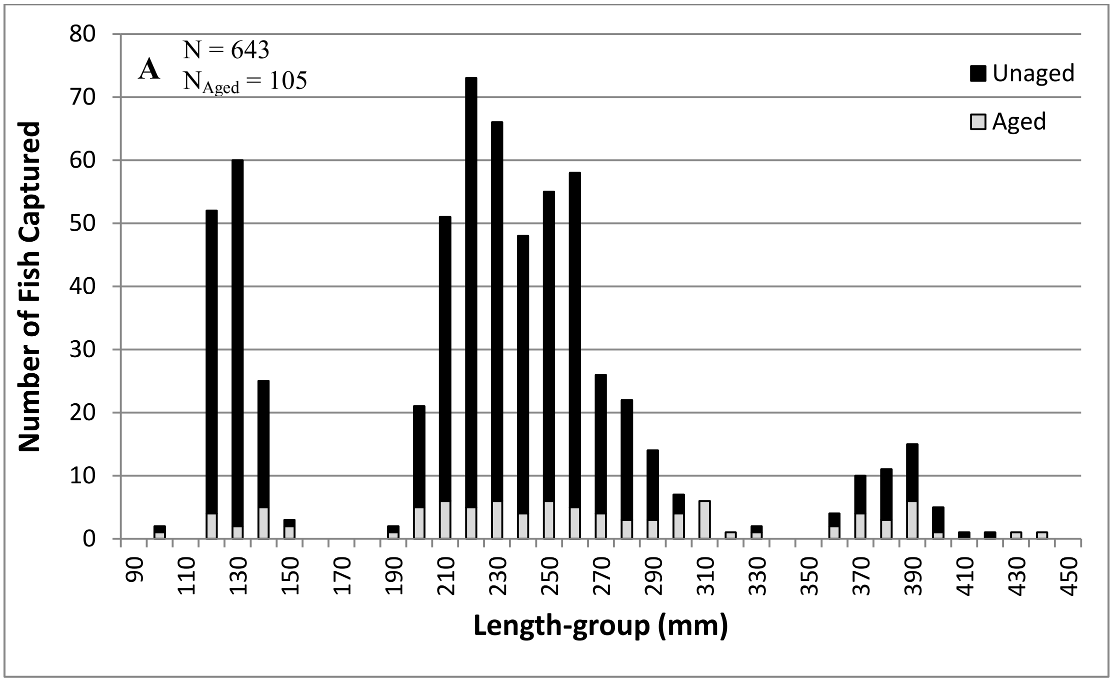


Figure 3.— Length-frequency graphs for Flathead Catfish *Pylodictis olivaris* sampled at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas, with aged fish in each 20-mm length-group denoted by the lightly shaded bars and unaged fish in each length-group denoted by black bars. N is the total number of Flathead Catfish collected and N_{Aged} is the total number of Flathead Catfish aged.



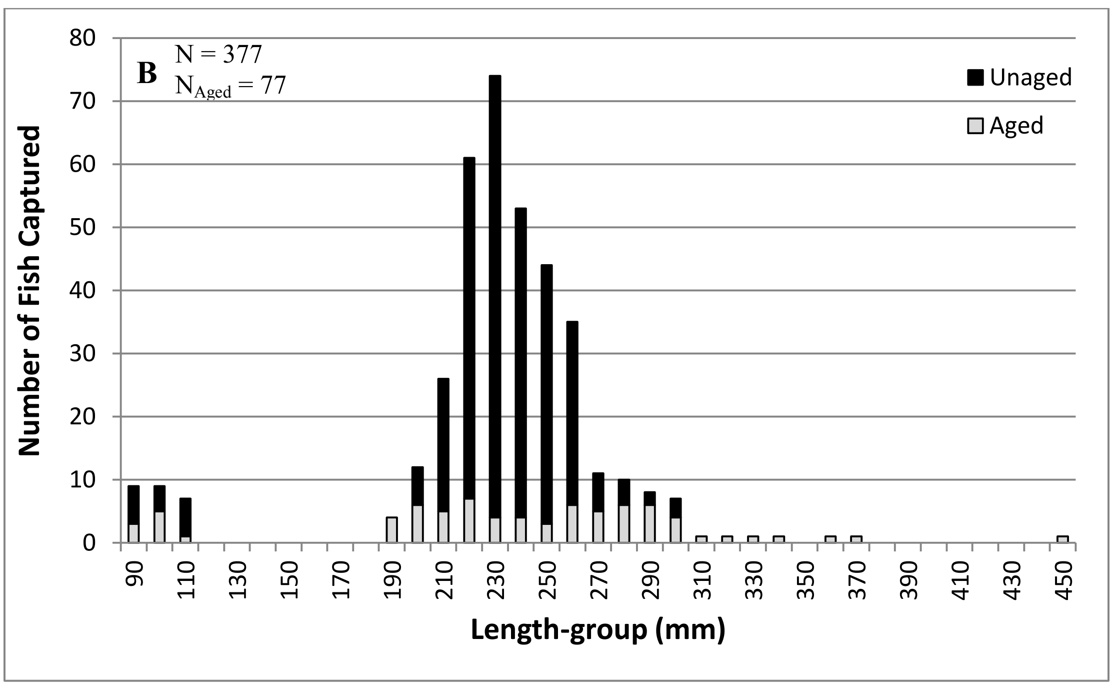


Figure 4.— Length-frequency graphs for Gizzard Shad *Dorosoma cepedianum* sampled at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas, with aged fish in each 10-mm length-group denoted by the lightly shaded bars and unaged fish in each length-group denoted by black bars. N is the total number of Gizzard Shad collected and N_{Aged} is the total number of Gizzard Shad aged.

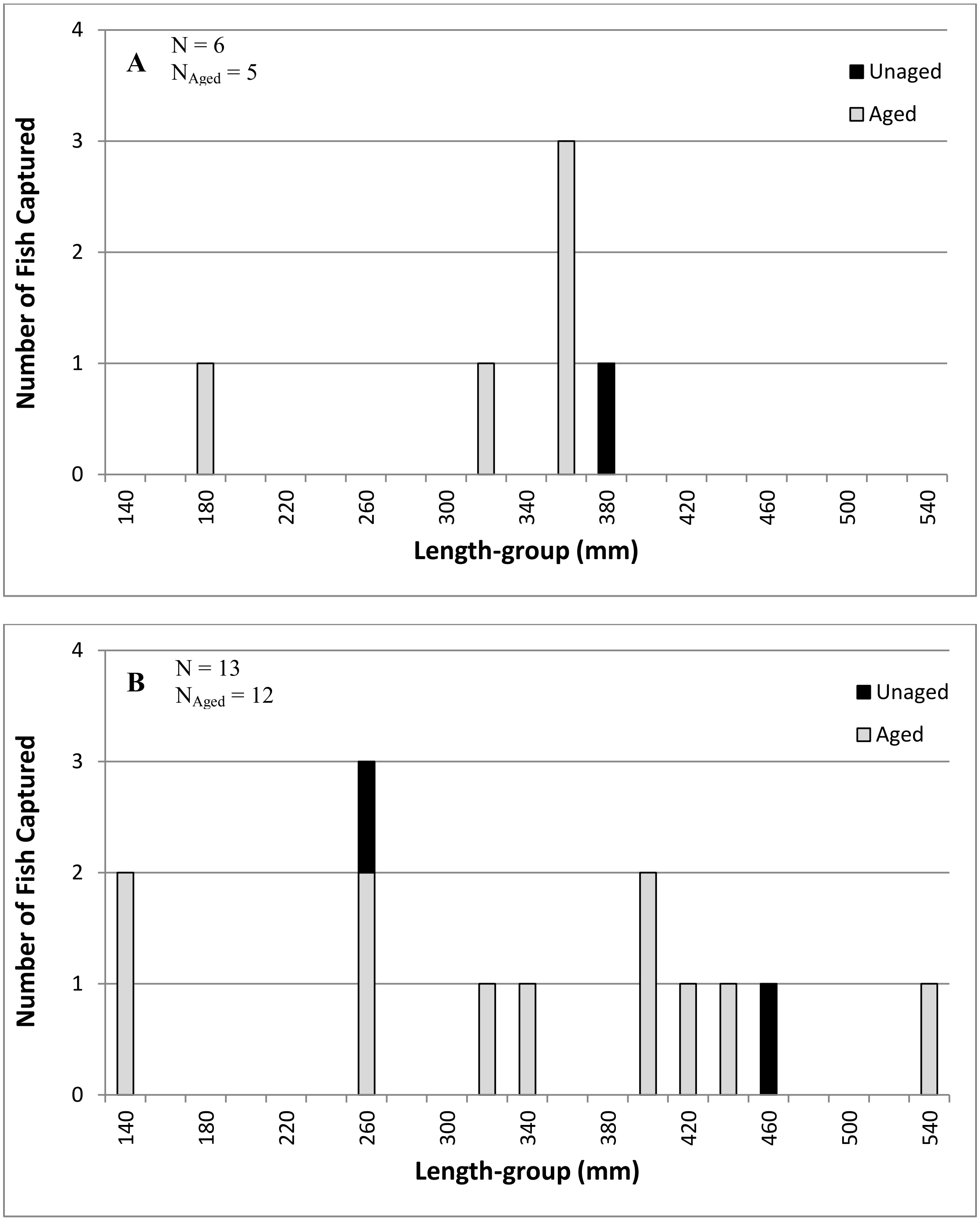
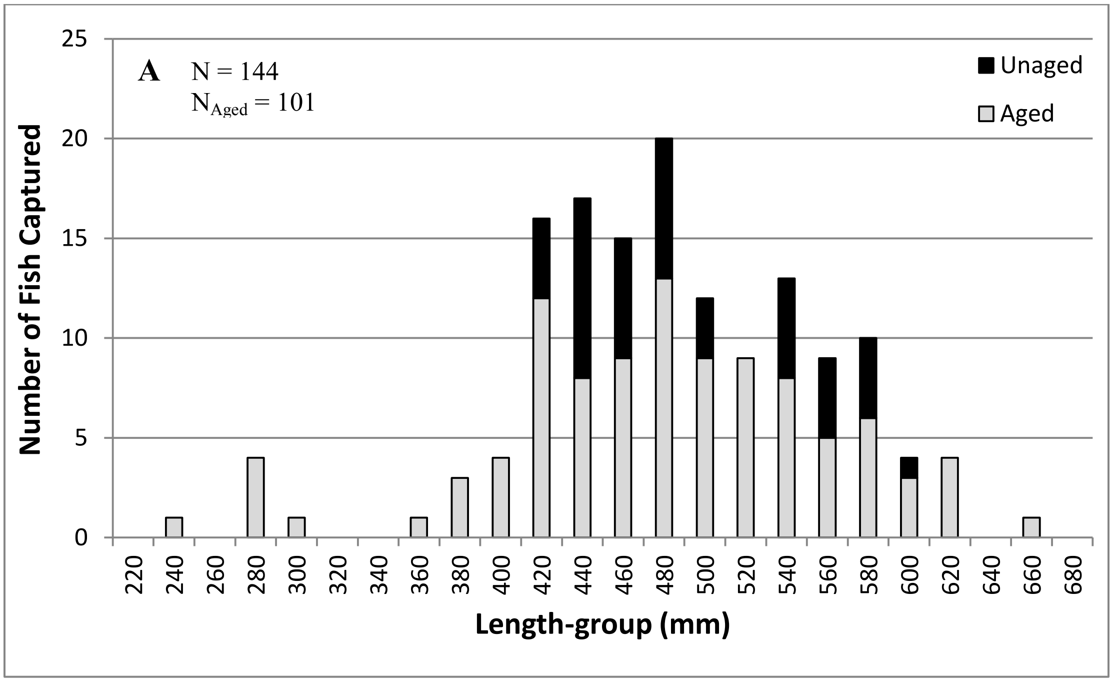


