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Gape:Body Size Relationship for Smallmouth Bass

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GAPE:BODY SIZE RELATIONSHIP FOR SMALLMOUTH BASS—The types and sizes of prey fishes consumed by predatory fish often are limited by gape dimensions of the predator (Slaughter and Jacobson 2008). In general, the size of prey consumed is positively related to predator size when prey are available across a wide range of sizes (Werner and Hall 1974). Opportunistic predators with large gape dimensions, such as smallmouth bass (*Micropterus dolomieu*), may consume a wide range of prey types and sizes, thereby exerting top-down influences on prey population dynamics and potentially restructuring aquatic communities (e.g., Werner and Hall 1974, Jackson 2002). Although feeding ecology of smallmouth bass varies with location and prey availability, they typically undergo several ontogenetic diet shifts throughout their development. After yolk sac depletion and as smallmouth bass increase in size from larvae to juveniles (~50 mm total length; TL), targeted prey typically proceeds from microcrustaceans (e.g., copepods) to larger zooplankters (e.g., cladocerans) to macroinvertebrates (e.g., ephemeropterans; Brown et al. 2009). Opportunistic feeding behaviors become more apparent during the juvenile stage (TL > 50 mm) when smallmouth bass begin to consume readily available aquatic macroinvertebrates and prey fishes (Clady 1974, Easton and Orth 1992). Studies evaluating adult feeding ecology highlight the importance of crayfish (Gangl et al. 1997, Liao et al. 2002, Bacula 2009) but also reveal the piscivorous nature of smallmouth bass in some locations (e.g., Jackson 2002, Liao et al. 2002, Bacula 2009, Wuellner et al. 2010).

Predation by smallmouth bass has the potential to influence population dynamics of prey fishes and to restructure aquatic communities. For example, high consumption rates by introduced populations of smallmouth bass lead to extirpation of several native cyprinids in Ontario waters (Jackson 2002). Additionally, there is concern in South Dakota that smallmouth bass predation may be adversely influencing recruitment of yellow perch ([*Perca flavescens*]; e.g., Bacula 2009). To understand the potential top-down influences on prey fish populations by predatory fishes such as smallmouth bass, it is important to understand the limitations of that predator's gape.

Although smallmouth bass diets and predatory impacts have been previously evaluated, relationships between horizontal gape width (GW) and total length (TL) have not been defined; previous studies have used the published relationship for ecomorphologically similar butterfly peacock bass ([*Cichla ocellaris*]; GW = 0.12[TL] – 2.69; Norton and Brainerd 1993, Hill et al. 2004, Wuellner et al. 2010). Use of ecomorphological surrogates in estimating predation potential may lead to erroneous conclusions regarding the extent of predation and magnitude of predatory impacts, especially if the surrogate relationship substantially over- or underestimates horizontal GW. The primary objective of this study was to quantify the relationship between GW and TL for smallmouth bass. A secondary objective was to compare the GW:TL relationship developed for smallmouth bass to the GW:TL relationship previously developed for butterfly peacock bass.

We collected smallmouth bass from Clear Lake, Marshall County, South Dakota during August and September 2013 primarily using nighttime shoreline electrofishing for adults (i.e., >180 mm TL) and beach seines for juveniles (i.e., <180 mm TL), although some juvenile bass were collected via electrofishing. Additionally, catches of adult smallmouth bass were supplemented with fish captured via hook and line by a regional recreational angling association. For all smallmouth bass collected, we measured TL and maximum horizontal GW to the nearest mm; maximum horizontal GW was measured by stretching the mouth open and measuring the distance between the outside edges of the maxillary bone (Lawrence 1958, Hill et al. 2004, Slaughter and Jacobson 2008). We used simple linear regression to quantify the relationship between GW and TL, and to estimate the percent of variability in GW explained by TL. Once the GW:TL relationship was defined, we estimated horizontal GW for a population of smallmouth bass in Lake Sharpe, South Dakota, using the empirical equation for smallmouth bass defined herein and the previously-defined equation for butterfly peacock bass. We collected smallmouth bass from the lower reaches of Lake Sharpe from May to October 2006–2007 using short-term and overnight experimental gill net sets; we measured TL of all bass (Wuellner et al. 2010). We compared predicted mean horizontal GW as estimated with each equation using a two-sample t-test. We evaluated differences in the relationships between GW and TL defined by each equation using an analysis of covariance (ANCOVA). For all tests, differences were deemed statistically significant at $\alpha = 0.05$. All statistical analyses were performed using the Statistical Analysis System software package (SAS Institute 2010).

