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Comparisons of Growth for Hybrid Striped Bass in North America

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Abstract.—Growth of hybrid striped bass (white bass *Morone chrysops* × striped bass *M. saxatilis*) throughout North America was summarized to evaluate latitudinal differences in growth. Age was estimated from scales and otoliths (nondifferentiated) collected from 29 populations in 12 states. Hybrid striped bass populations were delineated by midwestern, southeastern, and southwestern regions. Growth among regions was compared by fitting a von Bertalanffy growth model to each population and by comparing mean length at capture (fall-sampled fish) for ages 1 and 3 and maximum ages. Midwestern populations exemplified the highest theoretical maximum length (L_∞), followed by southeastern populations, although differences were not significant among regions. Likewise, growth coefficients (K) and maximum ages did not differ among regions. Southeastern populations had greater length at age than midwestern populations but were similar to southwestern values. These results provide a framework for comparing North American hybrid striped bass populations and for managing this important sport fish in reservoir systems.

Introduction

Many states have stocked hybrid striped bass (male white bass *Morone chrysops* × female striped bass *M. saxatilis*) (also referred to as original cross or palmetto bass) due to its popularity among anglers. In particular, hybrid striped bass exhibit fast growth, are aggressive, are considered to have superior fighting abilities, and are capable of reaching large sizes and providing a trophy fishery (Jahn et al. 1987). Additionally, biologists have been interested in using this species to restructure stunted panfish populations (Layzer and Clady 1984; Jahn et al. 1987; Neal et al. 1999; Hutt et al. 2008), control invasive species (Iowa Department of Natural Resources, unpublished data), and manage abundant gizzard shad *Dorosoma cepedianum* populations (Dettmers et al. 1996). Although hybrid striped bass continue to expand their distribution through movement and additional

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stockings, little is known about growth of hybrid striped bass.

An understanding of growth is important for properly managing sport fish and prey populations. Growth is allied with environmental conditions (e.g., temperature and water quality; Miranda and Durocher 1986; Woiwode and Adelman 1991; McInerny and Cross 1999; Quist et al. 2003; Wuellner et al. 2010), prey availability (Dettmers et al. 1996; Olson et al. 2007; Thompson and Rice 2013, this volume) and genetic factors (Avise and Van Den Avyle 1984; Leitner et al. 2002), making it a useful metric to evaluate habitat suitability, prey availability, or the effect of management strategies targeting sport fish and their prey. In addition, growth assessments are commonly used to assess potential problems (e.g., overfishing; Schultz and Dodd 2008) and management actions, such as regulations (Paukert et al. 2007), lake renovations (Heman et al. 1969), and prey stockings (Noble 1981).

Hybrid striped bass populations have been established across a range of latitudes and climatic zones, primarily in the midwestern and southern United States. Their habitat ranges from large, deep impoundments (Kilpatrick and Ney 2013, this volume) to shallow urban lakes (Schultz and Dodd 2008) and ponds (Neal et al. 1999). However, stockings have had mixed success, dependent upon habitat quality (Ruane et al. 2013, this volume) and prey size (Crandall 1979; Dennerline and Van Den Avyle 2000) and quantity (Ott and Malvestuto 1984; Dennerline and Van Den Avyle 2000). Previous research has demonstrated that fish in southern latitudes generally have greater growth but less longevity than fish in northern latitudes (Colby et al. 1979). Beverton (1987) compared walleye *Sander vitreus* populations along a latitudinal gradient from Canada to Texas and showed that southern walleye populations grew faster, matured later, but died earlier than more northern populations. Although latitudinal differences in temperature and growing season are known to influence walleye population dynamics (Quist et al. 2003), fish assemblage structure also differs with latitude (Hansen et al. 2010), confounding latitudinal effects on sport fish populations, through differences in prey availability (Santucci and Wahl 1993). For example, southern aquatic systems have higher species diversity, potentially increasing the number and abundance of available prey species (Quist et al. 2003). Likewise, latitudinal differences in growing season, temperature, and prey composition may have similar effects on hybrid striped bass populations, but this theory has not been tested.

