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# Standard Weight ($W_s$) Equation and Length Categories for Shovelnose Sturgeon

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*Abstract.*—Weight–length data were compiled from 32 populations of shovelnose sturgeon *Scaphirhynchus platorynchus* ($N = 11{,}820$) from nine states within the geographic distribution of the species. We used the regression-line-percentile technique, which provides a 75th-percentile standard, to develop the standard weight ($W_s$) equation. The proposed equation in metric units is $\log_{10}W_s = -6.287 + 3.330\ \log_{10}\text{FL}$; $W_s$ is weight in grams and FL is fork length in millimeters. The equivalent equation in English units is $\log_{10}W_s = -4.266 + 3.330\ \log_{10}\text{FL}$; $W_s$ is weight in pounds and FL is fork length in inches. These equations are proposed for use with shovelnose sturgeon between 120 mm (5 in) and 1,050 mm (41 in). Values for relative weight ($W_r$) calculated with the $W_s$ equation did not consistently increase or decrease with increasing fish length, indicating absence of length bias. We propose the following length categories for calculation of proportional stock density (PSD) and relative stock densities (RSDs): stock, 250 mm (10 in); quality, 380 mm (15 in); preferred, 510 mm (20 in); memorable, 640 mm (25 in); and trophy, 810 mm (32 in). We found significant relations between size structure indices and mean population $W_r$. Additionally, we found significant differences among incremental $W_r$ values. We believe the $W_s$ equation and length category designations will be useful tools for managing shovelnose sturgeon populations.

Relative weight [$W_r = 100 \cdot W/W_s$, where $W$ is the observed weight and $W_s$ is the length-specific standard weight value for the species; Wege and Anderson (1978)] is commonly used as a management tool to assess the physiological well-being of fishes (i.e., condition). Relative weight is easier to interpret than the traditional Fulton condition factor ($K$), because unlike $K$, $W_r$ neither increases with increasing fish length nor varies by species. Thus, $W_r$ is useful when comparing within and among fish populations.

Stock density indices are also useful management tools to assess fish populations. Proportional stock density [PSD = (number of fish greater than or equal to quality length/number of fish greater than or equal to stock length) $\cdot$ 100] and relative stock density [RSD = (number of fish greater than or equal to a specified length/number of fish greater than or equal to stock length) $\cdot$ 100] are commonly used to assess size structure. However, before PSD or RSD can be calculated for a fish population, species-specific length categories must be defined. See Gabelhouse (1984a) for methods to determine stock, quality, preferred, memorable, and trophy lengths.

Despite the widespread use of $W_r$ and stock density indices with warmwater sportfish, $W_s$ equations and length categories are virtually nonexistent for large-river, nongame fishes. Therefore, the objectives of this study were to (1) develop a $W_s$ equation for shovelnose sturgeon *Scaphirhynchus platorynchus* based on the regression-line-percentile (RLP) technique, (2) evaluate the consistency of $W_r$ across various lengths, (3) evaluate $W_r$ distributions of individuals and populations, (4) determine length categories (i.e., stock, quality, preferred, memorable, and trophy lengths), and (5) assess the relations between $W_r$ and size structure for shovelnose sturgeon populations.

## Methods

Weight–length data for shovelnose sturgeon were solicited from biologists within the geographical distribution of the species (Lee et al. 1980). Populations represented by less than 30 individuals were omitted from all analyses. All data were evaluated as fork lengths (FL). One data set submitted as total lengths (TL) was converted to fork length with an equation developed from data sets that included both FL and TL [FL (mm) = (TL − 43.14)/1.02; $r = 0.99$, $P = 0.0001$]. Additionally, all weights and lengths were converted to grams and millimeters.

The RLP technique was used to develop the $W_s$ equation for shovelnose sturgeon (Murphy et al. 1991). The minimum length for weight precision was determined by plotting the variance-to-mean ratio by 1-cm length-groups, as suggested by Murphy et al. (1990). Minimum length was set where the variance-to-mean ratio exceeded approximate-

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ly 0.01 (Neumann and Murphy 1991). Minimum sample size for the application of the RLP technique was determined by methods described in Brown and Murphy (1996). Independence of $W_r$ across length-classes for each study population was evaluated by assessing the number of significant positive and negative slopes of $W_r$ regressed on fish length. The total number of significant positive and negative slopes were compared with a binomial test to detect any length-related bias in the $W_s$ equation (Mehta and Patel 1995).

