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Relative Condition Parameters for Fishes of Montana, USA

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Abstract: Body condition indices are commonly used in the management of fish populations and are a surrogate to physiological attributes such as tissue-energy reserves. Relative condition factor (K_n) describes the condition of species relative to populations in a geographic area. We developed models to allow for the calculation of K_n in Montana, USA by using the weight–length data collected by Montana Fish, Wildlife & Parks. We generated $\log_{10}$weight–$\log_{10}$length relationships to obtain Montana specific parameter estimates for relative condition equations (W') for 51 species and three subspecies. We developed separate models by water type (e.g., lotic and lentic) and sex for five species due to varying growth based on sexual dimorphism and varying ecosystem types. Relative condition offers the advantage of describing body condition relative to species in Montana, provides a condition index for species that do not have standard-weight models developed for relative weight (Wr), and affords more information for the global database on weight–length relationships of fishes.

Keywords: body condition indices; weight–length relationship; relative condition; K_n

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1. Introduction

Weight and length measurements are commonly recorded in fisheries surveys and provide the foundation for research and management [1,2]. Fisheries biologists use weight–length relationships to estimate weight based on length, and vice versa, or to assess the variation from the expected weight for length as an index of relative plumpness of a fish [3]. Because weight is directly related to fish length, ratios between weight and length have been termed condition and are often used as a surrogate to physiological attributes (e.g., tissue-energy reserves) [2,4,5].

Fulton's condition factor (K), relative condition factor (K_n), and relative weight (Wr) are the three most commonly used metrics to assess body condition in fishes [2]. Relative condition factor ($K_n = W/W'$), where W is the individual weight of a fish and W' is the length-specific mean weight of a fish in the population under study and describes the condition of a species relative to populations in a geographic area [6]. This is achieved by comparing the weight of a fish to a standard predicted by a weight–length regression from the geographic area representing where the fish was sampled [3,6]. Geographic areas used to represent average weight–length relationships (W') can be individual small waterbodies [7,8] or large watersheds and seas [9,10]. Swingle and Shell [6] used the state of Alabama as their geographic area for the development of W' for 25 species. Here, we aim to replicate Swingle and Shell's concept of a statewide condition index for Montana specific parameter estimates for relative condition.

2. Materials and Methods

We used fish weight and length data obtained from Montana Fish, Wildlife & Parks spanning the years 1951–2020 for fish sampled within the state of Montana. Each species data were downloaded individually using a query of species identification code, and weight and length greater than zero. Outliers were identified and excluded from future analysis as having an absolute value greater than three from a standardized residual cutoff on the $\log_e$ weight–$\log_e$ length linear relationship, which was repeated twice [11]. Due to the high variance in weights on small fish, all individuals below an identified minimum length were excluded from analysis [2]. We used the minimum length specified for species that currently have standard weight equations developed [2,12–15] and for species without a standard weight equation, a variance to mean ratio was used to find the centimeter length group that had a value less than 0.02 [16,17]. Weight can be predicted from the curvilinear model:

$$W = aL^b,$$

where W is weight, a is a constant, L is length, and b is an exponent that is generally different among species. The curvilinear model can be transformed to the following equation [18]:

$$\log_{10}(W) = a' + b \times \log_{10}(L),$$

where W is weight, L is length, a' is the $\log_{10}(a)$ and the y-intercept, and b is the slope. Using R package MCMC pack [19], an uninformed Bayesian linear regression was used to obtain parameter estimates of a' and b for 51 fish species and three subspecies in Montana [20]. By using a Bayesian framework, we can infer the probability of varying estimates of a' and b.

Average K_n was calculated for the years 1980 and 2020 from the Yellowstone River and Missouri River for rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta*.

3. Results

Weight–length data from 51 species and three subspecies and 2,948,583 individuals were used to create parameter estimates for a' and b and 95% credible intervals (Figures S1–S7). Lengths varied from 50 to 1,473 mm and weights varied from 2 to 56,246 g (Table 1). Intercept values (a') varied from −6.962 to −4.157 and slopes (b) varied from 2.603 to 3.716 (Table 2).