Despite the effort and resources expended to stock hybrid striped bass, their importance to anglers, and their potential role in restructuring prey communities, little is known about how their growth compares throughout their distribution (Carlander 1997). Therefore, the objective of this study was to gain an understanding of hybrid striped bass growth across its distribution, with emphasis on latitudinal differences. Specifically, we compared regional growth by fitting a von Bertalanffy growth model to each population and comparing mean length at ages 1 and 3 and maximum ages for 29 populations in 12 states to provide a framework for comparing growth among North American hybrid striped bass populations.

Methods

Age and growth data on hybrid striped bass (fall sampled; length at age) were solicited from state natural resource agencies throughout the geographical distribution of hybrid striped bass. Growth data were based on ages derived from both scales and otoliths. Although some structures may provide biased age estimates depending on latitude or age (DeVries and Frie 1996), it was assumed that growth data provided by agencies utilized structures that provided relatively accurate estimates of age for their region (Maceina et al. 2007). Populations were not differentiated based on sex. In addition, few biologists responded with data on both palmetto bass (male white bass × female striped bass) and sunshine bass (female white bass × male striped bass). The number of sunshine bass populations (N = 4) was relatively low, and therefore this cross was not included in any analyses. Hybrid striped bass populations were separated into one of three regions: (1) midwestern populations (Illinois, Indiana, Kansas, Nebraska, and Ohio), (2) southeastern populations (Georgia, Kentucky, North Carolina, Tennessee, and Virginia), and (3) southwestern populations (Oklahoma and Texas) (Figure 1). Data were truncated to only include age-8 and younger fish because few populations contained fish older than 8 years old, but also to reduce potential errors in aging by scales and to minimize the effects that a few, long-lived, slow growing populations might have on the overall analysis. We limited the number of lakes within each region to no more than 10 to minimize the influence of any one region (Jackson et al. 2008). Lakes were chosen based on the largest sample sizes, after first ensuring that all possible states were included within a region. When growth data were provided for more than 1 year for a particular lake, the study with the largest sample size was chosen. Our objective was to compare growth of hybrid striped bass in the regions. This was done by first fitting a von Bertalanffy growth model to each population. We used the model

$$L_{age} = L_{\infty}[1 - e^{-K(\text{age} - t_0)}],$$

where L_{age} is the mean length at age, L_{∞} is the theoretical maximum length, K is the growth coefficient, and t_0 is the theoretical age when length equals zero. Growth models were fit to L_{age} data using nonlinear regression techniques (PROC NLIN) in the Statistical Analysis System (SAS; Freund and Littell 1991) following methods described in Quist et al. (2003). Analysis of variance (ANOVA) was used to determine differences in growth variables (L_{∞}, K, mean length at ages 1 and 3, and maximum age) among hybrid striped bass populations by region. Results were considered significantly different at P < 0.05.

