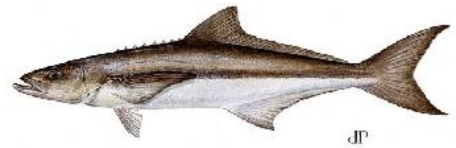

Sustainability: Challenges

Fillet Contaminants
PCB 5X Lower
Mercury 4X Lower
FCR 1.46

1. Complete independence from natural stocks through **DOMESTICATION**
2. Improved / more cost-effective **SEED PRODUCTION**
3. Better targeted **SPECIES SELECTION**
4. Development of more efficient stocks through **SELECTIVE BREEDING**
5. More **MICROBIAL MANAGEMENT** for more sustainable production
6. Better understanding of **IMMUNE SYSTEMS** in vertebrates and invertebrates
7. More **INTEGRATED PRODUCTION SYSTEMS** for plant and animal farming
8. **COASTAL AND OFF-SHORE FARMS** of food and energy
9. Full independence from fisheries stocks for **LIPID AND PROTEIN INGREDIENTS** in aquatic feeds
10. More attention for **INTEGRATION** of restocking activities with **FISHERIES** management
11. **SOCIETAL LEVERAGE:**
    1. multi-stakeholder interaction
    2. International cooperation on a win-win basis

Aquaculture, The Blue Biotechnology of the Future
Patrick Sorgeloos
World Aquaculture, 2013

Turning Carnivorous Fish into Vegetarians

http://www.gizmag.com
/fishless-fish-

Why Salmon Eating Insects Instead of Fish Is Better for Environment

Companies in Europe have developed new kinds of feed for salmon farms that could help the environment—if they can scale up quickly.

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Potential of insect-based diets for Atlantic salmon (*Salmo salar*)

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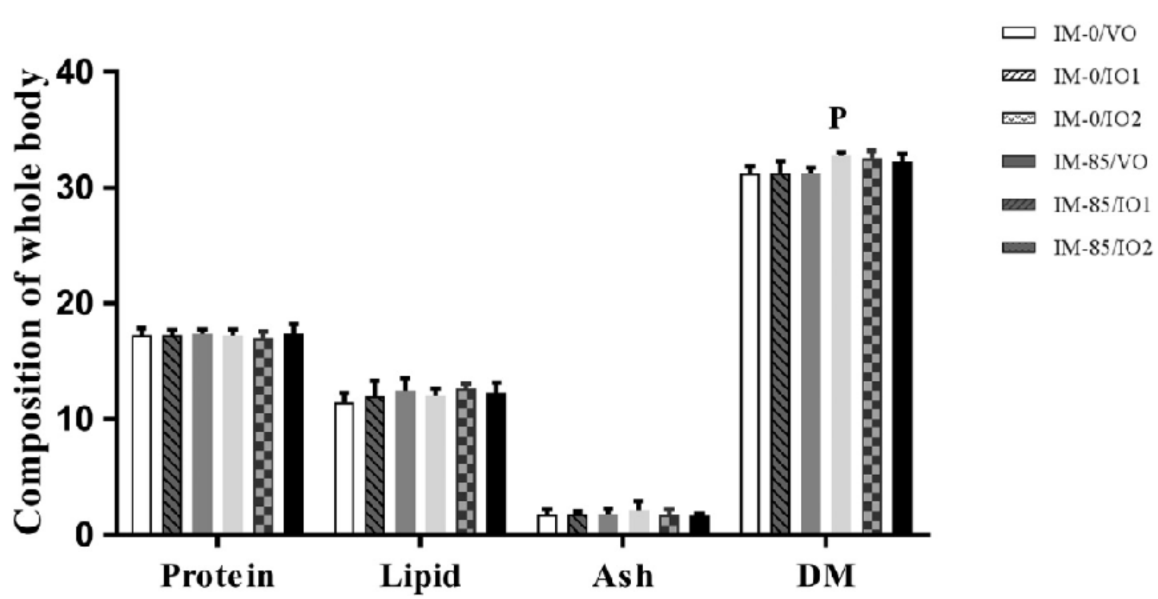
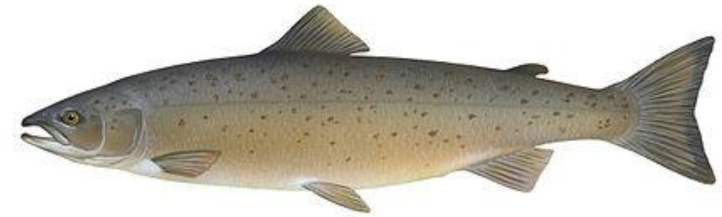