Figure 5.— Length-frequency graphs for Largemouth Bass *Micropterus salmoides* sampled at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas, with aged fish in each 20-mm length-group denoted by the lightly shaded bars and unaged fish in each length-group denoted by black bars. N is the total number of Largemouth Bass collected and N_{Aged} is the total number of Largemouth Bass aged.



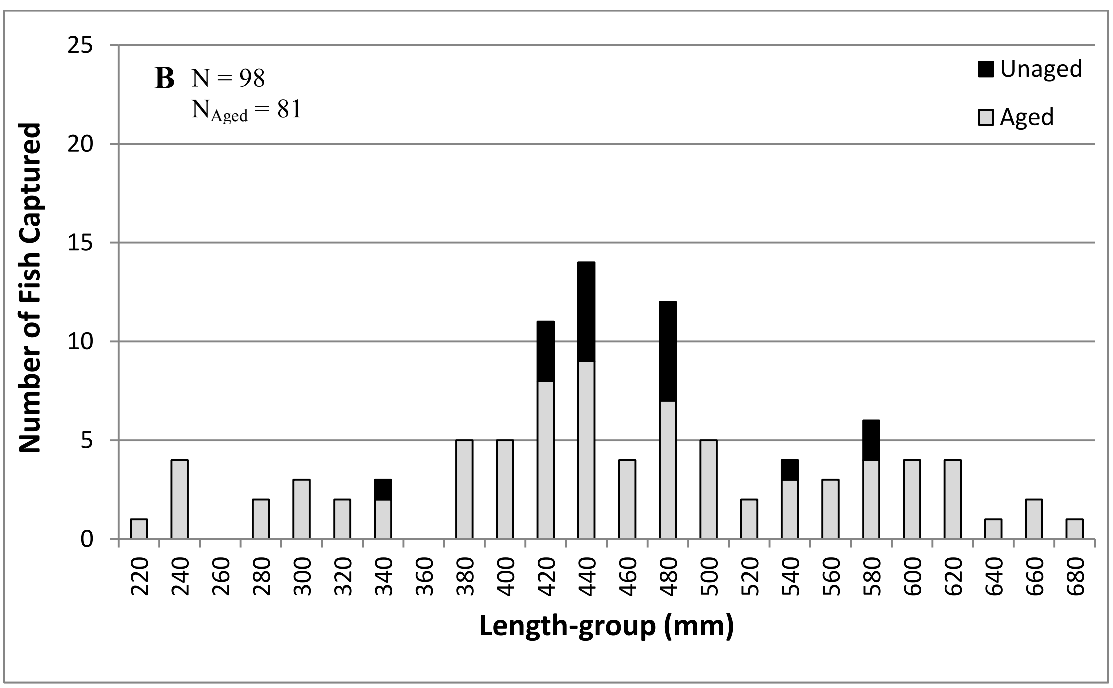


Figure 6.— Length-frequency graphs for Walleye *Sander vitreus* sampled at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas, with aged fish in each 20-mm length-group denoted by the lightly shaded bars and unaged fish in each length-group denoted by black bars. N is the total number of Walleye collected and N_{Aged} is the total number of Walleye aged.

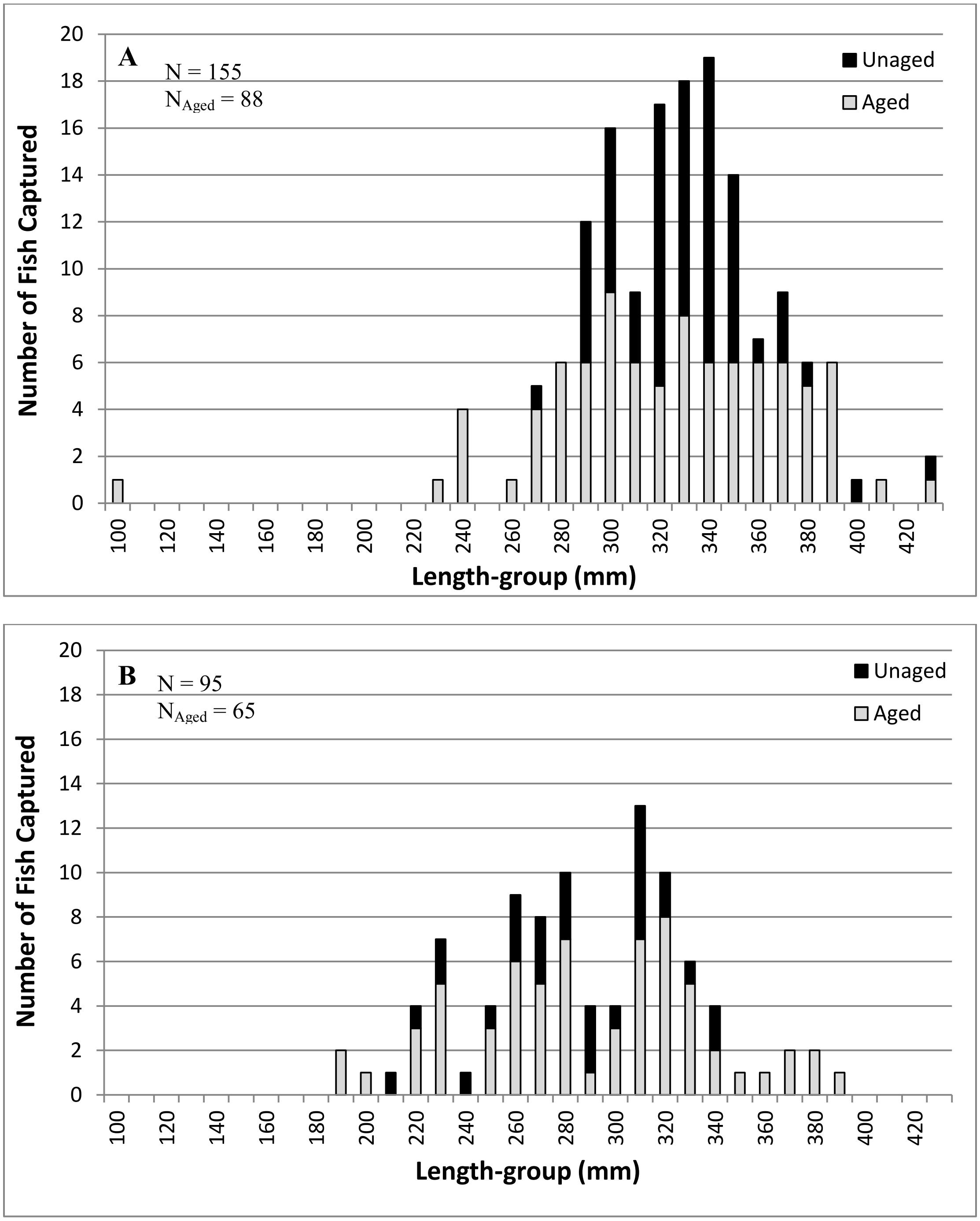


Figure 7.— Length-frequency graphs for White Bass *Morone chrysops* sampled at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas, with aged fish in each 10-mm length-group denoted by the lightly shaded bars and unaged fish in each length-group denoted by black bars. N is the total number of White Bass collected and N_{Aged} is the total number of White Bass aged.

