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Research Article

Length-Weight Relationships for 44 Central Appalachian Fish Species

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Species-specific length-weight relationships can inform researchers and managers about the growth patterns and health of fish populations. Few length-weight relationships exist for Appalachian stream fish species despite the high amount of biodiversity within the region. The main purpose of our study was to determine the length-weight relationships for stream fish species found in Central Appalachia. We sampled 16 streams and captured over 14,000 individual fish among 44 species. We identified each fish to species and recorded total length (mm) and weight (g) for each individual. These data were $\log_{10}$ transformed and analyzed using linear regression to calculate the length-weight parameters for each species. Relationships were calculated for 44 different stream fish species. Searches in FishBase.org revealed that of the 44 species in our data, 9 species have no current data in FishBase.org (Froese and Pauly, 2016), while 20 others have no previous representation from Central Appalachia. The relationships obtained in this study are some of the first published for these species in this region. Availability of species- and region-specific data on length-weight relationships could help inform future research and management of these species.

1. Introduction

The Appalachian region is a well-known hub of biodiversity for many taxa. Elevation and temperature gradients, along with isolation, throughout the region have contributed to the high degree of speciation [1]. Amphibian, reptile, and fish species found in the region are especially diverse and are a vital part of the native ecosystem. Despite the high diversity and importance of these communities, published information for Appalachian fish, particularly nongame species, is often lacking.

Length-weight relationships (LWRs) are a valuable tool that can be used to provide more information about the diverse fish communities in Central Appalachia. These relationships can be used to calculate and explore components of population dynamics such as growth patterns, body condition, biomass estimates, responses to habitat conditions, and life history [2–4].

Despite global importance of LWRs to inform fish ecology and management, these relationships have been mostly applied in fisheries research with a focus on game species [5], with very little information existent for nongame Appalachian stream fish species [6]. The goal of this study was to expand the number of species in Appalachia with published LWRs. Here, we derived LWRs for 44 fish species based on collections of 14,000 individuals across species. The LWRs contained within this publication provide valuable information on these Appalachian species and can aid in future research and management.

2. Methods

We collected fish from 15 West Virginia streams (Figure 1) with high-frequency (~60 Hz) DC electrofishing utilizing ETS ABP-4 backpack electroshockers, a tow barge electrofishing unit (ETS model SDC-1), and dip nets with 4.7 mm

