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Assessment of Smallmouth Bass Growth and Mortality in Nebraska Waters

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ABSTRACT Smallmouth bass (*Micropterus dolomieu*) have been introduced across Nebraska into a variety of waterbodies. However, an estimate of smallmouth bass growth and mortality in Nebraska waters has not been produced. The objectives of this study were to use historic sampling data to describe the growth of smallmouth bass in Nebraska lakes in relation to other regional models, growth among waterbody types (reservoirs, Interstate 80 [I-80] lakes, and rivers), estimates of age at quality, preferred, and memorable lengths, and mortality for Nebraska smallmouth bass populations. Mean length ± SE of Nebraska smallmouth bass at age 7 was 383 ± 21 mm, which is similar to national and regional values. Mean lengths at age of smallmouth bass in I-80 lakes and reservoirs were similar, but lengths were larger in rivers than in I-80 lakes and reservoirs at ages 3–5. Mean total annual mortality measured 0.41 (± 0.06 SE). These growth and mortality rates allow biologists to set appropriate management objectives and assess local sampling results with proper perspectives.

KEY WORDS growth, *Micropterus dolomieu*, mortality, Nebraska, smallmouth bass.

Smallmouth bass (*Micropterus dolomieu*) are a popular sportfish throughout the world. Originally native to the Mississippi, Ohio, and Tennessee River systems and the Great Lakes, smallmouth bass have been introduced throughout North America and in over 20 countries globally to provide angling opportunities (Robbins and MacCrimmon 1974, Carey et al. 2011). Angling interest for this species has provided significant economic contribution outside of its native range (Carey et al. 2011). Smallmouth bass are not native to Nebraska, and the initial Nebraska stocking occurred in 1898 for recreational purposes (Jones 1963, Robbins and MacCrimmon 1974). Introduction efforts have continued by the Nebraska Game and Parks Commission (NGPC) in 22 different waterbodies since 1990, ranging from large irrigation reservoirs to small borrow pits along the Interstate 80 corridor (I-80 lakes).

Previous smallmouth bass studies indicate that population dynamic information is variable among specific populations. The age that smallmouth bass reached quality length (Gabelhouse 1984) varied from 1.8 to 9 years across several North American populations (Beamesderfer and North 1995). Total annual mortality rate of adult smallmouth bass often exceeds 50% (Paragamian and Coble 1975, Paragamian 1984, Austen and Orth 1988, Hoff 1995) and has been 40% when highly restrictive length regulations are imposed (Newman and Hoff 2000). Environmental factors including mean air temperature (Beamesderfer and North 1995), length of growing season (Mullner and Hubert 1993, Robertson and Winemiller 2001), and stable water levels (DiCenzo et al. 1995) have all been positively correlated to growth in black bass species, whereas latitude was negatively correlated (Beamesderfer and North 1995).

Descriptions of regional growth and mortality estimates are useful for the management and regulation of smallmouth bass and understanding their ecological role as introduced species in riverine and lacustrine systems. Regulations can vary between waterbodies, but statewide smallmouth bass minimum length limits (MLL) range from no length limit to 380 mm across all states. Current statewide management of smallmouth bass in Nebraska includes a 380 mm MLL on all black bass species and waterbody types. Several regional models of smallmouth bass growth have been produced (Carlander 1977, Beamesderfer and North 1995, Willis et al. 2001, Jackson et al. 2008), but limited data from Nebraska was included in these summaries. Additionally, mortality estimates for smallmouth bass have not been constructed for any Nebraska populations.

Regional descriptions of age and mortality are important for furthering the understanding of the scope and range of population dynamics a species can exhibit outside of their native range. To provide growth and mortality estimates for comparison to other populations as well as providing direction for local management efforts, the primary objectives of our study were to: 1) describe the growth of smallmouth bass in Nebraska lakes in relation to other regional models; 2) describe growth of smallmouth bass in I-80 lakes, reservoirs, and rivers; 3) develop estimates of age that smallmouth bass reach quality (280 mm), preferred (350 mm), and memorable (430 mm) length; and 4) describe mortality estimates for Nebraska smallmouth bass populations.

