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LENGTH, MASS, AND CALORIFIC RELATIONSHIPS OF EVERGLADES ANIMALS

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ABSTRACT: *Meristic and calorific relationships were determined for aquatic animals from southern Florida. The relationships derived included wet mass to length (52 species, 2 families), dry mass to length (17 species), dry mass to wet mass (17 species), and calorific value (44 taxa). The analyses we present are the first available for most of the species. Such relationships can be used in estimating standing stock and energy flow in aquatic systems.*

KNOWLEDGE of the energy dynamics of populations is fundamental to understanding how ecosystems function (Paine, 1971). However, energy flow and energy standing stock are expensive and usually impractical to measure directly in that each application would require extensive collections and calorimetic determines (Richman and Slobodkin, 1960) of the specific material under study. More commonly, studies approach the problem indirectly by converting some measured property of the specimens to calorific content using average caloric density of the study material or more typically, of similar material described in the literature (Cummins and Wuycheck 1971). The most useful measured property is dry mass, which eliminates variability owing to water content. Wet mass is often measured instead of dry mass because it is easier and faster. When sample sizes are large or weighing is impractical, linear measurements are usually taken. Linear measurement may be total length or length of some body part. In many studies, linear measurements are the only ones possible or practicable. As an example, partially digested food items found in stomach samples are not amendable to direct and accurate measurement of mass. Because of such circumstances, mass-length regressions have proven to be convenient mechanisms for estimating mass. Once relationships among linear size, wet mass, dry mass, and caloric density are known, energetic relationships can then be explored.

Mass-length relationships are available for some terrestrial and aquatic organisms. Rogers and coworkers (1976, 1977), Smock (1980), and Sage (1982) have provided data for invertebrates. Carlander (1969, 1977) has compiled available relationships for freshwater fishes. Most information for North American fishes is from temperate areas. It is expected that relationships between mass and length would be different in subtropical climates such as south Florida. In this paper, we present meristic and calorific relationships for aquatic animals associated with the Everglades. Future studies can apply these relationships to estimate standing stock and energy flow in the Everglades, associated estuaries, and in other similar situations for which such relationships are not available.

METHODS—Common and scientific names of the animals follow Robins et al. (1980), Collins et al. (1978), Usinger (1973), Pennak (1978), and Voss (1976).

All specimens used in this study were collected in and near freshwater marshes and the estuaries of the southern Florida Everglades (Tabb et al., 1962, Loftus and Kushlan, 1985). Specimens were obtained during routine sampling programs and specific studies from 1977 to 1981 by using throw traps (Kushlan, 1981), rotenone, electrofishers, seines, cast nets, gill nets, and dip nets. Because of the diversity of trapping methods used and the extensive collecting effort, it is expected that the sample size obtained for each species is a reflection of its relative population level in the Everglades. Thus, the largest samples are of species that are most common in the Everglades, and we generally have small sample sizes of species that are rare, even though we specifically attempted to collect adequate numbers.

We preserved specimens in 10% formalin and stored them in 40% isopropanol prior to measuring. No linear shrinkage occurred in formalin of four test fish species (N = 20 per species).

We measured lengths to the nearest 0.5 mm. We determined the standard length of all fishes, except we measured total length of *Lepisosteus platyrhincus* and *Amia calva*. We measured the snout-vent length of amphibians, the total length of insects, and total length of crustaceans from the anterior point of rostrum to the terminus of the uropod. We measured the longest axis of the operculum for snails and weighed the wet tissue mass excluding the shell. We also measured the lengths of selected insect and crustacean body parts that were commonly found in predator stomach samples and related these to the mass of entire specimens.

We measured wet mass to the nearest 0.001 g on a Mettler H-30 balance after blotting specimens dry to remove excess liquid. We measured specimens having a mass greater than 160 g on a top loading Torsion PL-800 balance. We determined dry mass by weighing the specimen on the Mettler H-30 balance after drying at 50-60°C. for 24 hrs.

We obtained calorific values in triplicate from a single sample of many individuals using a Parr adiabatic calorimeter, after drying to constant mass at 60°C. These values include ash components.

DATA TREATMENT—The mass-length relationshps of fishes (Ricker, 1975) and insects (Rogers et al., 1977; Smock, 1980) fit a parabolic or power curve (Eqn. 1).

$$Y = {}_{B_0}X^{B_1} \qquad (1)$$

Where Y = mass, X = length, and B_0 and B_1 are constants for a population. This relationship was linearized as $\log Y = \log B_0 + B_1 \log X$. We derived our relationships by the least squares (LS) regression method (Kleinbaum and Kupper, 1978) using the SPSS statistical package (Nie et al., 1975) on a Univac 1100. We also generated scatter diagrams of length and weight data points for each species. Although not included in this paper, they are available from the authors.

Ricker (1973) advocated use of the geometric mean functional regression (GMFR) method for mass-length applications. Jolicoeur (1975) and Sprent and Dolby (1980) provided convincing arguments against its use in favor of the standard LS method. If desirable, the GMF regression can be derived from the data and statistics we present in this paper (Ricker, 1973).

Our symbolism follows Kleinbaum and Kupper (1978): B_0 is the intercept; B_1 is the slope; N is the number of observations; Y is the dependent variable; Y is the predicted value of Y; X is the in-

TABLE 1. Data used to generate mass (Y), in g, to length (X), in mm, relationship for Everglades animals.

