Juvenile Coho Salmonid Energy Expenditure in a Turbulent Flow Field

EISI REU Summer 2014 Final Presentation

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Hydraulic Variables

- TKE

TKE (m^2/s^2)	$TKE = 0.5\ (\sigma_x^2 + \sigma_y^2 + \sigma_z^2)$ σ is the standard deviation of the velocity in a given direction
Strain (s^{-1})	$= \sqrt{\left(\frac{u_{i+1} - u_i}{x_{i+1} - x_i} + \frac{u_i - u_{i-1}}{x_i - x_{i-1}}\right)^2 + \left(\frac{v_{i+1} - v_i}{y_{i+1} - y_i} + \frac{v_i - v_{i-1}}{y_i - y_{i-1}}\right)^2 + \left(\frac{w_{i+1} - w_i}{z_{i+1} - z_i} + \frac{w_i - w_{i-1}}{z_i - z_{i-1}}\right)}$

- Strain

Energy Expenditure Equations

Metabolism Total (Joules/Day)	= *Standard* + *Activity*	InSTREAM
Standard Metabolism (Joules/Day)	$= (30*W^{0.784})*e^{(.0693*T)}$	InSTREAM
Active Metabolism (Joules/Day)	$= (feedTime/24)*[e^{(.03*V)}-1]*Standard$	InSTREAM
Feed Time (hours)	= dayLength + 2	InSTREAM
Weight (grams)	$= .0134* L^{2.96}$	InSTREAM Van Winkle et al. (1996)

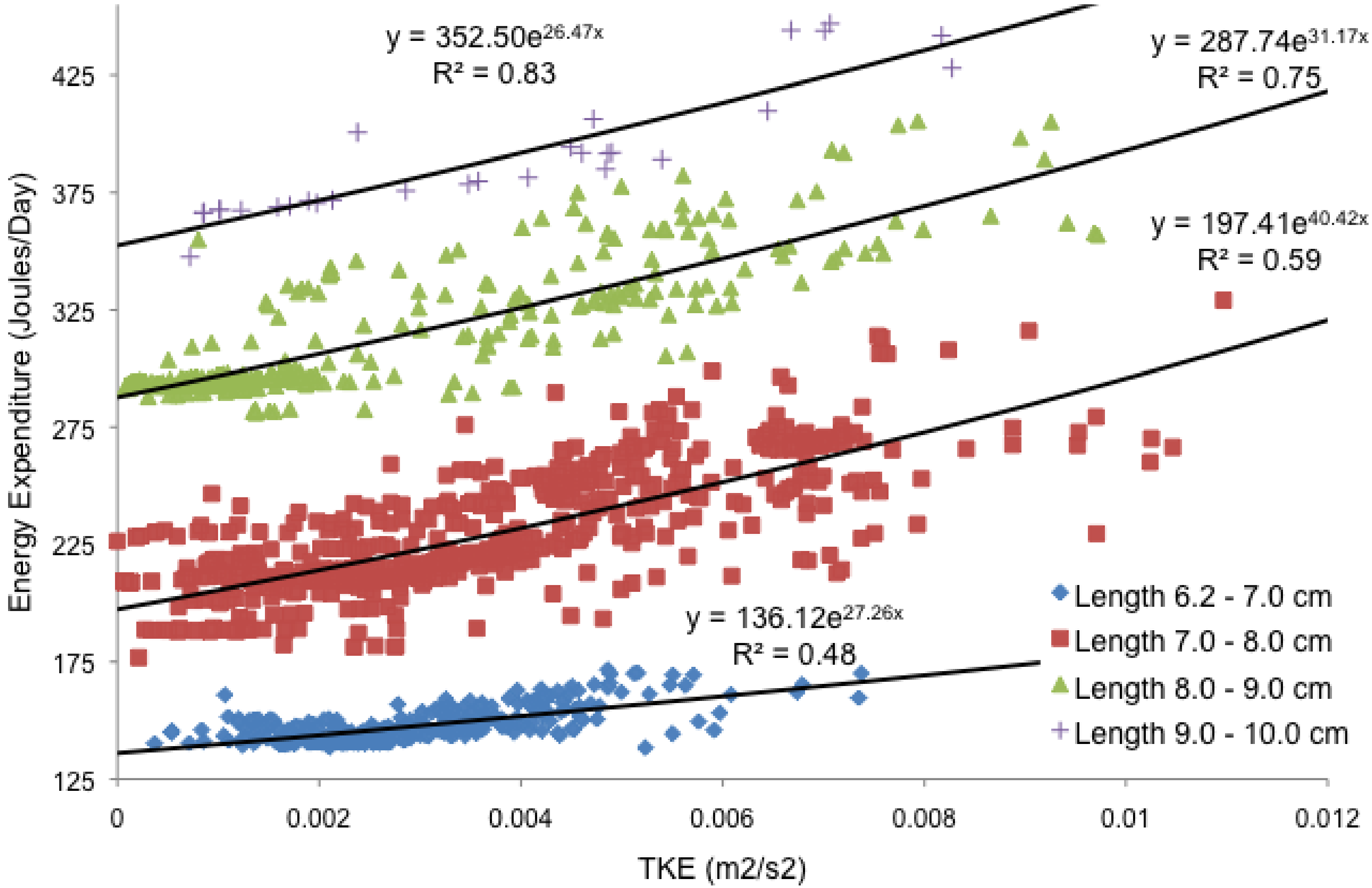
L = Fish Length (cm)   W = Fish weight (g)   V = Swimming Speed (m/s)

