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Size-Based Mortality Caps as Thresholds for Managing Hybrid Striped Bass in Kansas Reservoirs

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Abstract.— Total annual mortality and mortality caps (maximum mortality thresholds) were estimated for hybrid striped bass (striped bass *Morone saxatilis* × white bass *M. chrysops*) populations sampled in six large Kansas reservoirs spanning 1995–2001; all reservoirs lacked a minimum length limit but had a 2/d creel limit. Total annual mortality of age-1 and older hybrid striped bass was estimated using a weighted catch curve. Mortality caps were modeled by varying growth rates and management objectives. Mortality rates that approach the cap signal the need for increased monitoring to determine what additional management action should be taken (e.g., harvest regulations to reduce mortality) or to reevaluate the size objective (targeted mean length of harvested fish) for the fishery. Estimated mortality caps were then compared with observed growth and mortality rates. Total annual mortality rates for all reservoirs varied from 22% to 52% (mean = 38%; SE = 4.9). All but two reservoirs had total annual mortality rates greater than 40%. Analysis of mortality caps indicated that when the objective was to maintain the mean length of harvested hybrid striped bass at current levels, total annual mortality was lower than the mortality cap for most reservoirs if a 381 mm total length (TL) minimum length limit (i.e., preferred length) were to be imposed. A management objective of 500 mm TL for the mean length of harvested hybrid striped bass was realistic for all reservoirs modeled with a 457-mm-TL length limit (special regulation available to managers) but only for two reservoirs with a 381-mm-TL length limit. Likewise, only two of the study reservoirs could support a management objective of 550 mm TL (herein defined as trophy length) for mean length of harvested hybrid striped bass when modeled with a 457-mm-TL length limit. Our analysis illustrates the potential of mortality caps for monitoring and establishing realistic management goals for hybrid striped bass fisheries.

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Introduction

Hybrid striped bass is a cross between striped bass *Morone saxatilis* and white bass *M. chrysops*. The "original" cross (male white bass × female striped bass), also referred to as palmetto bass, was developed in South Carolina in the mid-1960s (Bayless 1968; Bishop 1968). The reciprocal cross (female white bass × male striped bass), or sunshine bass, is also produced and stocked by some state agencies. Hybrid striped bass have been stocked as an alternative to striped bass, which in some reservoirs experience a temperature–dissolved oxygen squeeze that can constrain growth or result in mortalities (Van Horn 2013, this volume). Hybrid striped bass have been successfully stocked into ponds, lakes, streams, and reservoirs for their sport fish potential. Additionally, these fish have been stocked in an attempt to restructure panfish communities (Layzer and Clady 1984; Jahn et al. 1987; Neal et al. 1999; Hutt et al. 2008) and control invasive species (Iowa Department of Natural Resources, unpublished data). Hybrid striped bass have also been introduced to help control abundant prey species such as gizzard shad *Dorosoma cepedianum* (Dettmers et al. 1996). Dettmers et al. (1998) indicated control of gizzard shad could only occur when hybrid striped bass are stocked at high densities in impoundments with low natural mortality and intermediate densities of gizzard shad.

The three primary factors regulating fish population dynamics are growth, recruitment, and mortality (Ricker 1975) and are particularly important with regard to the management of sport fishes. Growth is important because it integrates the effects of environmental conditions (e.g., temperature and water quality), prey availability, and genetic factors, making it a useful metric to evaluate habitat suitability or the effect of management strategies targeting sport fishes and their prey (Avise and Van Den Avyle 1984; Miranda and Durocher 1986; McInerny and Cross 1999; Leitner et al. 2002; Quist et al. 2003; Schultz et al. 2008; Thompson and Rice 2013, this volume). In addition, growth assessments are commonly used to assess potential problems (e.g., overfishing) and management manipulations, such as regulations, lake renovations, and prey stockings (Heman et al. 1969; Noble 1981; Maceina et al. 2007; Paukert et al. 2007; Schultz and Dodd 2008). Thus, knowledge of growth is important for management of sport fish populations and their prey. Recruitment of many fish populations is highly variable, depending greatly on environmental vagaries and density and size structure of the parental stock. These recruitment fluxes interact with both growth and mortality. In hybrid striped bass fisheries, the variability of recruitment is generally constrained as juvenile fish are stocked, often at a constant density.