Length categories were determined by methods described by Gabelhouse (1984a). He suggested that minimum stock, quality, preferred, memorable, and trophy lengths be determined from lengths encompassed by 20–26%, 36–41%, 45–55%, 59–64%, and 74–80% of world record length, respectively. We used the largest fish in our data set (1,052 mm FL; 8,164 g) as the world record length because the largest shovelnose sturgeon recorded by the National Freshwater Fishing Hall of Fame weighed 2,155 g.

Several authors have noted seasonal variations in stock density indices (Carline et al. 1984; Serns 1985; Willis et al. 1993). However, nearly all data sets represented summer or early fall sampling, which made separation by season impractical. Similarly, size-related biases can result from gear selectivity (Hamley 1975; Reynolds and Simpson 1978). Relations between $W_r$ and size structure were determined for those populations known to be sampled with gill or trammel nets from riverine habitats. Mean $W_r$ was plotted as a function of PSD and as a function of incremental $W_r$ and RSDs [i.e., stock to quality (S–Q), quality to preferred (Q–P), preferred to memorable (P–M), and memorable to trophy length (M–T)]. The relationships were analyzed with correlation techniques. Differences of $W_r$ among length categories were tested with analysis of variance (ANOVA; SAS 1989). A probability level of 0.05 was used to reject the null hypothesis in all statistical tests.

## Results and Discussion

Weight–length regressions were developed for 32 shovelnose sturgeon populations from nine states ($N = 11{,}820$; Table 1). We found that 30 populations were required to develop a $W_s$ equation with the RLP technique (sample variance of slopes = 0.0018; Michael L. Brown, South Dakota State University, personal communication). Shovelnose sturgeon 120 mm and longer were included in the weight–length regressions because the variance-to-mean ratio was below 0.01 for all fish used. All weight–length regressions were significant ($P \leq 0.0001$), and all but three correlation coefficients were 0.93 or higher (Table 1).

The following $W_s$ equation for shovelnose sturgeon was calculated with the 75th-percentile RLP technique:

$$\log_{10} W_s = -6.287 + 3.330 \log_{10}\text{FL};$$

where $W_s$ is standard weight in grams and FL is in millimeters. The equivalent in English units is

$$\log_{10} W_s = -4.266 + 3.330 \log_{10}\text{FL};$$

where $W_s$ is standard weight in pounds and FL is in inches. These equations are proposed for use with shovelnose sturgeon from 120 mm (5 in) to 1,050 mm (41 in).

Although $W_r$ may vary among lengths in a given population, there should be no consistent pattern of increasing or decreasing $W_r$ values for a series of populations. When $W_r$ was regressed on fish length for 32 populations, 20 populations had significant slopes ($P \leq 0.05$). The number of positive slopes (11 slopes) was not significantly different than the number of negative slopes (9 slopes; $P = 0.41$), indicating no length bias associated with the $W_s$ equation.

Forty-three percent of the populations had mean $W_r$ values within the suggested benchmark target range of 95–100 (Wege and Anderson 1978). Although this is similar to those percentages reported for white bass *Morone chrysops* (37%), palmetto bass (a hybrid of female striped bass *Morone saxatilis* × male white bass; 32%; Brown and Murphy 1991), and white crappie *Pomoxis annualaris* (Neumann and Murphy 1991), 85% of these populations were from Montana. Sixty percent of the Montana populations had mean population $W_r$ values between 95 and 105. Conversely, 66% of the shovelnose sturgeon populations from states other than Montana had mean population $W_r$ values between 80 and 90. These data suggest that universal target values may be inappropriate for shovelnose sturgeon.

Numerous researchers have described differences in $W_r$ values associated with lentic and lotic populations (e.g., Fisher et al. 1996); however, we are unaware of any studies identifying variation in $W_r$ along a longitudinal scale in lotic ecosystems. The variability between lentic and lotic systems has prompted the development of differing target ranges for $W_r$. For example, Fisher et al. (1996) found that $W_r$ values for burbot *Lota lota* were consistently lower in lotic ecosystems than in len-

TABLE 1.—Sample size (*N*; fish $\geq$ 120 mm), intercept (*a*), slope (*b*), and correlation coefficient (*r*) for regressions of $\log_{10}$weight (g) on $\log_{10}$fork length (mm). Mean relative weight ($W_r$) values for shovelnose sturgeon length categories (stock to quality, S–Q; quality to preferred, Q–P; preferred to memorable, P–M; and memorable to trophy, M–T) are provided. Numbers in parentheses below the mean are sample size and SD of mean. All regressions were significant at $P \leq 0.0001$.