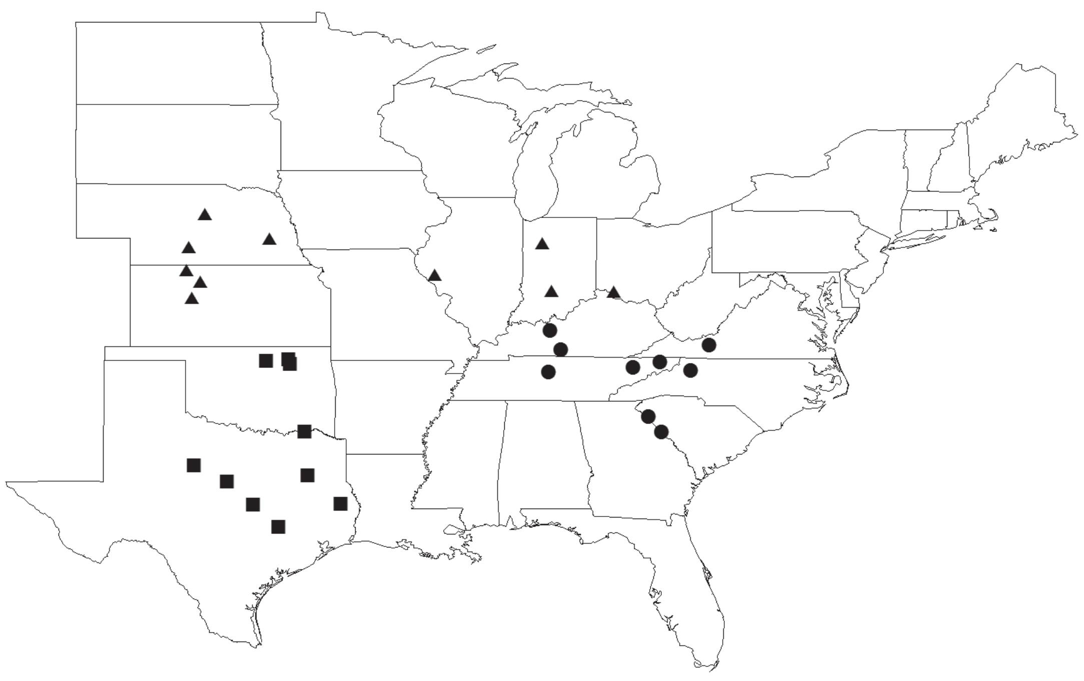

FIGURE 1. Water bodies used in current study. Midwestern lakes are identified by triangles, southeastern lakes by circles, and southwestern lakes by squares.

Results

Growth data were obtained from 29 populations representing 12 states (Table 1). The number of populations from individual states varied from 1 to 31, with Nebraska having the largest number of midwestern sites (*N* = 14 populations), Texas having the largest number of southwestern sites (*N* = 31 populations), and Tennessee contributing three sites for the southeastern region. Less than one-third of the sites selected for analyses had hybrid striped bass greater than 8 years old.

Standard growth models (Figure 2) indicated that midwestern populations had the highest L_∞, followed by southeastern populations, although differences were not significant among regions (ANOVA; $F = 2.28$, df = 2, 28; $P = 0.12$). However, growth coefficients (*K*) were highest in the southern regions, although differences were not significant (ANOVA; $F = 1.93$; df = 2, 28; $P = 0.17$). Southwestern populations had the oldest fish (8.4 years ± 1.6 SD), followed by southeastern populations (8.2 years ± 1.9 SD). Maximum age for midwestern populations was 7.3 years ± 1.2 SD. Maximum age did not differ among the three regions (ANOVA; $F = 1.45$; df = 2, 28; $P = 0.25$). Mean lengths at ages 1 and 3 were highest for southeastern populations (age 1 = 358 mm total length [TL]; age 3 = 530 mm TL), followed by southwestern populations (age 1 = 327 mm TL; age 3 = 497 mm TL). Midwestern populations had mean lengths at age 1 equaling 289 mm; mean lengths at age 3 were 475 mm. Significant differences for mean lengths at age occurred between southeastern and midwestern populations (ANOVA; $F > 3.52$; df = 2, 28; $P < 0.05$; Table 2).

Discussion

Age estimates of hybrid striped bass used in this study contained a mixture of scales and otoliths. Because concern exists over whether scales accurately portray maximum ages and, therefore, growth at older ages, we truncated the ages that were included in the analysis to 8 years and younger. Additionally, this allowed us to minimize the effects that a few, long-lived, slow-growing populations might have on the overall analysis. Welch et al. (1993) showed that age estimates are more precise for striped bass otoliths than scales, but precision is similar between otoliths and scales for white bass (Soupir et al. 1997). Unfortunately, precision between otoliths and scales for hybrid striped bass has not been evaluated. Even though different structures were used to obtain age estimates, this should not be problematic. For example, Jackson et al. (2008) found that growth standards did not differ among structures for nine North American species.