METHODS

We obtained mean back-calculated length at age data for 1994–2011 from the NGPC standard sampling database (Francis 2000) to develop growth curves for smallmouth bass in Nebraska. Smallmouth bass were collected using a variety of techniques during different seasons, although primarily by fall boat electrofishing. Total lengths (TL) and back-calculated lengths at age from scales were available data. The NGPC standard sampling protocol for smallmouth bass is to measure TL and collect scales for aging from up to 10 individuals per cm length class.

We developed criteria for a waterbody to be included in the statewide growth analysis a priori to ensure that growth rates represent managed smallmouth bass populations. The first criterion was the lake must have been connected to a waterbody stocked with smallmouth bass by the NGPC between 1990 and 2011. Lewis and Clark Lake, located on the border of Nebraska and South Dakota, was included because historic sampling data was available, but the NGPC was not solely responsible for management. The second criterion was that a minimum sample size of 15 fish needed to be recorded from NGPC sampling efforts. The third criterion was at least two year classes were present in the population (Uphoff and Schoenebeck 2012).

For each lake meeting all inclusion criteria (n = 8) we compiled year-class specific mean length at age data and determined weighted mean lengths at age using an age-length key. Year-class specific mean length at age was assessed for Lee's phenomenon using an analysis of variance but was similar at all ages (P<0.05). Therefore, all back-calculated length at age data was utilized to avoid potential bias associated with sampling gear and time. We created a von Bertalanffy growth curve for each lake meeting the inclusion criteria using all available length at age data (Allen and Hightower 2010). We removed any lake (n = 1) from analysis where the asymptotic length (L_∞) calculated using the von Bertalanffy growth model did not converge upon analysis (Uphoff and Schoenebeck 2012), leaving seven lakes with 456 smallmouth bass for development of the combined lake growth model.

To give equal representation among waterbodies, we calculated the combined Nebraska lakes growth model from the lake-specific mean length at age data for the seven remaining lakes. We fit a combined Nebraska lakes von Bertalanffy growth curve to the seven lake-specific mean length at age data through age 7 using methods described by Quist et al. (2003). Additionally, we utilized a maximum age of 7 years for comparisons with the national and regional length at age averages. We used age and growth values from the combined Nebraska lakes model to provide a timeline for achievement of specific length categories related to management of this species (Gabelhouse 1984).

We determined mean lengths at age of Nebraska smallmouth bass from reservoirs (> 600 ha), I-80 lakes (< 25 hectares), and rivers from examination of the same NGPC database. Waterbodies used in our analysis included four reservoirs (Lake Maloney, Lake McConaughy, Lewis and Clark Lake, and Merritt Reservoir), three I-80 lakes (Hershey Lake, Ft. McPherson Lake, and War Axe Lake), and three river sections (St. Helena [Rm 801–795], Upper Boyd County [Rm 875–866], and Verdel [Rm 861–851]). We summarized mean length at age of 235 smallmouth bass for five river samples taken in 2003 and 2004. We utilized maximum age of 6 years when making growth comparisons with Nebraska rivers. We used procedures similar to those described above to develop back-calculated lengths at age and von Bertalanffy growth curves for each waterbody type.

Catch curves were used to estimate total annual mortality (A) from smallmouth bass age frequency distributions obtained from the NGPC database (Ricker 1975). Total annual mortality was calculated from any sample of age 3 and older fish from 1994–2011 with a sample size greater than or equal to 15 fish. We then calculated a mean from individual values (n = 8).

Statistical Analysis

We made statistical comparisons of mean lengths at age to the combined Nebraska lakes growth model with regional values provided by Carlander (1977), South Dakota values provided by Willis et al. (2001), and values for Nebraska rivers. Age and growth data in these studies were also derived from scales, making comparisons possible. Additionally, we compared mean lengths at age among our three waterbody types. We tested all length at age data for normality using a Shapiro-Wilk test. We used an independent t-test to compare mean lengths at age of the combined Nebraska lakes model to the South Dakota, Nebraska rivers, and Carlander (1977) regional values through ages 5,6, and 7, respectively. We used an analysis of variance to compare lengths at age among waterbody types through age 6 and a post-hoc Tukey's Honest Significant Difference test to determine significance among waterbody types. An a-value of 0.05 was selected a priori for all significance tests.