Fig. 2. Composition of whole body (% of wet weight) of freshwater Atlantic salmon fed a control diet (IM-0/VO) or diets containing IM and/or IO1 or IO2 for a period of 8 weeks. Values are means, with their standard deviation represented by vertical bars. P, significant effect of dietary protein source. O, significant effect of dietary lipid source. P × O, interaction between the main effects of the two factors ($P < 0.05$, two-way ANOVA). DM; P ≤0.01, O = 0.75, P × O = 0.75.



Atlantic Salmon Diet

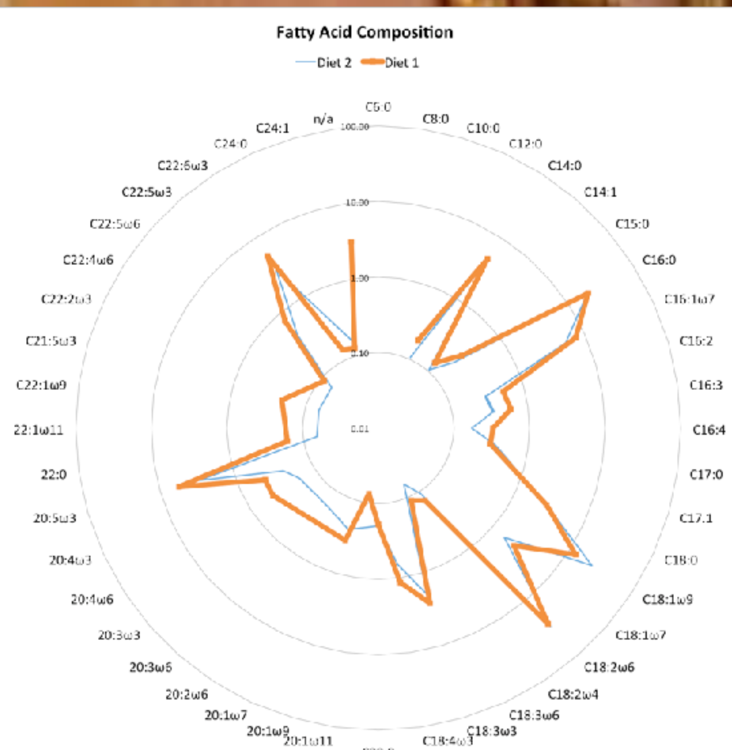
Insect Digestibility

Protein 89 ± 3.84

Lipids 92 ± 3.84

Diet 2

Moisture	3.85 %
Protein (crude)	46.07 %
Fat (crude)	15.71 %
Fiber (crude)	2.69 %
Ash	8.30 %

