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Proposed Revision of the Standard Weight (W_s) Equation for Redear Sunfish

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ABSTRACT

Weight-length data were compiled from 289 redear sunfish *Lepomis microlophus* populations. We applied the regression-line-percentile (RLP) technique to weight-length data for 150 redear sunfish populations to develop a new 75th-percentile standard weight (W_s) equation. The proposed RLP W_s equation, $\log_{10} W_s = -4.968 + 3.119 \log_{10} TL$ where W_s is the standard weight in grams and TL is the total length in millimeters, is valid for fish ≥ 70 mm TL. The English-unit equivalent, $\log_{10} W_s = -3.263 + 3.119 \log_{10} TL$ where W_s is the standard weight in pounds and TL is the total length in inches, is valid for fish ≥ 3 in TL. We used the remaining 139 independent populations to evaluate the current [$\log_{10} W_s = -5.164 + 3.227(\log_{10} TL)$] and RLP W_s equations for any length-related biases. We confirmed that the current W_s equation is length-biased. That is, relative weight (W_r) values significantly decreased with increasing fish length for far more populations ($N=45$) than they increased ($N=7$). We tested the proposed RLP W_s equation with the same 139 populations, and found no consistent length-related bias in W_r values calculated with the proposed RLP W_s equation ($N=38, 29$). Thus, we recommend the use of the proposed RLP W_s equation for redear sunfish.

INTRODUCTION

Since its development, relative weight (W_r ; Wege and Anderson 1978) has been used to assess fish condition for several species (Murphy et al. 1991). The index is $W_r = 100 \cdot W / W_s$; where W is the weight of an individual fish and W_s is the standard weight for fish of that species and total length (TL). The primary advantage of W_r is that, in theory, it avoids the length-related bias of Fulton condition factors, which increase with increasing fish length (Anderson and Gutreuter 1983). If W_s equations are free of length bias (i.e., W_r does not consistently increase or decrease with increasing fish length), any trends in W_r with respect to length should be indicative of environmental influences (Murphy et al. 1990). However, several original W_s equations developed using the 75th-percentile mean weights from Carlander (1969, 1977) have been found to contain length-related biases (e.g. Neumann and Murphy 1991, Kolander et al. 1993). Thus, the purposes of this investigation were to (1) develop a new W_s equation for redear sunfish *Lepomis microlophus* using the regression-line-percentile (RLP; Murphy et al. 1990) technique and (2) to evaluate the current and RLP W_s equations for any length biases.

DATA BASE

Weight-length data for redear sunfish were solicited from biologists in nineteen states (Figure 1). When data from more than one sample year for a particular population were received, we used the year that contained the most observations. Some populations were excluded from analyses due to insufficient sample size (<10 fish) or poor coefficient of determination for $\log_{10}$ -transformed weight-length regressions ($r^2 < 0.80$). Anyone wishing to obtain weight-length regressions for individual populations can contact the authors.

Figure 1. Geographic distribution of 289 redear sunfish populations used to develop (stars) the proposed standard weight (W_s) equation and to test (diamonds) the current and proposed W_s equations.

DEVELOPMENT OF RLP W_s EQUATION

Determination of Minimum Length

The minimum length for weight precision was determined by plotting the variance/mean ratio for $\log_{10}$ weight by 1-cm groups as suggested by Murphy et al. (1990). The minimum acceptable TL was the inflection point that occurred as the ratio declined (70 mm; Figure 2). At lengths shorter than this inflection point, weight measurements were likely imprecise.

Proposed RLP Equation

$\log_{10}$ weight- $\log_{10}$ length regression equations were calculated for 70-mm and longer fish from each redear sunfish population. We randomly selected 150 populations whose $\log_{10}$ weight- $\log_{10}$ length regression slopes were not on the extremes of the range of population regression slopes. Mid South in

Arizona, Shawnee Twin #2 in Oklahoma, and Waxahachie in Texas (Figure 3) were eliminated for development purposes because they contained weights and lengths for fish in a narrow length range with few larger fish, which influenced their weight-length regressions. However, these three populations were used in the testing of the current and proposed RLP W_s equations.