Information on mortality is important for the management of fish populations. Changes in either natural or fishing mortality may be related to environmental factors, predator–prey interactions, or exploitation. However, mortality limits are not typically used by management agencies to manage freshwater fisheries. Miranda (2002) suggested that resource managers develop size-based mortality caps, that is, mortality rates above which mean length objectives for the fishery will not be attained. Although size objectives could vary by different management goals, here we describe size objectives as the targeted mean length of harvested hybrid striped bass.

Mortality rates that approach the cap signal the need for increased monitoring to determine what additional management action should be taken to allow further growth of the fish (e.g., harvest regulations to reduce mortality) or reevaluate the mean length objective for the fishery (Miranda 2002). Since this call to action, the use of mortality caps in freshwater systems is increasing. Quist et al. (2004) determined that a 500 mm mean length objective for eight Kansas walleye *Sander vitreus* populations was only realistic if a 457 mm minimum length limit were to be imposed. Scholten and Bettoli (2005) combined the Beverton–Holt equilibrium yield equation and spawning potential ratios with mortality caps to substantiate paddlefish *Polyodon spathula* commercial fishing regulation changes. Makinster and Paukert (2008) used mortality caps to determine levels of total annual mortality (*A*) for flathead catfish that would sustain size structure in separate reaches of the Kansas River.

Although the popularity of hybrid striped bass to recreational anglers and resource managers continues after more than four decades, most studies have focused on recruitment (i.e., stocking rates) but only limited effort has been placed on measuring growth and mortality. Our objectives were to evaluate the utility of mortality caps for managing hybrid striped bass in large Kansas reservoirs and provide guidance for resource managers on effective use of mortality caps in fisheries management.

Methods

Hybrid striped bass were sampled from Cedar Bluff, Cheney, Lovewell, Milford, Norton, and Webster reservoirs in Kansas during fall, 1995–2001. Typical of most large federal reservoirs in Kansas, the study reservoirs (mean size 2,553 ha, SE 897 ha) are relatively shallow (mean depth 6.3 m, SE 0.6 m), turbid, and seldom thermally stratified due to strong, persistent winds. Most of the reservoirs have rocky shorelines with gradual slopes and little aquatic vegetation. The watersheds (mean size 5,397 km^2, SE 2,209 km^2) are dominated by grassland habitat. Gizzard shad are the primary prey species in all reservoirs, with dominant sport fish populations including channel catfish *Ictalurus punctatus*, hybrid striped bass, largemouth bass *Micropterus salmoides*, white bass, white crappie *Pomoxis annularis*, and walleye.

Sampling consisted of a gill-net complement comprising four separate monofilament gill nets, each measuring 30.5 × 2.4 m with mesh sizes of 25, 38, 64, and 102 mm bar measure (Mosher and Willis 1997). Scale samples were taken from all captured hybrid striped bass at the point where the tip of the pectoral fin meets the body. Scales were selected for aging due to their ease of collection, avoidance of sacrificing large hybrid striped bass, and because no special setup was required prior to aging, compared to using otoliths (Isely and Grabowski 2007). Scales are the most common structure used to age moronids, although it is widely recognized that scales fail to accurately age fish to their maximum age (Maceina et al. 2007). Although otoliths have been shown to provide more precise age estimates than scales for striped bass (Welch et al. 1993), precision is similar between otoliths and scales for white bass (Soupir et al. 1997). Scales were read independently by two readers. When disagreements occurred (less than 5% of the samples), scales were analyzed by both readers until consensus was reached.

