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 (WS) equation. The proposed RLP WS equation, \( \log_{10} WS = -4.968 + 3.119 \log_{10} TL \) where WS is the standard weight in grams and TL is the total length in millimeters, is valid for fish \( \geq 70 \) mm TL. The English-unit equivalent, \( \log_{10} WS = -3.263 + 3.119 \log_{10} TL \) where WS is the standard weight in pounds and TL is the total length in inches, is valid for fish \( \geq 3 \) in TL. We used the remaining 139 independent populations to evaluate the current \( \log_{10} WS = -5.164 + 3.227(\log_{10} TL) \) and RLP WS equations for any length-related biases. We confirmed that the current WS equation is length-biased. That is, relative weight (WR) values significantly decreased with increasing fish length for far more populations (N=45) than they increased (N=7). We tested the proposed RLP WS equation with the same 139 populations, and found no consistent length-related bias in WR values calculated with the proposed RLP WS equation (N=38, 29). Thus, we recommend the use of the proposed RLP WS equation for redear sunfish.

INTRODUCTION

Since its development, relative weight (WR; Wege and Anderson 1978) has been used to assess fish condition for several species (Murphy et al. 1991). The index is \( WR = 100 \cdot W/WS \); where \( W \) is the weight of an individual fish and WS is the standard weight for fish of that species and total length (TL).

The primary advantage of WR 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 WS equations are free of length bias (i.e., WR does not consistently increase or decrease with increasing fish length), any trends in WR with respect to length should be indicative of environmental influences (Murphy et al. 1990). However, several original WS 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 WS 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 WS equations for any length biases.
DATA BASE

Weight-length data for reedear 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.

![Map of the United States with numbers indicating population counts](image)

Figure 1. Geographic distribution of 289 reedear 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 reedear sunfish population. We randomly selected 150 populations whose $\log_{10}$ weight-$\log_{10}$ length regression slopes where 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; Smokey 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.](image-url)
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 $WR$ values calculated with the current $W_S$ equation had a consistent length-related bias. The $WR$ values of individual fish were regressed on length for each test population. The consistency of $WR$ values across length for each test population was evaluated by assessment ($t$-test) of significant ($H_0: \beta_2=0$; $P<0.05$) slopes of regressions of $WR$ 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 $WR$ values calculated with the current $W_S$ equation were regressed on length, 52 of 139 test populations exhibited significant slopes for the relationship between $WR$ 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, $WR$ 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.](image-url)
EVALUATION OF RLP \( W_s \) EQUATION

We used the independent data set (N=139) and the same testing procedure used to evaluate the current \( W_s \) equation to determine whether \( W_r \) values calculated with the RLP \( W_s \) equation had a length-related bias. When \( W_r \) values calculated with the proposed RLP \( W_s \) equation were regressed on length, 67 of the 139 test populations exhibited significant slopes for the relationship between \( W_r \) 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 \( W_r \) values calculated with the current and proposed RLP \( W_s \) equations is presented in Table 1. A \( W_r \) of 100 was difficult to attain with the current \( W_s \) equation, and was less likely to occur as fish length increased.

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

<table>
<thead>
<tr>
<th>Total length (mm)</th>
<th>Proposed RLP</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (g)</td>
<td>( W_r )</td>
<td>( W_r )</td>
</tr>
<tr>
<td>100</td>
<td>18.6</td>
<td>100</td>
</tr>
<tr>
<td>125</td>
<td>37.3</td>
<td>100</td>
</tr>
<tr>
<td>150</td>
<td>66.0</td>
<td>100</td>
</tr>
<tr>
<td>175</td>
<td>106.7</td>
<td>100</td>
</tr>
<tr>
<td>200</td>
<td>161.8</td>
<td>100</td>
</tr>
<tr>
<td>225</td>
<td>233.6</td>
<td>100</td>
</tr>
<tr>
<td>250</td>
<td>324.5</td>
<td>100</td>
</tr>
<tr>
<td>275</td>
<td>436.8</td>
<td>100</td>
</tr>
<tr>
<td>300</td>
<td>573.0</td>
<td>100</td>
</tr>
<tr>
<td>325</td>
<td>735.5</td>
<td>100</td>
</tr>
</tbody>
</table>

CONCLUSION

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