| State and location | *N* | *a* | *b* | *r* | Mean $W_r$ values for length categories: | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | S–Q | Q–P | P–M | M–T |
| Illinois, Missouri | | | | | | | | |
| Mississippi River, Pool 26 | 30 | −5.392 | 2.941 | 0.91 | 122<br>(15, 32.17) | | 58<br>(6, 14.19) | 53<br>[a] |
| Mississippi River, Cape Girardeau | 72 | −6.473 | 3.381 | 0.96 | 86<br>(15, 21.38) | 99<br>(23, 23.17) | 96<br>(25, 32.16) | 78<br>(8, 20.65) |
| Iowa, Illinois | | | | | | | | |
| Mississippi River, Pool 13 | 149 | −7.292 | 3.678 | 0.98 | 75<br>(5, 10.66) | 86<br>(50, 8.55) | 90<br>(80, 9.50) | 98<br>(14, 13.19) |
| Kansas | | | | | | | | |
| Kansas River, Lawrence | 125 | −5.793 | 3.119 | 0.99 | 91<br>(11, 10.97) | 83<br>(29, 5.94) | 84<br>(80, 6.88) | 76<br>[a] |
| Kansas River, Ogden | 233 | −6.619 | 3.426 | 0.95 | 79<br>[a] | 82<br>(24, 6.81) | 84<br>(206, 6.81) | 82<br>[a] |
| Kansas, Missouri | | | | | | | | |
| Missouri River, St. Joseph | 47 | −5.972 | 3.174 | 0.99 | 78<br>(5, 7.29) | 80<br>(13, 7.42) | 78<br>(21, 11.93) | 79<br>[a] |
| Missouri River, Kansas City | 39 | −6.196 | 3.265 | 0.99 | 81<br>[a] | 81<br>(8, 4.88) | 82<br>(23, 6.52) | 89<br>[a] |
| Louisiana | | | | | | | | |
| Red River | 45 | −4.925 | 2.824 | 0.96 | 151<br>[a] | 106<br>(8, 23.87) | 91<br>(27, 10.70) | 91<br>(9, 7.60) |
| Montana | | | | | | | | |
| Big Muddy River | 357 | −6.206 | 3.294 | 0.98 | 98<br>(14, 20.44) | 95<br>(47, 13.16) | 99<br>(212, 11.02) | 92<br>(74, 8.01) |
| Marias River | 54 | −6.432 | 3.380 | 0.95 | | | 96<br>[a] | 100<br>(36, 12.20) |
| Missouri River, Loma | 1,160 | −6.089 | 3.267 | 0.95 | | 96<br>[a] | 105<br>(49, 16.00) | 106<br>(590, 12.33) |
| Missouri River, Whiteside | 69 | −6.246 | 3.323 | 0.99 | 126<br>[a] | 103<br>(11, 8.61) | 98<br>(5, 3.56) | 108<br>(37, 12.82) |
| Missouri River, Stafford Ferry | 441 | −6.540 | 3.423 | 0.98 | 102<br>[a] | 95<br>(27, 10.59) | 97<br>(51, 12.79) | 103<br>(256, 11.04) |
| Missouri River, Robinson Bridge | 1,922 | −6.457 | 3.394 | 0.97 | 105<br>(16, 14.54) | 92<br>(85, 1.32) | 107<br>(599, 14.45) | 102<br>(1,004, 11.19) |
| Missouri River, Fort Peck | 732 | −6.290 | 3.317 | 0.96 | | 91<br>(11, 7.66) | 93<br>(454, 9.00) | 91<br>(262, 9.17) |
| Missouri River, Milk River confluence | 168 | −5.874 | 3.159 | 0.96 | | 93<br>(12, 5.81) | 88<br>(108, 7.52) | 83<br>(46, 7.95) |
| Missouri River, Wolf Point | 112 | −6.084 | 3.229 | 0.97 | | 89<br>(25, 9.28) | 84<br>(73, 8.35) | 82<br>(14, 8.63) |
| Missouri River, Red Water River confluence | 58 | −6.041 | 3.229 | 0.98 | | 82<br>[a] | 89<br>[a] | 91<br>(5, 8.11) |
| Missouri and Yellowstone River confluence | 782 | −6.449 | 3.382 | 0.98 | 90<br>(15, 114.77) | 90<br>(61, 10.94) | 98<br>(484, 11.55) | 95<br>(188, 10.11) |
| Powder River | 70 | −7.540 | 3.768 | 0.95 | | | 96<br>[a] | 101<br>(54, 8.92) |
| Tongue River | 272 | −6.706 | 3.474 | 0.93 | | | 96<br>[a] | 100<br>(178, 10.59) |
| Yellowstone River, Highway 23 bridge | 133 | −6.736 | 3.478 | 0.98 | 110<br>[a] | 90<br>(21, 11.99) | 91<br>(48, 11.81) | 95<br>(55, 10.49) |
| Yellowstone River, Forsyth | 187 | −6.988 | 3.574 | 0.97 | | | 96<br>(12, 7.05) | 100<br>(101, 11.73) |
| Yellowstone River, Miles City | 60 | −8.211 | 4.000 | 0.97 | | | 93<br>(8, 10.11) | 96<br>(36, 9.85) |
| Yellowstone River, Powder River confluence | 588 | −7.189 | 3.643 | 0.96 | 91<br>[a] | 93<br>[a] | 91<br>(37, 9.35) | 99<br>(400, 11.07) |
| Yellowstone River, Glendive | 853 | −6.821 | 3.509 | 0.98 | 89<br>(7, 7.74) | 93<br>(29, 14.64) | 90<br>(123, 7.67) | 95<br>(501, 11.23) |