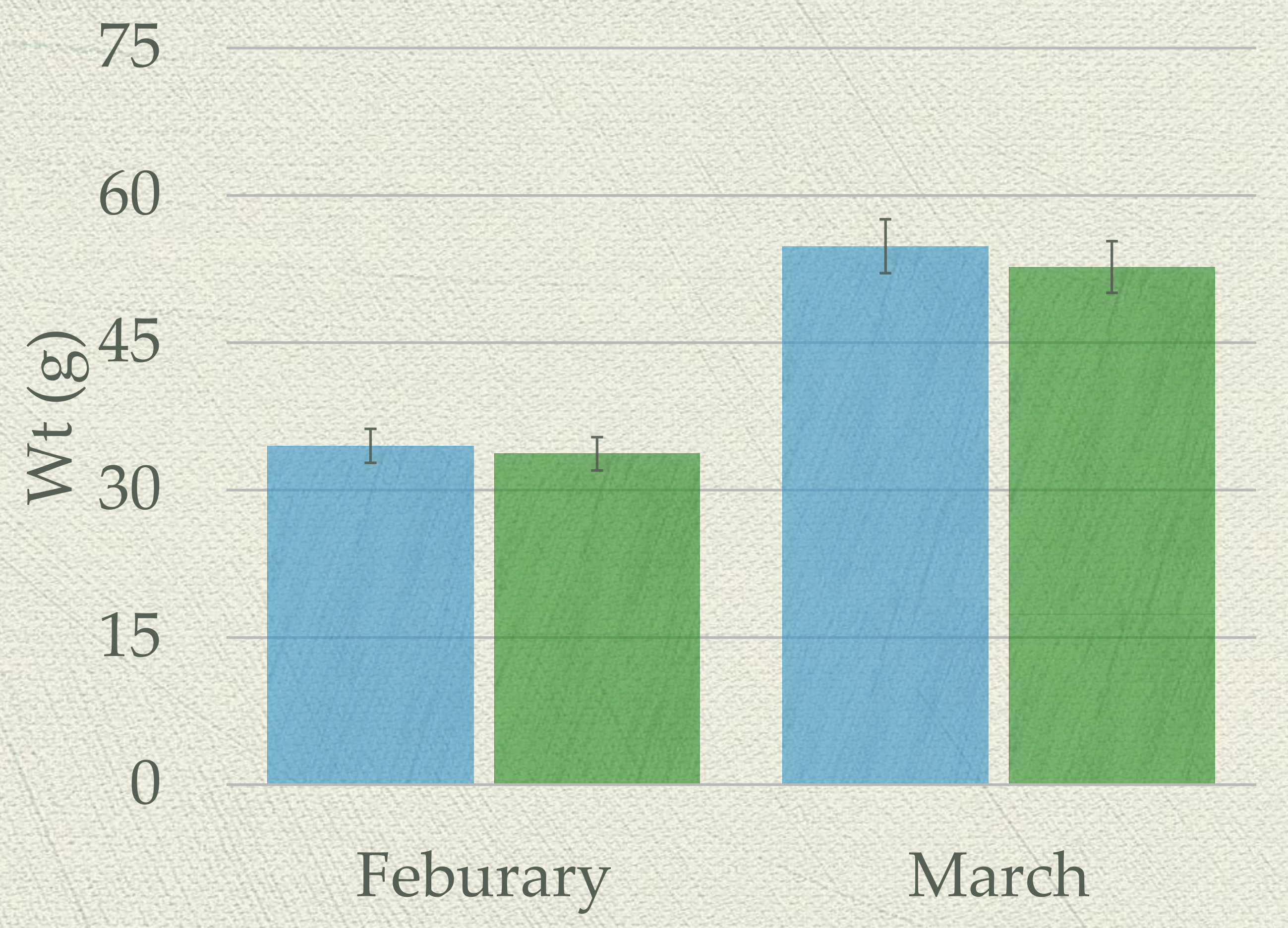


Code		Description	Actual	Percent
5592700		Profine VF	575.0000	28.7500
9008600	O	AP INSECT MEAL-CO	466.6000	23.3300
5522000		CN GLUTEN 60%	306.8000	15.3400
4463000		WHEAT FLOUR BAGGED	300.8000	15.0400
3422100		MENH GOLD OIL TOPDRESS	119.2000	5.9600
6610400		MONOCALCIUM PHOSPHATE FG	79.0000	3.9500
3430000		LECITHIN FG	60.0000	3.0000
8302000		TAURINE 98.5% FG	30.0000	1.5000
8877000		L LYSINE 98.5%	15.0000	0.7500
7758000		CHOLINE CL-70%	12.0000	0.6000
6626000		POTASSIUM CHLORIDE (DYNA K) FG	11.2000	0.5600
8880000		DL METHIONINE 99	9.0000	0.4500
6636000		SALT	5.6000	0.2800
7769200		TIGER C-35	4.0000	0.2000
9076620		PREMIX AQUA-VIT	2.4000	0.1200
9098000		PREMIX AQUA-MIN FISH	2.4000	0.1200
6641000		MAGNESIUM OXIDE FG	1.0000	0.0500