Mortality estimates were calculated for fish captured in each reservoir. Based on catch curve analyses, age-1 hybrid striped bass were considered fully recruited to the sampling gear and were used to index recruitment. Catch curves were limited to age-1 and older hybrid striped bass because age-0 hybrid striped bass were not fully recruited to the sampling gear. We assumed that the standard gill-net complement put equal pressure on the age cohorts of interest. Total annual mortality (*A*) was estimated from the descending limb of catch curves using weighted regression (Ricker 1975; Slipke and Maceina 2000). A von Bertalanffy growth function was used to estimate the theoretical maximum length (L_∞), growth coefficient (*K*), and age at which total length is zero (t_0; Ricker 1975). Mortality caps for hybrid striped bass were estimated following model 1 as described by Miranda (2002). This model allows for the incorporation of different management objectives and harvest regulations, based on growth parameter estimates from the von Bertalanffy growth model:

$$\text{Model 1: } Z = K \times [(L_\infty - L_{mean}) \times (L_{mean} - L_x)^{-1}],$$

where *Z* is instantaneous total annual mortality, *K* is the growth coefficient and L_∞ is the theoretical maximum length from the von

Bertalanffy growth model, L_{mean} is the management objective for the average length of harvested fish, and L_x is the minimum length at which fish become vulnerable to capture or harvest (e.g., length limit). Estimates of Z were transformed into A by the equation $A = 1 - e^{-Z}$ (Ricker 1975). Mortality caps were estimated for each reservoir with annual and overall estimates of L_∞ and K. Because L_{mean} (length objectives) have not been established for Kansas hybrid striped bass, we chose length objectives of 500 and 550 mm (all lengths hereafter are millimeters total length). These lengths correspond roughly to memorable and trophy lengths for hybrid striped bass, respectively (Anderson and Neumann 1996). We modeled these lengths because many agencies cite the fast growth and trophy capability of hybrid striped bass as reasons for popularity among anglers and continued stocking. Additionally, we also modeled mortality caps with L_{mean} equal to the mean length of harvested hybrid striped bass, which equates to default current length objectives. The mean length of harvested hybrid striped bass was obtained from creel data concurrent with fish collections (1994–2002). Five years of creel survey data were available for Cedar Bluff and Norton reservoirs; four for Cheney, Lovewell, and Webster reservoirs; and three for Milford Reservoir.

We used 381 and 457 mm as the minimum lengths available for harvest (L_x). Surveys indicated that 305 mm was about the minimum length at which anglers were willing to harvest hybrid striped bass (Kansas Department of Wildlife and Parks, unpublished data). Additionally, Kansas does not have a statewide length limit for hybrid striped bass, but managers have the option of implementing a 457 mm minimum length limit as a special regulation, which had not been implemented on the study impoundments at the time of this study. As such, empirical total annual mortality rates were plotted against mortality cap estimates to determine whether length objectives were realistic given current growth and mortality rates.

Results and Discussion

A total of 1,770 hybrid striped bass was sampled and aged from the study reservoirs (Table 1), and von Bertalanffy growth parameter estimates were determined (Slipke and Maceina 2000; Table 2). Maximum age of hybrid striped bass in this study was 9 years, but 69% of the fish were less than 4 years old.

Total annual mortality of age-1 and older hybrid striped bass was relatively high and variable among reservoirs (mean 38%, SE 4.9%, range 22–52%; Figure 1). Based on our specified size objectives, all of the reservoirs would likely maintain current harvest rates if a 381 mm minimum length limit were imposed (Figure 2). For Milford, Norton and Webster reservoirs, the current mean length of harvested hybrid striped bass was above 457 mm (Figure 2) and thus able to support current harvest lengths at this minimum length limit.

Managing hybrid striped bass with an objective of memorable length (500 mm) as the mean length of harvested fish utilizing a 381 mm minimum length limit was only realistic in Cedar Bluff and Norton reservoirs. All other reservoirs had the capability to reach this management objective only when minimum length for harvest was 457 mm. At current total annual mortality, growth rates, and mean lengths available for harvest, again, only Cedar Bluff and Norton reservoirs are likely to realize a targeted mean length of harvested hybrid striped bass equal to trophy length (defined herein as 550 mm) but only if a 457 mm length limit were imposed. This is not to imply that some fish of this size do not exist in the study reservoirs because 15% of sampled hybrid striped bass were 550 mm or larger.