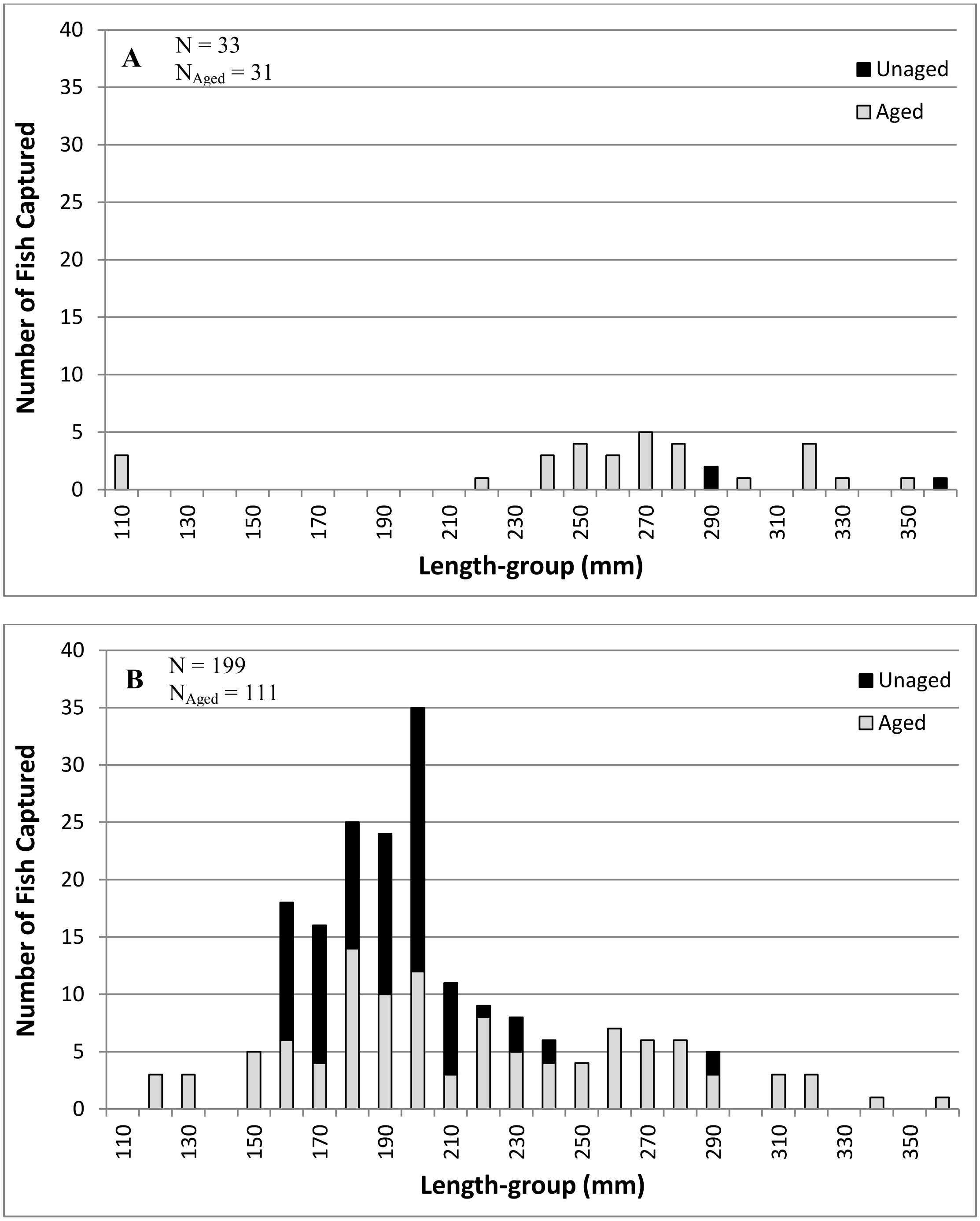


Figure 8.— Length-frequency graphs for White Crappie *Pomoxis annularis* sampled at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas, with aged fish in each 10-mm length-group denoted by the lightly shaded bars and unaged fish in each length-group denoted by black bars. N is the total number of White Crappie collected and N_{Aged} is the total number of White Crappie aged.

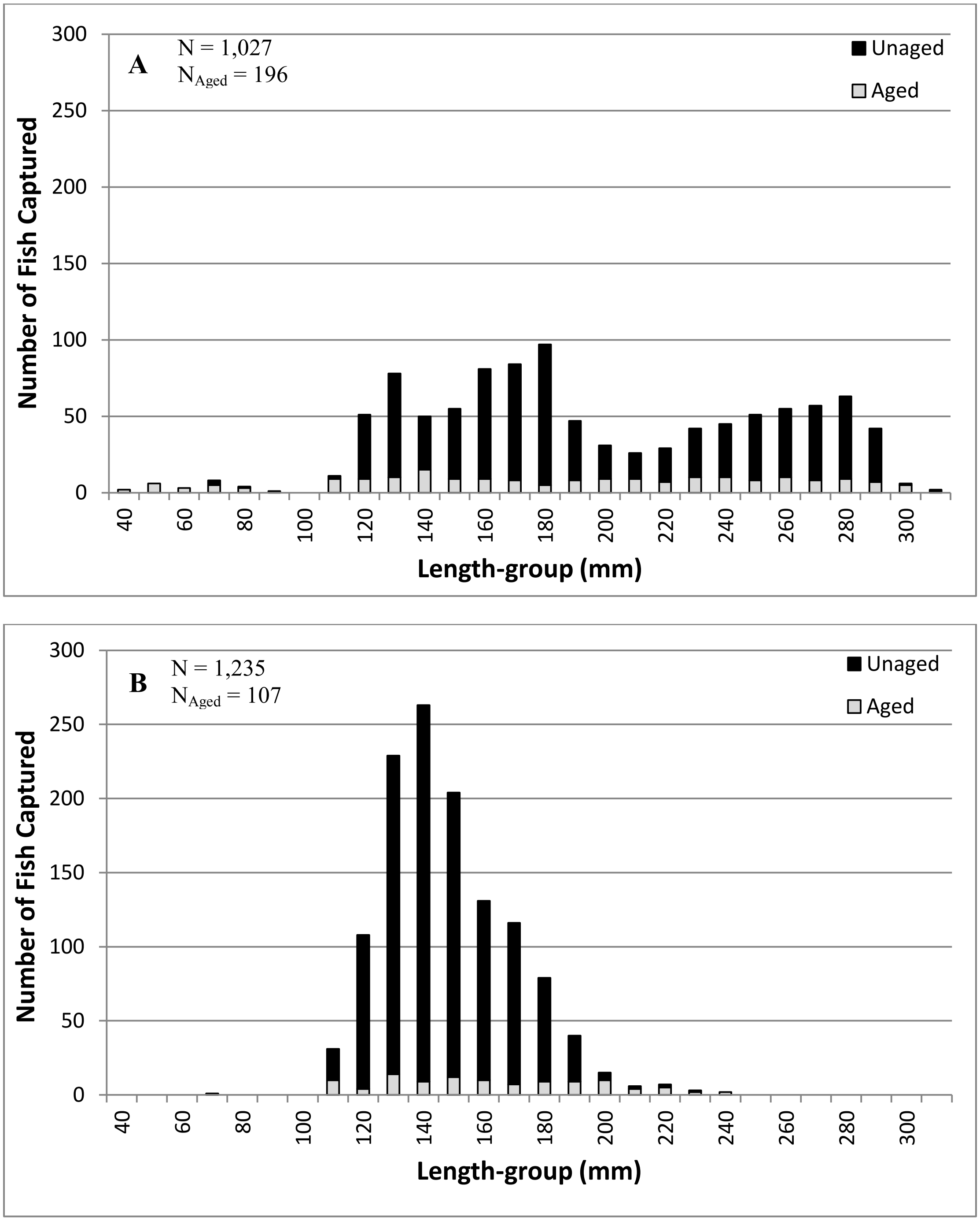
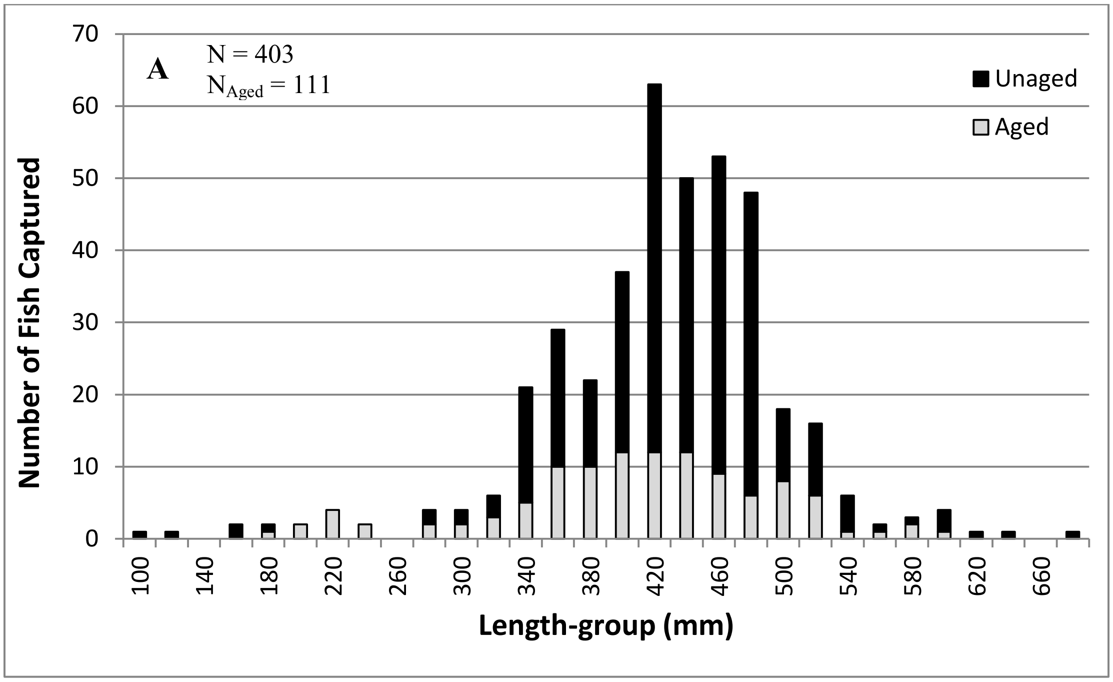


Figure 9.— Length-frequency graphs for White Perch *Morone americana* sampled at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas, with aged fish in each 10-mm length-group denoted by the lightly shaded bars and unaged fish in each length-group denoted by black bars. N is the total number of White Perch collected and N_{Aged} is the total number of White Perch aged.