TABLE 1.—Continued.

| State and location | $N$ | $a$ | $b$ | $r$ | Mean $W_r$ values for length categories: S–Q | Q–P | P–M | M–T |
|---|---|---|---|---|---|---|---|---|
| Yellowstone River, above Intake | 565 | −6.483 | 3.399 | 0.97 |  | 101<br>(6, 18.86) | 100<br>(60, 11.25) | 101<br>(334, 10.39) |
| Yellowstone River, below Intake | 1,158 | −6.349 | 3.337 | 0.99 | 96<br>(29, 18.44) | 92<br>(95, 10.86) | 90<br>(337, 8.27) | 92<br>(582, 9.67) |
| Nebraska |  |  |  |  |  |  |  |  |
| Platte River | 117 | −6.001 | 3.203 | 0.94 |  | 88<br>(13, 12.09) | 87<br>(97, 7.99) | 90<br>(7, 3.83) |
| North Dakota |  |  |  |  |  |  |  |  |
| Lake Oahe | 91 | −4.579 | 2.669 | 0.88 |  |  | 78<br>(38, 9.41) | 69<br>(53, 8.56) |
| Lake Sakakawea | 45 | −5.826 | 3.134 | 0.98 | 86<br>(15, 21.00) | 99<br>(23, 23.17) | 89<br>(12, 6.21) | 78<br>(21, 11.19) |
| Wisconsin |  |  |  |  |  |  |  |  |
| Chippewa River | 1,085 | −4.572 | 3.381 | 0.85 |  | 81<br>[a] | 89<br>(522, 8.09) | 83<br>(562, 7.84) |

[a] Represents less than five individuals.

tic ecosystems. Consequently, they suggested target values of 95–105 for lentic populations and 75–85 for lotic ecosystems. Kruse and Hubert (1997) found similar relations with cutthroat trout *Oncorhynchus clarki* but elected to develop separate equations for lotic and lentic populations rather than propose different target values. Similarly, Willis et al. (1991) identified a broad distribution in body condition of yellow perch *Perca flavescens* and suggested that the variability in condition reinforces the concept that universal target values may be inappropriate in many situations. Therefore, we suggest target values of 95–105 for Montana populations and 80–90 for other populations of shovelnose sturgeon.

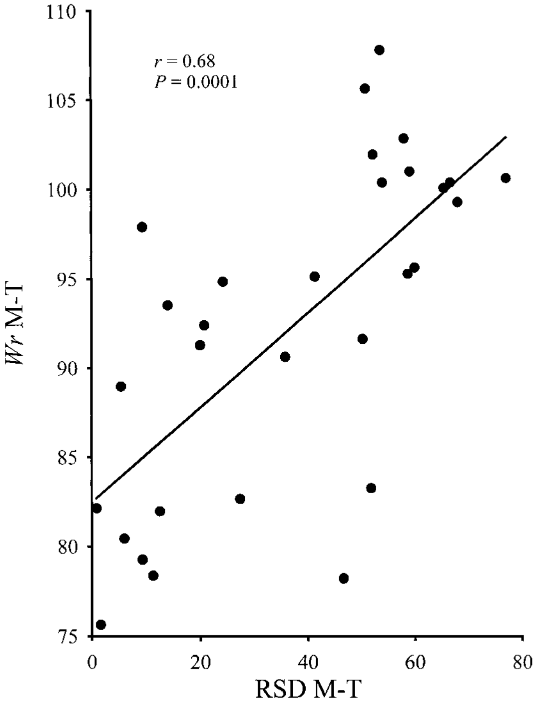

FIGURE 1.—Relationship between mean population relative weight of memorable length to trophy length ($W_r$ M–T) and relative stock density of memorable length to trophy length (RSD M–T) for shovelnose sturgeon.

