289-F

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Proposed Standard Weight (W_s) Equations and Standard Length Categories for 18 Warmwater Nongame and Riverine Fish Species

TIMOTHY J. BISTER, DAVID W. WILLIS,* AND MICHAEL L. BROWN

Department of Wildlife and Fisheries Sciences, Box 2140B, South Dakota State University, Brookings, South Dakota 57007, USA

STEPHEN M. JORDAN AND ROBERT M. NEUMANN

Department of Natural Resources Management and Engineering, Box U-87, University of Connecticut, Storrs, Connecticut 06269, USA

MICHAEL C. QUIST AND CHRISTOPHER S. GUY

Kansas Cooperative Fish and Wildlife Research Unit,[1] *205 Leasure Hall, Division of Biology, Kansas State University, Manhattan, Kansas 66506, USA*

Abstract.—Relative weight (W_r) is one of several condition indices used to assess the general health of fishes. Standard weight (W_s) equations are required to calculate W_r, but are unavailable for many nongame and riverine fish species. Therefore, we developed W_s equations for the following taxa: longnose gar *Lepisosteus osseus,* spotted gar *L. oculatus,* common carp *Cyprinus carpio,* bigmouth buffalo *Ictiobus cyprinellus,* river carpsucker *Carpiodes carpio,* shorthead redhorse *Moxostoma macrolepidotum,* smallmouth buffalo *I. bubalus,* white sucker *Catostomus commersoni,* black bullhead *Ameiurus melas,* brown bullhead *A. nebulosus,* flathead catfish *Pylodictis olivaris,* white catfish *A. catus,* yellow bullhead *A. natalis,* white perch *Morone americana,* yellow bass *M. mississippiensis,* green sunfish *Lepomis cyanellus,* rock bass *Ambloplites rupestris,* and warmouth *L. gulosus.* These W_s equations were evaluated with statistical validation approaches similar to previously defined regression-line-percentile equations. Standard length categories were developed or revised for 10 of these 18 species (longnose gar, spotted gar, bigmouth buffalo, river carpsucker, shorthead redhorse, smallmouth buffalo, white sucker, brown bullhead, white catfish, and yellow bullhead) to allow for comparison of mean W_r values within and among length categories instead of assessing only population mean W_r.

Introduction

Relative weight (W_r = the ratio of a fish's weight, W, to the weight of a ''standard'' fish of the same length, W_s) is a commonly used fish condition index (Blackwell et al. 2000). Before fishery biologists can assess the utility of W_r for various fish species, W_s equations must first be available. Anderson and Neumann (1996) reported accepted W_s equations for 33 fish species. Most of these species are considered to be sport fishes. To further assist biologists in fishery assessments, we developed W_s equations for the following nongame and riverine fish species: longnose gar *Lepisosteus osseus*, spotted gar *L. oculatus*, common carp *Cyprinus carpio*, bigmouth buffalo *Ictiobus cyprinellus*, river carpsucker *Carpiodes carpio*, shorthead redhorse *Moxostoma macrolepidotum*, smallmouth buffalo *I. bubalus*, white sucker *Catostomus commersoni*, black bullhead *Ameiurus melas*, brown bullhead *A. nebulosus*, flathead catfish *Pylodictis olivaris*, white catfish *A. catus*, yellow bullhead *A. natalis*, white perch *Morone americana*, yellow bass *M. mississippiensis*, green sunfish *Lepomis cyanellus*, rock bass *Ambloplites rupestris*, and warmouth *L. gulosus.*

The objectives of this study were to develop or revise W_s equations for these 18 species, which would allow for expanded use of W_r in population and community assessments for these nongame and riverine species. Standard length categories were also developed or revised for 10 of these species (longnose gar, spotted gar, bigmouth buffalo, river carpsucker, shorthead redhorse, smallmouth buffalo, white sucker, brown bullhead, white catfish, and yellow bullhead) so that condition assessment could be evaluated for incremental length-groups rather than population mean W_r values (Murphy et al. 1991).

Methods

Letters soliciting contributions of weight–length data for 30 warmwater fish species were sent to fishery administrators of state and provincial con-

* Corresponding author: david_willis@sdstate.edu

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servation agencies and several U.S. Fish and Wildlife Service regional offices. Sufficient data were received to develop W_s equations for 18 warmwater species.

These W_s equations were developed using the regression-line-percentile (RLP) technique proposed by Murphy et al. (1990). The validity of the solicited data was assessed by plotting the weight–total length (grams and millimeters, respectively) relationships for each population separately so that individual outliers could be identified. Outliers, which were probably a result of measurement errors, were deleted from the data sets. Next, the RLP technique required determination of the minimum total length (TL) to be used in the W_s equation development. Primarily, we sought to avoid inaccurate or imprecise weights for small fish. We calculated an error estimate (variance to mean ratio) for mean $\log_{10}$weight by centimeter TL group (SAS Institute 1996), which was then plotted as a function of TL. The minimum TL was selected where variance: mean error was less than 0.02, which corresponded to the inflection point in the plot for each species (Willis et al. 1991). We calculated a $\log_{10}$weight–$\log_{10}$TL regression equation for each population in the data set using only fish longer than the minimum TL selected in the previous step. Populations were removed from the database at this point if correlation coefficients (r) were less than 0.90. Slopes were then plotted as a function of intercepts (Pope et al. 1995) to identify and remove population outliers caused by insufficient sample size, narrow length range, or misidentified length measurements other than TL (i.e., body length, fork length, or standard length).