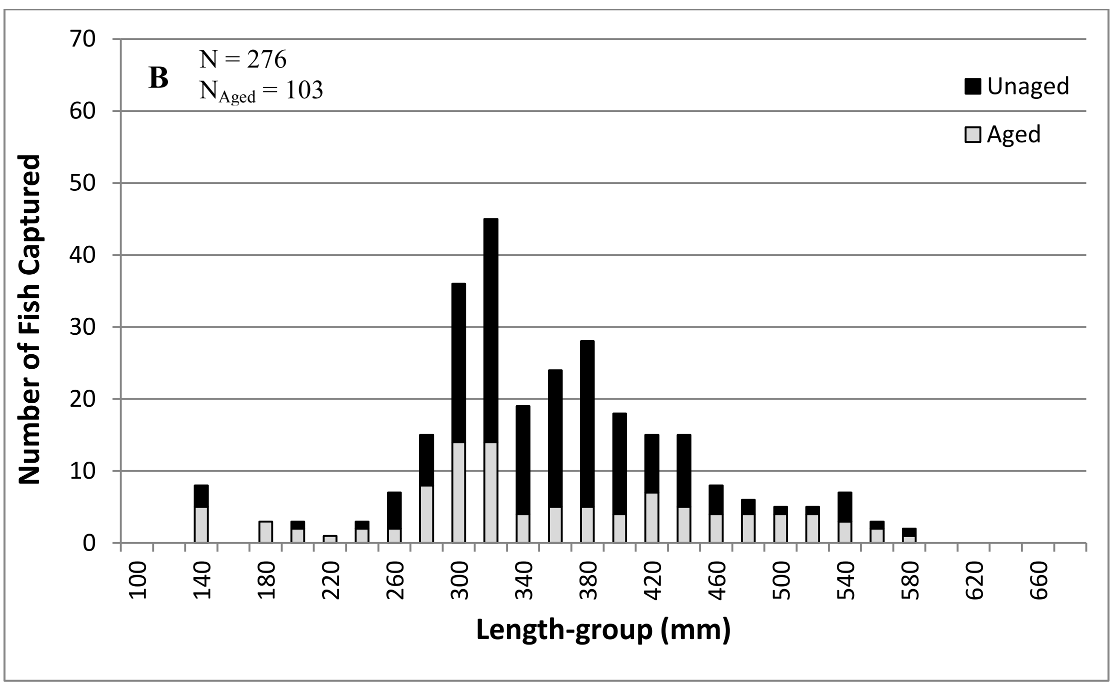


Figure 10.— Length-frequency graphs for palmetto bass *Morone saxatilis* × *M. chrysops* sampled at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas, with aged fish in each 20-mm length-group denoted by the lightly shaded bars and unaged fish in each length-group denoted by black bars. N is the total number of palmetto bass collected and N_{Aged} is the total number of palmetto bass aged.

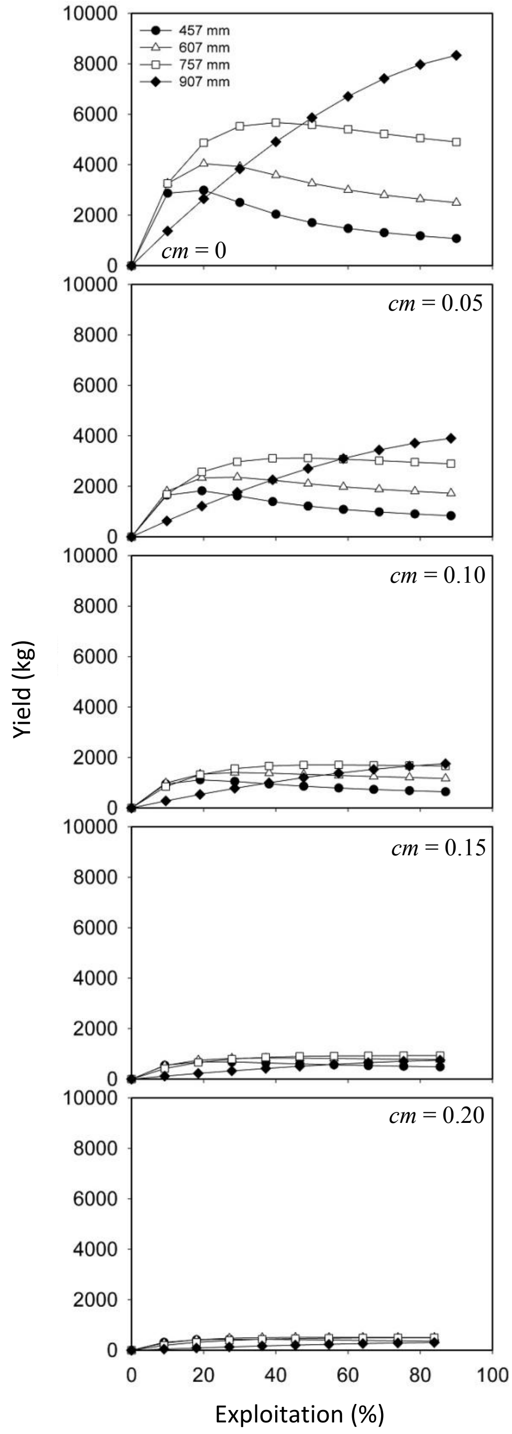


Figure 11.— Yield-per-recruit model for Blue Catfish *Ictalurus furcatus* at El Dorado Reservoir in Kansas in response to five potential length limits, where *cm* represents conditional natural mortality. Yield in kilograms is displayed on the Y-axis, while percent exploitation is on the X-axis.

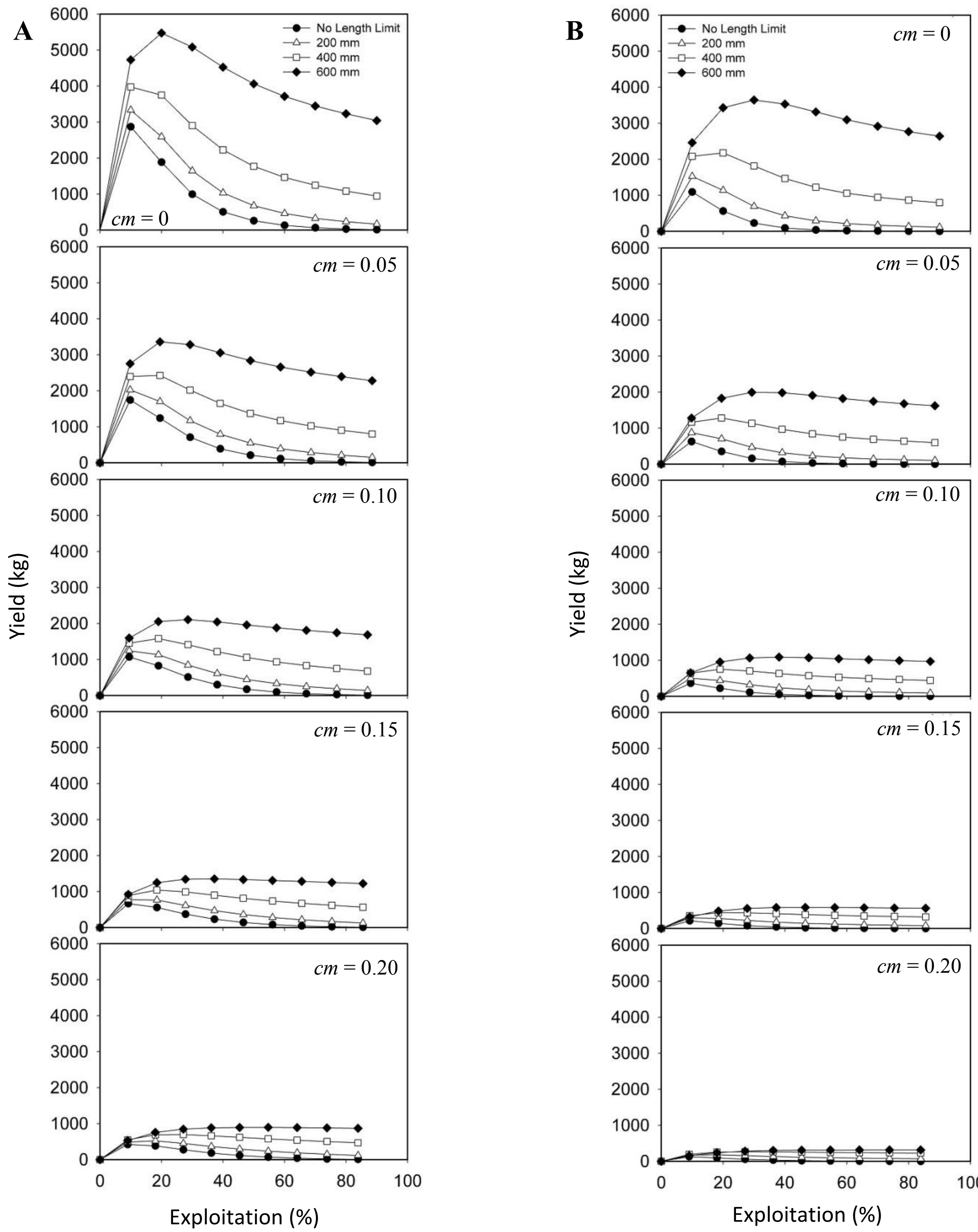


Figure 12.— Yield-per-recruit models for Flathead Catfish *Pylodictis olivaris* at (A) Cheney and (B) El Dorado reservoirs in Kansas in response to four potential length limits, where *cm* represents conditional natural mortality. Yield in kilograms is displayed on the Y-axis, while percent exploitation is on the X-axis.

