Evaluation of total-body electrical conductivity to estimate whole-body water content of yellow perch, *Perca flavescens,* and alewife, *Alosa pseudoharengus**

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Abstract.–We evaluated the use of total body electrical conductivity (TOBEC) for determination of whole-body water content of yellow perch, *Perca flavescens*, and alewife, *Alosa pseudoharengus*. We used multiple linear regression with backwards stepwise elimination to test the capability of TOBEC values, wet weight, and total length in predicting whole-body water content of yellow perch and alewife. We found that wet weight was the best predictor of whole-body water content. The inclusion of TOBEC values in multiple linear regressions did not improve the predictive capability of wet weight over simple linear regressions that used wet weight alone (r^2 increased by only 0.00002 to 0.0005). We reanalyzed the data from three previous studies that used TOBEC to evaluate the tissue composition of fish. Again we found that the inclusion of TOBEC values in regression functions with wet weight as the other independent variable did not substantially improve the predictive capability of functions that used wet weight alone (r^2 increased by only 0.00003 to 0.0007).

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Attempts to construct energy budgets for many important fish species are often hampered by the lack of data on their energy density. Further, the study of energy flow in aquatic communities is complicated by seasonal variation of the energy density within organisms and relative differences in energy content of predator and prey (Craig, 1977; Stewart et al., 1983; Stewart and Binkowski, 1986; Rand et al., 1994). The shortage of useful data is due in part to the difficulty of determining the energy content of large numbers of individuals. Estimation of fish energy density has been simplified with development of relationships, based on calorimetric analysis, between percentage dry weight (100 × (dry weight/wet weight)) and wet weight energy density (Stewart and Binkowski, 1986; Rand et al., 1994; Hartman and Brandt, 1995; Lantry, 1997). The measurement of dry weights on substantial numbers of large individual fish, however, can be problematic, because they require considerable time to dry, use large amounts of oven space, and may require time-consuming sectioning or grinding procedures.

Measurement of total body electrical conductivity (TOBEC) has been presented in the literature as a reliable alternative to the sacrifice of organisms to evaluate tissue composition. Lipid content and lean body mass have been accurately estimated by measuring TOBEC in humans, swine, rats and birds (Domermuth et al., 1976; Bracco et al., 1983; Presta et al. 1983; Keim et al., 1988; Walsberg, 1988; Castro et al., 1990). TOBEC has recently been used for the estimation of body composition of three fish species: sunshine bass (a white bass [*Morone chrysops*] × striped bass [*Morone saxatilis*] hybrid, Brown et al., 1993); red drum (*Sciaenops ocellatus*, Bai et al., 1994); and channel catfish (*Ictalurus punctatus*, Jaramillo et al., 1994).

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In our analyses of fish community dynamics in Lake Ontario and Oneida Lake, New York, we used bioenergetics to evaluate trophic transfer and tissue growth (Rand et al., 1995; Lantry, 1997). To model trophic energy flux accurately, we needed to estimate fish energy content throughout the years being simulated. Because of the difficulty encountered in drying large numbers of fish and in drying large individuals, we sought an alternative method—measurement of whole-body water content. Our objective here was to evaluate the use of TOBEC as an alternative to drying, for estimating the whole-body water content of yellow perch (*Perca flavescens*), an important prey and sport fish component of both lakes, and alewife (*Alosa pseudoharengus*), the dominant planktivore and prey fish in Lake Ontario.

Materials and methods

We used the “EM-SCAN Inc., SA2 Small Research Animal Body Composition Analyzer” to obtain TOBEC values for yellow perch and alewife. The measurement principle of the EM-SCAN has been published elsewhere (Fiorotto et al., 1987; Walsberg, 1988; Brown et al., 1993). The scanner uses a radiating coil to set up a low-frequency electromagnetic field to measure the electrical conductivity of an animal. Because electricity is conducted by the ions dissolved in body water, the most direct relationship that can be drawn from the TOBEC values is the amount of water contained within an animal. By initially measuring the wet weight of a fish and then measuring the whole-body water content with the scanner, we could obtain the dry weight of the fish by difference, and calculate the percentage dry weight, which is the key parameter we needed to estimate energy density.

Sample collection and processing

We collected 43 yellow perch in bottom trawls from Oneida Lake, NY, over four dates in 1992: 23 April, n=10; 9 June, n=5; 30 September, n=10; and 23 November, n=18. We collected 47 alewife from the New York waters of Lake Ontario with a 3-m bag seine on 2 May (n=13) and 4–5 July (n=34) 1993. Yellow perch were kept alive in lake water during sampling, and alewife were placed on ice immediately after capture. All fish were frozen in water upon arrival at the laboratory.