RESULTS

Overall, smallmouth bass in the combined Nebraska lakes model are growing through age 7 at similar rates (P > 0.05) to the regional averages provided by Carlander (1977; Fig. 1). Compared to South Dakota, smallmouth bass are longer in Nebraska at age 1 (t_9 = 2.45, P = 0.037) but similar for ages 2-5 (P > 0.05); (Willis et al. 2001). Mean length at age of smallmouth bass recorded for each lake demonstrated the intrastate variability in growth, as length at age 7 derived from the von Bertalanffy equation ranged from 352 mm at Lake Maloney to 417 mm at Merritt Reservoir.

Mean lengths at age of smallmouth bass in Nebraska res-

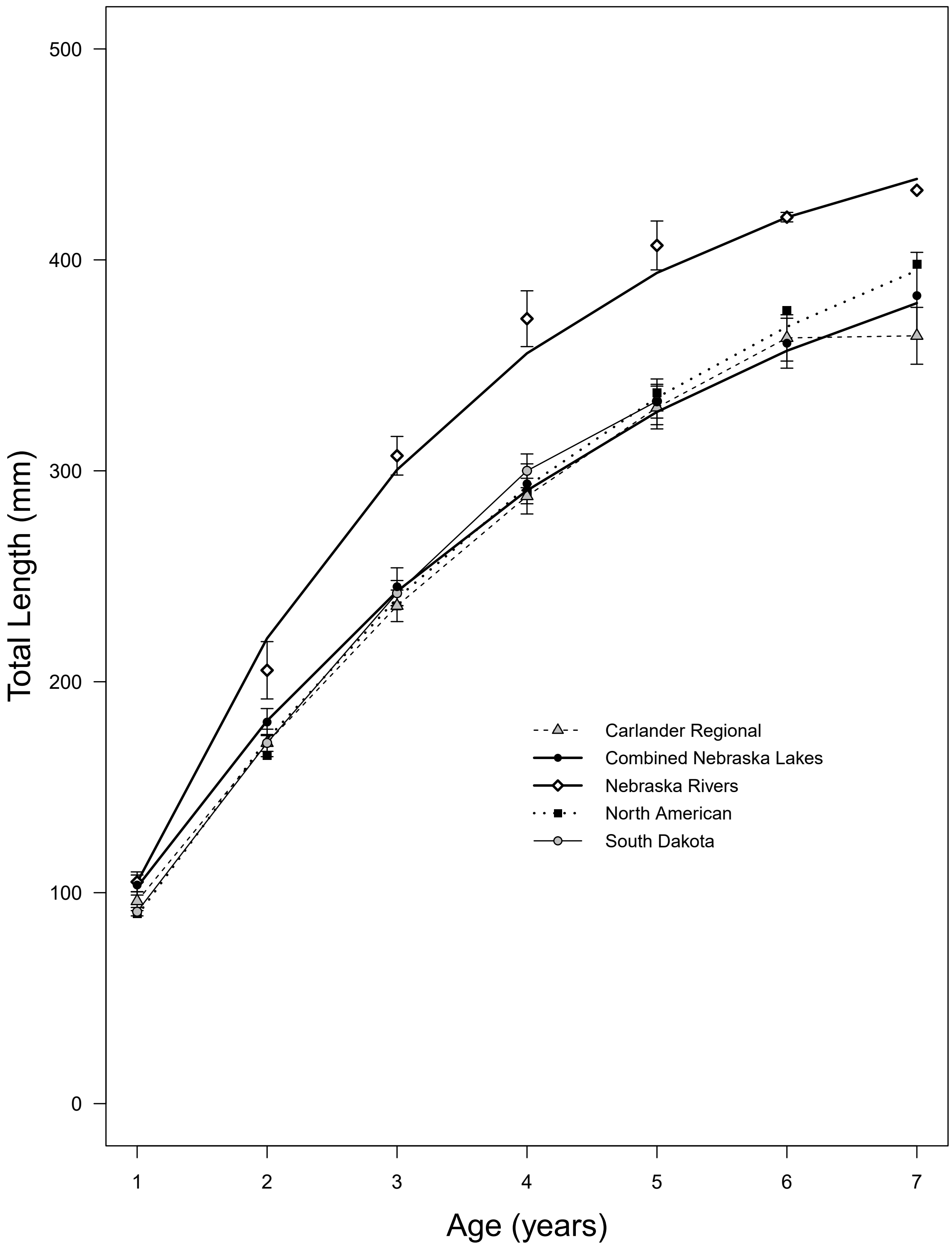

Figure 1. Mean back-calculated length at age calculated for smallmouth bass in Nebraska lakes (Combined Nebraska Lakes) and rivers (Nebraska Rivers) through age 7 using historical data from 1994-2011 with comparison to the North American standard (North American; Jackson et al. 2008), Ohio-Nebraska regional (Carlander Regional; Carlander 1977), and South Dakota (South Dakota; Willis et al. 2001) growth curves. Standard error bars about the mean lengths at age are provided for all models except the North American. Lines for the Combined Nebraska Lakes, Nebraska Rivers, and North American data were derived from the von Bertalanffy equation.