State agencies have been lax in evaluating population dynamics of hybrid striped bass (Collier et al. 2013, this volume). Currently, Kansas lacks a statewide minimum length limit for hybrid striped bass, but managers do have the option of a 457 mm minimum length limit as a special regulation. Mortality cap analysis illustrated several trends in

TABLE 1. Mean total length (mm) at age of hybrid striped bass collected from six Kansas reservoirs during 1995–2001. Parenthetic values are standard errors; *N* is number per age-class.

	Age							
Reservoir	1	2	3	4	5	6	7	8
Cedar Bluff	336 (3.0) *N* = 108	428 (6.3) *N* = 50	505 (3.9) *N* = 71	543 (4.3) *N* = 53	587 (4.6) *N* = 38	602 (9.2) *N* = 16		
Cheney	350 (4.3) *N* = 61	434 (5.1) *N* = 49	483 (5.5) *N* = 33	495 (14.3) *N* = 12	559 (16.0) *N* = 2			572 – *N* = 1
Lovewell	345 (3.3) *N* = 63	414 (4.4) *N* = 62	456 (6.9) *N* = 49	516 (5.7) *N* = 14	529 (5.0) *N* = 16	624 (47.5) *N* = 2		
Milford	274 (6.0) *N* = 60	361 (8.6) *N* = 70	458 (9.0) *N* = 62	501 (5.7) *N* = 56	550 (8.1) *N* = 23	599 (7.9) *N* = 16	560 – *N* = 1	687 (23) *N* = 2
Norton	368 (3.1) *N* = 63	452 (2.3) *N* = 67	500 (2.4) *N* = 62	558 (4.4) *N* = 29	599 (4.1) *N* = 26	623 (6.4) *N* = 26	675 (22.8) *N* = 28	675 (8.4) *N* = 11
Webster	333 (11.8) *N* = 42	438 (5.2) *N* = 57	484 (5.3) *N* = 62	526 (3.4) *N* = 110	616 (7.2) *N* = 53	627 (9.7) *N* = 25	715 (6.5) *N* = 6	

Kansas hybrid striped bass populations, suggesting that it may be a useful assessment tool for management of these and similar fisheries. This study revealed that although a minimum length limit of 381 mm will sustain a status quo management objective (maintain current mean length of harvested hybrid striped bass), a minimum length limit of 457 mm has the potential to allow biologists to manage for memorable-length (500 mm) hybrid striped bass. The possibility of maintaining harvest with a mean length of 550 mm (i.e., trophy length) is not likely without reducing fishing mortality through highly restrictive harvest regulations (>457 mm), decreasing natural mortality, or increasing growth rates.

A major concern with minimum length limits, particularly in Kansas' shallow, turbid reservoirs, is the effect of delayed mortality (e.g., hooking mortality) from catch-and-release angling in summer (Bettinger and Wilde 2013; Coutant 2013; both this volume). Muoneke and Childress (1994) report that at temperatures of 25–30°C, palmetto bass had a 29% hooking mortality rate. Carlson et al. (1995) reported that hybrid striped bass held at 29°C showed signs of thermal stress; this temperature is commonly exceeded in Kansas reservoirs from July to September. Therefore, in the event of imposition of length limits in Kansas' hybrid striped bass populations, monitoring hooking mortality will be essential in determining the overall effect of increased regulations on this fishery.

Miranda (2002) and Quist et al. (2003) recommended the use of mortality caps to assist with management of important sport fish species, recognizing that caution should be

TABLE 2. Von Bertalanffy growth parameter estimates (theoretical maximum length [L_∞], growth coefficient [K], and theoretical age when length equals zero [t_0]) from hybrid striped bass sampled in six Kansas reservoirs. The coefficient of determination (R^2) and P-values signify model fit.