During processing, fish were thawed under warm running water, blotted dry, weighed to the nearest 0.1 g and measured for total length (mm). We obtained TOBEC values according to the procedures outlined in the scanner manual (EM-SCAN Inc., 1991). Because the positioning of the animal is important in obtaining consistent conductivity readings, fish were placed on their right sides headfirst on the animal carrier trays with the portion of their bodies anterior to the distal end of the shortest ray of the pelvic fin lined up in front of the scribed mark on the tray. Each fish was scanned five times in the scanner’s fixed mode and the readings were averaged to produce a mean TOBEC value. After scanning, all fish were dried to a constant weight at 65°C.

Statistical analysis

We constructed simple and multiple linear regression models to predict whole-body water content (WC, g). Following earlier fish studies (Brown et al., 1993; Bai et al., 1994; Jaramillo et al., 1994) we included wet weight (WWT, g), total length (TL, mm), and $TOBEC$ as independent variables in regressions. We graphed these variables against fish WC (determined from drying individuals) to evaluate the shape of the relationships. We transformed independent variables when relationships with WC departed from linear trends. We used SYSTAT 5.03 for Windows (1993) to perform stepwise multiple linear regressions with backwards elimination on all variables (inclusion probability: $P \geq 0.15$) to determine which independent variables accounted for most of the variation in predictive equations (Zar, 1984; Neter et al., 1985). The resulting regression models were then used to predict WC and calculate percentage error (PE):

$$PE = \left\{ \left(\left| \text{actual} - \text{predicted} \right| / \text{actual} \right) \times 100 \right\}.$$

Finally, we calculated percentage dry weight from both actual (determined from drying) and predicted (from regression equations) water content and compared the variation between these values to the range of percentage dry weights commonly observed for yellow perch and alewife (Tables 1 and 2).

Results

Significant ($P<0.05$) positive relationships were found in simple linear regressions between the dependent variable WC and the independent variables $TOBEC$, WWT, and TL for both yellow perch and alewife (r^2=0.66 to 0.99). Simple linear regressions of $TOBEC$ on WC produced r^2 values of 0.933 and 0.667 for yellow perch and alewife, respectively. Multiple linear regressions with two independent variables (WWT and $TOBEC$) gave excellent fits to the data for both species. The equation for yellow perch was

$$WC = 3.46239 + 0.69844 \times WWT + 0.00559 \times TOBEC \quad (r^2=0.998).$$

Table 1

Yellow perch individual water content (g) from measurements (act) and predicted (pred) from regression functions. TOBEC is the average scanner conductivity index (based on five consecutive measurements). %DWT is the percentage dry weight and is equivalent to: {(|wet weight – water|)/wet weight} × 100. Values in parentheses are percentage errors (PEs) referring to water (g) and %DWT, and are equivalent to {(|actual – predicted|)/actual} × 100.