Species	X^1_i	Length (mm) $\overline{X}$	S_X	(Min.-Max.)	Y^1_i	Mass (g) $\overline{Y}$	S_y	(Min.-Max.)	N
CRUSTACEA									
Procambarus alleni	X_2	31.1	14.45	(6.5- 85.0)	Y_1	1.050	1.694	(0.005 - 17.336)	971
	X_5	22.5	6.81	(11.0- 39.0)	Y_1	2.651	2.807	(0.260 - 13.590)	107
	X_7	15.8	5.48	(8.0- 32.0)	Y_1	2.656	2.805	(0.260 - 13.590)	107
	X_6	11.2	5.51	(5.0- 36.0)	Y_1	2.665	2.817	(0.260 - 13.590)	106
Palaemonetes paludosus	X_2	23.7	5.07	(12.0- 33.0)	Y_1	0.110	0.074	(0.009 - 0.347)	50
Alphaeidae	X_7	10.9	1.99	(6.8- 14.1)	Y_1	1.303	0.680	(0.260 - 2.660)	26
INSECTA									
Libelluidae (naiad)	X_2	18.2	4.01	(9.0- 27.0)	Y_1	0.215	0.113	(0.037 - 0.479)	37
Belostoma sp.	X_2	19.3	4.07	(11.5- 24.5)	Y_1	0.212	0.105	(0.050 - 0.409)	44
	X_3	3.7	0.64	(2.5- 4.8)	Y_1	0.212	0.105	(0.050 - 0.409)	44
	X_4	3.5	0.90	(2.0- 4.8)	Y_1	0.212	0.105	(0.050 - 0.409)	44
	X_5	9.5	2.11	(5.3- 12.3)	Y_1	0.209	0.105	(0.050 - 0.409)	43
MOLLUSCA									
Pomacea paludosa	X_9	21.7	3.58	(13.0- 32.0)	Y_3	3.965	2.016	(0.832 - 12.041)	39
OSTEICHTHYES									
Amia calva	X_2	467.0	135.84	(77.5-644.0)	Y_1	1307.29	934.22	(6.585 -3150.00)	22
Lepisosteus platyrhincus	X_2	287.7	121.50	(55.5-617.0)	Y_1	182.47	220.34	(0.612 -1240.00)	41
Elops saurus	X_1	333.6	58.46	(253.1-464.0)	Y_1	346.66	172.87	(163.87 - 675.49)	13
Notemigonus crysoleucas	X_1	46.3	22.95	(17.5-107.0)	Y_1	3.232	5.160	(0.060 - 20.557)	88
	X_1	32.0	8.54	(18.0- 52.0)	Y_2	0.152	0.109	(0.021 - 0.464)	28
Notropis petersoni	X_1	26.7	6.16	(16.5- 36.5)	Y_1	0.287	0.209	(0.044 - 0.705)	45
Erimyzon sucetta	X_1	44.6	56.50	(6.5-256.0)	Y_1	22.14	63.54	(0.003 - 417.23)	97
	X_1	20.0	6.21	(14.0- 30.0)	Y_2	0.023	0.023	(0.005 - 0.069)	8
Ictalurus natalis	X_1	83.1	44.43	(15.5-230.0)	Y_1	28.98	55.24	(0.096 - 307.64)	169
	X_1	62.0	23.08	(16.0-119.0)	Y_2	1.719	2.469	(0.011 - 11.972)	59
Noturus gyrinus	X_1	35.0	12.28	(14.0- 65.0)	Y_1	1.388	1.476	(0.053 - 6.240)	57
Clarias batrachus	X_1	136.8	56.59	(10.5-318.5)	Y_1	40.46	57.48	(0.025 - 343.75)	106
Bagre marinus	X_1	282.9	71.27	(69.0-404.1)	Y_1	464.40	262.00	(4.663 -1181.75)	56
Opsanus beta	X_1	81.1	21.46	(27.0-132.0)	Y_1	14.92	11.13	(0.004 - 56.80)	189
Strongylura notata	X_1	113.7	54.05	(52.0-246.2)	Y_1	3.89	6.84	(0.20 - 31.42)	20