Table 1. Mean von Bertalanffy growth model parameters and weighted mean back-calculated lengths at age (± SE in parentheses) for age 1 through age 7 smallmouth bass for the combined Nebraska lakes growth model, all reservoirs used in analysis, all Interstate 80 (I-80) lakes used in analysis, and the statewide river model in Nebraska. Values provided for L_∞ and K statistics are given in millimeters (mm), t_0 is given in years, and n is the number of individuals used in analysis.

					Mean Back-Calculated Length at Age (mm)						
Location	n	L_∞	k	t_0	1	2	3	4	5	6	7
Combined Nebraska lakes	456	460	0.25	0.005	104 (5)	181 (6)	245 (9)*	293 (9)*	332 (11)*	360 (11)*	380 (19)
Nebraska reservoirs	330	479	0.23	0.035	97 (6)	172 (8)	240 (14)*	288 (14)*	329 (16)*	357 (17)	385 (27)
Nebraska I-80 lakes	126	440	0.28	–0.029	112 (6)	192 (7)	251 (11)*	300 (12)*	336 (16)*	363 (18)	375 (37)
Nebraska rivers	235	484	0.38	0.406	105 (5)	205 (14)	307 (9)	372 (13)	407 (12)	420 (2)	433

* Significantly different from Nebraska rivers value ($P < 0.05$)

ervoirs, I-80 lakes and rivers displayed differences. Mean back-calculated lengths at age were found to be larger ($P < 0.05$) for river populations than reservoir and I-80 lakes populations at ages 3–5 (Table 1). River populations also had larger mean back-calculated lengths at ages 3–6 when compared to the combined Nebraska lakes model (Table 1). Mean length at age of smallmouth bass through age 7 is similar ($P > 0.05$) between I-80 lakes and reservoirs (Table 1).

Based on the estimated growth rate of smallmouth bass using the von Bertalanffy growth parameters for the combined Nebraska lakes model, smallmouth bass in Nebraska will reach quality length between ages 3 and 4 and preferred length by age 6 (Table 1), and memorable length would not be attained until age 11. Additionally, smallmouth bass in rivers will reach a quality length between ages 2 and 3, preferred length between ages 3 and 4, and memorable length between ages 6 and 7 (Table 1).

A broad range of A values were calculated among waterbodies for smallmouth bass. Mean A for the samples used in analysis was 0.41 (± 0.06 SE) and ranged from 0.22 to 0.66. Four of the eight samples used in the mortality estimates had fish 8 years or older, and the maximum age of smallmouth bass collected in Nebraska rivers, reservoirs, and I-80 lakes were 7, 9, and 10 years, respectively.

DISCUSSION

Regional growth of smallmouth bass is highly varied. Smallmouth bass age at quality length in Nebraska falls in the middle of values provided by other studies (Beamesderfer and North 1995). Growth rates and age at quality and preferred lengths in Nebraska's lentic waters were similar to regional values reported by Carlander (1977) and appear to be similar to the North American standard (Jackson et al. 2008), although statistical comparison could not be made. The moderate growth corresponds with Nebraska being at a central latitude of the North American range for smallmouth bass. Latitudinal effects on growth of smallmouth bass have been documented (Beamesderfer and North 1995) as Texas populations have been shown to reach quality size before age 2 (Robertson and Winemiller 2001). The lack of growth difference between Nebraska and South Dakota populations may be a function of regional variation over-riding the ability to detect differences across this latitudinal gradient and the sharing of Lewis and Clark Lake in both the Nebraska and South Dakota growth estimates.