Total length (mm)	Wet weight (g)	TOBEC	Water (g) (act)	Water[1] (g) (pred)		Water[2] (g) (pred)		%DWT (act)	%DWT[1] (pred)		%DWT[2] (pred)	
196	99.5	138.6	76.8	73.73	(3.99)	76.02	(1.01)	22.81	25.90	(13.51)	23.59	(3.42)
166	66.5	65.6	50.8	50.28	(1.03)	51.30	(0.98)	23.61	24.40	(3.34)	22.86	(3.15)
148	51.0	42.6	39.2	39.32	(0.31)	39.83	(1.61)	23.14	22.90	(1.03)	21.90	(5.36)
157	51.2	40.4	39.2	39.45	(0.63)	39.79	(1.50)	23.44	22.95	(2.07)	22.29	(4.91)
160	57.1	48.8	44.0	43.62	(0.87)	44.18	(0.42)	22.94	23.61	(2.93)	22.62	(1.40)
151	46.8	28.2	35.6	36.31	(1.99)	35.94	(0.95)	23.93	22.42	(6.31)	23.21	(3.02)
137	31.4	17.6	25.2	25.49	(1.16)	25.00	(0.81)	19.75	18.82	(4.71)	20.40	(3.31)
141	35.0	20.8	27.2	28.02	(3.03)	27.66	(1.68)	22.29	19.93	(10.57)	20.98	(5.86)
133	27.9	12.8	21.7	23.02	(6.08)	22.14	(2.05)	22.22	17.49	(21.30)	20.63	(7.12)
135	29.7	14.6	23.3	24.29	(4.24)	23.54	(1.02)	21.55	18.22	(15.43)	20.75	(3.70)
239	223.1	346.6	154.7	161.22	(4.20)	161.76	(4.54)	30.64	27.73	(9.49)	27.49	(10.28)
275	288.6	481.9	199.8	207.73	(3.96)	206.90	(3.55)	30.76	28.02	(8.92)	28.31	(7.99)
265	296.6	466.8	204.2	213.23	(4.43)	211.67	(3.66)	31.16	28.11	(9.79)	28.64	(8.09)
271	290.3	415.9	203.4	208.55	(2.54)	206.44	(1.51)	29.94	28.16	(5.95)	28.89	(3.52)
229	210.9	361.5	151.4	152.79	(0.88)	154.37	(1.93)	28.19	27.56	(2.25)	26.81	(4.91)
242	284.6	642.5	204.6	205.83	(0.57)	207.73	(1.51)	28.10	27.68	(1.50)	27.01	(3.88)
258	301.5	586.0	217.5	217.32	(0.09)	217.39	(0.06)	27.86	27.92	(0.23)	27.90	(0.15)
256	260.2	538.4	198.2	188.21	(5.03)	190.02	(4.12)	23.84	27.67	(16.08)	26.97	(13.16)
261	280.0	561.7	210.9	202.17	(4.12)	203.15	(3.65)	24.69	27.80	(12.57)	27.44	(11.15)
201	106.2	108.3	82.1	78.24	(4.64)	78.94	(3.79)	22.74	26.33	(15.78)	25.67	(12.89)
195	101.1	96.8	77.3	74.62	(3.50)	75.12	(2.85)	23.51	26.20	(11.40)	25.70	(9.28)
209	132.9	155.2	100.4	97.15	(3.20)	98.03	(2.32)	24.48	26.90	(9.88)	26.24	(7.17)
205	139.6	179.1	107.4	101.97	(5.04)	103.23	(3.86)	23.08	26.96	(16.80)	26.05	(12.87)
163	54.6	36.2	39.1	41.80	(6.82)	41.62	(6.37)	28.33	23.44	(17.26)	23.77	(16.11)
144	41.8	24.2	31.8	32.79	(3.11)	32.36	(1.74)	23.91	21.55	(9.88)	24.34	(5.88)
156	45.4	26.8	34.5	35.32	(2.37)	34.91	(1.18)	24.00	22.20	(7.51)	23.10	(3.75)
147	40.6	22.1	31.2	31.94	(2.44)	31.37	(0.61)	23.20	21.32	(8.08)	22.73	(2.03)
131	27.9	11.0	21.6	23.01	(6.34)	21.88	(1.14)	22.44	17.53	(21.90)	21.56	(3.92)
128	26.4	10.8	20.6	21.96	(6.42)	20.90	(1.26)	21.83	16.81	(22.99)	20.84	(4.52)
116	17.6	5.8	13.8	15.79	(14.35)	14.40	(4.32)	21.55	10.30	(52.22)	18.16	(15.74)
127	23.7	10.0	18.8	20.07	(6.64)	19.05	(1.21)	20.59	15.31	(25.62)	19.62	(4.68)
129	25.7	11.2	20.4	21.48	(5.30)	20.51	(0.57)	20.64	16.44	(20.37)	20.19	(2.18)
224	172.2	222.2	130.7	124.99	(4.37)	125.58	(3.93)	24.10	27.42	(13.77)	27.08	(12.36)
215	138.4	156.3	105.8	100.97	(4.60)	101.56	(4.04)	23.50	27.02	(14.97)	26.60	(13.15)
281	285.9	378.8	211.9	205.24	(3.13)	202.67	(4.34)	25.88	28.20	(8.96)	29.10	(12.42)
294	387.6	818.4	281.3	278.74	(0.92)	276.73	(1.63)	27.42	28.08	(2.43)	28.60	(4.32)
173	83.0	79.2	62.0	61.90	(0.11)	62.65	(1.10)	25.37	25.45	(0.34)	24.55	(3.22)
227	183.4	273.3	130.6	133.11	(1.94)	134.36	(2.89)	28.81	27.43	(4.79)	26.76	(7.15)
240	237.5	407.6	167.4	171.60	(2.49)	172.50	(3.03)	29.49	27.74	(5.95)	27.36	(7.25)
272	295.5	592.5	215.6	213.10	(1.16)	213.67	(0.91)	27.02	27.86	(3.12)	27.68	(2.47)
278	333.7	784.7	233.4	240.89	(3.23)	241.71	(3.58)	30.06	27.80	(7.52)	27.56	(8.33)
339	434.2	1165	314.3	313.26	(0.32)	312.02	(0.71)	27.63	27.86	(0.83)	28.14	(1.86)
Mean PE's					(3.33)		(2.23)			(10.60)		(6.59)

[1] Predicted (pred) values from the regression function with wet weight (g) and TOBEC as the independent variables.

[2] Predicted (pred) values from the regression function with wet weight (g) and square root transformed scanner conductivity index as the independent variables.