TABLE 1. Continued

Species	X'_i	Length (mm) $\overline{X}$	S_X	(Min.-Max.)	Y'_i	Mass (g) $\overline{Y}$	S_y	(Min.-Max.)	N
Adinia xenica	X_1	27.8	4.36	(17.0- 34.5)	Y_1	0.689	0.322	(0.137 - 1.414)	40
Cyprinodon variegatus	X_1	18.8	6.46	(7.0- 37.5)	Y_1	0.319	0.369	(0.002 - 2.186)	434
	X_1	16.4	5.23	(8.0- 34.5)	Y_2	0.033	0.044	(0.0008- 0.368)	212
Floridichthlys carpio	X_1	29.8	8.05	(17.0- 44.0)	Y_1	1.111	0.873	(0.143 - 2.915)	25
Fundulus chrysotus	X_1	21.1	10.11	(4.5- 73.0)	Y_1	0.358	0.608	(0.0003- 8.474)	3460
	X_1	21.6	12.30	(4.5- 62.0)	Y_2	0.089	0.148	(0.0002- 1.205)	559
Fundulus confluentus	X_1	24.8	11.08	(9.5- 65.0)	Y_1	0.521	0.732	(0.007 - 6.313)	600
	X_1	27.2	11.57	(9.5- 65.0)	Y_2	0.134	0.192	(0.003 - 1.100)	162
Fundulus grandis	X_1	69.3	17.01	(44.0-106.0)	Y_1	9.936	8.684	(1.460 - 29.265)	28
Fundulus seminolis	X_1	72.2	14.50	(48.0- 94.0)	Y_1	5.848	3.171	(1.560 - 12.049)	13
Jordanella floridae	X_1	18.8	5.90	(5.0- 40.0)	Y_1	0.313	0.303	(0.002 - 2.488)	2426
	X_1	20.5	7.48	(5.0- 40.0)	Y_2	0.076	0.078	(0.0002- 0.626)	757
Lucania goodei	X_1	17.6	4.47	(2.0- 41.5)	Y_1	0.124	0.091	(0.0005- 1.434)	9072
	X_1	18.1	5.05	(6.0- 34.0)	Y_2	0.025	0.021	(0.0003- 0.194)	1140
Lucania parva	X_1	20.1	4.92	(8.0- 35.0)	Y_1	0.194	0.145	(0.012 - 0.902)	60
Gambusia affinis	X_1	15.4	4.45	(4.5- 41.0)	Y_1	0.085	0.084	(0.0005- 1.340)	13371
	X_1	16.7	5.00	(6.0- 41.0)	Y_2	0.024	0.027	(0.0002- 0.414)	2774
Heterandria formosa	X_1	11.9	2.24	(4.0- 21.0)	Y_1	0.039	0.025	(0.0003- 0.219)	8297
	X_1	12.2	2.61	(5.0- 19.0)	Y_2	0.008	0.006	(0.0001- 0.047)	1191
Poecilia latipinna	X_1	18.4	6.22	(7.0- 48.0)	Y_1	0.240	0.295	(0.004 - 2.978)	5193
	X_1	19.5	9.35	(7.0- 48.0)	Y_2	0.079	0.114	(0.001 - 0.717)	778
Labidesthes sicculus	X_1	40.9	8.87	(26.0- 57.0)	Y_1	0.518	0.345	(0.114 - 1.506)	33
Menidia beryllina	X_1	41.7	6.96	(20.0- 61.0)	Y_1	0.799	0.396	(0.084 - 2.583)	87
Elassoma evergladei	X_1	17.0	2.96	(7.0- 26.0)	Y_1	0.155	0.075	(0.008 - 0.645)	322
	X_1	16.4	3.14	(9.0- 22.0)	Y_2	0.027	0.014	(0.002 - 0.062)	74
Enneacanthus gloriosus	X_1	22.2	7.10	(8.0- 46.0)	Y_1	0.508	0.557	(0.011 - 3.749)	354
	X_1	21.1	5.87	(10.5- 34.5)	Y_2	0.072	0.063	(0.005 - 0.281)	111
Lepomis gulosus	X_1	88.7	31.73	(9.5-172.0)	Y_1	36.76	35.67	(0.020 - 221.69)	188
	X_1	68.3	45.03	(19.0-116.0)	Y_2	5.666	7.078	(0.025 - 16.047)	5
Lepomis macrochirus	X_1	76.0	24.43	(21.5-170.0)	Y_1	21.214	27.370	(0.194 - 183.00)	92

Lepomis marginatus	X_1	34.7	11.71	(8.0- 66.0)	Y_1	2.069	2.055	(0.012 - 14.293)	341
	X_1	26.3	12.04	(8.0- 54.0)	Y_2	0.249	0.393	(0.002 - 1.562)	37
Lepomis microlophus	X_1	76.6	37.89	(18.0-188.0)	Y_1	30.79	57.18	(0.220 - 331.66)	60
	X_1	84.1	71.30	(26.5-188.0)	Y_2	21.843	41.362	(0.094 - 83.870)	4
Lepomis punctatus	X_1	39.4	26.93	(7.5-132.0)	Y_1	7.009	14.747	(0.008 - 103.740)	512
	X_1	31.0	21.11	(8.5-104.0)	Y_2	0.773	1.932	(0.002 - 11.442)	111
Lepomis[2]	X_1	50.6	32.58	(7.5-188.0)	Y_2	12.58	25.936	(0.008 - 331.66)	1193
Sunfish[2]	X_1	44.1	31.18	(7.5-188.0)	Y_2	9.82	23.333	(0.008 - 331.66)	1547
Micropterus salmoides	X_1	147.7	54.54	(18.0-270.0)	Y_1	103.99	113.84	(0.106 - 579.10)	84
Etheostoma fusiforme	X_1	33.2	6.41	(22.0- 43.0)	Y_1	0.422	0.254	(0.090 - 0.964)	12
Eucinostomus gula	X_1	48.0	8.39	(36.0- 63.0)	Y_1	2.875	1.636	(0.955 - 6.464)	24
Haemulon plumieri	X_1	59.9	13.21	(42.5- 83.5)	Y_1	6.200	3.930	(1.728 - 14.129)	25
Lagodon rhomboides	X_1	63.0	15.31	(37.5- 82.0)	Y_1	7.132	3.630	(1.596 - 13.711)	25
Bairdiella chrysoura	X_1	67.1	13.66	(38.8- 80.1)	Y_1	7.10	3.00	(1.24 - 10.26)	12
Cichlasoma bimaculatum	X_1	60.4	11.42	(40.0- 88.5)	Y_1	13.041	6.951	(3.550 - 33.500)	42
Fish[2]	X_1	17.3	9.72	(2.00-188.0)	Y_1	0.481	4.691	(0.0001- 331.66)	44724
Amphibia									
Pseudobranchus striatus	X_8	46.0	19.55	(9.5- 85.0)	Y_1	0.577	0.593	(0.013 - 2.020)	17
Siren lacertina	X_8	117.9	121.42	(16.0-364.0)	Y_1	88.53	183.16	(0.043 - 614.85)	14
Notopthalmus viridescens	X_8	21.8	4.84	(16.0- 32.0)	Y_1	0.358	0.181	(0.142 - 0.746)	17
Acris gryllus (adult)	X_8	14.9	2.94	(10.5- 19.0)	Y_1	0.400	0.227	(0.145 - 0.787)	18
Rana grylio (tadpole)	X_8	28.3	9.39	(8.5- 45.0)	Y_1	4.503	3.134	(0.091 - 11.064)	54
Rana sphenocephala (tadpole)	X_8	15.7	8.80	(4.0- 36.0)	Y_1	1.209	1.518	(0.004 - 4.486)	40

[1]Length (X_i): X_1 = standard length; X_2 = total length; X_3 = head length; X_4 = thorax length; X_5 = abdomen length; X_6 = cheliped (claw) length; X_7 = carapace length; X_8 = snout-vent length; X_9 = operculum length. Mass (Y_i): Y_1 = wet mass; Y_2 = dry mass, and Y_3 = wet tissue mass.
[2]See Results and Discussion section of text for species included in these categories.