Several studies have shown that fish from northern latitudes demonstrate slower growth but greater longevity (Colby et al. 1979; Graham 1999; Quist et al. 2003). This phenomenon has been linked to an increased growing season, warmer water, and a higher diversity of prey in southern latitudes. Although our initial expectation was that hybrid striped bass populations would exhibit latitudinal differences in growth, our study did not fully support this generalization. We did not observe a difference in theoretical maximum length nor maximum ages between midwestern, southeastern, and southwestern populations of hybrid striped bass. However, it is known that the apparent maximum age of a population may be influenced by the extent of angler harvest, which can truncate size and age distributions (Maceina et al. 1998; Isermann and Paukert 2010). Additionally, small numbers of older fish may not be representative in samples and can alter von Bertalanffy growth models. The growth coefficient (i.e., *K*), however, was greatest for fish in southern populations, but differences did not exist among regions. Mean lengths at capture for both ages 1 and 3 were greatest in the southeastern region. Differences were marginally significant over that observed in the midwestern region ($P = 0.044$); however, differences between southeastern and midwestern regions for mean length at age 3 were highly significant ($P = 0.01$). Mean length at capture for both ages

TABLE 1. Waterbody, von Bertalanffy parameter estimates (theoretical maximum length [L_∞, mm], growth coefficient [K], theoretical age when length equals zero [t_0]) and maximum age (Age_{max}) for hybrid striped bass populations across North America.

Water body	L_∞	K	t_0	Age_{max}
Midwestern lakes				
Illinois				
Lake Pittsfield	685	0.394	0.471	6
Indiana				
Lake Freeman	786	0.275	–1.086	6
Monroe Reservoir	641	0.498	–0.130	9
Kansas				
Cedar Bluff Reservoir	665	0.342	–1.06	6
Norton Reservoir	731	0.274	–1.393	8
Webster Reservoir	843	0.204	–1.294	7
Nebraska				
Branched Oak Lake	658	0.323	–0.979	9
Calamus Reservoir	663	0.274	–1.086	7
Elwood Reservoir	651	0.334	–1.047	8
Ohio				
East Fork Lake	624	0.341	–0.171	7
Southeastern lakes				
Georgia				
Clarks Hill Reservoir	673	0.374	–0.830	7
Lake Hartwell	709	0.251	–2.171	7
Kentucky				
Barren River Lake	645	0.520	–0.545	9
Rough River Lake	617	0.254	–1.992	6
North Carolina				
West Kerr Scott Reservoir	684	0.636	–0.041	6
Tennessee				
Boone Reservoir	629	0.544	–0.755	10
Cherokee Reservoir	693	0.365	–0.692	8
J. Percy Priest Reservoir	670	0.435	–1.124	10
Virginia				
Claytor Lake	610	0.408	–1.203	11
Southwestern lakes				
Oklahoma				
Birch Lake	537	0.581	–0.865	8
Skiatook Lake	633	0.266	–2.268	9
Sooner Lake	502	0.630	–0.870	8
Texas				
Belton Lake	760	0.244	–1.211	8
Fort Phantom Hill Lake	666	0.347	–0.391	8
Lake Sommers	712	0.224	–2.869	6
Lake Palestine	603	0.585	–0.142	11
Pat Mayse Lake	672	0.334	–1.436	7
Proctor Lake	612	0.543	–0.182	11
Sam Rayburn Reservoir	639	0.490	0.288	8