The Standard Methodology

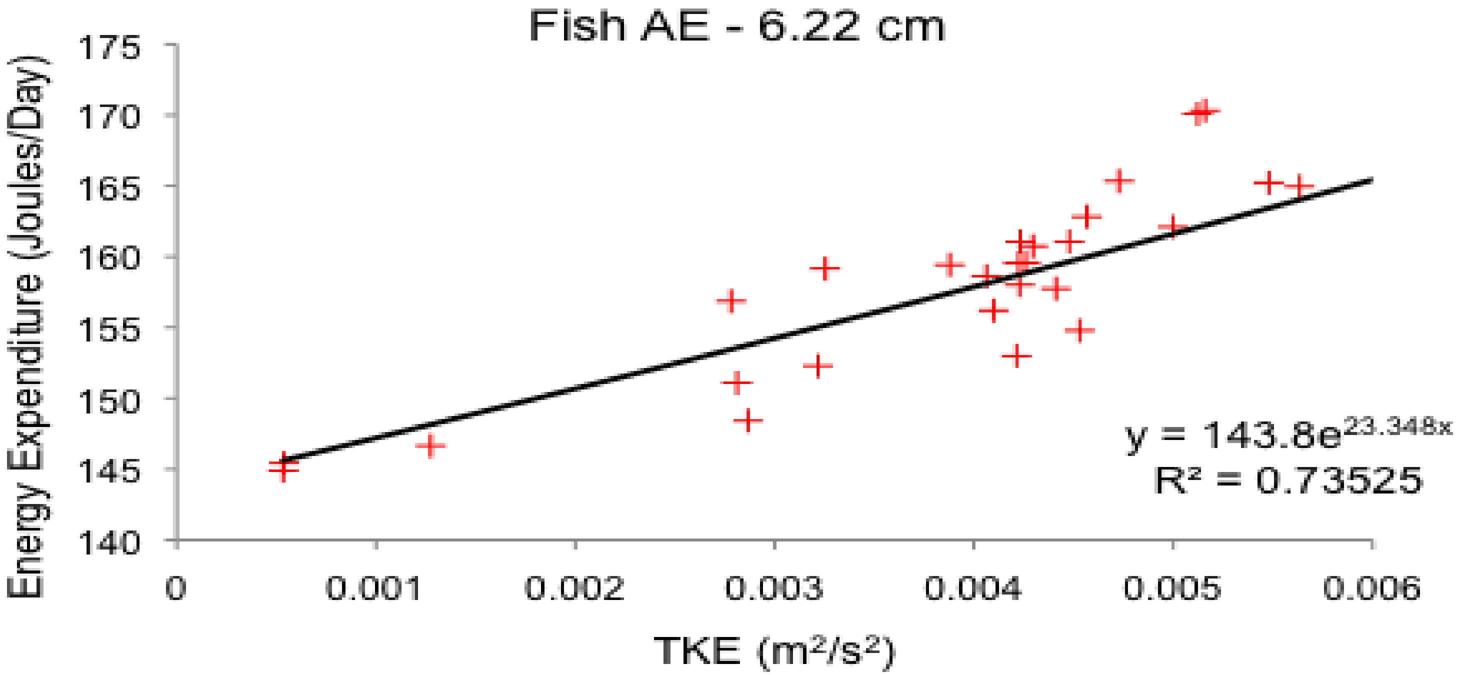
- Use a current meter to measure the velocity of the water at 2/3 the depth of the thalweg
- Single point measurement
- Assumes the fish swims at the speed of the flow