dependent variable; Y is the mean of all inputed Y values; X is the mean of all inputed X values; S is any standard deviation; S_X is the standard deviation of inputed X values; S_Y is the standard deviation of inputed Y values; S_{B_1} is the standard error of the slope; SSE is residual sum of squares, $\Sigma(Y_{\hat{i}}-Y_i)^2$; SSY-SSE is sum of squares due to regression; $S_{Y/X}$ is the standard error of the estimate $(SSE/(N-2))^{1/2}$; MSE is the mean square error of the residuals, SSE/(N-2); r is the sample correlation coefficient; and F is the value of the F ratio of the sums of squares. We used $\alpha = 0.01$, and all regressions were significant at that level.

Results and Discussion—We derived allometric relationships for 52 species and 2 family groups of Everglades animals (Table 1). Sample size exceeded 13,000 specimens for the most common species. For 6 other species, we had over 1000 specimens each. However, for some rare species, we had only a few specimens, and we urge caution in using the relationships derived from these data. The distribution and range of sizes for specimens are representative of the characteristic sizes of animals usually found in the Everglades and adjacent estuaries. The minimum and maximum sizes used in deriving the relationships (Table 1) should be considered by users. At either end of the size distribution error increases, so we do not advocate extrapolating these relationships beyond the data used.

Wet Mass—Length Relationships—We derived 63 wet mass (Y_1) to length relationships for 53 species or higher taxa of Everglades animals (Table 2). Most are exceptionally good fits, and only one had a correlation coefficient below 0.90. As a result, estimates can be made of the wet mass of additional specimens having lengths within the ranges of those presented for each species in Table 1. Examination of plots of the residuals versus predicted values showed no substantial deviations from assumptions of homoscedasticity. Untransformed linear models in all cases gave poorer fits than log transformed ones. It should be noted that retransformation of the regression statistics must be done with caution (Beauchamp and Olson, 1973).

The slope B_1 of a transformed length-mass curve is theoretically about 3.0 for animals (Carlander, 1977) to the extent that weight varies roughly as a cubic function of linear measurements. For our data, B_1 ranges from 1.2 to 5.0 for fishes. This variability suggests that B_1 may be interpretable in some cases as a condition factor (LeCren, 1951; Zaret, 1980).

In some studies, it is difficult to identify a fish to species. Therefore, we have derived relationships that combine certain similarly appearing species. "*Lepomis*" (n = 1193) included *Lepomis gulosus*, *L. macrochirus*, *L. microlophus*, *L. punctatus*, and *L. marginatus*. "Sunfish" (n = 1527) included the above species plus *Enneacanthus gloriosus*. "Fish" included the common fishes of the Everglades (N = 44,724), i.e., the 6 species above, plus *Gambusia affinis*, *Poecilia latipinna*, *Cyprinodon variegatus*, *Fundulus confluentus*, *Jordanella floridae*, *Heterandria formosa*, *Lucania goodei*, and *Fundulus chrysotus*.

Mass-length relationships for most species that we examined have been unavailable previously. We know of published wet mass-length data for only 7 of our species: *Ictalurus natalis* (Carlander, 1969); *Lepomis gulosus*

TABLE 2. Relationship of mass (Y), in g, to length (X), in mm, of Everglades animals.[1]

	$\log \hat{Y}_i$	Equation		$\log \hat{X}_i$	r	S_{β_1}	$S_{Y/X}$	SSY-SSE	SSE	MSE
	i	a	b	i						
Procambarus alleni	1	−4.067	2.926	2	0.970	0.023	0.152	354.647	22.271	0.023
	1	−3.929	3.118	5	0.980	0.062	0.083	17.488	0.731	0.007
	1	−3.090	2.823	7	0.974	0.064	0.094	17.287	0.928	0.009
	1	−1.862	2.074	6	0.913	0.091	0.170	15.174	3.024	0.029
Palaemonetes paludosus	1	−5.597	3.321	2	0.984	0.087	0.061	5.463	0.179	0.004
Alphaeidae	1	−3.383	3.320	7	0.954	0.213	0.092	2.058	0.202	0.008
Libellulidae (naiad)	1	−3.687	2.364	2	0.927	0.162	0.101	2.186	0.359	0.010
Belostoma sp.	1	−3.837	2.430	2	0.940	0.138	0.090	2.529	0.344	0.008
	1	−2.426	2.982	3	0.908	0.212	0.110	2.368	0.505	0.012
	1	−1.756	1.941	4	0.898	0.147	0.115	2.316	0.557	0.013
	1	−2.879	2.204	5	0.890	0.176	0.119	2.220	0.583	0.014
Pomacea paludosa	3	−3.267	2.864	9	0.949	0.157	0.072	1.724	0.191	0.005
Amia calva	1	−4.971	2.989	2	0.992	0.083	0.074	7.141	0.110	0.006
Lepisosteus platyrhincus	1	−6.344	3.408	2	0.990	0.077	0.125	30.644	0.608	0.016
Elops saurus	1	−4.260	2.683	1	0.951	0.263	0.066	0.455	0.048	0.004
Notemigonus crysoleucas	1	−4.974	3.104	1	0.993	0.039	0.076	36.992	0.495	0.006
	2	−5.434	3.009	1	0.961	0.169	0.106	3.565	0.291	0.011
Notropis petersoni	1	−5.540	3.443	1	0.993	0.063	0.043	5.444	0.078	0.002
Erimyzon sucetta	1	−5.236	3.305	1	0.998	0.022	0.084	165.182	0.672	0.007
	2	−6.084	3.316	1	0.996	0.127	0.044	1.340	0.012	0.002
Ictalurus natalis	1	−4.736	3.046	1	0.995	0.023	0.075	95.670	0.945	0.006
	2	−6.062	3.385	1	0.992	0.056	0.077	21.535	0.341	0.006
Noturus gyrinus	1	−4.552	2.947	1	0.998	0.062	0.074	12.348	0.301	0.006
Clarias batrachus	1	−4.844	2.920	1	0.991	0.038	0.081	39.324	0.689	0.007
Bagre marinus	1	−4.848	3.037	1	0.985	0.073	0.076	10.019	0.309	0.006
Opsanus beta	1	−4.557	2.949	1	0.852	0.133	0.225	24.876	9.425	0.050
Strongylura notata	1	−4.769	2.500	1	0.949	0.196	0.167	4.566	0.503	0.028
Adinia xenica	1	−4.987	3.319	1	0.995	0.055	0.025	2.313	0.028	0.0006
Cyprinodon variegatus	1	−5.204	3.543	1	0.981	0.034	0.107	125.403	4.983	0.012
	2	−6.152	3.684	1	0.983	0.048	0.097	55.449	1.979	0.009