After the minimum TL was determined and the data set finalized, the W_s equation was developed using the RLP technique (Murphy et al. 1990). First, we predicted mean fish weight in 1-cm intervals for each population. Then, we found the 75th percentile of mean weights in each interval and regressed these means on TL to determine the proposed W_s equation. Some previous RLP equations were developed after dividing data sets into a development subset and a subset for testing potential length-related bias in W_r values (e.g., Pope et al. 1995). This was in reality a test of the RLP method itself. Because the RLP method of W_s equation development has proven useful (i.e., no length-related bias) in many previous cases, we did not believe it was necessary to test the RLP technique again. In addition, many data sets for species in this study contained too few populations to allow splitting into two data sets. To evaluate the W_s equations, a test (H_o: ß = 0; $P < 0.05$) was conducted to determine if there was a consistent length-related bias in W_r values calculated with the proposed W_s equation (Willis 1989; Neumann and Murphy 1991). Regressions of W_r on fish TL were done for each population. We expected that some populations would have slopes significantly different than zero ($P < 0.05$); however, if the numbers of negative and positive significant slopes were not significantly different, we accepted the W_s equation.

Finally, we determined whether sufficient populations were available to reliably determine a W_s equation. Brown and Murphy (1996) reported that a minimum of 50 populations would consistently provide reliable W_s equations. For data sets with fewer than 50 populations, they recommended using a bootstrap approach to determine whether the number of populations was sufficient. Slopes from each population $\log_{10}$weight–$\log_{10}$TL regression were randomly selected at sequential intervals of three, with 100 iterations done to determine the variance about the regression slope means. The sample variance for slopes decreased as sample size increased. We used the benchmark for a minimum level of precision ($s^2 < 0.002$) that was recommended by Brown and Murphy (1996).

Length categories were developed or revised for 10 of the 18 fish species in this study. Gabelhouse (1984) recommended that minimum stock, quality, preferred, memorable, and trophy lengths be set at 20–26, 36–41, 45–55, 59–64, and 74–80% of the world record length for each species, respectively. We compared world record lengths, obtained from the National Freshwater Fishing Hall of Fame and the International Game Fish Association, with the longest fish in our database for each species. We based the development of the length categories for a particular species on the longest fish in our database if that length exceeded the world record length.

Results and Discussion

The results from steps performed during the RLP development of these W_s equations are lengthy and are therefore summarized in Bister et al. (1999). These results include population sample size, minimum length determination, population $\log_{10}$weight–$\log_{10}$TL regression parameters, bootstrap results, proportional stock density (PSD; Anderson and Neumann 1996), and mean W_r by length category for each population used in the W_s equation development. Parameters for $\log_{10}$weight − $\log_{10}$length regression formulas for these 18 spe-

TABLE 1.—Parameters for $\log_{10}$weight − $\log_{10}$length regression formulas for 18 warmwater fish species. Values for metric equations were in millimeters and grams; values for English equations were in inches and pounds. Political units are the number of states or provinces that contributed data for each species. Equations were previously unavailable for all species, except those marked with an asterisk, which are revised.

Species	Intercept (*a*) Metric	Intercept (*a*) English	Slope (*b*)	Minimum total length (mm)	Number of populations	Number of political units
Longnose gar	−6.811	−4.623	3.449	200	32	13
Spotted gar	−6.551	−4.388	3.431	250	47	8
Common carp*	−4.639	−3.194	2.920	200	167	22
Bigmouth buffalo*	−5.069	−3.346	3.118	150	39	9
River carpsucker*	−4.839	−3.293	2.992	130	61	13
Shorthead redhorse	−4.841	−3.337	2.962	100	45	13
Smallmouth buffalo*	−5.298	−3.448	3.208	200	66	13
White sucker	−4.755	−3.282	2.940	100	172	6
Black bullhead	−4.974	−3.297	3.085	130	87	11
Brown bullhead	−5.076	−3.371	3.105	130	74	12
Flathead catfish	−5.542	−3.661	3.230	130	74	14
White catfish	−5.851	−3.739	3.395	100	21	6
Yellow bullhead	−5.374	−3.491	3.232	60	62	12
White perch	−5.122	−3.373	3.136	80	43	10
Yellow bass	−5.142	−3.398	3.133	70	22	7
Green sunfish*	−4.915	−3.216	3.101	60	43	9
Rock bass*	−4.827	−3.166	3.074	80	129	12
Warmouth	−5.180	−3.284	3.241	80	66	12