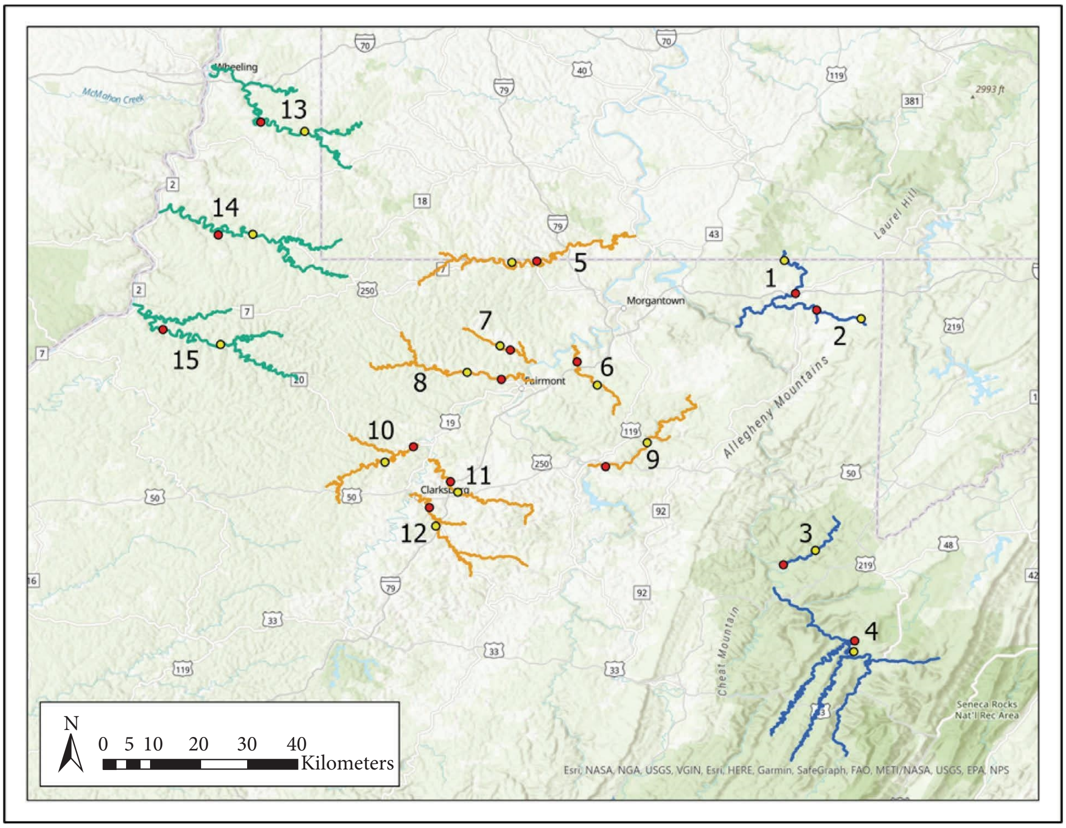

Figure 1: Map of 15 study streams (including major tributaries) and 30 sample sites in northcentral West Virginia. Blue-colored streams are in the Cheat R. watershed, orange-colored streams are in the Monongahela R. watershed, and green-colored streams are in the Ohio R. watershed. Red markers are the downstream sample sites for each stream, and yellow markers are the upstream sample sites for each stream. Streams are labeled as follows: Big Sandy Crk. (1), Beaver Crk. (2), Horseshoe Rn. (3), Dry Fork (4), Dunkard Crk. (5), Whiteday Crk. (6), Paw Paw Crk. (7), Buffalo Crk. (8), Three Fork Crk. (9), Tenmile Crk. (10), Simpson Crk. (11), Elk Crk. (12), Wheeling Crk. (13), Fish Crk. (14), and Fishing Crk. (15), which are developed with ArcGIS Pro software.

mesh. Fish were sampled within approximately 200 m (range = 100–299 m) stream reaches while moving upstream. Stunned fish were netted and placed in livewells for further processing. Upon completing a sample collection, fish were identified to species, weighed to the nearest hundredth of a gram, and total length was measured to the nearest millimeter. Processed fish ≥100 mm total length were released alive, while individuals <100 mm total length were preserved in 10% formalin for laboratory processing.

In the laboratory, preserved fish were identified to species. We did not include specimens under 32 millimeters in length in the dataset due to inadequate sampling efficiency toward the goals of a companion project. As was done for larger fish in the field, the total length of each retained specimen was measured to the nearest millimeter and wet weighed to the nearest hundredth of a gram (Table 1). We included only species that passed the following criteria: (1) had length and weight measurements for at least 10 individuals, (2) had relatively even distribution of individuals among sizes (no severely clumped or nonrepresentative distributions), and (3) was not suspected of being a hybrid, resulting in 44 species that met these requirements. All morphometric data were entered into Microsoft Excel, and SAS v9.4 was used for analyses.

All lengths and weights were $\log_{10}$ transformed. The length (log)–weight (log) relationship in a linear regression will be as follows: $\log_{10}(W) = \log_{10}(a) + b\ \log_{10}(L)$. We plotted $\log_{10}$ wet weight (g) against $\log_{10}$ length (cm) for each species to visually inspect relationships and assess outliers. The resulting linear regression parameters were used to estimate the values of the length and weight equation $W = a \cdot L^b$ [2, 5]. The value a is the antilogarithm of the y intercept, and the b value is the slope from the linear regression. The minimum and maximum length values were also recorded (cm).

3. Results

We provide LWRs for 44 species representing 11 families (Table 2). Although there were other species in this dataset, they were not included due to low sample size ($n < 10$), clumped distributions, or presence of suspected hybridization. Of the 44 species included, 9 of them had no existing LWR records available in FishBase.org [6] and another 20 species did have LWRs but had no representation from Central Appalachia (including the U.S. states of West Virginia, Pennsylvania, Virginia, Kentucky, Tennessee, and North Carolina). We reference the availability of LWRs in

Table 1: Numbers of samples and length and weight descriptive statistics for 44 fish species from Central Appalachia.