Table 2

Alewife individual water content (g) from measurements (act) and predicted (pred) from regression functions. TOBEC is the average scanner conductivity index (based on five consecutive measurements). %DWT is the percentage dry weight and is equivalent to {(|wet weight – water|)/wet weight} × 100. Values in parentheses are percentage errors (PEs) referring to water (g) and %DWT and are equivalent to {(|actual – predicted|)/actual} × 100. Predicted (pred) values are from the regression function with wet weight (g) and TOBEC as the independent variables.

Total length (mm)	Wet weight (g)	TOBEC	Water (g) (act)	Water (g) (pred)		%DWT (act)	%DWT (pred)	
153	22.85	11.0	18.24	18.70	(2.49)	20.15	18.16	(9.88)
158	27.68	17.0	22.25	22.53	(1.25)	19.62	18.61	(5.14)
166	28.11	14.2	23.69	23.02	(2.83)	15.73	18.12	(15.17)
160	27.02	12.2	21.65	22.18	(2.45)	19.87	17.91	(9.87)
163	29.08	17.4	23.77	23.69	(0.33)	18.24	18.51	(1.50)
164	27.92	13.4	22.29	22.89	(2.72)	20.18	18.01	(10.74)
163	30.41	17.4	23.18	24.82	(7.10)	23.78	18.37	(22.75)
149	22.83	10.6	19.09	18.70	(2.04)	16.38	18.08	(10.42)
163	28.92	15.8	23.99	23.63	(1.48)	17.06	18.28	(7.18)
156	24.91	15.0	20.47	20.27	(0.96)	17.83	18.62	(4.45)
142	20.87	13.8	16.51	16.90	(2.36)	20.89	19.02	(8.95)
155	22.86	12.2	18.93	18.66	(1.42)	17.21	18.39	(6.81)
156	21.14	10.2	17.58	17.29	(1.64)	16.86	18.22	(8.07)
186	41.05	19.6	33.78	33.74	(0.11)	17.71	17.81	(0.53)
183	47.84	26.6	37.94	39.19	(3.29)	20.70	18.09	(12.60)
168	37.97	17.0	30.58	31.25	(2.20)	19.48	17.71	(9.08)
178	40.16	23.2	33.42	32.83	(1.76)	16.79	18.25	(8.70)
171	31.80	13.8	26.25	26.16	(0.33)	17.46	17.74	(1.56)
168	31.88	13.6	26.81	26.23	(2.17)	15.88	17.70	(11.48)
166	32.07	15.4	25.90	26.32	(1.63)	19.25	17.93	(6.85)
166	32.49	12.2	26.94	26.81	(0.47)	17.08	17.47	(2.29)
158	32.83	13.8	27.62	27.04	(2.12)	15.87	17.66	(11.25)
174	40.39	20.4	33.58	33.15	(1.29)	16.86	17.93	(6.36)
148	27.02	11.4	21.71	22.21	(2.34)	19.66	17.78	(9.55)
160	34.66	14.6	27.41	28.55	(4.16)	20.92	17.64	(15.71)
176	32.51	11.8	27.31	26.85	(1.69)	15.99	17.41	(8.89)
175	37.82	16.8	31.31	31.13	(0.58)	17.21	17.70	(2.80)
159	27.34	13.6	22.81	22.39	(1.85)	16.56	18.10	(9.35)
166	40.33	16.6	33.16	33.26	(0.30)	17.77	17.52	(1.39)
171	37.15	16.0	30.78	30.60	(0.59)	17.16	17.64	(2.83)
172	37.97	21.6	31.04	31.04	(0.00)	18.24	18.24	(0.02)
162	32.89	16.0	26.38	26.99	(2.31)	19.80	17.95	(9.34)
180	44.45	21.0	36.61	36.56	(0.12)	17.65	17.75	(0.55)
170	37.20	16.2	29.65	30.63	(3.30)	20.29	17.66	(12.95)
177	39.38	18.2	32.54	32.38	(0.48)	17.36	17.76	(2.28)
141	21.28	10.2	17.48	17.41	(0.39)	17.88	18.20	(1.80)
165	33.97	20.4	28.37	27.71	(2.32)	16.49	18.43	(11.77)
172	42.46	23.4	35.99	34.77	(3.38)	15.25	18.11	(18.79)
157	31.02	16.6	24.79	25.38	(2.38)	20.10	18.19	(9.47)
161	38.78	19.2	32.26	31.84	(1.33)	16.80	17.91	(6.58)
150	33.79	14.8	27.80	27.8	(0.01)	17.73	17.72	(0.05)
158	38.00	17.4	31.69	31.25	(1.36)	16.62	17.75	(6.83)
167	31.96	15.2	26.80	26.23	(2.11)	16.15	17.92	(10.94)
157	23.84	13.4	19.61	19.43	(0.92)	17.72	18.48	(4.29)
148	24.24	11.8	19.94	19.84	(0.51)	17.72	18.14	(2.37)
143	23.68	11.8	19.52	19.37	(0.80)	17.55	18.20	(3.74)
Mean PE's					(1.67)			(7.40)