TABLE 2. Continued

	$\log \hat{Y}_i$	Equation		$\log \hat{X}_i$	r	S_{β_1}	$S_{Y/X}$	SSY-SSE	SSE	MSE
	i	a	b	i						
Floridichthys carpio	1	−4.750	3.186	1	0.997	0.054	0.032	3.585	0.024	0.001
Fundulus chrysotus	1	−4.876	3.131	1	0.989	0.008	0.097	1418.545	32.335	0.009
	2	−5.814	3.278	1	0.989	0.021	0.127	402.588	9.039	0.016
Fundulus confluentus	1	−4.526	2.887	1	0.978	0.025	0.118	179.696	8.299	0.014
	2	−5.545	3.094	1	0.983	0.046	0.110	54.815	1.952	0.012
Fundulus grandis	1	−5.297	3.366	1	0.988	0.101	0.054	3.170	0.075	0.003
Fundulus seminolis	1	−4.521	2.822	1	0.987	0.140	0.045	0.815	0.022	0.002
Jordanella floridae	1	−4.643	3.145	1	0.981	0.013	0.088	485.967	18.819	0.008
	2	−5.782	3.406	1	0.985	0.022	0.109	294.287	8.926	0.012
Lucania goodei	1	−4.782	3.042	1	0.975	0.007	0.082	1190.680	61.467	0.007
	2	−5.788	3.237	1	0.965	0.026	0.120	222.868	16.534	0.014
Lucania parva	1	−4.670	2.980	1	0.985	0.068	0.063	7.522	0.229	0.004
Gambusia affinis	1	−4.786	3.032	1	0.971	0.006	0.095	1990.057	120.110	0.009
	2	−5.882	3.368	1	0.970	0.016	0.116	590.585	37.030	0.013
Heterandria formosa	1	−4.837	3.130	1	0.943	0.012	0.094	587.766	72.904	0.009
	2	−5.901	3.435	1	0.932	0.039	0.135	144.654	21.716	0.018
Poecilia latipinna	1	−4.750	3.142	1	0.985	0.008	0.080	1042.818	32.985	0.006
	2	−5.993	3.522	1	0.988	0.020	0.114	416.256	10.129	0.013
Labidesthes sicculus	1	−5.290	3.065	1	0.988	0.085	0.047	2.864	0.068	0.002
Menidia beryllina	1	−5.079	3.052	1	0.992	0.043	0.031	4.899	0.082	0.001
Elassoma evergladei	1	−4.581	3.031	1	0.967	0.045	0.068	21.067	1.463	0.005
	2	−5.544	3.225	1	0.969	0.098	0.076	6.390	0.420	0.006
Enneacanthus gloriosus	1	−4.624	3.113	1	0.989	0.025	0.067	68.748	1.599	0.004
	2	−5.660	3.321	1	0.984	0.058	0.077	18.957	0.642	0.006
Lepomis gulosus	1	−4.889	3.224	1	0.991	0.031	0.091	88.860	1.539	0.008
	2	−6.112	3.512	1	0.991	0.076	0.054	6.335	0.009	0.003
Lepomis macrochirus	1	−5.100	3.325	1	0.990	0.049	0.069	21.607	0.432	0.005
Lepomis marginatus	1	−4.811	3.225	1	0.995	0.017	0.052	94.904	0.915	0.003
	2	−5.900	3.490	1	0.994	0.066	0.082	18.712	0.235	0.007
Lepomis microlophus	1	−4.876	3.198	1	0.996	0.036	0.062	29.853	0.221	0.004
	2	−5.993	3.478	1	0.999	0.062	0.037	4.475	0.003	0.001

Lepomis punctatus	1	−4.807	3.222	1	0.996	0.013	0.081	405.224	3.351	0.007
	2	−5.935	3.498	1	0.996	0.029	0.078	89.597	0.668	0.006
Lepomis[3]	1	−4.699	3.139	1	0.996	0.008	0.082	939.299	7.929	0.007
Sunfish[3]	1	−4.648	3.112	1	0.996	0.007	0.080	1215.720	9.884	0.006
Micropterus salmoides	1	−5.203	3.244	1	0.995	0.035	0.062	32.978	0.314	0.004
Etheostoma fusiforme	1	−5.686	3.453	1	0.990	0.158	0.046	1.035	0.022	0.002
Eucinostomus gula	1	−4.843	3.128	1	0.984	0.121	0.043	1.250	0.041	0.002
Haemulon plumieri	1	−4.574	2.986	1	0.983	0.117	0.055	1.964	0.070	0.003
Lagodon rhomboides	1	−3.463	2.377	1	0.986	0.084	0.047	1.779	0.051	0.002
Fish[3]	1	−4.939	3.214	1	0.976	0.003	0.1217	13092.323	662.273	0.148
Bairdiella chrysoura	1	−4.115	2.700	1	0.974	0.197	0.066	0.812	0.043	0.004
Cichlasoma bimaculatum	1	−4.114	2.912	1	0.990	0.064	0.034	2.469	0.047	0.001
Pseudobranchus striatus	1	−4.345	2.389	8	0.988	0.096	0.086	4.538	0.111	0.007
Siren lacertina	1	−5.165	3.058	8	0.998	0.050	0.080	23.623	0.077	0.006
Notopthalmus viridescens	1	−3.676	2.390	8	0.975	0.140	0.052	0.780	0.040	0.003
Acris gryllus (adult)	1	−3.903	2.943	8	0.976	0.164	0.059	1.134	0.056	0.004
Rana grylio (tadpole)	1	−3.869	3.034	8	0.988	0.065	0.085	16.062	0.379	0.007
Rana sphenocephala (tadpole)	1	−4.231	3.334	8	0.991	0.073	0.120	30.010	0.550	0.014