We measured horizontal GW (range = 4 mm to 65 mm) for 214 smallmouth bass ranging from 48 mm to 486 mm TL. As expected, GW increased linearly with increasing TL (Fig. 1), and approximately 97% ($P < 0.001$) of the variation in GW was explained by TL. The relationship between GW and TL for smallmouth bass is expressed as GW = 0.13(TL) – 1.05. Across the range of TL, GW estimated with the equation defined herein was significantly greater than GW estimated with the equation for butterfly peacock bass ($t_{1248} = –9.48$, $P < 0.001$). Additionally, the difference in GW estimated with each equation was greater for larger smallmouth bass ($F_{1,1246} = 1{,}533.11$, $P < 0.001$; Fig. 2).

Collectively, our results provide important information relative to estimating the predation potential of smallmouth bass on other organisms. By quantitatively defining the relationship between GW and TL for smallmouth bass, we have provided the basis for further evaluation of gape limitation, extent of predation, and magnitude of predatory impacts in systems where bass are present or may be introduced (*sen-*

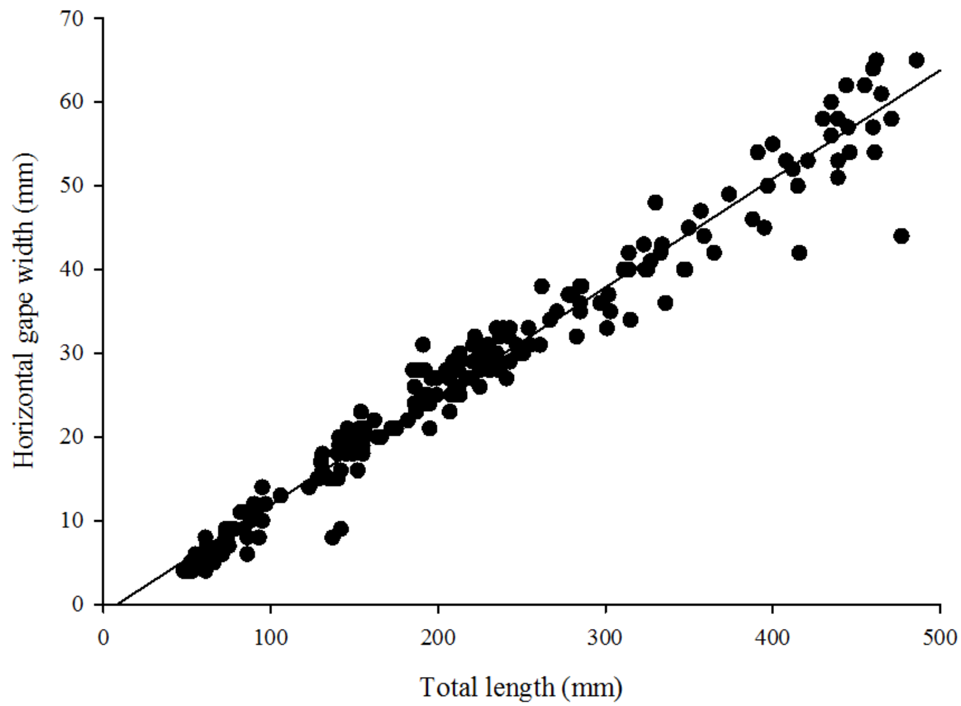

Figure 1. Scatterplot and trend line depicting the empirical relationship between maximum horizontal gape width and total length of smallmouth bass collected from Clear Lake, Marshall County, South Dakota, USA, August–September 2013.