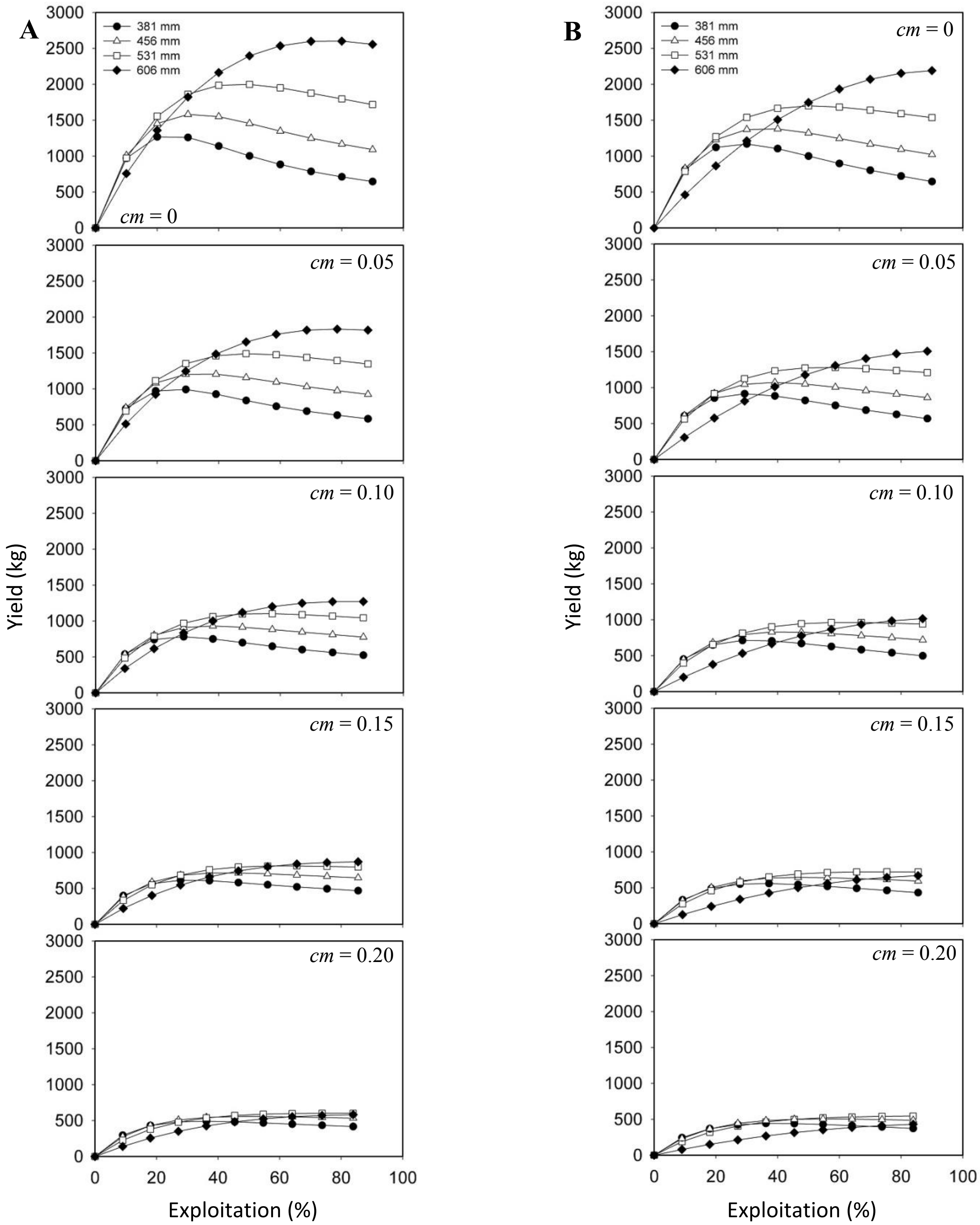


Figure 13.— Yield-per-recruit models for Walleye *Sander vitreus* at (A) Cheney and (B) El Dorado reservoirs in Kansas in response to four potential length limits, where *cm* represents conditional natural mortality. Yield in kilograms is displayed on the Y-axis, while percent exploitation is on the X-axis.

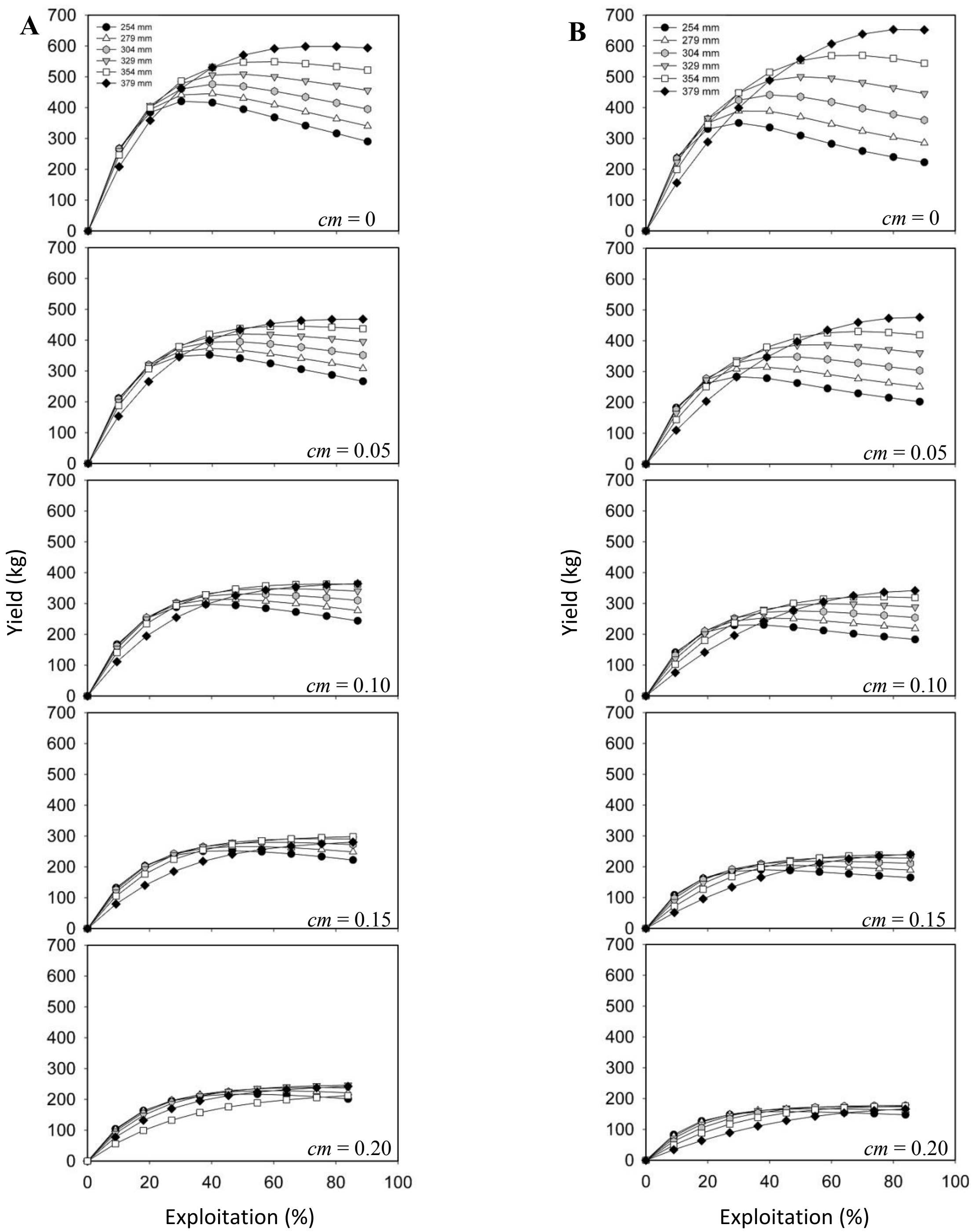


Figure 14.— Yield-per-recruit models for White Bass *Morone chrysops* at (A) Cheney and (B) El Dorado reservoirs in Kansas in response to six potential length limits, where *cm* represents conditional natural mortality. Yield in kilograms is displayed on the Y-axis, while percent exploitation is on the X-axis.

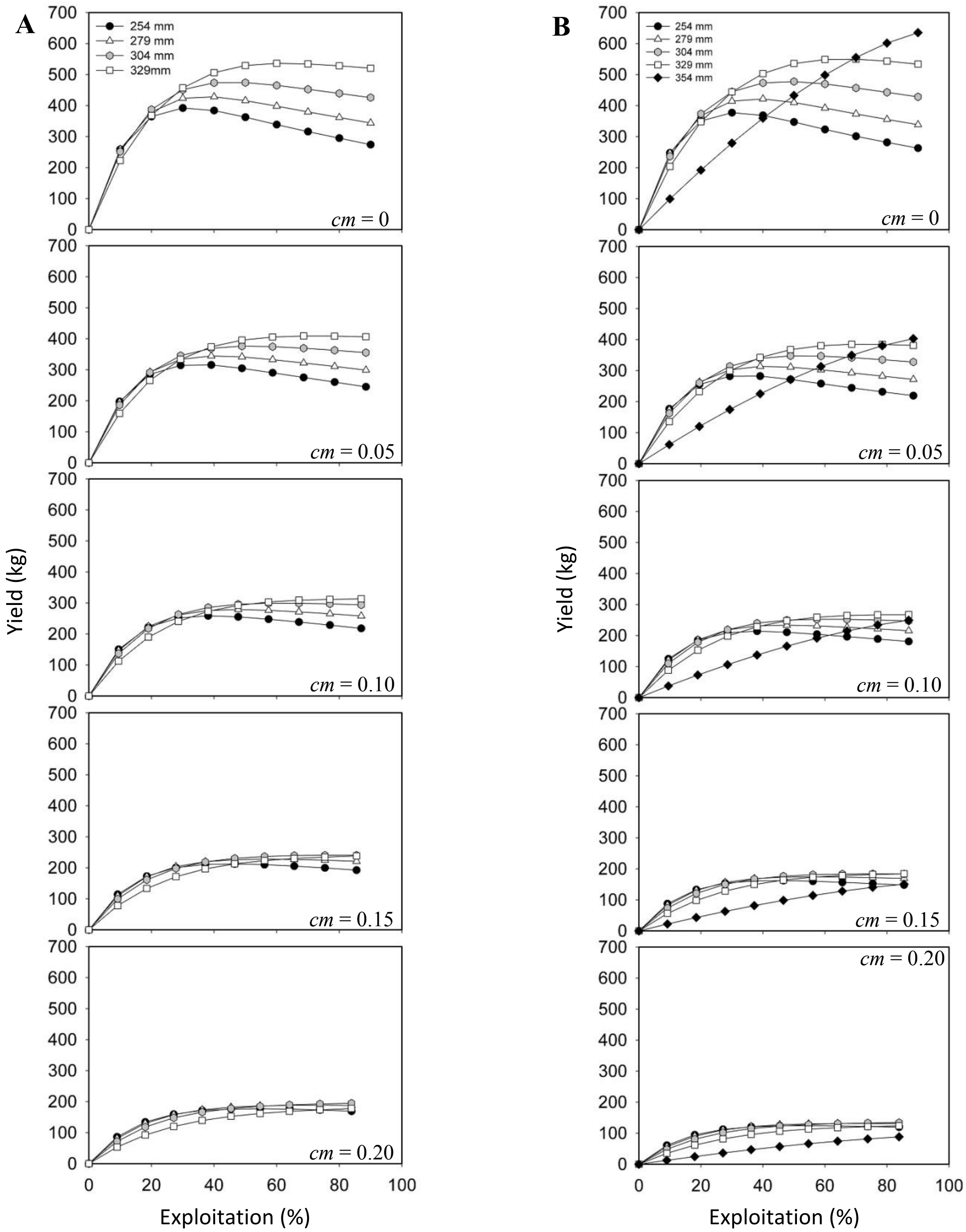


Figure 15.— Yield-per-recruit models for White Crappie *Pomoxis annularis* at (A) Cheney and (B) El Dorado reservoirs in Kansas in response to four (Cheney Reservoir) or five (El Dorado Reservori) potential length limits, where *cm* represents conditional natural mortality. Yield in kilograms is displayed on the Y-axis, while percent exploitation is on the X-axis.