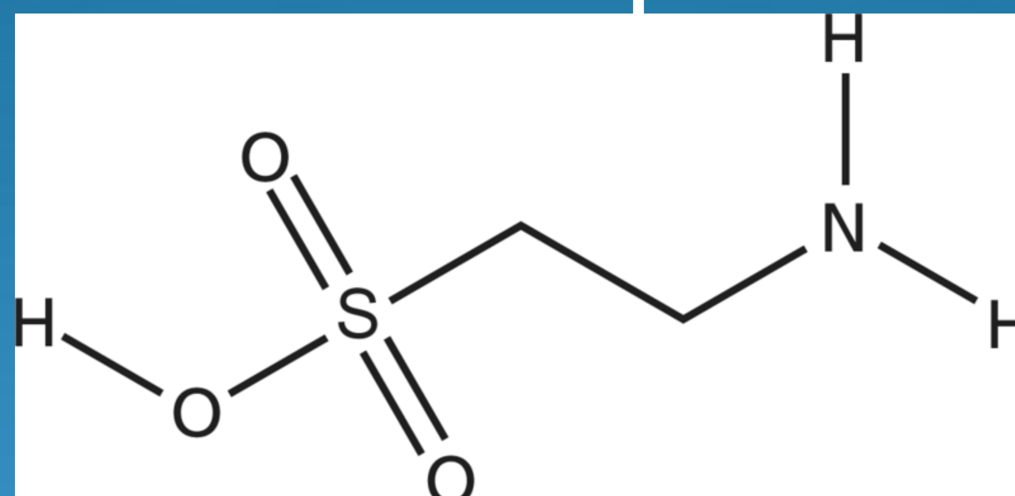
Digestibilities

	Seabass		Salmon	
Diet	ADC % Nitrogen	ADC % Carbon	ADC % Nitrogen	ADC % Carbon
0 % Insect Meal	94.8	92.2	86.0	88.3
30% Insect Meal	90.1	93.2	79.0	78.4
50% Insect Meal	90.2	83.2	83.1	83.2
80% Insect Meal	92.7	92.2	88.7	83.2

Growth Trial



Taurine
The missing ingredient for development of fish free diets for aquaculture?



Supplement Facts Serving Size 8.0 fl.oz. (240 ml) Serving Per Container 3		
Calories	100	
Total Carb	27g	9%
Sugars	27g	
Vitamin B2	1.7mg	100%
Vitamin B3	20mg	100%
Vitamin B6	2mg	100%
Vitamin B12	6mcg	100%
Sodium	180mg	8%
Taurine	1000mg	
Panax Ginseng	200mg	
Energy Blend 2500mg L-Carntine, Glucose, Caffeine, Guarana Inositol, Glucuronolactone, Maltodetrin		
Percent Daily Values are based on a 2000 calorie diet.		

Aaron Watson, Ph.D. Rick Barrows, Allen R. Place

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CENTER FOR ENVIRONMENTAL SCIENCE

Atlantic salmon (*Salmo salar*) require increased dietary levels of B-vitamins when fed diets with high inclusion of plant based ingredients

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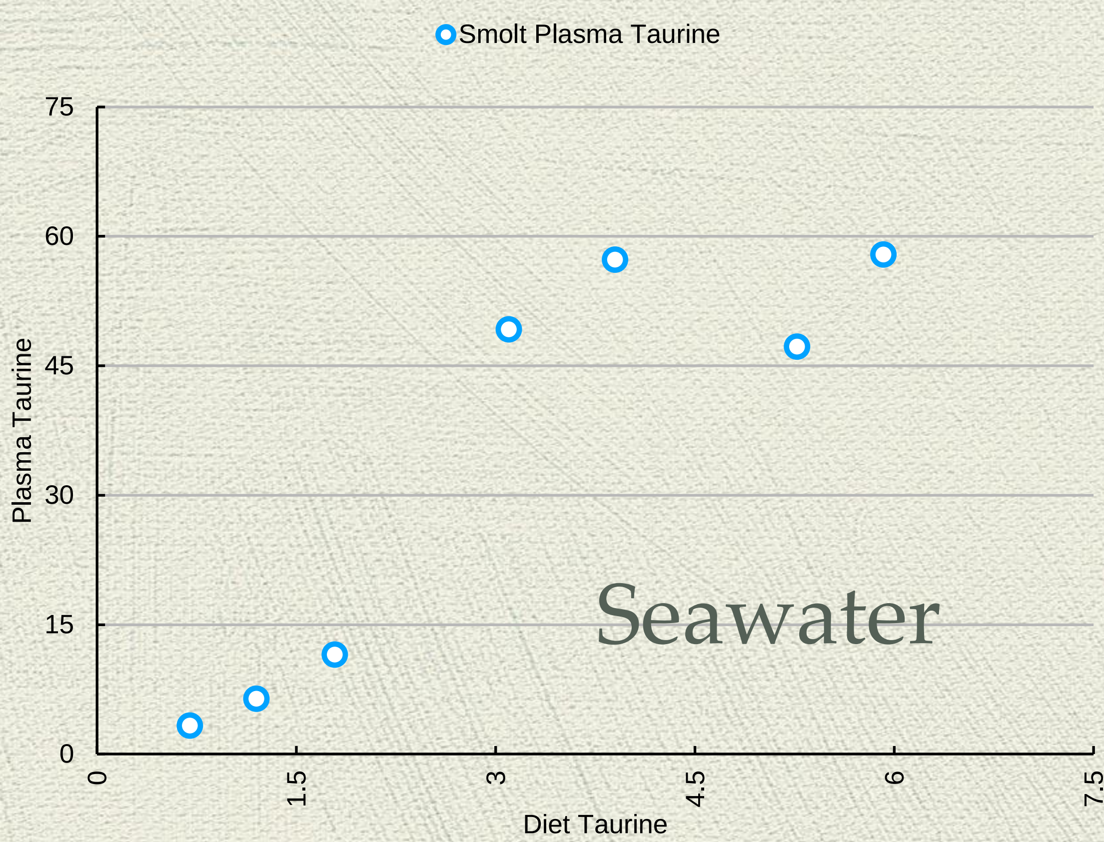