Table 1. Minimum and maximum length and weight used to create weight–length relationship for 51 Montana fish species and three subspecies. All lengths are reported as total length except paddlefish, noted by †, that is measured from eye to fork of caudal fin. *Cottidae* species are noted with a ‡ as they are being described as new species. Columbia slimy sculpin were previously referred to as slimy sculpin *Cottus cognatus* and Rocky Mountain sculpin were previously referred to as mottled sculpin *C. bairdii*.

Species	Scientific Name	Length (mm)		Weight (g)		K_n	
		Min	Max	Min	Max	Min	Max
Acipenseridae							
Pallid sturgeon	*Scaphirhynchus albus*	325	1472	94	15,876	0.64	1.40
White sturgeon	*Acipenser transmontanus*	701	1460	1160	17,222	0.76	1.39
Catostomidae							
Bigmouth buffalo	*Ictiobus cyprinellus*	163	905	73	13,450	0.76	1.29
Blue sucker	*Cycleptus elongatus*	437	884	680	7100	0.68	1.45
Largescale sucker	*Catostomus macrocheilus*	110	647	10	2774	0.66	1.55
Longnose sucker	*Catostomus catostomus*	90	597	6	2767	0.66	1.53
Mountain sucker	*Catostomus platyrhynchus*	100	246	9	181	0.45	2.30
River carpsucker	*Carpiodes carpio*	130	762	27	7711	0.70	1.43
Shorthead redhorse	*Moxostoma macrolepidotum*	100	581	9	2675	0.69	1.47
Smallmouth buffalo	*Ictiobus bubalus*	201	870	150	11,067	0.68	1.45
White sucker	*Catostomus commersonii*	100	564	8	2259	0.69	1.44

Table 1. *Cont.*

Species	Scientific Name	Length (mm)		Weight (g)		K_n	
		Min	Max	Min	Max	Min	Max
Centrarchidae							
Black crappie	*Pomoxis nigromaculatus*	100	396	9	960	0.59	1.72
Bluegill	*Lepomis macrochirus*	80	254	5	572	0.50	2.02
Green sunfish	*Lepomis cyanellus*	61	226	5	260	0.40	2.40
Largemouth bass	*Micropterus salmoides*	150	520	40	2630	0.67	1.50
Pumpkinseed	*Lepomis gibbosus*	53	260	3	317	0.53	1.93
Smallmouth bass	*Micropterus dolomieu*	151	561	27	3500	0.60	1.67
Cottidae							
Columbia slimy sculpin	*Uranidea* sp. *cf. cognata* ‡	90	138	6	43	0.54	1.63
Rocky mountain sculpin	*Uranidea* sp. *cf. bairdii* ‡	90	597	6	2767	0.66	1.53
Cyprinidae							
Common carp	*Cyprinus carpio*	200	851	90	10,610	0.69	1.45
Esocidae							
Northern Pike	*Esox lucius*	102	1118	5	13,617	0.62	1.61
Tiger muskellunge	*Esox masquinongy x lucius*	254	1270	68	14,515	0.71	1.45
Hiodontidae							
Goldeye	*Hiodon alosoides*	100	505	9	1501	0.68	1.48
Ictaluridae							
Black bullhead	*Ameiurus melas*	130	353	20	850	0.60	1.66
Stonecat	*Noturus flavus*	90	269	5	272	0.56	1.78
Yellow bullhead	*Ameiurus natalis*	124	360	20	750	0.71	1.41
Leuciscidae							
Flathead chub	*Platygobio gracilis*	100	272	9	213	0.40	2.37
Golden shiner	*Notemigonus crysoleucas*	71	452	5	1021	0.52	1.91
Lake chub	*Couesius plumbeus*	50	183	2	73	0.41	2.63
Longnose dace	*Rhinichthys cataractae*	110	168	10	54	0.54	2.22
Northern pikeminnow	*Ptychocheilus oregonensis*	250	642	92	2988	0.67	1.48
Peamouth	*Mylocheilus caurinus*	102	414	7	778	0.68	1.47
Redside shiner	*Richardsonius balteatus*	90	193	4	70	0.54	2.01
Utah chub	*Gila atraria*	109	462	14	1061	0.63	1.61
Lotidae							
Burbot	*Lota lota*	200	914	36	4649	0.57	1.77
Percidae							
Sauger	*Sander canadensis*	84	676	5	3400	0.64	1.62
Walleye	*Sander vitreus*	150	856	18	7475	0.70	1.44
Yellow perch	*Perca flavescens*	101	569	9	3470	0.59	1.68
Polyodontidae							
Paddlefish †	*Polyodon spathula*						
Overall		711	1473	4990	56,246	0.68	1.46
Female		914	1473	12,247	56,246	0.72	1.37
Male		711	1143	4990	25,855	0.73	1.39
Salmonidae							
Arctic grayling	*Thymallus arcticus*	150	477	23	1139	0.56	1.82
Brook trout	*Salvelinus fontinalis*	120	562	11	1846	0.59	1.69
Brown trout	*Salmo trutta*						
Lentic		140	777	27	6056	0.63	1.59
Lotic		140	820	20	6000	0.68	1.46
Bull trout	*Salvelinus confluentus*	120	900	10	7306	0.66	1.53
Cisco	*Coregonus artedi*	102	463	9	918	0.63	1.57