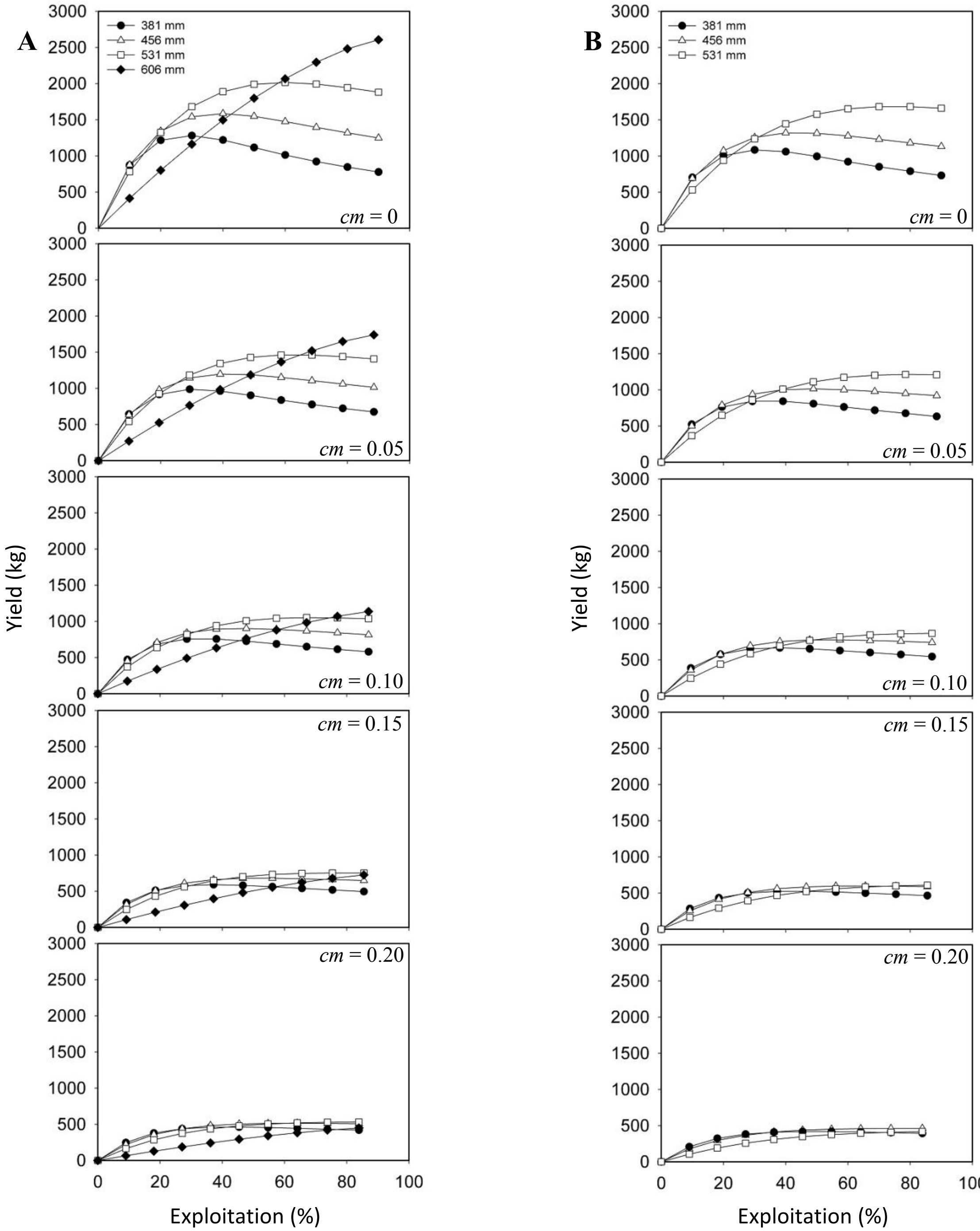


Figure 16.— Yield-per-recruit models for palmetto bass *Morone saxatilis* × *M. chrysops* at (A) Cheney and (B) El Dorado reservoirs in Kansas in response to four (Cheney Reservoir) or three (El Dorado Reservoir) potential length limits, where *cm* represents conditional natural mortality. Yield in kilograms is displayed on the Y-axis, while percent exploitation is on the X-axis.

Appendix A—Agreement of ages between readers, where N = total number of fish aged, F_I = number of fish aged that were initially agreed upon, and F_F = number of fish agreed upon after a third reader aged discrepancies. Reader agreement for fish collected at (A) Cheney Reservoir and (B) El Dorado Reservoir in Kansas.

A Species	F_I	N	Initial Percent Agreement	F_F	N	Final Percent Agreement
Blue Catfish	41	42	97.62%	42	42	100.00%
Flathead Catfish	27	36	75.00%	33	36	91.67%
Gizzard Shad	70	105	66.67%	92	105	87.62%
Largemouth Bass	5	5	100.00%	5	5	100.00%
Walleye	85	101	84.16%	101	101	100.00%
White Bass	87	88	98.86%	88	88	100.00%
White Crappie	28	31	90.32%	30	31	96.77%
White Perch	192	196	97.96%	194	196	98.98%
Palmetto bass	109	111	98.20%	111	111	100.00%
Overall	644	715	90.07%	696	715	97.34%

B Species	F_I	N	Initial Percent Agreement	F_F	N	Final Percent Agreement
Blue Catfish	62	97	63.92%	96	97	98.97%
Flathead Catfish	49	90	54.44%	78	90	86.67%
Gizzard Shad	62	77	80.52%	76	77	98.70%
Largemouth Bass	11	12	91.67%	11	12	91.67%
Walleye	81	81	100.00%	81	81	100.00%
White Bass	61	65	93.85%	65	65	100.00%
White Crappie	109	111	98.20%	111	111	100.00%
White Perch	105	107	98.13%	107	107	100.00%
Palmetto bass	99	103	96.12%	103	103	100.00%
Overall	639	743	86.00%	728	743	97.98%

Appendix B— Age-length key modified from Devries and Frie (1996) for Blue Catfish *Ictalurus furcatus* aged at Cheney Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)	Age 11 (%)	Age 12 (%)
340	3(2)	100.0										
360	5(2)	100.0										
380	5(2)	100.0										
400	5(2)	100.0										
420	5(2)	100.0										
440	7(2)	100.0										
460	6(2)	100.0										
480	4(2)	100.0										
500	1(2)	100.0										
520												
540												
560												
580												
600												
620												
640												
660												
680												
700												
720												
740	1(12)											100.0
Total	[42]	97.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.38

Appendix C— Age-length key modified from Devries and Frie (1996) for Flathead Catfish *Pylodictis olivaris* aged at Cheney Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)	Age 11 (%)	Age 12 (%)
160	1(1)	100.0											
180													
200	1(1) 1(2)	50.0	50.0										
220	1(1)	100.0											
240													
260	1(3)			100.0									
280	1(2)		100.0										
300	2(2)		100.0										
320	1(1) 1(2)	50.0	50.0										
340	1(2)		100.0										
360													
380	1(3)			100.0									
400													
420	1(3)			100.0									
440	2(4)				100.0								
460	1(2) 1(4)		50.0		50.0								
480	1(8)								100.0				
500	1(3) 1(7)			50.0				50.0					
520	1(5)					100.0							
540	1(4)				100.0								
560	1(4) 1(6)				50.0		50.0						

Appendix C continued.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)	Age 11 (%)	Age 12 (%)
580													
600													
620													
640													
660													
680	1(6)						100.0						
700													
720													
740													
760	1(6)						100.0						
780	1(8) 1(11)								50.0			50.0	
800	1(10)										100.0		
820	1(12)												100.0
840													
860													
880													
900													
920	1(7)							100.0					
940	1(11)											100.0	
960													
980	1(12)												100.0
Total	[33]	12.1	21.2	12.1	15.2	3.0	9.1	6.1	6.1	0.0	3.0	6.1	6.1

Appendix D—Age-length key modified from Devries and Frie (1996) for Gizzard Shad *Dorosoma cepedianum* aged at Cheney Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)
100	1(1)		100.0									
110												
120	3(0) 1(1)	75.0	25.0									
130	2(0)	100.0										
140	3(0) 2(1)	60.0	40.0									
150	2(1)		100.0									
160												
170												
180												
190	1(2)			100.0								
200	5(2)			100.0								
210	6(2)			100.0								
220	1(1) 4(2)		20.0	80.0								
230	6(2)			100.0								
240	4(2)			100.0								
250	6(2)			100.0								
260	5(2)			100.0								
270	4(2)			100.0								
280	3(2)			100.0								
290	3(2)			100.0								
300	4(2)			100.0								
310	6(2)			100.0								