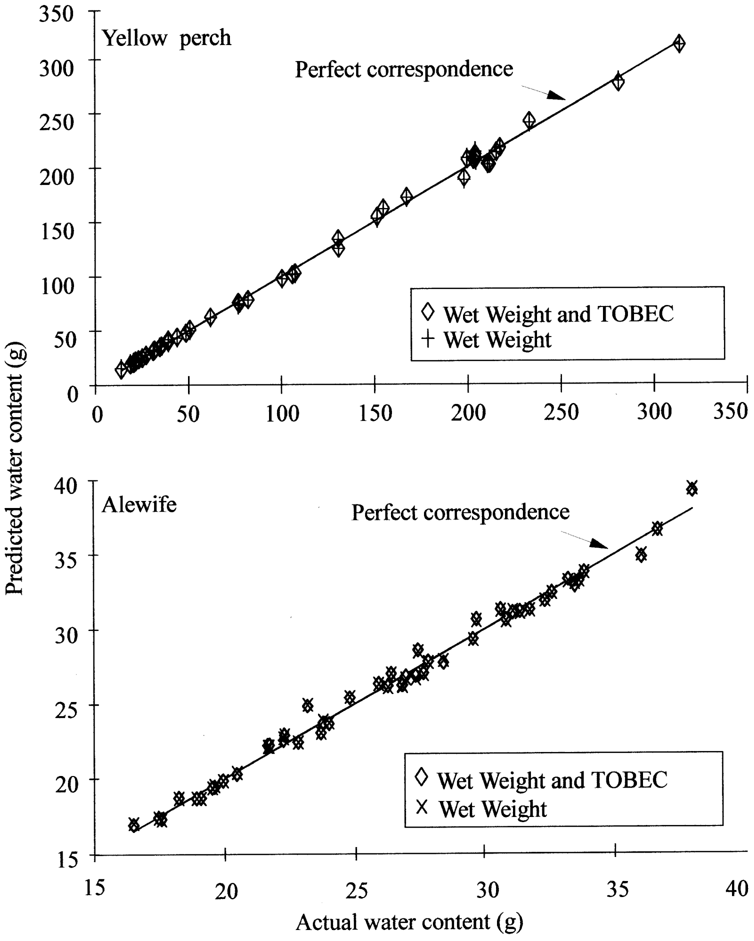

Figure 1

Comparison of the predicted and measured values of water content (g) of yellow perch and alewife. Predicted values are from multiple linear regressions with wet weight and total body electrical conductivity (TOBEC) as independent variables and from simple linear regressions with wet weight as the only independent variable.

The equation for alewife was

$$WC = -0.17206 + 0.8471 \times WWT - 0.0439 \times TOBEC \quad (r^2=0.990).$$

The slope coefficient for wet weight and the intercept in the yellow perch regression model were both significant ($P<0.01$), whereas the *TOBEC* coefficient was not ($P=0.529$). The slope coefficient for wet weight in the alewife regression was significant ($P<0.0001$), whereas both the *TOBEC* coefficient and the intercept were not ($P=0.295$ and 0.679, respectively). Both the yellow perch and alewife predictive equations provided good fit to the data for water content with mean *PE*s from all values in each data set of 3.33% and 1.67%, respectively. Wet weight, however, accounted for most of the variance within each relationship. When wet weight was used as the only independent variable in each regression model, r^2 values were both about 0.99, and were greater than the r^2 values from regressions that used only *TOBEC* as the independent variable. Predictions from these simple linear regressions (*WWT* as the only independent variable) provided nearly as good a fit to the data as the multiple linear regressions (r^2 values decreased only by about 0.00002 to 0.0005, Fig. 1).

Total length and *TOBEC* were not linearly related to water content for yellow perch. Natural log transformations for total length (Ln*TL)* and square root transformations of *TOBEC* values (sq*TOBEC*) returned linear trends. When we replaced *TOBEC* with sq*TOBEC* in the regression model for yellow perch to account for nonlinearity, the r^2 value increased slightly (+0.0002) and the mean percentage error decreased (Table 1). The new yellow perch equation became

$$WC = 0.767 + 0.638 \times WWT + 0.996 \times \mathrm{sq}TOBEC \quad (r^2{=}0.998).$$

Backwards stepwise multiple linear regression analysis of the yellow perch data eliminated Ln*TL* from the regression model and indicated that four other independent variables (*WWT*, sq*TOBEC*, *TL*, and an offset constant) be included. The inclusion of *TL* in the new regression model increased the r^2 value by only 0.0002, but the mean *PE* also increased to 2.56% in the new model from 2.23% in the model that included only *WWT* and sq*TOBEC*. Backwards stepwise multiple linear regression analysis of the alewife data indicated that only *WWT* was a sufficient predictor of water content in that data set.