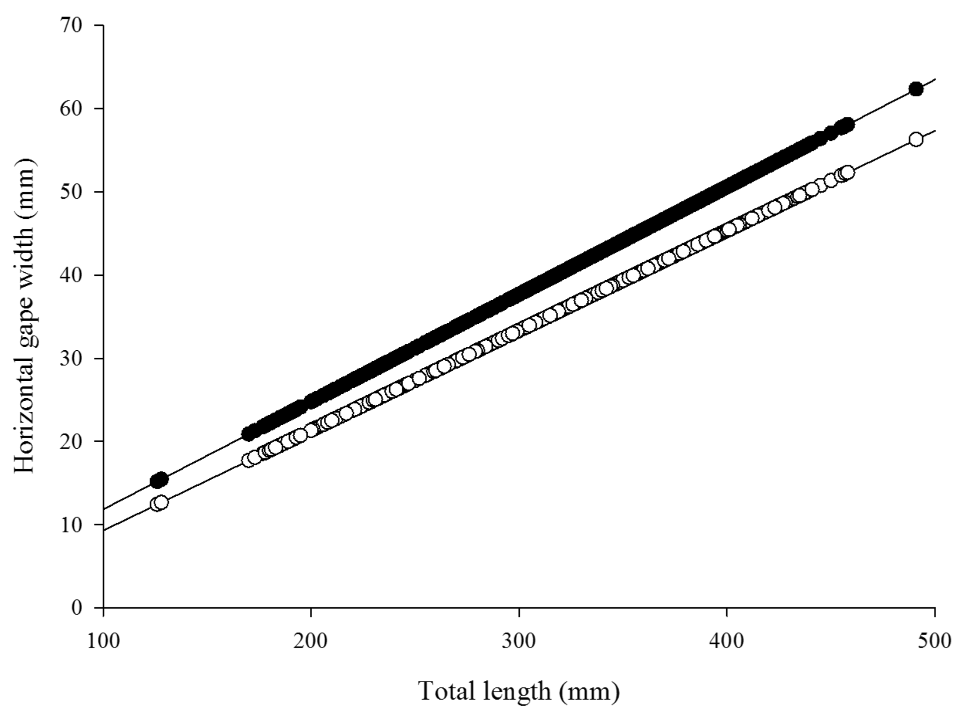

Figure 2. Predicted horizontal gape widths of smallmouth bass derived from gape width (GW):total length (TL) relationships for smallmouth bass (filled circles; GW = 0.13[TL] – 1.05) and butterfly peacock bass (open circles; GW = 0.12[TL] – 2.69). Note the greater divergence in estimated gape width at larger total length.

su Slaughter and Jacobson 2008). Furthermore, our results demonstrate that previous studies applying the GW:TL relationship for butterfly peacock bass to smallmouth bass may have substantially underestimated the extent of predation and magnitude of predatory impacts of smallmouth bass. For example, Wuellner et al. (2010) estimated GW of smallmouth bass using the published relationship for butterfly peacock bass to compare the sizes of gizzard shad (*Dorosoma cepedianum*) consumed between smallmouth bass and walleye (*Sander vitreus*) and to make inferences regarding the extent of competitive interactions between smallmouth bass and walleye in Lake Sharpe, South Dakota. Owing partially to differences in gape limitation, smallmouth bass consumed a narrower length range of gizzard shad than walleye, which may have reduced the potential for interspecific competition for available prey resources. However, our findings suggested that actual smallmouth bass gape limitations were underestimated using the relationship for butterfly peacock bass. Thus, a larger length range of gizzard shad was vulnerable to predation by smallmouth bass, indicating that the sizes of shad consumed may be more similar between the two predators than previously thought.

We anticipate that application of this relationship will be useful in assessing predatory and competitive interactions between smallmouth bass and other fishes and are continuing work to estimate the upper size limit of prey available for consumption by various sizes of smallmouth bass. Further work also is underway to estimate relationships between prey body depth and smallmouth bass GW, with specific application to estimating relative vulnerability (Hambright 1991) of yellow perch and other prey items (e.g., crayfish) to predation by smallmouth bass across a broad range of TL.

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