Scientific name	Common name	# of streams present	*n*	Length range (cm)	Weight range (g)
Lampetra aepyptera	Least brook lamprey	2	10	7.1–17	1–10.1
Lepisosteus osseus	Longnose gar	3	15	11.1–70	1–769
Dorosoma cepedianum	Gizzard shad	2	13	4.5–38.3	0.88–642
Semotilus atromaculatus	Creek chub	13	200	3.2–16.6	0.35–61
Nocomis micropogon	River chub	8	367	3.2–25.3	0.28–174
Campostoma anomalum	Central stoneroller	12	1259	3.2–14	0.25–33
Rhinichthys atralatus	Blacknose dace	4	72	4.2–6.7	0.78–3.16
Rhinichthys cataractae	Longnose dace	4	117	3.2–12.5	0.32–23.21
Cyprinella spiloptera	Spotfin shiner	8	189	3.5–10.7	0.28–12.68
Luxilus chrysocephalus	Striped shiner	11	298	3.2–16	0.26–52
Pimephales notatus	Bluntnose minnow	10	1416	3.2–9.7	0.17–10
Notropis photogenis	Silver shiner	6	157	3.2–12.4	0.23–18
Notropis rubellus	Rosyface shiner	9	1224	3.2–9.9	0.18–7.5
Notropis stramineus	Sand shiner	8	1864	3.2–7.4	0.26–4.04
Notropis volucellus	Mimic shiner	3	186	3.5–6.8	0.41–2.32
Notropis buccatus	Silverjaw minnow	5	54	3.2–8.5	0.29–5.35
Catostomus commersonii	White sucker	9	84	4.3–45.7	0.98–986
Hypentelium nigricans	Northern hogsucker	15	398	3.2–38.7	0.34–923
Moxostoma duquensi	Black redhorse	6	40	12.5–43.4	17–772
Moxostoma erythrurum	Golden redhorse	10	297	12.1–45.3	15–1148
Moxostoma anisurum	Silver redhorse	6	44	12.4–52.6	18–1541
Moxostoma breviceps	Smallmouth redhorse	4	48	13.4–60.7	25–700
Ictalurus punctatus	Channel catfish	4	24	4.1–62.5	0.62–3052
Ameiurus natalis	Yellow bullhead	10	48	3.2–26.7	0.55–261
Noturus flavus	Stonecat madtom	5	24	3.8–18.7	0.73–65
Salmo trutta	Brown trout	2	21	25.4–35	113–427
Cottus bairdii	Mottled sculpin	4	700	3.6–9.5	0.99–13.55
Pomoxis annularis	White crappie	1	14	5.7–38.1	3–774
Ambloplites repestris	Rock bass	14	538	4.7–24.8	1.77–334
Micropterus salmoides	Largemouth bass	10	61	3.2–35	0.3–584
Micropterus dolomieu	Smallmouth bass	14	699	3.2–46.5	0.44–1183
Lepomis cyanellus	Green sunfish	16	198	4.4–15.5	1.27–83
Lepomis macrochirus	Bluegill	12	135	3.5–20	0.63–178
Lepomis megalotis	Longear sunfish	7	90	4.3–14.4	1.34–56
Lepomis auritus	Redbreast sunfish	1	30	4.5–18.8	1–126
Percina maculata	Blackside darter	6	89	3.2–7.5	0.27–4.3
Percina caprodes	Logperch	9	103	4.7–16.9	0.86–44
Etheostoma nigrum	Johnny darter	8	210	3.2–6.1	0.17–2.06
Etheostoma blennioides	Greenside darter	11	1399	3.2–9.6	0.23–9.97
Etheostoma variatum	Variegate darter	5	480	3.2–9.3	0.23–11.44
Etheostoma zonale	Banded darter	8	377	3.2–6.2	0.29–2.85
Etheostoma caeruleum	Rainbow darter	8	264	3.2–40.3	0.28–686
Etheostoma flabellare	Fantail darter	9	316	3.2–7.2	0.23–4.09
Aplodinotus grunniens	Freshwater drum	6	34	5.9–68.6	2.1–2953

FishBase.org not intending it in an inclusive way, but rather as an index of relative availability, other data may be available for these species outside of the FishBase.org [6] database.