Table 1. *Cont.*

Species	Scientific Name	Length (mm)		Weight (g)		K_n	
		Min	Max	Min	Max	Min	Max
Golden trout	*O. mykiss aguabonita*	124	566	23	1724	0.51	1.94
Kokanee	*Oncorhynchus nerka*	121	676	14	2957	0.69	1.46
Lake trout	*Salvelinus namaycush*	280	1110	145	11,225	0.67	1.49
Lake whitefish	*Coregonus clupeaformis*	100	650	5	3098	0.65	1.57
Mountain whitefish	*Prosopium williamsoni*	140	577	16	2014	0.65	1.55
Pygmy whitefish	*Prosopium coulterii*	90	235	4	116	0.70	1.41
Rainbow trout	*Oncorhynchus mykiss*						
Lentic		122	808	18	6144	0.63	1.60
Lotic		120	829	13	7469	0.67	1.50
Westslope cutthroat trout	*O. clarkii lewisi*						
Lentic		130	597	15	2400	0.67	1.50
Lotic		130	546	14	1735	0.64	1.56
Yellowstone cutthroat trout	*O. clarkii bouvieri*						
Lentic		132	632	14	2500	0.55	1.82
Lotic		131	608	16	2415	0.67	1.48
Sciaenidae							
Freshwater drum	*Aplodinotus grunniens*	114	680	20	4800	0.67	1.53

Table 2. Parameter estimates for a' and b used for W' for 51 Montana fish species and three subspecies with 95% credible intervals in parentheses. Equation parameters for metric units are in millimeters and grams and values for English units are in inches and pounds. All lengths are reported as total length except paddlefish, noted by †, that is measured from eye to fork of caudal fin. Asterisks (*) on minimal total length indicate values obtained from standard-weight, W_s, equations [2]. *Cottidae* species are noted with a ‡ as they are being described as new species. Columbia slimy sculpin were previously referred to as slimy sculpin *Cottus cognatus* and Rocky Mountain sculpin were previously referred to as mottled sculpin *C. bairdii*.