Reservoir Year	L_∞ (mm)	K	t_0	R^2	P
Cedar Bluff					
1996	810	0.19	–1.54	0.96	0.0001
1997	740	0.23	–1.45	0.96	0.0005
1998	725	0.25	–1.33	0.98	0.0001
1999	791	0.15	–3.89	0.68	0.0001
2000	679	0.33	–1.01	0.98	0.0001
2001	679	0.3	–1.35	0.94	0.0001
All years	665	0.34	–1.06	0.99	0.0001
Cheney					
1995	633	0.25	–3.37	0.93	0.002
1996	587	0.44	–0.91	0.99	0.0001
1998	601	0.31	–1.69	0.93	0.002
1999	692	0.28	–0.98	0.95	0.0001
2000	619	0.42	–0.92	0.91	0.0001
2001	582	0.67	0.27	0.72	0.0001
All years	583	0.69	–1.05	0.99	0.0001
Lovewell					
1995	773	0.19	–1.89	0.93	0.002
1996	637	0.38	–0.84	0.93	0.002
1997	772	0.17	–2.52	0.99	0.006
1998	621	0.27	–1.97	0.99	0.0001
1999	615	0.31	–1.79	0.96	0.003
2000	888	0.11	–3.81	0.98	0.0002
2001	953	0.16	–1.09	0.93	0.002
All years	712	0.19	–2.53	0.99	0.0009
Milford					
1996	741	0.2	–1.47	0.98	0.0002
1998	718	0.19	–1.37	0.98	0.0001
1999	650	0.33	–0.99	0.98	0.0002
2000	677	0.42	–0.56	0.94	0.0001
2001	688	0.36	–0.11	0.92	0.0002
All years	875	0.15	–1.56	0.97	0.0001
Norton					
1995	935	0.16	–1.83	0.96	0.0001
1996	688	0.35	–1.2	0.98	0.0002
1998	681	0.34	–1.24	0.97	0.0001
1999	713	0.3	–1.27	0.96	0.0001
2001	792	0.16	–2.98	0.93	0.0001
All years	731	0.27	–1.39	0.99	0.0001

TABLE 2. Continued.

Reservoir Year	L_∞ (mm)	K	t_0	R^2	P
Webster					
1995	640	0.52	–0.15	0.92	0.003
1996	891	0.18	–1.31	0.99	0.0001
1998	711	0.3	–1.03	0.97	0.0003
1999	948	0.19	–1.29	0.96	0.0001
2000	913	0.18	–1.37	0.99	0.0001
2001	1,025	0.12	–1.86	0.96	0.0001
All years	843	0.2	–1.29	0.98	0.0001

used in interpreting results for populations where observed mortality approaches calculated mortality caps (Miranda 2002). In such situations, it is appropriate to assess a population's total mortality accurately prior to instituting more stringent harvest regulations. Churchill and Black (2007) recommended that more frequent estimation of total mortality in Tennessee's black bass populations be conducted when observed mortality is ≤5% of the mortality cap at a desired mean harvest length goal. This is exemplified in the current study, whereas yearly variability in total annual mortality (Figure 2) depicted that a 1-year snapshot of many of the Kansas hybrid striped bass populations may have differed greatly from the mean of several yearly estimates. Sammons and Maceina (2008) noted a lack in agreement between mortality caps and yield models in predicting the effectiveness of length limits to improve size structure of redbreast sunfish *Lepomis auritus* populations. Explanation provided by the authors surrounded size-selective predation on redbreast sunfish by flathead catfish *Pylodictis olivaris*, leading to high natural mortality unaccounted for in the yield models and uncertainty in the ability of minimum length limits to restructure redbreast sunfish populations where heavy flathead catfish predation on redbreast sunfish may be occurring. Again, results from Sammons and Maceina (2008) depict the necessity of accurate mortality assessments before imposing length limit changes. We concur with Churchill and Black (2007) that regulation changes should not be undertaken without numerous years of population dynamics data.

Growth of hybrid striped bass is sufficient in Kansas reservoirs to create an exceptional angling opportunity. Similar to flathead catfish (Quinn 1993; Arterburn et al. 2002), the trophy potential of hybrid striped bass may lend angler support for harvest regulations to protect and encourage this potential. Continued monitoring of growth, mortality, and lengths of harvested fish should accompany regulation changes to determine if population dynamics change due to regulation changes. The current study can be useful to managers for assessing current conditions, establishing realistic management goals, and providing guidance on effective use of mortality caps in management of hybrid striped bass fisheries. Similar studies should be conducted in other areas where hybrid striped bass are stocked to provide further insight into the application of mortality caps to manage this popular fishery.