Percentage errors in predicted values for water content were consistently larger than the mean *PE*s for *TOBEC* values ≤ 15 (<30 g yellow perch; <35 g alewife; Tables 1 and 2). Previous work indicated that the scanner is accurate for predicting lean body mass in birds down to a body weight of 20 g (Castro et. al. 1990). We found that fish sizes that returned *TOBEC* values below 10 yielded such poor results that we did not include them in our analysis (<24 g yellow perch; <16 g alewife).

Discussion

In fish, water content of the individual is strongly correlated with the whole-body wet weight and, hence, many relationships developed for the EM-SCAN use wet weight as an independent variable (Brown et al., 1993; Bai et al., 1994; Jaramillo et al., 1994). Although wet weight alone could be used to predict many of these values, assessment of the subtle differences in tissue constituents relevant to energy-balance calculations could not be accomplished. Many studies on terrestrial vertebrates have used TOBEC alone to predict tissue composition (Presta et al., 1983; Keim et al., 1988; Walsberg, 1988; Castro et al., 1990); however, all fish TOBEC studies to date have used wet weight and TOBEC as the predictor variables in regression functions. In our work, TOBEC values did not increase the predictive ability of regression functions with wet weight as the other independent variable.

Three previous studies have indicated that TOBEC can accurately predict water content in fish (Brown et al., 1993; Bai et al., 1994; Jaramillo et al., 1994). Each study indicated that TOBEC and wet weight values were correlated to body tissue constituents and water content. The inclusion of TOBEC values in regressions with wet weight as the other predictor of whole-body body water content produced slight increases in r^2 values and decreased the mean square error. We ran regression analyses with backwards stepwise elimination and found that TOBEC was eliminated from the sunshine bass data set (Brown et al., 1993) when wet weight was untransformed but was included when wet weight was $\log_e$ transformed. The regressions for sunshine bass with untransformed wet weight alone and combined with TOBEC both produced lower PEs (2.6 and 2.5 respectively) than did the Brown et al. (1993) equation with $\log_e$-transformed wet weight (PE=3.9). TOBEC was significant in regressions with wet weight for red drum (Bai et al., 1994) and channel catfish (Jaramillo et al., 1994). In these data sets, regressions, including the TOBEC variable, increased the PE from 2.2 to 3.0 for red drum (Bai et al., 1994) and decreased the PE from 4.0 to 2.7 for channel catfish (Jaramillo et al., 1994) versus the regressions with wet weight as the only independent variable. Inclusion of TOBEC values in regressions with wet weight did not substantially or consistently improve the predictions of water content over simple linear regressions with wet weight alone.

When fat is burned and replaced by water in a fish, changes in the total quantity of electrolytic salts should be reflected in TOBEC values. Hence, TOBEC values alone should be able to successfully predict water content. TOBEC values alone can predict water content values in terrestial vertebrates (r^2>0.80) and fish (r^2=0.67 to 0.988). In fish however, TOBEC predicted total wet weight equally well. If more than just test animal size affects conductivity readings, then evidence of changes in the total body content of electrolytic salts should also be apparent when TOBEC and water content values are divided by wet weight. Wet-weight–standardized TOBEC and water content values were not related for alewife, sunshine bass, or red drum (Fig. 2). The apparent trend in the yellow perch data is counterintuitive (Fig. 2) to the expected trend of increased conductance with increased water content. The strength of predictive equations for fish in the above four data sets may be solely due to effects from fish size (e.g. serum and cellular fluid volumes). The expected relationship for these parameters is apparent in our plot of the test data set from Jaramillo et al. (1994; Fig. 2). The nutrient content of diets fed to fish in those experiments was carefully controlled within groups and varied only between groups. Evidence from our study indicates some promise for using TOBEC for fish in situ-