Species	Scientific Name	Intercept (a')		Slope (b)	Minimal Total Length (mm)	n
		Metric	English			
Acipenseridae						
Pallid sturgeon	*Scaphirhynchus albus*	−6.397 (−6.501, −6.292)	−4.377 (−4.428, −4.327)	3.329 (3.290, 3.367)	320	464
White sturgeon	*Acipenser transmontanus*	−6.692 (−6.895, −6.487)	−4.497 (−4.604, −4.390)	3.454 (3.384, 3.522)	700 *	328
Catostomidae						
Bigmouth buffalo	*Ictiobus cyprinellus*	−5.130 (−5.229, −5.031)	−3.401 (−3.450, −3.352)	3.122 (3.086, 3.157)	150 *	312
Blue sucker	*Cycleptus elongatus*	−5.850 (−6.068, −5.631)	−3.903 (−4.014, −3.792)	3.277 (3.200, 3.353)	240 *	807
Largescale sucker	*Catostomus macrocheilus*	−5.134 (−5.146, −5.122)	−3.509 (−3.514, −3.504)	3.048 (3.043, 3.053)	110	26,035
Longnose sucker	*Catostomus catostomus*	−5.012 (−5.020, −5.004)	−3.433 (−3.437, −3.430)	3.015 (3.012, 3.018)	90	43,717
Mountain sucker	*Catostomus platyrhynchus*	−4.633 (−4.748, −4.517)	−3.267 (−3.307, −3.226)	2.864 (2.810, 2.917)	100	2030
River carpsucker	*Carpiodes carpio*	−5.134 (−5.159, −5.109)	−3.434 (−3.445, −3.422)	3.102 (3.092, 3.111)	130 *	14,017
Shorthead redhorse	*Moxostoma macrolepidotum*	−4.964 (−4.976, −4.952)	−3.407 (−3.413, −3.402)	2.999 (2.994, 3.004)	100 *	26,877
Smallmouth buffalo	*Ictiobus bubalus*	−4.621 (−4.675, −4.567)	−3.157 (−3.184, −3.130)	2.933 (2.914, 2.953)	200 *	2945
White sucker	*Catostomus commersonii*	−5.243 (−5.248, −5.237)	−3.512 (−3.514, −3.510)	3.123 (3.121, 3.125)	100 *	134,086
Centrarchidae						
Black crappie	*Pomoxis nigromaculatus*	−5.150 (−5.173, −5.128)	−3.387 (−3.396, −3.378)	3.147 (3.137, 3.157)	100 *	16,650
Bluegill	*Lepomis macrochirus*	−5.435 (−5.502, −5.368)	−3.388 (−3.410, −3.365)	3.349 (3.317, 3.380)	80 *	4770
Green sunfish	*Lepomis cyanellus*	−4.702 (−4.820, −4.584)	−3.155 (−3.194, −3.117)	2.993 (2.936, 3.049)	60 *	1613
Largemouth bass	*Micropterus salmoides*	−5.178 (−5.217, −5.140)	−3.407 (−3.423, −3.391)	3.152 (3.136, 3.168)	150 *	4448
Pumpkinseed	*Lepomis gibbosus*	−4.998 (−5.050, −4.946)	−3.220 (−3.237, −3.203)	3.157 (3.132, 3.182)	50 *	5164
Smallmouth bass	*Micropterus dolomieu*	−5.302 (−5.321, −5.282)	−3.474 (−3.482, −3.466)	3.192 (3.184, 3.200)	150 *	19,325
Cottidae						
Columbia slimy sculpin	*Uranidea* sp. *cf. cognata* ‡	−5.488 (−6.065, −4.907)	−3.529 (−3.701, −3.356)	3.286 (2.994, 3.574)	90	260
Rocky mountain sculpin	*Uranidea* sp. *cf. bairdii* ‡	−5.012 (−5.020, −5.004)	−3.433 (−3.437, −3.430)	3.015 (3.012, 3.018)	80	43,717
Cyprinidae						
Common carp	*Cyprinus carpio*	−4.787 (−4.800, −4.773)	−3.280 (−3.287, −3.273)	2.964 (2.959, 2.969)	200 *	33,650