4. Discussion

The LWRs provided by this study can inform future research and management of the studied species as well as potentially provide more accurate length-weight information for Central Appalachian fishes. LWRs can vary throughout the year as fish weight fluctuates because of reproduction and spawning seasons, and this study was limited to just the summer season and the condition the species were in at the time of collection. There is a potential for continuing research using these results to assess site-specific variation in relative weight (W_r) for species of interest. Site-specific variation in W_r could arise, for example, from environmental conditions and/or food web community dynamics. Future studies could rely on LWRs and W_r as a tool to investigate effects of natural gradients and anthropogenic stressors such as acid mine drainage and invasive species which have been shown to affect stream and river ecology in our study region [7, 8]. The development of robust LWRs is the first step in developing such studies.

Increasing our knowledge of native species is becoming increasingly important in the Appalachian region, as emerging issues such as artificial range expansion and

Table 2: Length-weight relationships (LWRs) for 44 fish species from Central Appalachia. Values for a and b (length-weight relationship parameters) are provided, as well as 95% confidence intervals for a and b and the R squared coefficient of determination in the log–log LWR.

Scientific name	Common name	a	95% C.I. of a	b	95% C.I. of b	R^2
Lampetra aepyptera	Least brook lamprey[*1]	0.0046	0.0028–0.0057	2.66	2.471–2.835	0.95
Lepisosteus osseus	Longnose gar[1]	0.0004	0.0002–0.0009	3.36	3.191–3.532	0.99
Dorosoma cepedianum	Gizzard shad	0.0106	0.0086–0.0132	2.98	2.901–3.050	1.00
Semotilus atromaculatus	Creek chub	0.0127	0.0118–0.0138	2.94	2.901–2.986	0.99
Nocomis micropogon	River chub[*1]	0.0094	0.0089–0.0101	3.06	3.034–3.089	0.99
Campostoma anomalum	Central stoneroller	0.0114	0.0110–0.0118	3.02	2.998–3.038	0.99
Rhinichthys atralatus	Blacknose dace	0.0091	0.0069–0.0121	3.07	2.899–3.231	0.95
Rhinichthys cataractae	Longnose dace[*1]	0.0079	0.0070–0.0089	3.13	3.073–3.192	0.99
Cyprinella spiloptera	Spotfin shiner[1]	0.0055	0.0049–0.0063	3.23	3.166–3.298	0.98
Luxilus chrysocephalus	Striped shiner	0.0054	0.0050–0.0058	3.30	3.262–3.335	0.99
Pimephales notatus	Bluntnose minnow	0.0062	0.0058–0.0069	3.28	3.259–3.294	0.97
Notropis photogenis	Silver shiner[*1]	0.0091	0.0086–0.0097	2.92	2.890–2.954	1.00
Notropis rubellus	Rosyface shiner[1]	0.0097	0.0094–0.0102	2.81	2.786–2.839	0.97
Notropis stramineus	Sand shiner[1]	0.0088	0.0083–0.0093	3.03	2.993–3.067	0.93
Notropis volucellus	Mimic shiner[1]	0.0082	0.0071–0.0096	2.99	2.792–3.061	0.95
Notropis buccatus	Silverjaw minnow	0.0081	0.0069–0.0097	3.03	2.921–3.146	0.98
Catostomus commersonii	White sucker[1]	0.0126	0.0100–0.0156	2.94	2.863–3.021	0.99
Hypentelium nigricans	Northern hogsucker[1]	0.0100	0.0094–0.0107	3.05	3.021–3.072	0.99
Moxostoma duquensi	Black redhorse[1]	0.0076	0.0064–0.0090	3.07	3.017–3.115	1.00
Moxostoma erythrurum	Golden redhorse[1]	0.0077	0.0069–0.0086	3.09	3.059–3.125	0.99
Moxostoma anisurum	Silver redhorse[1]	0.0072	0.0065–0.0084	3.12	3.090–3.164	0.99