[1]log $\hat{X}_i$: X_1 = standard length; X_2 = total length; X_3 = head length; X_4 = thorax length; X_5 = abdomen length; X_6 = cheliped (claw) length; X_7 = carapace length; X_8 = snout-vent length; X_9 = operculum length. log $\hat{Y}_i$: Y_1 = wet mass; Y_2 = dry mass; Y_3 = tissue mass; r = sample correlation coefficient; S_{β_1} = standard error of the slope; Y/X = standard error of the regression line; SSY-SSE = sum of squares due to regression; SSE = residual sum of squares; MSE = mean square of residual.

[2]All equations are significant at $\alpha = 0.01$.

[3]See Results and Discussion section of text for species included in these categories.

(Carlander, 1977); *Lepomis macrochirus* (Carlander, 1977); *Lepomis punctatus* (Caldwell et al., 1957); *Micropterus salmoides* (Carlander, 1977; Beckman, 1945); *Notemigonus crysoleucas* (Carlander, 1977); and *Haemulon pulmieri* (Manooch, 1976). Herke (1959) studied several of these species in Florida. Eidman (1967) calculated regressions from *Strongylura* spp. specimens from the Everglades estuary, but *S. notata*, the species we analyzed, may have comprised only 20% of that sample (Roessler, 1970). Comparison of the slopes and intercepts of our equations with those previously available showed no consistently meaningful patterns. For the most part, unknown variability in sampling, habitat, and other factors make such comparisons of little value in the present context.

Dry Mass—We generated a relationship between dry mass (Y_2) and the length for 17 fish species (Table 1, 2). All regressions were significant and can be used with confidence to predict dry mass from the applicable linear measurement.

It is often desirable to estimate dry mass from wet mass of a specimen, and we were able to derive such relationships for 17 Everglades fishes (Table 3). Sample sizes ranged to over 2000 individuals, but in several instances included only a few specimens. We again urge caution in the application of these latter equations. The relationship (Table 4) between wet and dry mass is linear; transformations did not improve the fit. For most species, length was a better estimator of dry mass than was wet mass, no doubt because of the variable water content of wet specimens. For the fishes *Lucania goodei*, *Enneacanthus gloriosus*, *Lepomis gulosus*, *Lepomis marginatus*, and *Lepomis microlophus*, wet mass was a better estimator of dry mass than was length.

Calorific Content—The energy content of an animal can be estimated from dry weight by suitable conversion factors. We have determined the calorific content of 44 animal taxa from southern Florida (Table 5). We have also merged these into more encompassing taxa thereby providing values of general utility. Calorific values for most taxa ranged from 3 kcal/g of dry weight to 6 kcal/g of dry weight. Values for molluscs were lower because of the inclusion of shell material. Golley (1961) obtained similar results with crabs. Overall, the caloric content of animals measured was 4.95 kcal/g of dry weight, similar to the value generally used for animal material (Golley, 1961; Slobodkin, 1962).

Conclusions—From 1977 to 1981, over 70,000 aquatic animals were collected in the Everglades and estuarine habitats of southern Florida. The meristic and calorific relationships determined were based on large sample sizes for most of the 52 species. The strengths of the relationships presented are the most complete available for nearly all of the species and the only ones available for southern Florida. Use of the equations should be constrained by the size ranges of the specimens used. Equations for the new species with small sample sizes especially should be used cautiously, and their recalculation using additional specimens is desirable.

TABLE 3. Data used to generate dry mass (Y), in g, by wet mass (X), in g, relationships for Everglades animals.

Species	Wet Mass (g)			Dry Mass (g)			Sample Size
	$\bar{X}$	S_X	(Min-Max)	$\bar{Y}$	S_y	(Min-Max)	
Notemigonus crysoleucas	0.603	0.392	(0.100 - 1.440)	0.152	0.109	(0.021 - 0.464)	8
Erimyzon sucetta	0.139	0.120	(0.038 - 0.379)	0.023	0.023	(0.005 - 0.069)	8
Ictalurus natalis	7.740	10.655	(0.104 - 60.880)	1.719	2.469	(0.011 -11.972)	60
Cyprinodon variegatus	0.180	0.212	(0.002 - 1.625)	0.033	0.044	(0.0008- 0.368)	212
Fundulus chrysotus	0.451	0.736	(0.0003- 5.143)	0.089	0.148	(0.0002- 1.205)	559
Fundulus confluentus	0.646	0.880	(0.016 - 6.313)	0.134	0.192	(0.003 - 1.100)	162
Jordanella floridae	0.413	0.385	(0.002 - 2.490)	0.076	0.078	(0.0002- 0.626)	757
Lucania goodei	0.127	0.098	(0.002 - 0.770)	0.025	0.021	(0.0003- 0.194)	1140
Gambusia affinis	0.102	0.106	(0.0005- 1.340)	0.024	0.027	(0.0002- 0.414)	2774
Heterandria formosa	0.039	0.028	(0.0003- 0.175)	0.008	0.006	(0.0001- 0.047)	1191
Poecilia latipinna	0.349	0.463	(0.0066- 2.978)	0.079	0.114	(0.001 - 0.717)	778
Elassoma evergladei	0.146	0.075	(0.021 - 0.319)	0.027	0.014	(0.002 - 0.062)	74
Enneacanthus gloriosus	0.426	0.365	(0.032 - 1.543)	0.072	0.063	(0.005 - 0.281)	111
Lepomis gulosus	25.212	30.846	(0.181 - 71.000)	5.666	7.078	(0.025 -16.047)	5
Lepomis marginatus	1.176	1.749	(0.012 - 6.827)	0.249	0.393	(0.002 - 1.562)	37
Lepomis microlophus	85.99	163.81	(0.528 -331.66)	21.843	41.362	(0.094 -83.870)	4
Lepomis punctatus	3.504	8.579	(0.011 - 50.881)	0.773	1.932	(0.002 -11.442)	111