Table 2. *Cont.*

		Intercept (a')			Minimal Total Length	
Species	**Scientific Name**	**Metric**	**English**	**Slope (b)**	**(mm)**	***n***
Esocidae						
Northern pike	*Esox lucius*	−5.618 (−5.636, −5.600)	−3.839 (−3.848, −3.830)	3.158 (3.151, 3.164)	100 *	17,788
Tiger muskellunge	*Esox masquinongy x lucius*	−6.009 (−6.107, −5.911)	−4.041 (−4.090, −3.993)	3.292 (3.257, 3.327)	240 *	365
Hiodontidae						
Goldeye	*Hiodon alosoides*	−4.834 (−4.857, −4.810)	−3.399 (−3.409, −3.388)	2.913 (2.903, 2.922)	100	26,257
Ictaluridae						
Black bullhead	*Ameiurus melas*	−5.174 (−5.233, −5.115)	−3.401 (−3.424, −3.378)	3.154 (3.128, 3.179)	130 *	3157
Stonecat	*Noturus flavus*	−5.038 (−5.126, −4.948)	−3.467 (−3.501, −3.433)	3.009 (2.970, 3.049)	90	2609
Yellow bullhead	*Ameiurus natalis*	−5.442 (−5.531, −5.353)	−3.528 (−3.564, −3.491)	3.254 (3.217, 3.291)	60 *	1462
Leuciscidae						
Flathead chub	*Platygobio gracilis*	−4.453 (−4.561, −4.345)	−3.257 (−3.294, −3.219)	2.743 (2.693, 2.793)	100	3146
Golden shiner	*Notemigonus crysoleucas*	−4.261 (−4.398, −4.123)	−3.117 (−3.166, −3.067)	2.706 (2.642, 2.768)	50 *	454
Lake chub	*Couesius plumbeus*	−4.760 (−5.002, 4.517)	−3.331 (−3.402, −3.260)	2.908 (2.785, 3.031)	50	275
Longnose dace	*Rhinichthys cataractae*	−4.703 (−5.207, 4.197)	−3.338 (−3.506, −3.169)	2.863 (2.623, 3.102)	110	303
Northern pikeminnow	*Ptychocheilus oregonensis*	−5.630 (−5.655, 5.604)	−3.753 (−3.765, −3.742)	3.227 (3.217, 3.237)	250 *	10,663
Peamouth	*Mylocheilus caurinus*	−5.552 (−5.569, 5.536)	−3.718 (−3.725, −3.711)	3.197 (3.190, 3.204)	100	45,476
Redside shiner	*Richardsonius balteatus*	−5.864 (−5.997, 5.730)	−3.723 (−3.768, −3.677)	3.416 (3.353, 3.478)	90	1463
Utah chub	*Gila atraria*	−5.155 (−5.176, 5.133)	−3.444 (−3.453, −3.436)	3.109 (3.100, 3.118)	90 *	15,394
Lotidae						
Burbot	*Lota lota*	−4.944 (−4.968, 4.920)	−3.540 (−3.551, −3.528)	2.891 (2.882, 2.900)	200 *	14,913
Percidae						
Sauger	*Sander canadensis*	−5.606 (−5.628, 5.583)	−3.774 (−3.785, −3.764)	3.195 (3.186, 3.204)	70 *	15,293
Walleye	*Sander vitreus*	−5.688 (−5.695, 5.681)	−3.780 (−3.784, −3.777)	3.249 (3.247, 3.252)	150 *	73,814
Yellow perch	*Perca flavescens*	−5.507 (−5.518, 5.496)	−3.573 (−3.578, −3.569)	3.268 (3.263, 3.273)	100 *	94,512
Polyodontidae						
Paddlefish †	*Polyodon spathula*					
Overall		−7.010 (−7.090, 6.929)	−4.424 (−4.467, −4.381)	3.732 (3.705, 3.758)	280 *	7200
Female		−5.274 (−5.481, 5.066)	−3.480 (−3.592, −3.367)	3.169 (3.101, 3.236)	280 *	3785
Male		−4.530 (−4.692, 4.366)	−3.119 (−3.205, −3.032)	2.896 (2.841, 2.950)	280 *	3,379
Salmonidae						
Arctic grayling	*Thymallus arcticus*	−5.696 (−5.721, 5.671)	−3.781 (−3.792, −3.770)	3.254 (3.244, 3.265)	150 *	14,668
Brook trout	*Salvelinus fontinalis*	−5.248 (−5.256, 5.240)	−3.527 (−3.530, −3.524)	3.117 (3.113, 3.120)	120 *	84,064
Brown trout	*Salmo trutta*					
Lentic		−5.133 (−5.161, 5.105)	−3.510 (−3.523, −3.498)	3.046 (3.035, 3.057)	140 *	6381
Lotic		−4.783 (−4.786, 4.781)	−3.353 (−3.354, −3.352)	2.910 (2.909, 2.911)	140 *	841,787
Bull trout	*Salvelinus confluentus*	−5.125 (−5.133, 5.117)	−3.525 (−3.528, −3.522)	3.030 (3.027, 3.034)	120 *	26,930
Cisco	*Coregonus artedi*	−5.513 (−5.529, −5.498)	−3.677 (−3.684, −3.671)	3.198 (3.192, 3.205)	100 *	31,244
Golden trout	*O. mykiss aguabonita*	−4.713 (−4.834, −4.591)	−3.326 (−3.377, −3.274)	2.879 (2.829, 2.928)	120 *	972
Kokanee	*Oncorhynchus nerka*	−5.206 (−5.217, −5.195)	−3.549 (−3.554, −3.544)	3.071 (3.067, 3.075)	120 *	56,706
Lake trout	*Salvelinus namaycush*	−5.301 (−5.326, −5.276)	−3.635 (−3.647, −3.622)	3.078 (3.068, 3.087)	280 *	9714
Lake whitefish	*Coregonus clupeaformis*	−5.834 (−5.847, −5.820)	−3.858 (−3.864, −3.853)	3.297 (3.292, 3.302)	100 *	17,893
Mountain whitefish	*Prosopium williamsoni*	−5.226 (−5.234, −5.219)	−3.559 (−3.562, −3.556)	3.079 (3.076, 3.081)	140 *	170,721
Pygmy whitefish	*Prosopium coulterii*	−6.044 (−6.098, −5.990)	−3.916 (−3.934, −3.898)	3.406 (3.380, 3.432)	90	2965
Rainbow trout	*Oncorhynchus mykiss*					
Lentic		−4.906 (−4.926, −4.886)	−3.398 (−3.407, −3.389)	2.965 (2.957, 2.973)	120 *	18,967
Lotic		−4.841 (−4.844, −4.839)	−3.370 (−3.371, −3.369)	2.939 (2.938, 2.940)	120 *	780,901
Westslope cutthroat trout	*O. clarkii lewisi*					
Lentic		−5.322 (−5.344, −5.301)	−3.578 (−3.587, −3.569)	3.133 (3.124, 3.142)	130 *	12,006
Lotic		−5.086 (−5.092, −5.080)	−3.480 (−3.483, −3.478)	3.034 (3.032, 3.037)	130 *	94,520
Yellowstone cutthroat trout	*O. clarkii bouvieri*					
Lentic		−5.260 (−5.292, −5.227)	−3.577 (−3.591, −3.562)	3.089 (3.076, 3.102)	130 *	11,308
Lotic		−4.958 (−4.967, −4.949)	−3.421 (−3.425, −3.417)	2.985 (2.981, 2.989)	130 *	44,958
Sciaenidae						
Freshwater drum	*Aplodinotus grunniens*	−5.161 (−5.193, −5.130)	−3.454 (−3.468, −3.439)	3.107 (3.094, 3.119)	100 *	6155