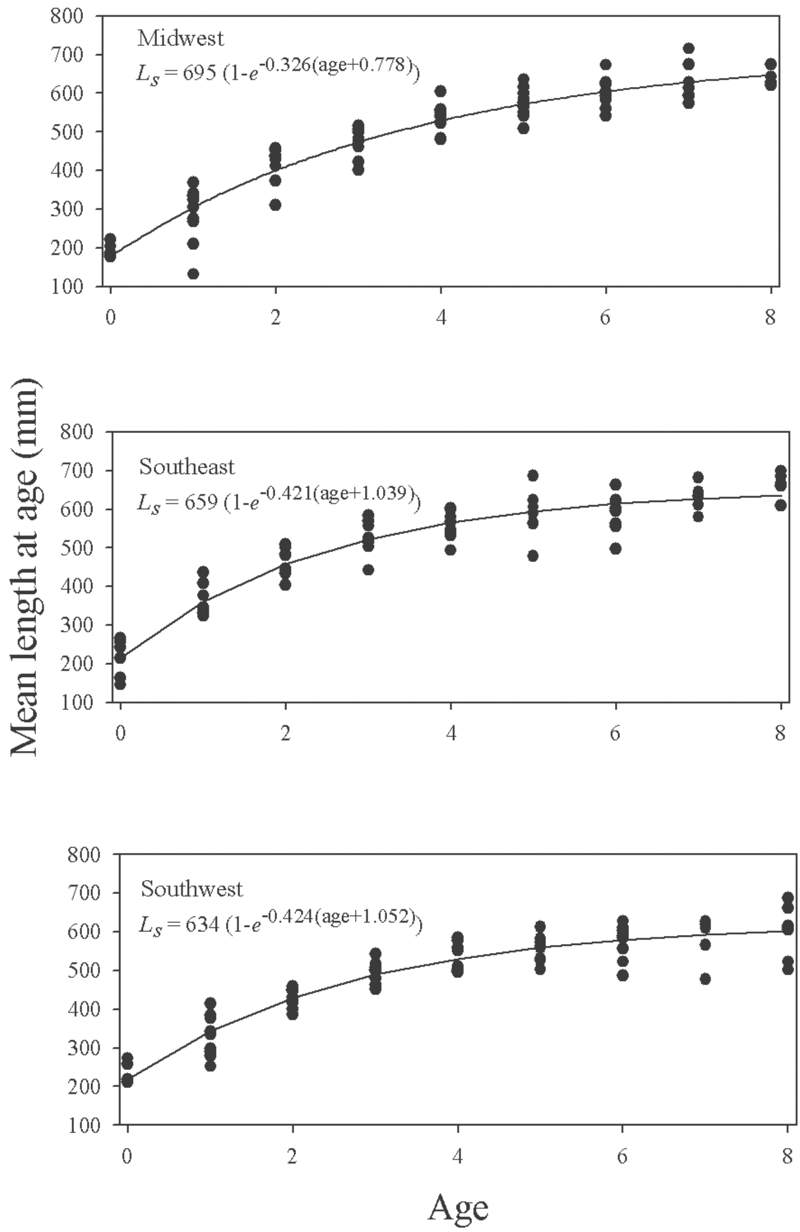

FIGURE 2. Mean length at age for hybrid striped bass populations throughout North America. The line represents the best-fit von Bertalanffy growth model (i.e., the standardized growth model) and was used to estimate age-specific standard lengths (i.e., L_s).

was intermediate in the southwestern populations. Hybrid striped bass may exhibit faster growth than either parental species (Carlander 1997). Therefore, hybrids may exemplify similar growth and age structure across a wider distribution than that which exists for either parental species. Unfortunately, studies to support or refute this supposition for hybrids are sparse. Hubert (1999) and Jackson (1999) found similar results where channel catfish *Ictalurus punctatus*

TABLE 2. Region, von Bertalanffy parameter estimates (theoretical maximum length [L_∞, mm], growth coefficient [K], theoretical age when length equals zero [t_0]), maximum age [Age_{max}], and lakes with ages > 8 years old [%] for North America hybrid striped bass populations.

Region	L_∞	K	t_0	Age_{max}	Ages > 8 years (%)
Midwestern lakes	695	0.326	–0.778	9	20
Southeastern lakes	659	0.421	–1.039	11	44
Southwestern lakes	634	0.424	–1.052	11	30

and flathead catfish *Pylodictis olivaris* did not exhibit regional differences in growth.

The results of this study are an important initial summarization of hybrid striped bass growth in North America. Latitudinal gradients in growth reveal that realistic expectations in hybrid striped bass growth are necessary for the management goals across their distributional range. Currently, little information is being reported for hybrid striped bass, especially in relation to striped bass (Bettoli 2013, this volume); this is especially true even for basic fisheries management information such as growth, recruitment and mortality. Continued development of population dynamics is needed to facilitate hybrid striped bass comparisons among populations to guide management activities. We encourage managers to evaluate and report population dynamics of hybrid striped bass they manage, utilizing this study as a starting point to better define management goals and objectives for this highly valuable sport fish species.

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