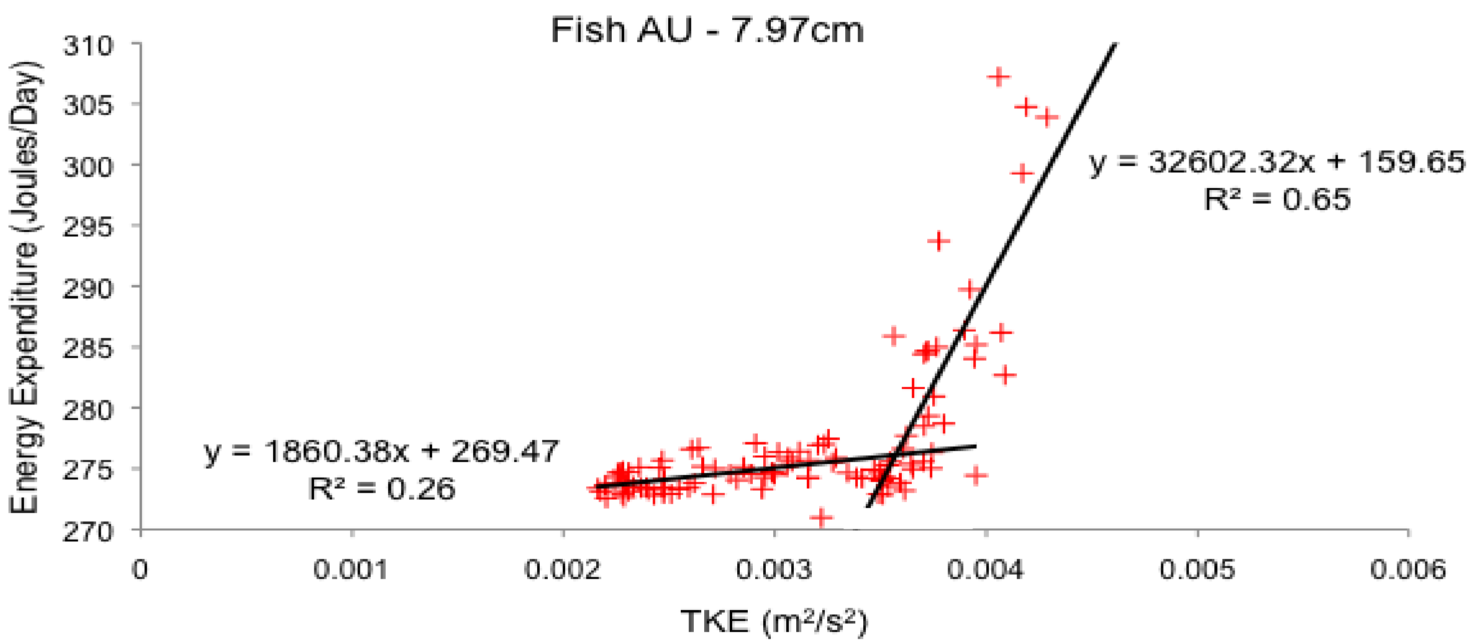
Photo from Environmental Science LEC

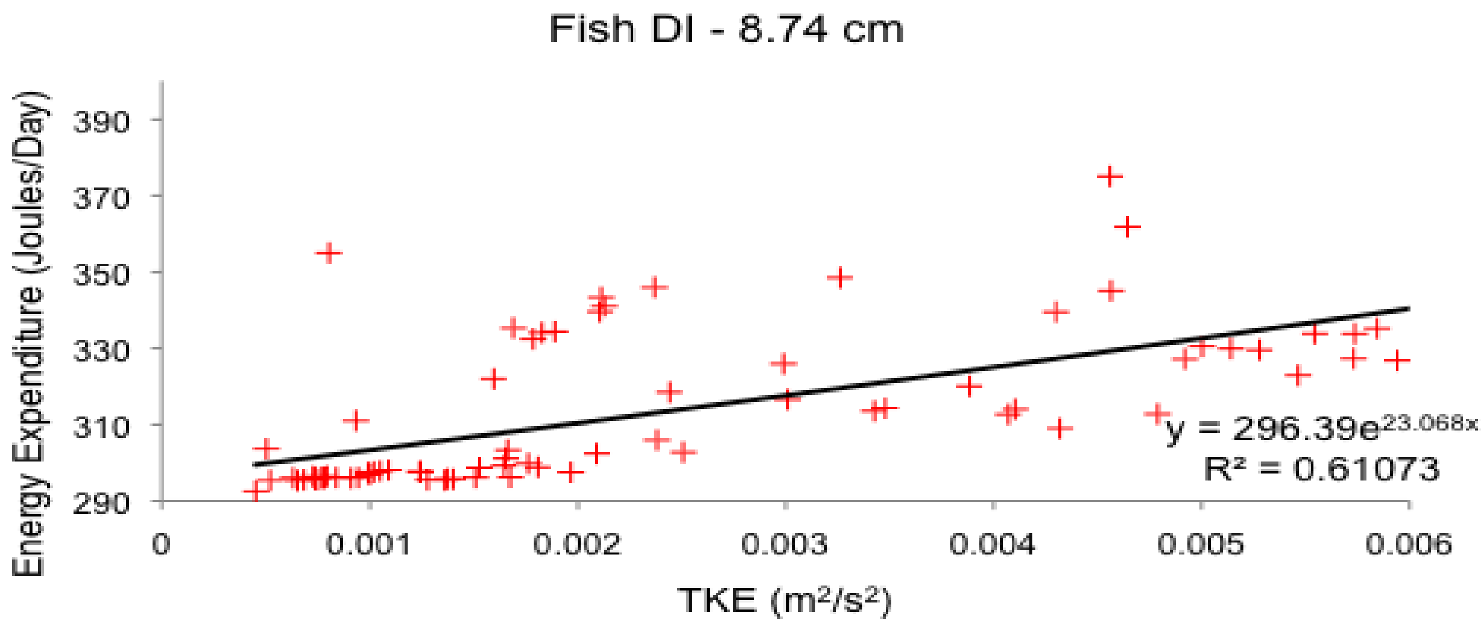
The Effect of TKE on Energy Expenditure For Fish of Different Sizes