Temporal and spatial variability in K_n for rainbow trout and brown trout was observed in two Montana rivers – these rivers were used as an example for illustrating the utility in assessing body condition. A decline in the average K_n was observed for both rainbow trout and brown trout in the Yellowstone River. Rainbow trout decreased from 1.11 in 1980 to 0.96 in 2020 while brown trout decreased from 1.12 in 1980 to 0.95 in 2020. Additionally, K_n for rainbow trout increased in the Missouri River from 0.97 in 1980 to 1.08 in 2020 while brown trout had a slight decline from 1.08 in 1980 to 1.02 in 2020.

4. Discussion

The analysis described here was conducted using data readily available from the statewide standardized web accessible database maintained by Montana Fish, Wildlife & Parks and contributes to the estimate of weight–length relationships for 26 species designated as game fishes in Montana statutes, 34 native fish species, and 19 invasive fish species for the state of Montana [21]. Due to varying growth based on sexual dimorphism and ecosystem type, separate models were developed by water type (e.g., lotic and lentic) for two species and two subspecies (e.g., brown trout *Salmo trutta*, rainbow trout *Oncorhynchus mykiss*, westslope cutthroat trout *Oncorhynchus clarkii lewisi*, and Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri*) and by sex for paddlefish *Polyodon spathula* [22–26]. The relative condition parameter estimates provide insight into growth patterns displayed in fishes and offers the ability to calculate a standardized condition factor for the 15 species that currently do not have standard-weight models developed (e.g., pygmy whitefish *Prosopium coulterii*).