Moxostoma breviceps	Smallmouth redhorse[*1]	0.0107	0.0081–0.0140	2.69	2.532–2.892	0.99
Ictalurus punctatus	Channel catfish	0.0072	0.0046–0.0114	3.06	2.937–3.183	0.99
Ameiurus natalis	Yellow bullhead[1]	0.0179	0.0148–0.0233	2.93	2.825–3.035	0.99
Noturus flavus	Stonecat madtom[1]	0.0165	0.0116–0.0234	2.79	2.639–2.936	0.99
Salmo trutta	Brown trout[1]	0.0224	0.0210–0.0236	3.10	2.964–3.178	0.93
Cottus bairdii	Mottled sculpin[*1]	0.0130	0.0126–0.0137	3.03	2.897–3.089	0.96
Pomoxis annularis	White crappie	0.0202	0.0163–0.0281	2.62	2.549–2.704	0.99
Ambloplites repestris	Rock bass[1]	0.0172	0.0154–0.0192	3.04	2.991–3.079	0.97
Micropterus salmoides	Largemouth bass	0.0119	0.0101–0.0140	3.04	2.953–3.128	0.99
Micropterus dolomieu	Smallmouth bass	0.0153	0.0097–0.0211	2.92	2.843–3.061	0.99
Lepomis cyanellus	Green sunfish	0.0114	0.0008–0.0126	3.19	3.134–3.207	0.94
Lepomis macrochirus	Bluegill	0.0126	0.0099–0.0160	3.16	3.052–3.263	0.96
Lepomis megalotis	Longear sunfish[1]	0.0124	0.0093–0.0165	3.23	3.100–3.363	0.96
Lepomis auritus	Redbreast sunfish[1]	0.0127	0.0118–0.0137	2.59	2.457–2.724	0.98
Percina maculata	Blackside darter[1]	0.0052	0.0043–0.0063	3.32	3.186–3.444	0.97
Percina caprodes	Logperch[*1]	0.0053	0.0044–0.0064	3.21	3.133–3.288	0.99
Etheostoma nigrum	Johnny darter	0.0061	0.0054–0.0069	3.23	3.144–3.318	0.96
Etheostoma blennioides	Greenside darter[*1]	0.0088	0.0084–0.0092	3.09	3.060–3.111	0.98
Etheostoma variatum	Variegate darter[*1]	0.0089	0.0084–0.0095	3.14	3.097–3.185	0.98
Etheostoma zonale	Banded darter[1]	0.0086	0.0073–0.1010	3.18	3.073–3.282	0.90
Etheostoma caeruleum	Rainbow darter	0.0114	0.0105–0.0124	3.03	2.977–3.079	0.98
Etheostoma flabellare	Fantail darter[1]	0.0105	0.0097–0.0112	2.89	2.839–2.942	0.95
Aplodinotus grunniens	Freshwater drum[1]	0.0089	0.0068–0.0117	3.08	3.005–3.161	1.00

The superscript * after the common name indicates the 9 species that at the time of publication did not have any LWR data in FishBase.org, while the superscript 1 indicates the 29 species that had no LWR data from the Central Appalachia region.

overharvest may threaten native species. For instance, variegate darter (*Etheostoma variatum*) range has been increasing in recent years due to bait bucket introductions and threatens the genetic integrity of established candy darter (*Etheostoma osburni*) populations, an endangered fish native only to a small part of West Virginia and Virginia [9]. Additionally, harvest of nongame fishes via several available techniques (i.e., rod and reel, bow fishing, snagging, and gigging) is common in Appalachian waterways, but regulations are often limited for these species [10]. Nongame native fishes, like longnose gar, sucker species (*Catostomidae*), and freshwater drum contained in this dataset, are frequently targeted, and populations may face risks from these activities, given limited regulations [10]. LWRs provided here can help to understand how invasive species and some angling practices may alter growth and body condition patterns of populations throughout the region.

Data Availability

The length-weight relationship data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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