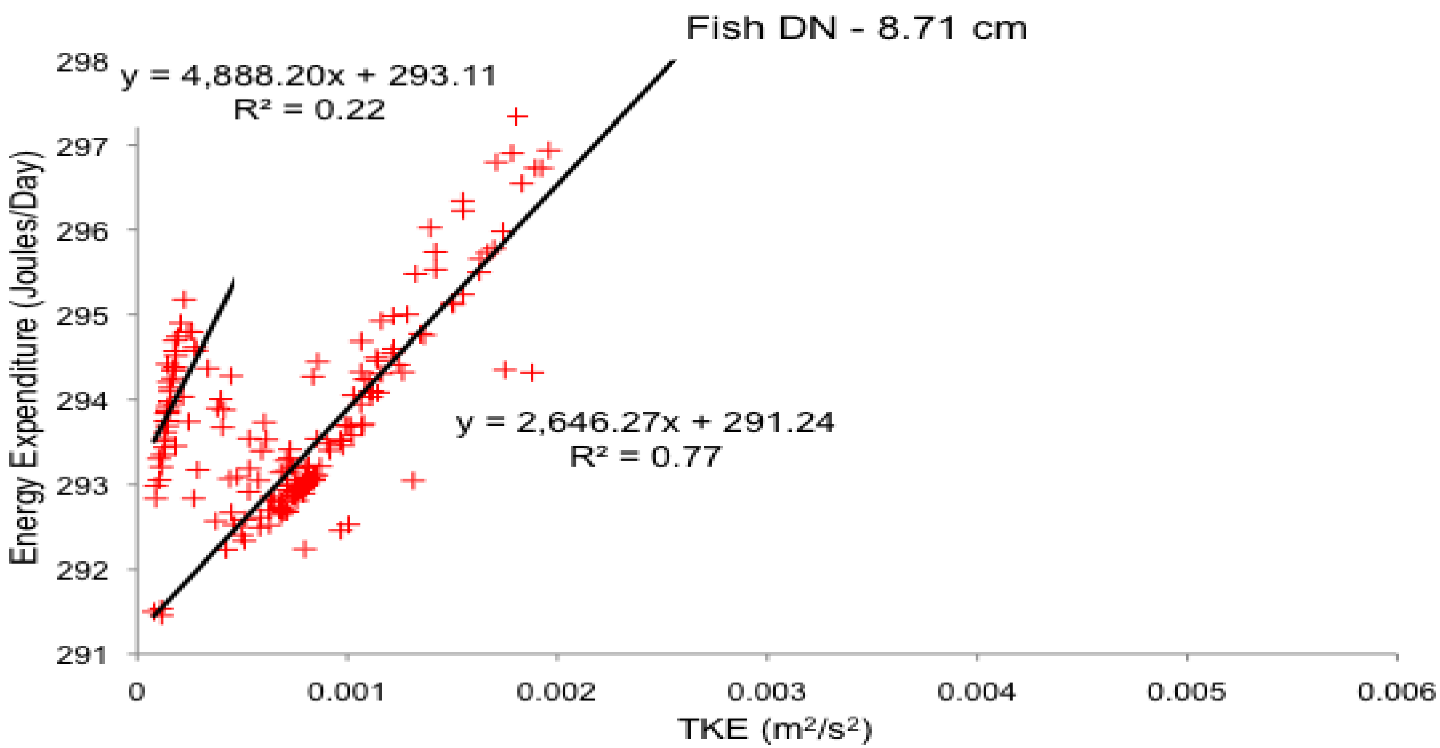


Fish Size Range (cm)	Equation Type	Slope	Intercept	R^2
6.2 – 7.0	Exponential	26.00	136.72	.41
7.0 – 8.0	Exponential	41.27	196.95	.61
8.0 – 9.0	Exponential	31.93	287.45	.74
9.0 – 10.0	Exponential	27.38	353.40	.68