Using the slope parameter, b, to describe the growth pattern of a fish, allometric growth ($b \neq 3$) represents a fish that has less girth as length increases ($b < 3$) or has an increase in plumpness as length increases ($b > 3$) [2] and occurs more commonly among fish species compared to isometric growth [27]. Isometric growth ($b = 3$) describes a fish that grows with an unchanging body form [28]. We identify six species (e.g., green sunfish *Lepomis cyanellus*, lake chub *Couesius plumbeus*, longnose dace *Rhinichthys cataractae*, shorthead redhorse *Moxostoma macrolepidotum*, Columbia slimy sculpin *Uranidea sp. cf. cognata*, and stonecat *Noturus flavus*) as having isometric growth based on the 95% credible intervals of b including 3.0.

Relative condition (K_n) requires parameters of a' and b to calculate W' ($\log_{10}W$) and offers fisheries biologists a quantitative approach to assess trends in fish condition as a potential indicator of environmental changes and general state of well-being at a regional level [1,2]. We used the years 1980 and 2020 for the Yellowstone River and Missouri River to demonstrate how comparisons of K_n can be used to assess condition both temporarily and spatially. Relative condition factor comparisons can be further informed with the addition of covariates such as discharge, which can affect fish condition factor by reducing refuge, altering prey abundance, and reducing water quality [29,30]. Furthermore, condition factors can be used as a tool to assess prey abundance or fish density, and the ability to detect changes in condition can help biologists make management recommendations concerning fish populations [1,2].

Thirty-nine species and sub-species will now have a standard weight (W_s) and W' relationship developed allowing for a regional, Montana, and range-wide index of comparison. One limitation of K_n is that a value of 1.0 is related to the average fish which may not describe a fish in good condition [2]. However, the relationship for W' was created from fish represented in a regional geographic area. Relative weight (W_r) which uses W_s to assess fish condition on a range wide scale can still be biased based on the geographic distribution and quantity of samples that define the W_s equation [31]. By using relative condition and relative weight, biologist can employ more tools to evaluate and monitor body condition of fishes.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/fishes8010028/s1. Figure S1: Scatter plot of $\log_{10}$weight–$\log_{10}$length for arctic grayling, bigmouth buffalo, black bullhead, black crappie, blue sucker, bluegill, brook trout, and brown trout where we propose W' parameters. Red line represents average fish in Montana as predicted from a Bayesian linear regression. Figure S2: Scatter plot of $\log_{10}$weight–$\log_{10}$length for bull trout, burbot, cisco, Columbia slimy sculpin, common carp, flathead chub, freshwater drum, golden shiner, and golden trout where we propose W' parameters. Red line represents average fish in Montana as predicted from a Bayesian linear regression. Figure S3: Scatter plot of $\log_{10}$weight–$\log_{10}$length for goldeye, green sunfish, kokanee, lake chub, lake trout, lake whitefish, largemouth bass, largescale sucker, and longnose dace where we propose W' parameters. Red line represents average fish in Montana as predicted from a Bayesian linear regression. Figure S4: Scatter plot of $\log_{10}$weight–$\log_{10}$length for longnose sucker, mountain sucker, mountain whitefish, northern pike, northern pikeminnow, paddlefish, and pallid sturgeon where we propose W' parameters. Red line represents average fish in Montana as predicted from a Bayesian linear regression. Figure S5: Scatter plot of $\log_{10}$weight–$\log_{10}$length for peamouth, pumpkinseed, pygmy whitefish, rainbow trout, redside shiner, river carpsucker, rocky mountain sculpin, and sauger where we propose W' parameters. Red line represents average fish in Montana as predicted from a Bayesian linear regression. Figure S6: Scatter plot of $\log_{10}$weight–$\log_{10}$length for shorthead redhorse, smallmouth bass, smallmouth buffalo, stonecat, tiger muskellunge, Utah chub, walleye, and westslope cutthroat trout where we propose W' parameters. Red line represents average fish in Montana as predicted from a Bayesian linear regression. Figure S7: Scatter plot of $\log_{10}$weight–$\log_{10}$length for white sturgeon, white sucker, yellow bullhead, yellow perch, and Yellowstone cutthroat trout where we propose W' parameters. Red line represents average fish in Montana as predicted from a Bayesian linear regression.

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