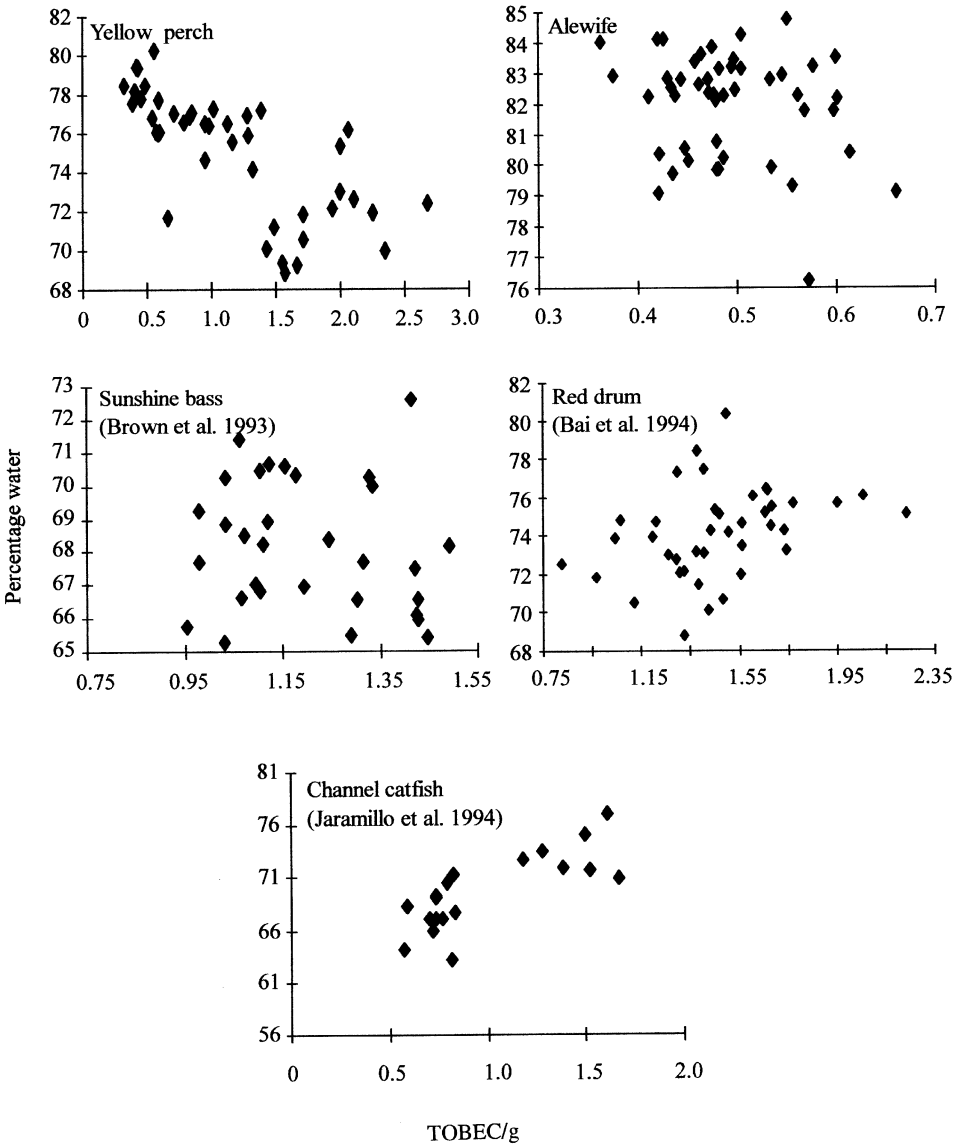

Figure 2

Comparisons between standardized values of percentage water (water content/wet weight) and total-body electrical conductivity (TOBEC/wet weight) for yellow perch, alewife, sunshine bass, red drum, and channel catfish. Data for sunshine bass, red drum, and channel catfish are from Brown et al. (1993), Bai et al. (1994), and Jaramillo et al. (1994).

ations where nutritional status can be controlled (e.g. in aquaculture) and electrolytic balance is given sufficient time to equilibrate throughout all bodily fluid (i.e. serum, cellular, and extracellular) compartments.

Our ultimate goal was to use our predictions of water content to assess the energy content of yellow perch and alewife. Our energy density relationships (Rand et al., 1994; Lantry, 1997) use percentage dry weight as the independent variable. Percentage dry weight values calculated from predicted water content did not, however, correspond to values calculated from measured water content for any of the five fish species used in TOBEC studies (Fig. 3). Our analysis indicates that further evaluations of the use of TOBEC to predict fish body composition are warranted. Fish size should be constrained to narrow ranges, and percentage water {(water content / wet weight) × 100} between individuals of different condition should be evaluated. By controlling fish size, conductivity differences due to body geometry could