We recommend the following length categories be used when calculating stock density indices for shovelnose sturgeon: stock, 250 mm (10 in); quality, 380 mm (15 in); preferred, 510 mm (20 in); memorable, 640 mm (25 in); and trophy, 810 mm (32 in). All populations had PSD values greater than 79, except for a Mississippi River population (Table 1). The number of populations with high PSD values is not surprising because shovelnose sturgeon are typically collected with large-mesh (250-mm-bar-measure) nets. The primary gears used to sample shovelnose sturgeon for this study were either gill or trammel nets. Thus, stock-length to quality-length shovelnose sturgeon were less likely to be sampled.

Stock density indices are used to quantify size structure of a fish population. It is debatable whether such indices reflect growth, mortality, and recruitment. However, Willis (1989) and Guy and Willis (1995) documented relations between PSD and growth. Gabelhouse (1984a) suggested that low PSD values may reflect poor habitat, overharvest, and reduced food supply. The relation between PSD and $W_r$ against growth are probably one of cause and effect (Willis 1989; Gabelhouse 1991; Guy and Willis 1995). We were unable to

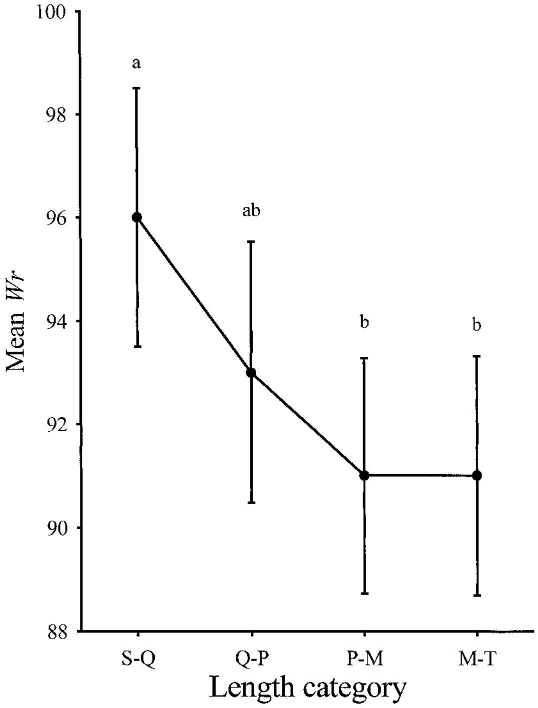

FIGURE 2.—Relations between mean relative weight ($W_r$) by length category—stock to quality (S–Q), quality to preferred (Q–P), preferred to memorable (P–M), and memorable to trophy (M–T)—for shovelnose sturgeon. Bars represent ±SE. Data points without a letter in common represent significant differences ($\alpha = 0.05$) among length categories.

obtain growth data for shovelnose sturgeon used in the development of the $W_s$ equation. Thus, we used relations between $W_r$ and PSD to evaluate the utility of these management tools for large-river species.

Mean population $W_r$ values were positively correlated ($r = 0.47$, $P = 0.033$) with PSD with a curvilinear regression model. Thus, populations with higher PSD values had higher mean condition values. Similar results have been reported for other species, such as northern pike *Esox lucius* (Willis and Scalet 1989), crappies *Pomoxis* spp. (Gabelhouse 1984b; Guy and Willis 1995), and brook trout *Salvelinus fontinalis* (Johnson et al. 1992). We also plotted relations between incremental RSD and $W_r$. The best relationship occurred between $W_r$ of M–T and RSD of M–T ($r = 0.68$, $P = 0.0001$; Figure 1). In addition, we found differences among incremental $W_r$ values. Mean $W_r$ generally decreased as fish attained greater lengths. Stock-length to quality-length shovelnose sturgeon had significantly greater $W_r$ values than P–M and M–T fish ($P \leq 0.05$; Figure 2). These data illustrate the importance of size-specific $W_r$ analyses.

Although the relation between PSD and $W_r$ probably will vary with growth, we surmise that these indices will be useful in assessing shovelnose sturgeon size structure and condition. At best, these indices will provide information on growth, mortality, and recruitment of shovelnose sturgeon in large-river ecosystems. We encourage fisheries biologists to develop $W_s$ equations and size structure categories for large-river species so that these tools will be available for condition and size structure assessment.

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