The comparison of smallmouth bass growth among waterbody types highlights a significant difference in growth between lentic and lotic systems. A previous study in Nebraska has indicated that waterbody type can significantly influence fish growth (Porath and Hurley 2005), but mean lengths at age of smallmouth bass between the Nebraska I-80 lakes and reservoirs showed little difference through age 7. However, smallmouth bass populations in Nebraska rivers have faster growth than lake populations (I-80 lakes, reservoirs, or combined). Growth of other species, such as freshwater drum (*Aplodinotus grunniens*), has been found to be faster in rivers compared to lakes (Rypel et al. 2006). A comprehensive study of the factors influencing growth rates of smallmouth bass in different waterbody types has not been conducted, and limited information exists concerning the mechanisms for faster growth in the state's rivers.

Several factors could influence the different growth rate of smallmouth bass in Nebraska rivers and lakes. Fluctuating water levels in reservoirs used for irrigation and flood control may impact available habitat, prey base, competition, and other biological conditions (DiCenzo et al. 1995, Olds et al. 2011, 2014), thereby influencing growth of smallmouth bass. Productivity of fish communities, measured in density and total biomass, have been found to be greater in rivers than in lakes due to allochthonous food inputs (Randall et al. 1995). Additionally, in highly turbid water smallmouth bass have a reduced reactive foraging distance, resulting in lower growth (Sweka and Hartman 2003) and have been found to grow faster in reservoirs with non-turbid, less fertile water (Edwards et al. 1983). However, smallmouth bass appear to have faster growth in Nebraska rivers which tend to be more turbid (Hesse and Newcomb 1982) than Nebraska reservoirs (Uphoff et al. 2013). Productivity and available resources appear to be more influential than turbidity or changing water levels on smallmouth bass growth in Nebraska, but the nature of these relationships needs to be further studied.

The combination of observed age structure, growth, and mortality rate of smallmouth bass in Nebraska suggests that a limited number of fish will be subject to legal harvest. Under a 380 MLL regulation, Nebraska smallmouth bass would not reach harvestable size until age 7, and few individuals were observed at sufficient ages. The NGPC sampling database used for these assessments identified less than 7% of the 546 smallmouth bass sampled in Nebraska as harvestable size. Therefore, the existing regulation has effectively created a catch and release fishery in Nebraska lakes.

Estimation of natural mortality can be interpreted from the observed *A* rate. Mean *A* for Nebraska (0.41 ± 0.06) was lower than the reported values for waterbodies with smaller MLLs than Nebraska (0.49-0.75; Paragamian and Coble 1975, Hoff 1995, Slipke et al. 1998). As stated above the existing statewide 380 mm MLL functions as a catch and release regulation. Hooking mortality associated with several species including smallmouth bass is generally low on released fish (Payer et al. 1989, Clapp and Clark, Jr. 1989). Therefore, the annual mortality rate determined from this data set can be considered to represent natural mortality. The estimated smallmouth bass natural mortality rate in Nebraska was higher than the average natural mortality rates across North America for smallmouth bass (Beamesderfer and North 1995) and largemouth bass (Allen et al. 2008).

One cautionary note about this data set is that ages were derived from scales, which may provide biased estimates and subsequently influence growth data. Aging using scales and otoliths has been validated through age 4 for smallmouth bass (Heidinger and Clodfelter 1987), but no technique has been validated for older ages. Use of scales has been shown to underestimate ages of older smallmouth bass and overestimate ages of younger individuals (Long and Fisher 2001). However, scales continue to be the most commonly used structure for aging black basses across North America because they are nonlethal (Maceina et al. 2007). Although other nonlethal structures have been suggested (Rude et al. 2013), survey results from 2006 indicated fewer than 12% of agencies use fin rays or spines to age black bass (Maceina et al. 2007), and collection of scales for aging black bass remains the standard protocol for many state natural resource agencies including the NGPC.

MANAGEMENT IMPLICATIONS

The findings from this statewide assessment of growth and mortality can be useful in future management decisions. First, smallmouth bass in Nebraska rivers have demonstrated a faster growth rate, reaching memorable size by age 6 compared to age 11 in Nebraska lakes. Managers may consider separate regulations for rivers and lakes based on the available growth and mortality data. For example, statewide regulations for black bass in Missouri include no MLL for impoundments but a 305 mm MLL in streams. Additionally, using 41% to represent natural mortality for this region would allow managers to more precisely model the impact of variable regulations. Managers also could realize that the natural mortality rate of smallmouth bass in this region exceeds national averages reported for largemouth bass and smallmouth bass, and the rate of natural mortality can alter the type of regulation that would be effective in obtaining management goals.

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