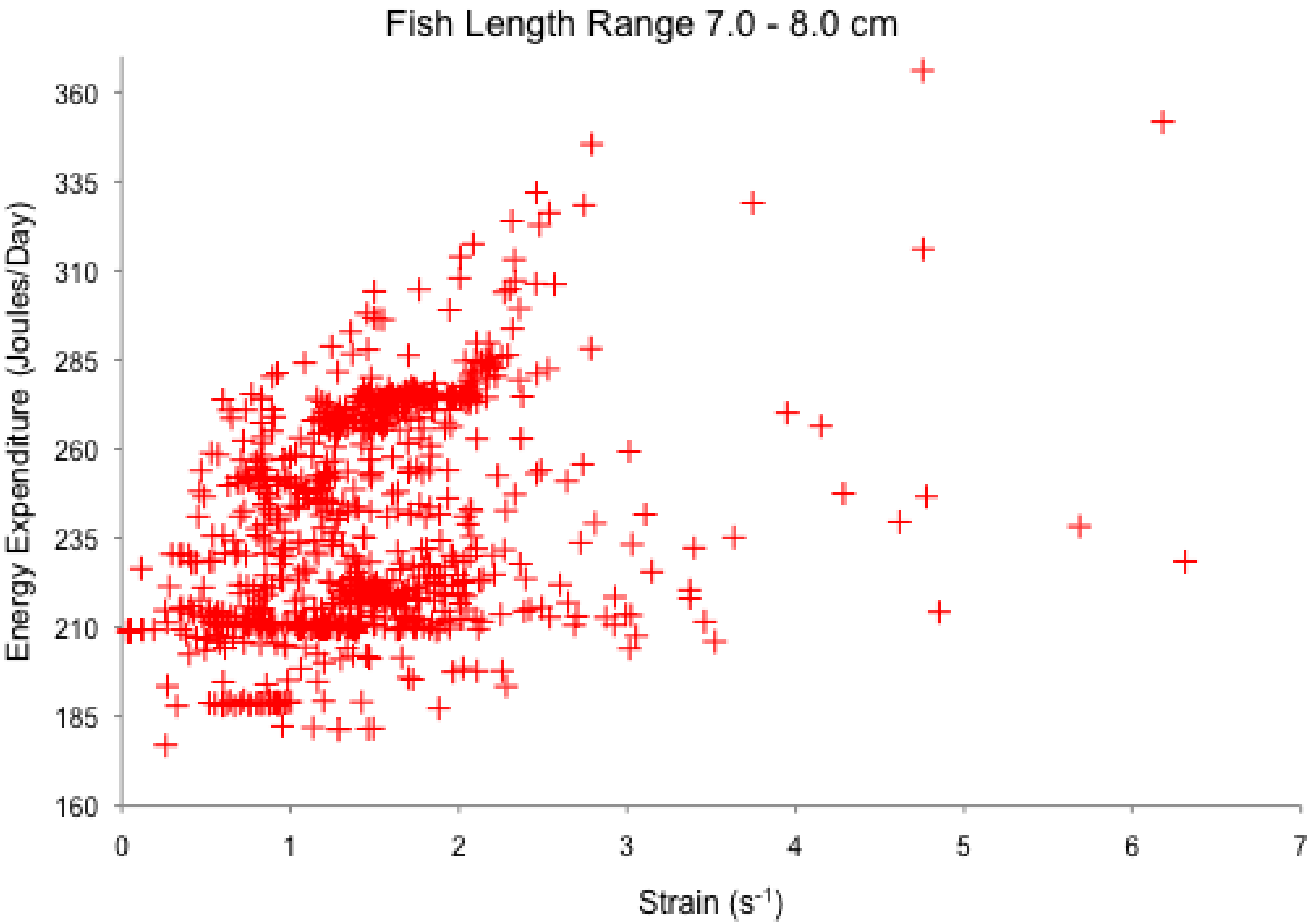

Fish AE - 6.22 cm
Energy Expenditure (Joules/Day)
175
170
165
160
155
150
145
140
0
0.001
0.002
0.003
0.004
0.005
0.006
TKE (m²/s²)
y = 143.8e^23.348x
R² = 0.73525


Fish AU - 7.97cm
Energy Expenditure (Joules/Day)
310
305
300
295
290
285
280
275
270
0
0.001
0.002
0.003
0.004
0.005
0.006
TKE (m²/s²)
y = 32602.32x + 159.65
R² = 0.65
y = 1860.38x + 269.47
R² = 0.26