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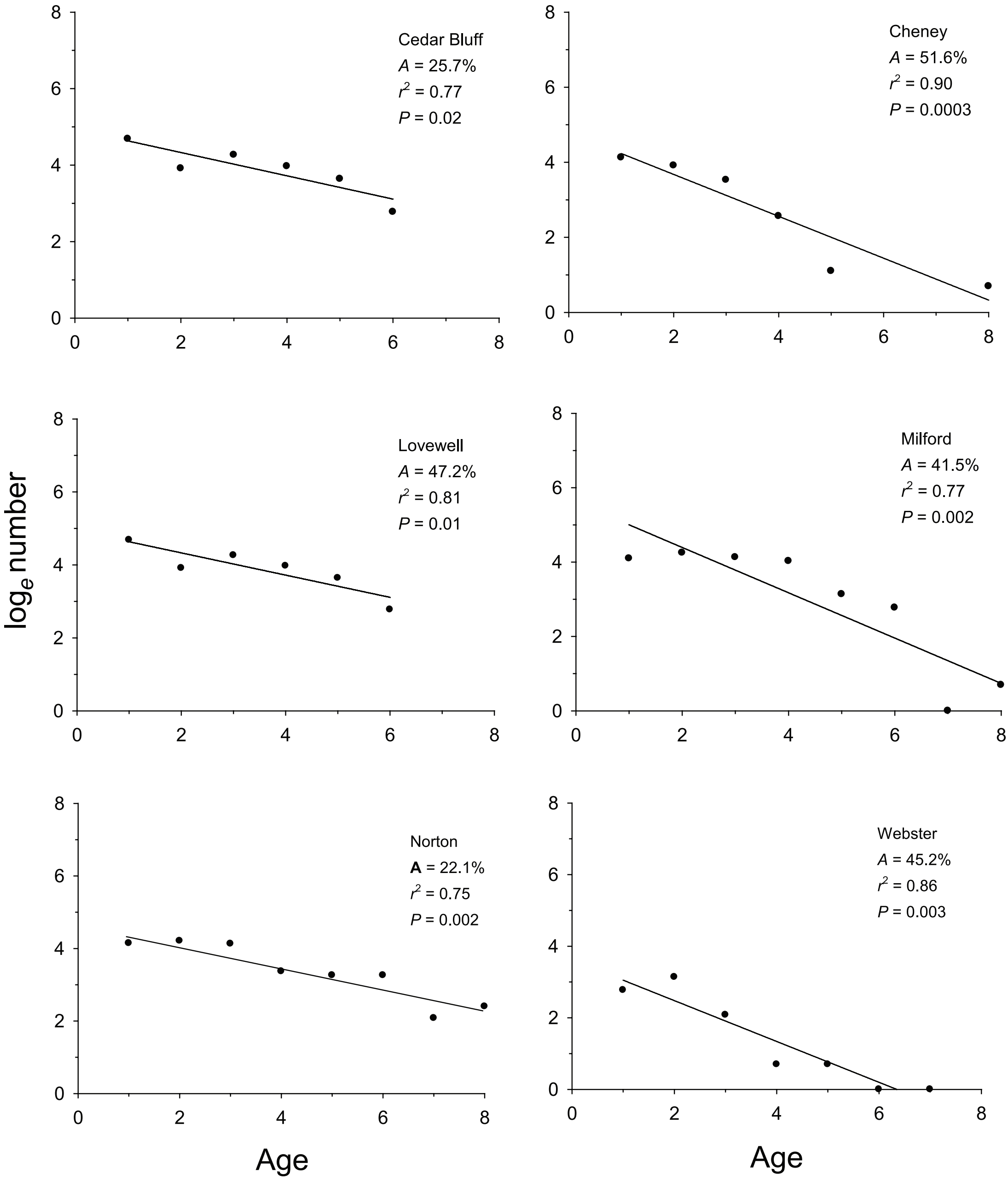

FIGURE 1. Weighted catch-curve regressions and total annual mortality (*A*) for age-1 and older hybrid striped bass sampled from six Kansas reservoirs between 1995 and 2001. The coefficient of determination (R^2) and *P*-values signify model fit.