TABLE 4. Relationships of dry mass (Y), in g, to wet mass (X), of Everglades animals[1].

Species	Equation Y	X	r	S_{β_1}	$S_{Y/X}$	SSY-SSE	SSE	MSE
Notemigonus crysoleucas	−0.009	0.267	0.958	0.016	0.032	0.296	0.027	0.001
Erimyzon sucetta	−0.003	0.190	0.994	0.008	0.003	0.0036	0.00004	0.00001
Ictalurus natalis	−0.049	0.228	0.986	0.005	0.420	349.328	10.218	0.176
Cyprinodon variegatus	−0.002	0.199	0.960	0.004	0.012	0.374	0.032	0.0002
Fundulus chrysotus	−0.001	0.199	0.986	0.001	0.025	11.940	0.343	0.0006
Fundulus confluentus	−0.004	0.213	0.977	0.004	0.041	5.639	0.269	0.002
Jordanella floridae	−0.005	0.196	0.973	0.002	0.018	4.304	0.245	0.0003
Lucania goodei	−0.002	0.211	0.965	0.002	0.006	0.486	0.036	0.00003
Gambusia affinis	−0.001	0.248	0.961	0.001	0.008	1.897	0.157	0.00006
Heterandria formosa	−0.001	0.188	0.887	0.003	0.003	0.034	0.009	0.00001
Poecilia latipinna	−0.004	0.239	0.974	0.002	0.026	9.507	0.508	0.0006
Elassoma evergladei	−0.0002	0.184	0.968	0.006	0.004	0.014	0.0009	0.00001
Enneacanthus gloriosus	−0.001	0.171	0.985	0.003	0.011	0.428	0.013	0.0001
Lepomis gulosus	−0.116	0.229	0.999	0.005	0.283	200.135	0.241	0.080
Lepomis marginatus	−1.468	0.224	0.997	0.003	0.031	5.532	0.033	0.001
Lepomis microlophus	−0.130	0.252	0.999	0.001	0.195	5132.410	0.076	0.038
Lepomis punctatus	−1.155	0.224	0.995	0.002	0.197	406.175	4.244	0.039

[1]Y = dry mass (g); X = wet mass (g); r = sample correlation coefficient; S_{β_1} = standard error of the slope; $S_{Y/X}$ = standard error of the regression line; SSY-SSE = sum of squares due to regression; SSE = residual sum of squares; MSE = mean square of residual.

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TABLE 5. Measured calorific values (kcal/g dry weight) for various Everglades animals (ash included), and mean values for groups.

Animals	Calorific value (Group Mean; S; N)
Annelida	
Nereidae	3.15
Lumbricus sp.	3.15
All annelida	(3.15; 0.00; 2)
Arthropoda	
Araneida	5.31
Ligia sp.	5.30
Palaemonetes paludosus	4.70
Procambarus alleni	4.31
Uca sp.	3.62
Cardisoma guanhumi	2.82
Aratus pisonii	3.19
All Decapoda	(3.73; 0.78; 5)
All Crustacea	(3.99; 0.95; 6)
Diplopoda	4.00
Ephemeroptera	5.86
Odonata	5.00
Periplantia americana	5.00
Belostoma sp.	5.20
Lethocerus americanus	5.82
Ranatra buenoi	5.30
Pelocoris sp.	5.44
All Hemiptera	(5.44; 0.27; 4)
Dytiscus sp. (adult)	5.96
Dytiscus sp. (larva)	5.30
Tropisternus lateralis	5.30
Enochrus perplexus	5.80
Hydrophilus insularis	5.81
Neohydrophilus castus	5.30
Platynus floridanus	5.70
All Coleoptera	(5.60; 0.29; 7)
Tabanus sp. (larva)	5.28
Chrysops flavidus (larva)	5.28
All Diptera	(5.28; 0.00; 2)
All Insecta	(5.46; 0.32; 16)
Mollusca	
Pomacea paludosa	1.17
Helisoma sp.	1.61
Olivella sp.	1.10
Cerithidea sp.	1.10
Unionidae	1.50
All Gastropoda	(1.25; 0.25; 4)
All Mollusca	(1.30; 0.24; 5)

TABLE 5. Continued

Animals	Calorific value (Group Mean; S; N)
Osteichthys	
Cyprinodon variegatus	4.66
Fundulus chrysotus	5.16
Fundulus confluentus	5.04
Jordanella floridae	5.00
Lucania goodei	5.50
Rivulus marmoratus	5.00
Gambusia affinis	5.51
Heterandria formosa	5.50
Enneacanthus gloriosus	5.00
Lepomis gulosus	4.96
All Osteichthys	(5.13; 0.28; 10)
Amphibia	
Rana grylio	4.62
Notopthalmus viridescens	5.10
All Amphibia	(4.95; 0.34; 2)
Reptilia	
Anolis carolinensis	5.12

LITERATURE CITED

BEAUCHAMP, J. J., AND J. S. OLSON. 1973. Corrections for bias in regression estimates after logarithmic transformation. Ecology 54:1403-1407.