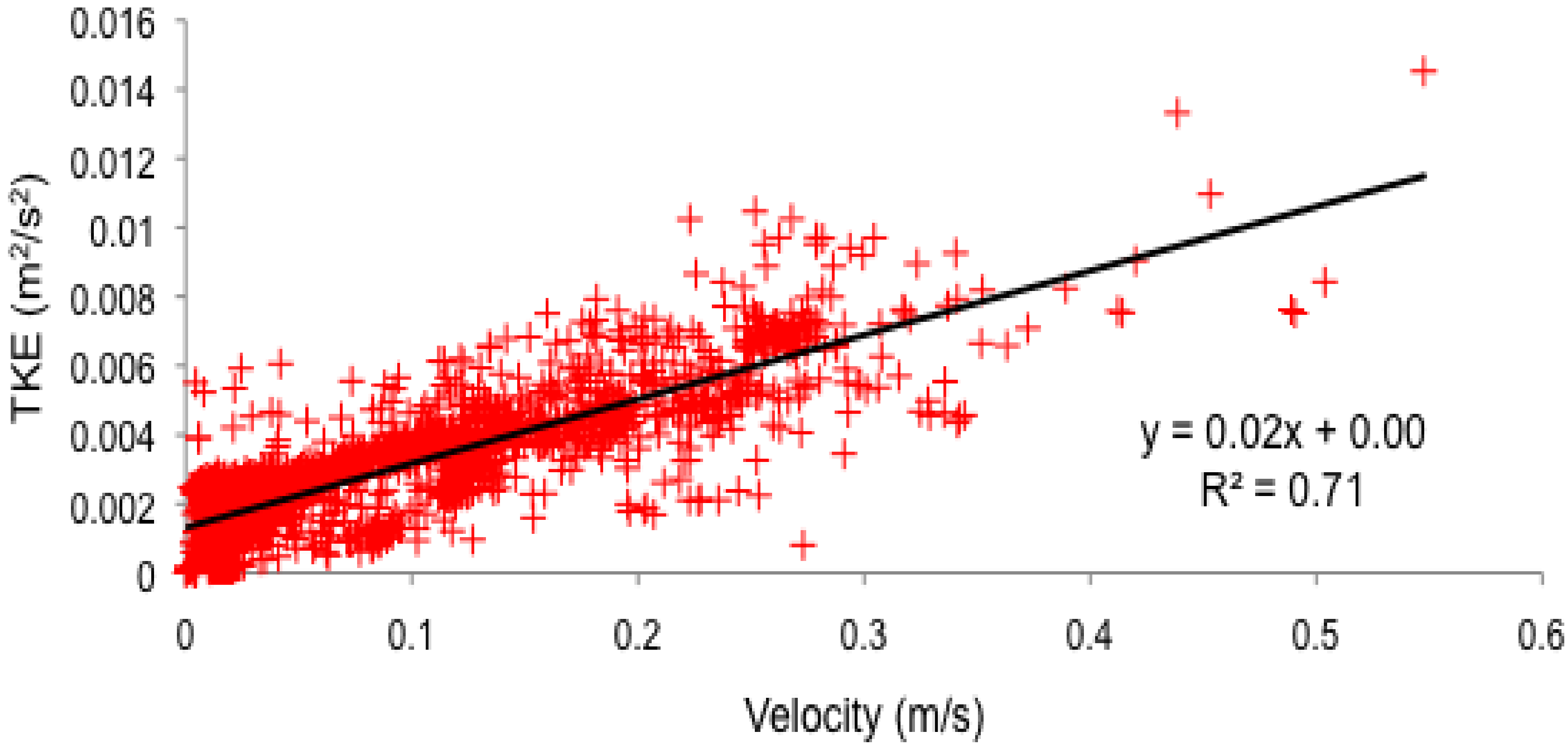

Fish DI - 8.74 cm
Energy Expenditure (Joules/Day)
390
370
350
330
310
290
0
0.001
0.002
0.003
0.004
0.005
0.006
TKE (m²/s²)
y = 296.39e^23.068x
R² = 0.61073