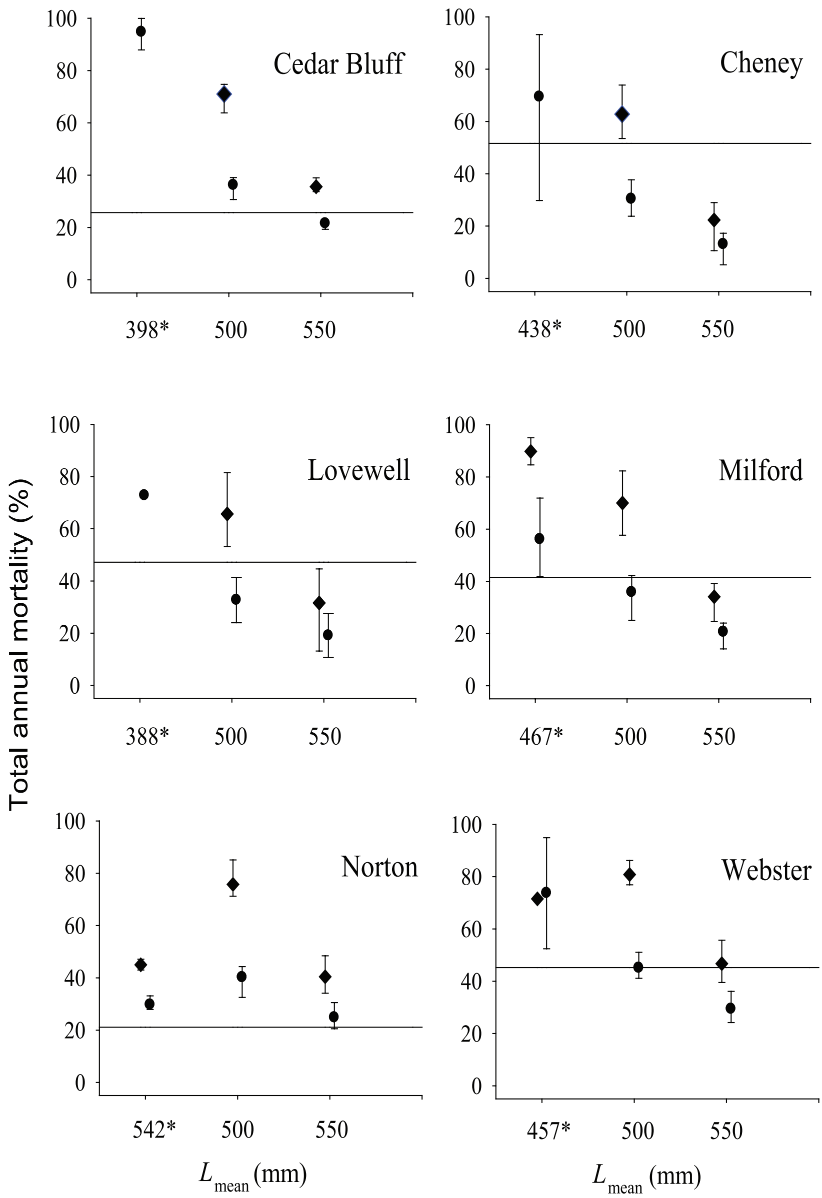

FIGURE 2. Estimated mortality caps for hybrid striped bass in six Kansas reservoirs. Overall mortality cap estimates (symbols) and year-specific mortality cap estimates (bars are maximum and minimum estimates) were calculated based on theoretical maximum length (L_∞) and the growth coefficient (K). Mortality caps were estimated for a mean length objective (L_{mean}) equal to the current mean length of harvested hybrid striped bass (asterisks) and for values of 500 mm total length (TL) and 550 mm TL. The minimum length available for harvest (L_x) was set at 381 mm TL (circles), and 457 mm TL (diamonds), the special regulation length available to Kansas managers for regulating hybrid striped bass. In Cedar Bluff, Cheney, and Lovewell reservoirs, the mortality cap for the current mean length of harvested hybrid striped bass (i.e., status quo) was not plotted when L_x = 457 mm because the current mean was below 457 mm for harvested hybrid striped bass in these reservoirs. The horizontal lines represent mean total annual mortality for each reservoir.

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