Mean weights were predicted for the midpoints of 1-cm length intervals from the minimum length determined from the variance/mean analysis (i.e., 70 mm TL; Figure 2) to world-record length (i.e., 444 mm TL; Smokie Holcomb, Florida Game and Freshwater Fish Commission, personal communication) for each population, and the 75th-percentile of the means in each interval was determined. Then, the 75th-percentile weights were regressed on length to develop the proposed W_s equation as suggested by Murphy et al. (1990).

Application of the RLP technique provided the 75th-percentile W_s equation

$$\log_{10} W_s = -4.968 + 3.119(\log_{10} TL),$$

where W_s is the standard weight in grams and TL is the total length in millimeters. The English equivalent of this equation is

$$\log_{10} W_s = -3.263 + 3.119(\log_{10} TL),$$

where W_s is the standard weight in pounds and TL is the total length in inches.

Figure 2. Variance/mean for $\log_{10}$ weight by 1-cm length groups for 28,875 redear sunfish.

EVALUATION OF CURRENT W_s EQUATION

The current metric W_s equation [$\log_{10} W_s = -5.164 + 3.227(\log_{10} TL)$; Murphy et al. 1991] was evaluated with the remaining 139 populations (i.e., those populations not used to develop the RLP W_s equation) to determine whether W_r values calculated with the current W_s equation had a consistent length-related bias. The W_r values of individual fish were regressed on length for each test population. The consistency of W_r values across length for each test population was evaluated by assessment (t-test) of significant ($H_0: \beta_0=0$; $P<0.05$) slopes of regressions of W_r as a function of length (Murphy et al. 1990) for the current W_s equation. The total numbers of significant positive and negative population slopes were compared using chi-square (goodness of fit) analysis to detect consistent length-related bias for the current W_s equation.

When W_r values calculated with the current W_s equation were regressed on length, 52 of 139 test populations exhibited significant slopes for the relationship between W_r and TL. Chi-square analysis showed the number of negative ($N=45$) slopes was significantly greater than the number of positive ($N=7$) slopes ($P<0.001$); that is, W_r decreased with increasing length for far more populations than it increased with length. Thus, we concluded that the current W_s equation contained a length-related bias.

Figure 3. Plot of y-intercept as a function of slope for weight-length regressions from 289 redear sunfish populations used in the present study. Redear populations from Mid South in Arizona, Shawnee Twin #2 in Oklahoma, and Waxahachie in Texas are indicated.

EVALUATION OF RLP $\underline{W}_s$ EQUATION

We used the independent data set (N=139) and the same testing procedure used to evaluate the current $\underline{W}_s$ equation to determine whether $\underline{W}_r$ values calculated with the RLP $\underline{W}_s$ equation had a length-related bias. When $\underline{W}_r$ values calculated with the proposed RLP $\underline{W}_s$ equation were regressed on length, 67 of the 139 test populations exhibited significant slopes for the relationship between $\underline{W}_r$ and TL. Chi-square analysis showed no significant difference ($P>0.25$) in the number of significant positive (N=29) and negative (N=38) slopes with the proposed RLP equation.

A functional comparison of $\underline{W}_r$ values calculated with the current and proposed RLP $\underline{W}_s$ equations is presented in Table 1. A $\underline{W}_r$ of 100 was difficult to attain with the current $\underline{W}_s$ equation, and was less likely to occur as fish length increased.

Table 1. A comparison of relative weight ($\underline{W}_r$) calculated for 10 redear sunfish using the proposed regression-line-percentile (RLP) standard weight equation and the current standard weight equation.

Total length (mm)	Weight (g)	Proposed RLP $\underline{W}_r$	Current $\underline{W}_r$
100	18.6	100	95
125	37.3	100	93
150	66.0	100	91
175	106.7	100	90
200	161.8	100	89
225	233.6	100	87
250	324.5	100	87
275	436.8	100	86
300	573.0	100	85
325	735.5	100	84

CONCLUSION

We recommend the use of the proposed RLP $\underline{W}_s$ equation for assessment of redear sunfish condition. This equation avoids the problem of length-related bias associated with the current $\underline{W}_s$ equation. If the proposed RLP $\underline{W}_s$ equation is used, we believe that trends in $\underline{W}_r$ across length in individual redear sunfish populations will be attributable to specific ecological factors rather than a length-biased $\underline{W}_s$ equation.

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