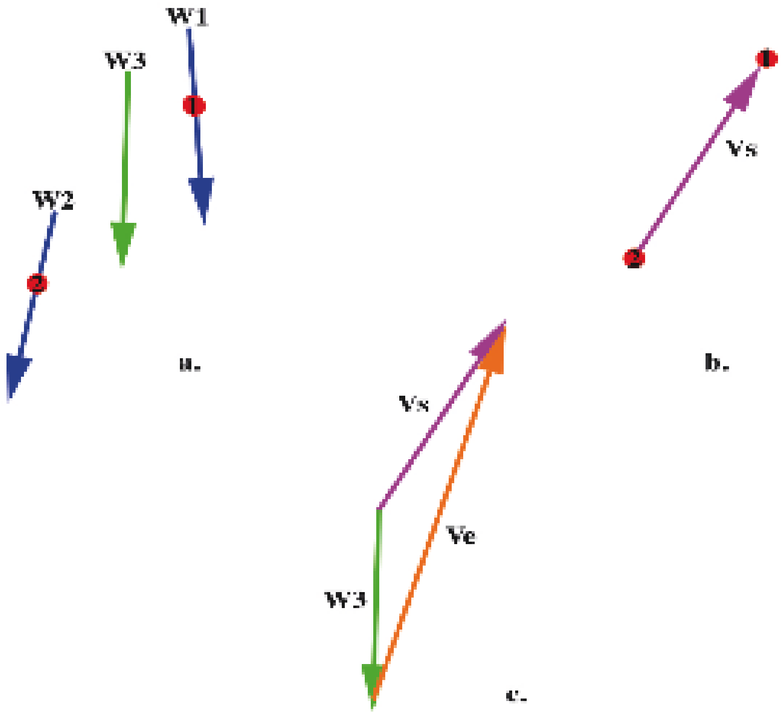

Fish DN - 8.71 cm
y = 4,888.20x + 293.11
R² = 0.22
y = 2,646.27x + 291.24
R² = 0.77
Energy Expenditure (Joules/Day)
298
297
296
295
294
293
292
291
0
0.001
0.002
0.003
0.004
0.005
0.006
TKE (m²/s²)

The Influence of Strain On Energy Expenditure



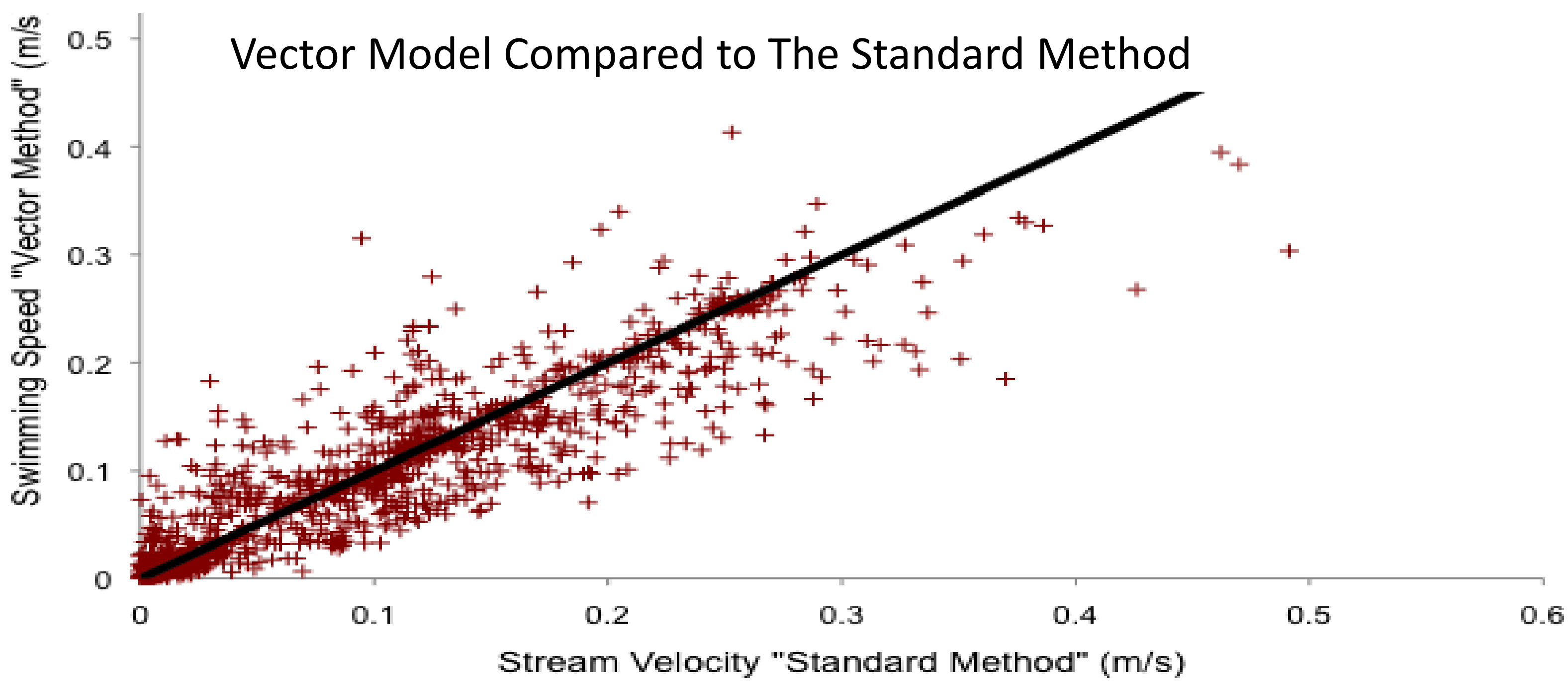
Correlation of Hydraulic Variables: Effect of Velocity on TKE