BECKMAN, W. C. 1945. The length-weight relationship, factors for conversions between standard and total lengths, and coefficients of condition for seven Michigan fishes. Trans. Am. Fish. Soc. 75:237-256.

CALDWELL, D. K., H. T. ODUM, T. R. HELLIER, JR., AND F. H. BERRY. 1957. Populations of spotted sunfish and Florida largemouth bass in a constant temperature spring. Trans. Am. Fish. Soc. 85:120-134.

CARLANDER, K. D. 1969. Handbook of Freshwater Fishery Biology; Volume One. The Iowa State Univ. Press, Ames, Iowa.

__________. 1977. Handbook of Freshwater Fishery Biology; Volume Two. The Iowa State Univ. Press, Ames, Iowa.

CUMMINS, K. W., AND J. C. WUYCHECK, 1971. Caloric equivalents for investigations in ecological energetics. M.H. int. Ver. Limnol. 18.

COLLINS, J. T., J. E. HUGHEY, J. L. KNIGHT, AND H. B. SMITH. 1978. Standard, common, and current scientific names for North American amphibians and reptiles. Soc. Study of Amphib. and Reptiles Herpetol. Cir. 7.

EIDMAN, M. 1967. Contribution to the biology of needlefishes, *Strongylura* spp., in south Florida. Unpubl. M.S. Thesis, Univ. of Miami, Coral Gables, Florida.

GOLLEY, F. B. 1961. Energy values of ecological material. Ecology 42:581-584.

HERKE, W. H. 1959. Comparison of the length-weight relationship of several species of fish from two different, but connected habitats. Proc. Ann. Conf. S.E. Assoc. Fish Wild. Comm. 13:299-313.

JOLICOEUR, P. 1975. Linear regressions in fisheries research: some comments. J. Fish. Res. Board Can. 32:1491-1494.

KLEINBAUM, D. G., AND L. L. KUPPER. 1978. Applied regression analysis and other multivariate methods. Duxbury Press, North Scituate, Massachusetts.

KUSHLAN, J. A. 1981. Sampling characteristics of enclosure fish traps. Trans. Am. Fish. Soc. 110:557-562.

LECREN, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch *(Perca fluviatilis)*. J. Anim. Ecol. 20:201-219.

LOFTUS, W. F., AND J. A. KUSHLAN. 1985. The freshwater fishes of southern Florida. Bull. Florida State Mus.

MANOOCH, C. S., III. 1976. Age, growth, and mortality of the white grunt *Haemulon plumieri* Lacepede (Pisces: Pomadasyidae) from North Carolina and South Carolina. Proc. Ann. Conf. S. E. Assoc. Fish Wild. Agen. 30:58-70.

NEI, N. H., C. H. HULL, J. G. JENKINS, K. STEINBRENNER, AND D. H. BENT. 1975. Statistical Package for the Social Sciences. 2nd ed. McGraw-Hill, New York, New York.

PAINE, R. T. 1971. The measurement and application of the calorie to ecological problems. Ann. Rev. Ecol. Syst. 2:145-164.

PENNAK, R. W. 1978. Freshwater Invertebrates of the United States. John Wiley and Sons, New York, New York.

RICHMAN, S., AND B. SLOBODKIN. 1960. A micro-bomb colorimeter for ecology. Bull. Ecol. Soc. Am. 41:88-89.

RICKER, W. E. 1973. Linear regressions is fishery research. J. Fish. Res. Board Can. 30:409-434.

__________. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191.

ROBINS, C. R., R. M. BAILEY, C. E. BOND, S. R. BROOKER, E. A. LACHNER, R. N. LEA, AND W. B. SCOTT. 1980. A List of Common and Scientific Names of Fishes from the United States and Canada. 4th ed. Am. Fish. Soc. Special Publ. No. 12.

ROESSLER, M. A. 1970. Checklist of fishes in Buttonwood Canal, Everglades National Park, Florida, and observations on the seasonal occurrence and life histories of selected species. Bull. Mar. Sci. 20:860-893.

ROGERS, L. E., R. L. BUSCHBOM, AND C. R. WATSON. 1977. Length-weight relationships of shrub-steppe invertebrates. Ann. Entom. Soc. Amer. 70:51-53.

__________, W. T. HINDS, AND R. L. BUSCHBOM. 1976. A general weight versus length relationship for insects. Ann. Entom. Soc. Amer. 69:387-389.

SAGE, R. D. 1982. Wet and dry-weight estimates of insects and spiders based on length. Amer. Midl. Nat. 108:407-411.

SLOBODKIN, L. B. 1962. Energy in animal ecology. Advan. Ecol. Res. 1:69-101.

SMOCK, L. A. 1980. Relationships between body size and biomass of aquatic insects. Freshwater Biol. 10:22-28.

SPRENT, P., AND G. R. DOLBY. 1980. Query: the geometric mean functional relationship. Biometrics 36:547-550.

TABB, D. C., D. L. DUBROW, AND R. B. MANNING. 1962. The ecology of northern Florida Bay and adjacent areas. Florida Bd. Conserv., Tech. Ser. 39.

USINGER, R. L. 1973. Aquatic Insects of California. Univ. California Press, Berkeley, California.

VOSS, G. L. 1976. Seashore life of Florida and the Caribbean. E. A. Seeman Publ., Inc., Miami, Florida.

ZARET, T. M. 1980. Life history and growth relationships of *Cichla ocellaris*, a predatory South American cichlid. Biotropica 12:144-157.

Florida Sci. 49(2): 65-79. 1986.

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