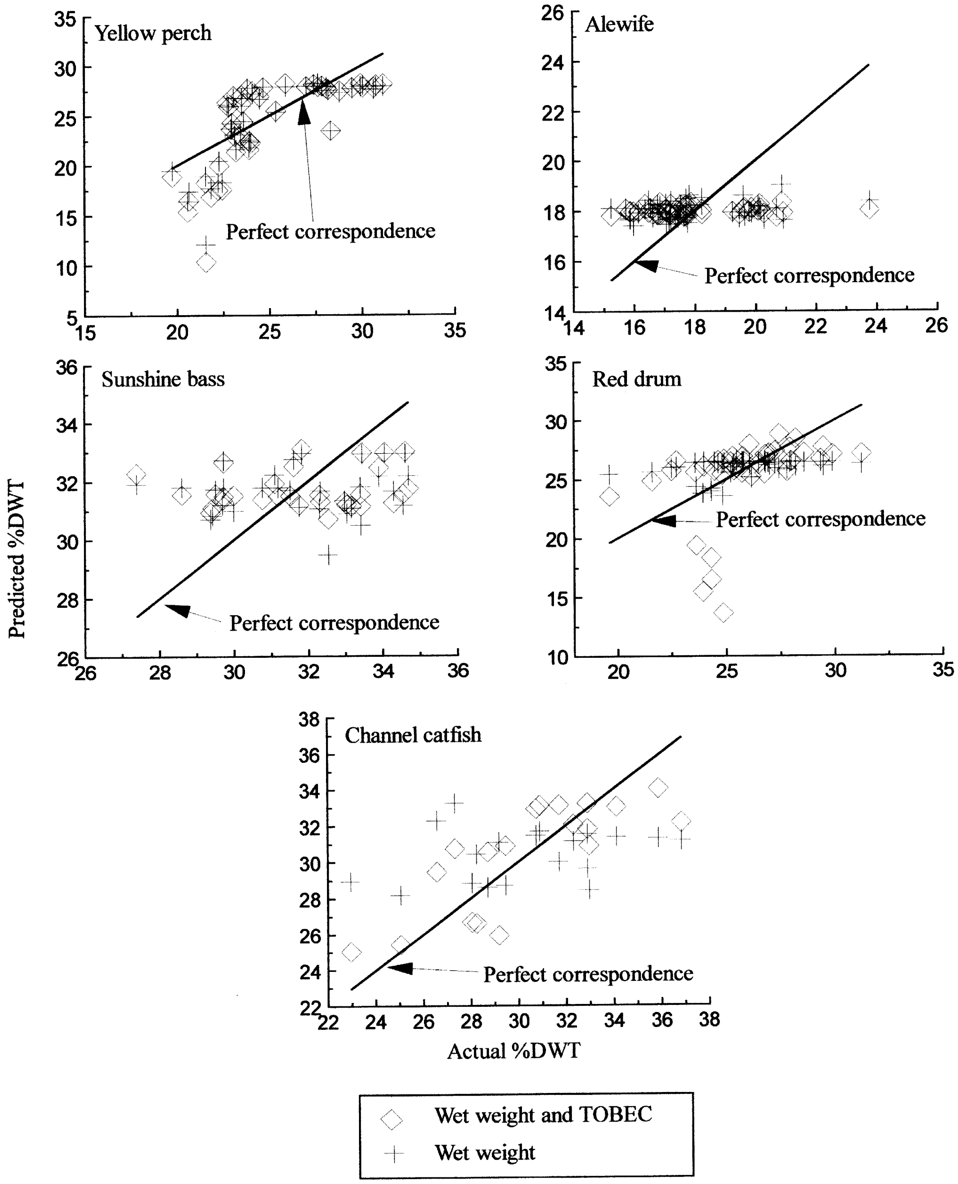

Figure 3

Comparisons between actual and predicted values of percentage dry weight (dry weight/wet weight) for yellow perch, alewife, sunshine bass, red drum, and channel catfish. Data for sunshine bass, red drum, and channel catfish are from Brown et al. (1993), Bai et al. (1994), and Jaramillo et al. (1994). The line in each panel represents the location of equivalence between actual and predicted.

be reduced and wet weight could be eliminated from prediction equations.

Variability associated with the scanning equipment, fish preparation prior to scanning, fish condition, and geometry of fish within the scanner chamber may generate errors too high to accurately predict ecologically significant changes in fish body composition. Analysis of TOBEC readings taken in fish fed, fasted, frozen, and thawed in Bai et al.'s study (1994) indicates that both physiological and physical states affect conductivity values. Dehydration in terrestial animals has also been observed to cause disproportionate changes in TOBEC values (Walsberg, 1988). Our fish were frozen in water and probably were not dehydrated; however, the death of the fish and the effect of freezing and thawing may have altered conductance. Also, the potential existed for exchange between body water and the water surrounding the fish during freezing and thawing. The measurement of TOBEC values, however, did not produce consistent improvement in the predictability of whole-body water content in fish from any of the five data sets considered. This analysis indicates that TOBEC procedures will not be able to predict with sufficient accuracy the water content of fish sampled from field situations and frozen in water for later analysis.

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