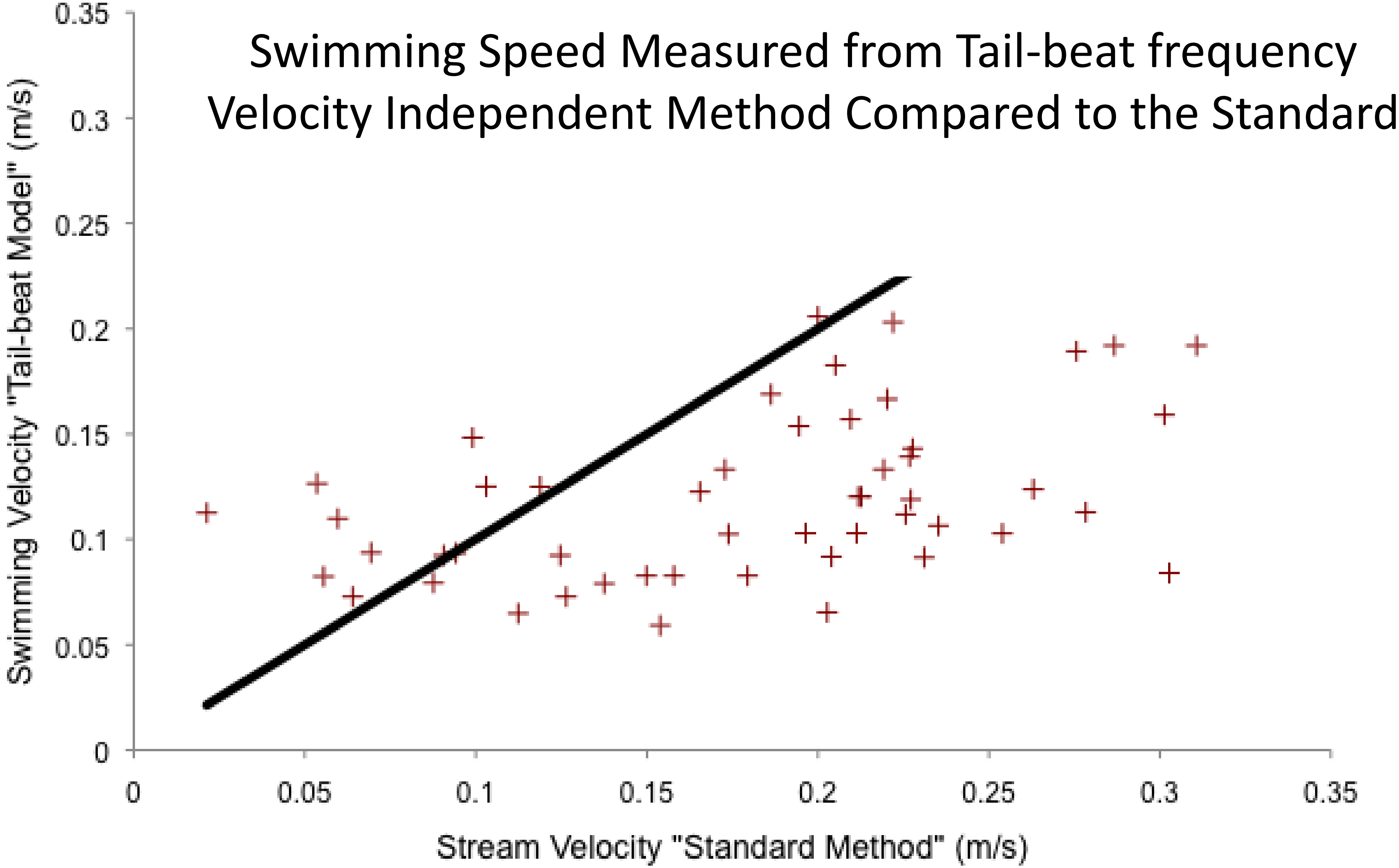




Vector Method of Modeling Swimming Speed Compared to the Standard Method of Measuring Swimming Speed

- Assumes that fish swim in a line from point to point
- Takes into account fish motion





Swimming speed	$V = (L * (f - 2.0\ L^{-1/3})) \div 1.56$	Webb 1984
L = Fish Length (cm) W = Fish Weight (g) T = Water Temperature (°C) V = Swimming Velocity (cm/s) f = Tail-beat Frequency (beats/s)		

Results

- Fish of different sizes do not discriminate habitat based on TKE values
- Larger fish expend more energy for a given TKE value
- Fish may exhibit a threshold TKE
- Using the standard method for swimming speed the relationship is predictable
- Standard method over-estimates the TRUE fish swimming speed

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