Appendix D continued.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)
320	1(2)			100.0								
330	1(2)			100.0								
340												
350												
360	1(6) 1(9)							50.0			50.0	
370	1(6) 3(7)							25.0	75.0			
380	1(6) 1(8) 1(9)							33.3		33.3	33.3	
390	1(6) 1(8) 3(9) 1(10)							16.7		16.7	50.0	16.7
400	1(8)									100.0		
410												
420												
430	1(7)								100.0			
440	1(7)								100.0			
Total	[92]	8.7	7.6	64.1	0.0	0.0	0.0	4.3	5.4	3.3	5.4	1.1

Appendix E—Age-length key modified from Devries and Frie (1996) for Largemouth Bass *Micropterus salmoides* aged at Cheney Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)
180	1(1)	100.0				
200						
220						
240						
260						
280						
300						
320	1(2)		100.0			
340						
360	1(4) 2(5)				33.3	66.7
Total	[5]	100.0	100.0	0	33.3	66.7

Appendix F—Age-length key modified from Devries and Frie (1996) for Walleye *Sander vitreus* aged at Cheney Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Aged)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Ag 5 (%)	Age 6 (%)
240	1(0)	100.0						
260								
280	1(0) 3(1)	25.0	75.0					
300	1(2)			100.0				
320								
340								
360	1(1)		100.0					
380	3(1)		100.0					
400	1(1) 1(2) 2(3)		25.0	25.0	50.0			
420	1(2) 9(3) 2(4)			8.3	75.0	16.7		
440	1 (2) 7(3)			12.5	87.5			
460	6(3) 1(4) 2(5)				66.7	11.1	22.2	
480	1(2) 5(3) 2(4) 5(5)			7.7	38.5	15.4	38.5	
500	3(3) 2(4) 4(5)				33.3	22.2	44.4	
520	5(3) 4(5)				55.6		44.4	
540	1(3) 2(4) 4(5) 1(6)				12.5	25.0	50.0	12.5
560	2(3) 2(4) 1(5)				40.0	40.0	20.0	
580	1(4) 5(5)					16.7	83.3	
600	2(5) 1(6)						66.7	33.3
620	1(5) 3(6)						25.0	75.0
640								
660	1(5)						100.0	
Total	[101]	2.0	7.9	5.0	39.6	11.9	28.7	5.0

Appendix G—Age-length key modified from Devries and Frie (1996) for White Bass *Morone chrysops* aged at Cheney Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets. Broken line represents a break in size classes where no individuals were aged.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)
100	1(0)	100.0						
110								
220								
230	1(1)		100.0					
240	4(1)		100.0					
250								
260	1(1)		100.0					
270	1(1) 3(2)		25.0	75.0				
280	1(1) 5(2)		16.7	83.3				
290	6(2)			100.0				
300	1(1) 7(2) 1(3)		11.1	77.8	11.1			
310	1(2) 5(3)			16.7	83.3			
320	5(3)				100.0			
330	8(3)				100.0			
340	1(2) 5(3)			16.7	83.3			
350	2(2) 2(3) 1(4) 1(5)			33.3	33.3	16.7	16.7	
360	5(3) 1(4)				83.3	16.7		
370	4(3) 1(5) 1(6)				66.7		16.7	16.7
380	3(3) 2(4)				60.0	40.0		

Appendix G continued.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)
390	1(3) 2(4) 2(5) 1(6)				16.7	33.3	33.3	16.7
400								
410	1(6)							100.0
420								
430	1(6)							100.0
Total	[88]	1.1	10.2	28.4	44.3	6.8	4.5	4.5

Appendix H—Age-length key modified from Devries and Frie (1996) for White Crappie *Pomoxis annularis* aged at Cheney Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)
110	3(0)	100.0					
120							
130							
140							
150							
160							
170							
180							
190							
200							
210							
220	1(2)			100.0			
230							
240	1(1) 2(2)		33.3	66.7			
250	4(2)			100.0			
260	1(2) 2(3)			33.3	66.7		
270	4(2) 1(3)			80.0	20.0		
280	1(2) 3(3)			25.0	75.0		
290							
300	1(4)					100.0	
310							

Appendix H continued.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)
320	4(4)					100.0	
330	1(4)					100.0	
340							
350	1(5)						100.0
Total	[30]	10.0	3.3	43.3	20.0	20.0	3.3

Appendix I—Age-length key modified from Devries and Frie (1996) for White Perch *Morone americana* aged at Cheney Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets. Extended on next page.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)
40	2(0)	100.0						
50	6(0)	100.0						
60	3(0)	100.0						
70	5(0)	100.0						
80	3(0)	100.0						
90								
100								
110	9(1)		100.0					
120	8(1) 1(2)		88.9	11.1				
130	10(2)			100.0				
140	15(2)			100.0				
150	9(2)			100.0				
160	9(2)			100.0				
170	8(2)			100.0				
180	5(2)			100.0				
190	8(2)			100.0				
200	9(2)			100.0				
210	1(2) 5(3) 2(4) 1(5)			11.1	55.6	22.2	11.1	
220	1(2) 3(3) 2(4) 1(5)			14.3	42.9	28.6	14.3	
230	1(3) 5(4) 4(5)				10.0	50.0	40.0	
240	2(3) 5(4) 3(5)				20.0	50.0	30.0	
250	1(2) 2(3) 2(4) 2(5) 1(6)			12.5	25.0	25.0	25.0	12.5
260	1(4) 1(5) 5(6) 1(7) 1(8) 1(10)					10.0	10.0	50.0
270	1(5) 3(6) 2(7) 1(8) 1(10)						12.5	37.5
280	1(5) 1(7) 6(8) 1(9)						11.1	
290	2(7) 3(8) 1(10) 1(11)							
300	1(7) 1(8) 2(10) 1(11)							
310	1(13)							
Total	[194]	9.8	8.8	39.7	6.7	8.8	7.2	4.6

Appendix I continued.

Length-group (mm)	N(Age)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)	Age 11 (%)	Age 12 (%)	Age 13 (%)
40	2(0)							
50	6(0)							
60	3(0)							
70	5(0)							
80	3(0)							
90								
100								
110	9(1)							
120	8(1) 1(2)							
130	10(2)							
140	15(2)							
150	9(2)							
160	9(2)							
170	8(2)							
180	5(2)							
190	8(2)							
200	9(2)							
210	1(2) 5(3) 2(4) 1(5)							
220	1(2) 3(3) 2(4) 1(5)							
230	1(3) 5(4) 4(5)							
240	2(3) 5(4) 3(5)							
250	1(2) 2(3) 2(4) 2(5) 1(6)							
260	1(4) 1(5) 5(6) 1(7) 1(8) 1(10)	10.0	10.0		10.0			
270	1(5) 3(6) 2(7) 1(8) 1(10)	25.0	12.5		12.5			
280	1(5) 1(7) 6(8) 1(9)	11.1	66.7	11.1				
290	2(7) 3(8) 1(10) 1(11)	28.6	42.9		14.3	14.3		
300	1(7) 1(8) 2(10) 1(11)	20.0	20.0		40.0	20.0		
310	1(13)							100.0
Total	[194]	3.6	6.2	0.5	2.6	1.0	0.0	0.5

Appendix J—Age-length key modified from Devries and Frie (1996) for palmetto bass *Morone saxatilis* × *M. chrysops* aged at Cheney Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)
180	1(0)	100.0						
200	2(0)	100.0						
220	2(0) 2(1)	50.0	50.0					
240	2(1)		100.0					
260								
280	2(1)		100.0					
300	1(1) 1(2)		50.0	50.0				
320	3(3)				100.0			
340	5(2)			100.0				
360	9(2) 1(3)			90.0	10.0			
380	8(2) 1(3) 1(5)			80.0	10.0		10.0	
400	1(2) 11(3)			8.3	91.7			
420	1(2) 11(3)			8.3	91.7			
440	1(2) 6(3) 5(4)			8.3	50.0	41.7		
460	5(3) 4(4)				55.6	44.4		
480	4(3) 2(4)				66.7	33.3		
500	2(3) 3(4) 3(5)				25.0	37.5	37.5	
520	5(5) 1(6)						83.3	16.7
540	1(6)							100.0
560	1(6)							100.0
580	1(5) 1(6)						50.0	50.0
600	1(5)						100.0	
Total	[111]	4.5	6.3	23.4	39.6	12.6	9.9	3.6

Appendix K—Age-length key modified from Devries and Frie (1996) for Blue Catfish *Ictalurus furcatus* aged at El Dorado Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)
120	1(1)	100.0								
140	1(1)	100.0								
160	2(1)	100.0								
180	1(1)	100.0								
200	2(1) 3(2) 1(3)	33.3	50.0	16.7						
220	4(2) 1(3)		80.0	20.0						
240	3(2) 1(3)		75.0	25.0						
260	2(2) 2(3) 1(4)		40.0	40.0	20.0					
280	1(2) 2(3)		33.3	66.7						
300	4(3) 1(4)			80.0	20.0					
320	3(3) 2(4)			60.0	40.0					
340	1(3) 1(4)			50.0	50.0					
360	1(3) 2(4) 1(5)			25.0	50.0	25.0				
380	1(3) 1(4) 1(5)			33.3	33.3	33.3				
400	5(4) 1(5)				83.3	16.7				
420	1(4) 1(5)				50.0	50.0				
440	1(4)				100.0					
460	1(3) 1(4) 1(5)			33.3	33.3	33.3				
480	2(4) 1(5)				66.7	33.3				
500	3(4) 2(5)				60.0	40.0				
520	1(5)					100.0				
540	3(4) 1(5) 1(6) 1(8)				50.0	16.7	16.7		16.7	

Appendix K continued.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)
560	1(5) 1(6) 1(8)					33.3	33.3		33.3	
580	1(6)						100.0			
600										
620	1(6) 1(7)						50.0	50.0		
640	1(6) 1(8)						50.0		50.0	
660	1(5) 1(6) 1(7) 1(8)					25.0	25.0	25.0	25.0	
680	1(8) 1(9)								50.0	50.0
700	2(8)								100.0	
720	2(9)									100.0
Total	[96]	7.3	13.5	18.8	29.2	12.5	6.3	2.1	7.3	3.1