cies are listed in Table 1. We are proposing revised W_s equations for common carp, bigmouth buffalo, river carpsucker, smallmouth buffalo, rock bass, and green sunfish. Of these previously available W_s equations, rock bass was the only species for which Anderson and Neumann (1996) reported a W_s equation. However, while this previous rock bass W_s equation was developed using a technique similar to the RLP method, it was based on mean weights rather than the 75th percentile (Blackwell et al. 2000). Thus, W_r values calculated with the previous equation would be higher than expected using the proposed 75th percentile RLP equation. We recommend the use of our revised W_s equation for rock bass to allow W_r comparisons among species (i.e., all based on 75th-percentile standards). Additionally, the previous W_s equations for common carp, bigmouth buffalo, smallmouth buffalo, and green sunfish were developed with methods now considered to be invalid (Murphy et al. 1991; Blackwell et al. 2000). Consequently, we recommend the use of our revised W_s equations for these species.

All W_s equations reported here were tested for length-related bias in the data sets (Bister et al. 1999). For example, the common carp data set contained 167 population samples; 109 samples had slopes for the W_r–TL regression that were not significantly different from zero, and 58 samples had slopes that were significantly different from zero. Of the 58 relationships with significant slopes, 25 were positive and 33 were negative. The occurrence of positive and negative slopes was not significantly different ($\chi^2 = 0.55$, $P = 0.46$).

Nuances in length-related condition anomalies can go undetected if population mean W_r is the only aspect of condition assessment. Population mean W_r values should not be calculated unless the influence of length has been quantified. Murphy et al. (1991) suggested that biologists either plot W_r as a function of fish length to look for length-related trends or calculate mean W_r values within the five-cell length categories proposed by Gabelhouse (1984). World record lengths for fishes not normally targeted by anglers may not be representative of actual growth potential. Therefore, we developed minimum lengths for each category (stock, quality, preferred, memorable, and trophy) based on either the world record length or the longest fish in each data set (Table 2), whichever was longer. We revised the length ranges proposed by Gabelhouse (1984) for shorthead redhorse because our database contained a fish substantially longer than the world record length on which original length categories were based (Table 2). Although these length categories may not seem applicable to nongame species, this is an accepted method of subdividing sampling data for many species and should be a useful tool in population condition and size structure analyses.

We had two primary goals when we initiated this study. First, we anticipated that development

TABLE 2.—Length categories (in inches and centimeters) that should be used to calculate mean relative weight (W_r) values and stock density indices (Gabelhouse 1984) for the 18 fish species included in this study.

	Category									
	Stock		Quality		Preferred		Memorable		Trophy	
Species	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)
Longnose gar[a]	16	41	27	69	36	91	45	114	55	140
Spotted gar[a]	12	30	19	48	25	64	31	79	39	99
Common carp[b]	11	28	16	41	21	53	26	66	33	84
Bigmouth buffalo[a]	11	28	18	46	24	61	30	76	37	94
River carpsucker[a]	7	18	11	28	14	36	18	46	22	56
Shorthead redhorse[c]	6	15	10	25	13	33	16	41	20	51
Smallmouth buffalo[a]	11	28	18	46	24	61	30	76	37	94
White sucker[a]	6	15	10	25	13	33	16	41	20	51
Black bullhead[b]	6	15	9	23	12	30	15	38	18	46
Brown bullhead[a]	5	13	8	20	11	28	14	36	17	43
Flathead catfish[d]	14	35	20	51	28	71	34	86	40	102
White catfish[a]	8	20	13	33	17	43	21	53	26	66
Yellow bullhead[a]	4	10	7	18	9	23	11	28	14	36
White perch[b]	5	13	8	20	10	25	12	30	15	38
Yellow bass[e]	4	10	7	18	9	23	11	28	13	33
Green sunfish[b]	3	8	6	15	8	20	10	25	12	30
Rock bass[b]	4	10	7	18	9	23	11	28	13	33
Warmouth[b]	3	8	6	15	8	20	10	25	12	30

[a] Developed during current study.
[b] Proposed by Gabelhouse (1984).
[c] Maximum total length in data set (651 mm) was substantially longer than the world record (521 mm); thus, we revised the length ranges proposed by Gabelhouse (1984).
[d] Proposed by Quinn (1991).
[e] Proposed by Anderson and Gutreuter (1983).

of W_s equations for nongame and riverine fishes would allow expanded use of W_r. Secondly, we hoped that this expansion would lead to continued evaluation of the usefulness of W_r as a fishery assessment tool. For example, W_r can serve as an indicator of prey availability (Wege and Anderson 1978; Liao et al. 1995; Marwitz and Hubert 1997; Porath and Peters 1997). With current interest in ecosystem-level approaches to management, we also hope that these W_s standards will facilitate assessment at the community level.

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