Appendix L—Age-length key modified from Devries and Frie (1996) for Flathead Catfish *Pylodictis olivaris* aged at El Dorado Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)	Age 11 (%)	Age 12 (%)
100	1(1)	100.0											
120	1(1)	100.0											
140	1(2)		100.0										
160	1(1) 3(2)	25.0	75.0										
180	2(1) 2(2)	50.0	50.0										
200	2(2)		100.0										
220	1(1) 3(2) 5(3)	11.1	33.3	55.6									
240	1(2) 3(3) 2(4)		16.7	50.0	33.3								
260	1(2) 2(3) 2(4)		20.0	40.0	40.0								
280	2(3) 2(4) 1(6)			40.0	40.0		20.0						
300	1(4) 1(5) 1(6) 1(7)				25.0	25.0	25.0	25.0					
320	1(4) 1(5) 1(6)				33.3	33.3	33.3						
340	1(5) 1(6) 1(7) 1(8)					25.0	25.0	25.0	25.0				
360	3(3) 1(10)			75.0							25.0		
380	1(3)			100.0									
400	1(4)				100.0								
420	1(7)							100.0					
440	1(4) 1(7)				50.0			50.0					
460	1(5) 2(6)					33.3	66.7						
480	2(5)					100.0							
500	1(3) 1(6) 1(7) 1(8)			25.0			25.0	25.0	25.0				

Appendix L continued.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)	Age 11 (%)	Age 12 (%)
520	1(4) 1(5)				50.0	50.0							
540	1(8)								100.0				
560	1(9)									100.0			
580													
600	1(3) 1(7)			50.0				50.0					
620	1(8)								100.0				
640	1(5)					100.0							
660													
680	1(12)												100.0
700													
720													
740													
760													
780													
800													
820													
840													
860													
880	1(11)											100.0	
900													
920	1(9)									100.0			
Total	[78]	7.7	16.7	23.1	14.1	10.3	9.0	7.7	5.1	2.6	1.3	1.3	1.3

Appendix M—Age-length key modified from Devries and Frie (1996) for Gizzard Shad *Dorosoma cepedianum* aged at El Dorado Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)
90	2(0) 1(1)	66.7	33.3									
100	3(0) 2(1)	60.0	40.0									
110	1(0)	100.0										
120												
130												
140												
150												
160												
170												
180												
190	4(2)			100.0								
200	6(2)			100.0								
210	3(2) 2(3)			60.0	40.0							
220	1(2) 6(3)			14.3	85.7							
230	1(1) 3(3)		25.0		75.0							
240	4(3)				100.0							
250	1(2) 2(3)			33.3	66.7							
260	6(3)				100.0							
270	5(3)				100.0							
280	6(3)				100.0							
290	1(2) 5(3)			16.7	83.3							

Appendix M continued.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)
300	3(3) 1(4)				75.0	25.0						
310	1(3)				100.0							
320	1(3)				100.0							
330	1(3)				100.0							
340	1(3)				100.0							
350												
360	1(3)				100.0							
370	1(6)							100.0				
380												
390												
400												
410												
420												
430												
440												
450	1(10)											100.0
Total	[76]	7.9	5.3	21.1	61.8	1.3	0.0	1.3	0.0	0.0	0.0	1.3

Appendix N—Age-length key modified from Devries and Frie (1996) for Largemouth Bass *Micropterus salmoides* aged at El Dorado Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)	Age 9 (%)	Age 10 (%)
140	2(1)	100.0									
160											
180											
200											
220											
240											
260	2(2)		100.0								
280											
300											
320	1(3)			100.0							
340	1(4)				100.0						
360											
380											
400	1(4) 1(5)				50.0	50.0					
420	1(4)				100.0						
440	1(10)										100.0
460											
480											
500											
520											
540	1(8)								100.0		
Total	11	18.2	18.2	9.1	27.3	9.1	0.0	0.0	9.1	0.0	9.1

Appendix O—Age-length key modified from Devries and Frie (1996) for Walleye *Sander vitreus* aged at El Dorado Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)
220	1(1)	100.0							
240	4(1)	100.0							
260									
280	2(1)	100.0							
300	2(1) 1(2)	66.7	33.3						
320	2(2)		100.0						
340	1(1) 1(3)	50.0		50.0					
360									
380	4(2) 1(3)		80.0	20.0					
400	3(2) 2(3)		60.0	40.0					
420	1(2) 6(3) 1(4)		12.5	75.0	12.5				
440	8(3) 1(4)			88.9	11.1				
460	3(3) 1(4)			75.0	25.0				
480	5(3) 1(4)			71.4	14.3		14.3		
500	5(3)			100.0					
520	1(3) 1(6)			50.0			50.0		
540	1(7) 2(8)							33.3	66.7
560	2(4) 1(6)				66.7		33.3		
580	1(4) 1(5) 1(6) 1(7)				25.0	25.0	25.0	25.0	
600	3(6) 1(7)						75.0	25.0	

Appendix O continued.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)
620	3(6) 1(7)						75.0	25.0	
640	1(7)							100.0	
660	2(8)								100.0
680	1(7)							100.0	
Total	81	12.3	13.6	39.5	8.6	1.2	12.3	7.4	4.9

Appendix P—Age-length key modified from Devries and Frie (1996) for White Bass *Morone chrysops* aged at El Dorado Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)
190	1(0) 1(1)	50.0	50.0						
200	1(1)		100.0						
210									
220	1(0) 2(1)	33.3	66.7						
230	3(1) 2(2)		60.0	40.0					
240									
250	1(1) 1(2) 1(3)	33.3	33.3	33.3					
260	1(1) 5(3)		16.7		83.3				
270	1(1) 4(3)		20.0		80.0				
280	1(2) 6(3)			14.3	85.7				
290	1(2)			100.0					
300	3(3)				100.0				
310	6(3) 1(4)				85.7	14.3			
320	8(3)				100.0				
330	4(3) 1(4)				80.0	20.0			
340	1(3) 1(4)				50.0	50.0			
350	1(3)				100.0				
360	1(4)					100.0			
370	1(4) 1(5)					50.0	50.0		
380	2(4)					100.0			
390	1(7)								100.0
Total	[65]	3.1	15.4	7.7	60.0	10.8	1.5	0.0	1.5

Appendix Q—Age-length key modified from Devries and Frie (1996) for White Crappie *Pomoxis annularis* aged at El Dorado Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)
120	3(1)	100.0							
130	3(1)	100.0							
140									
150	5(1)	100.0							
160	2(1) 2(2) 2(3)	33.3	33.3	33.3					
170	4(3)			100.0					
180	1(2) 13(3)		7.1	92.9					
190	1(2) 9(3)		10.0	90.0					
200	1(2) 11(3)		8.3	91.7					
210	2(2) 1(3)		66.7	33.3					
220	4(2) 4(3)		50.0	50.0					
230	1(2) 4(3)		20.0	80.0					
240	4(3)			100.0					
250	1(2) 3(3)		25.0	75.0					
260	1(2) 6(3)		14.3	85.7					
270	6(3)			100.0					
280	1(2) 3(3) 2(4)		16.7	50.0	33.3				
290	2(3) 1(6)			66.7			33.3		
300									
310	3(4)				100.0				
320	1(5) 2(6)					33.3	66.7		

Appendix Q continued.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)
330									
340	1(8)								100.0
350									
360	1(6)						100.0		
Total	[111]	11.7	13.5	64.9	4.5	0.9	3.6	0.0	0.9

Appendix R—Age-length key modified from Devries and Frie (1996) for White Perch *Morone americana* aged at El Dorado Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets.

Length-group (mm)	N(Age)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)
110	10(1)	100.0			
120	4(1)	100.0			
130	13(1) 1(2)	92.9	7.1		
140	7(1) 2(2)	77.8	22.2		
150	12(2)		100.0		
160	10(2)		100.0		
170	5(2) 2(3)		71.4	28.6	
180	2(2) 7(3)		22.2	77.8	
190	1(2) 8(3)		11.1	88.9	
200	1(2) 7(3) 2(4)		10.0	70.0	20.0
210	4(3)			100.0	
220	1(2) 4(3)		20.0	80.0	
230	1(3) 1(4)			50.0	50.0
240	2(4)				100.0
Total	[107]	31.8	32.7	30.8	4.7

Appendix S—Age-length key modified from Devries and Frie (1996) for palmetto bass *Morone saxatilis* × *M. chrysops* aged at El Dorado Reservoir in Kansas. N = the number of individuals in each age-class. Values within the table represent percentages of the total number of individuals aged for each age-class, and the values across the bottom represent percentages of the entire aged sample. Total number of aged individuals is in brackets

Length-group (mm)	N(Aged)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)
140	2(0) 3(1)	40.0	60.0							
160										
180	2(0) 1(1)	66.7	33.3							
200	2(1)		100.0							
220	1(1)		100.0							
240	1(1) 1(2)		50.0	50.0						
260	1(1) 1(2)		50.0	50.0						
280	1(1) 7(2)		12.5	87.5						
300	14(2)			100.0						
320	14(2)			100.0						
340	4(2)			100.0						
360	5(2)			100.0						
380	5(2)			100.0						
400	3(2) 1(3)			75.0	25.0					
420	1(2) 6(3)			14.3	85.7					
440	5(3)				100.0					
460	4(3)				100.0					
480	4(3)				100.0					

Appendix S continued.

Length-group (mm)	N(Aged)	Age 0 (%)	Age 1 (%)	Age 2 (%)	Age 3 (%)	Age 4 (%)	Age 5 (%)	Age 6 (%)	Age 7 (%)	Age 8 (%)
500	4(3)				100.0					
520	1(5) 2(7) 1(8)						25.0		50.0	25.0
540	3(7)								100.0	
560	2(7)								100.0	
580	1(5)						100.0			
Total	[103]	3.9	9.7	53.4	23.3	0.0	1.9	0.0	6.8	1.0