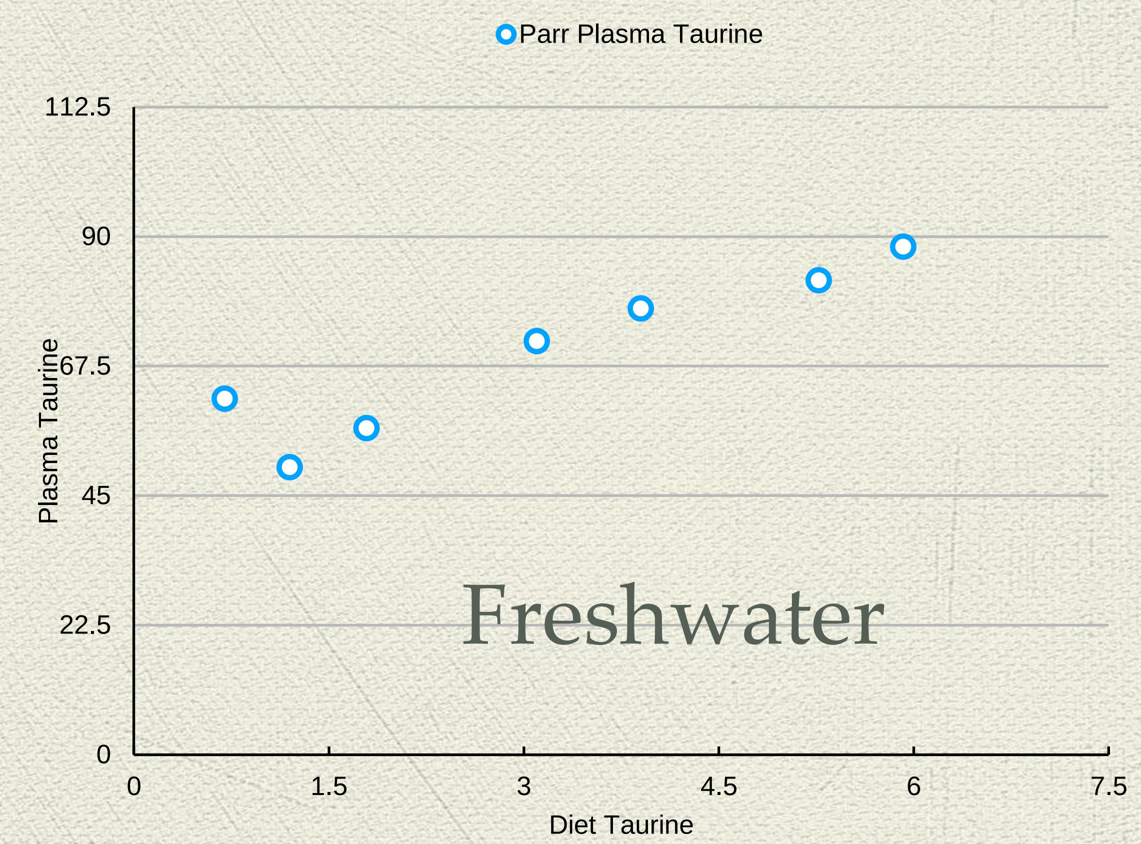

TABLE 4. Vitamin, choline, and inositol content of selected insect species on an as is basis

Vitamin	Crickets	Mealworms	Superworms	Waxworms
Vitamin A (IU/kg - from retinol)	<1,000[a,c]	<1,000[a,c]	<1,000[a,c]	<1,000[a,c]
Vitamin D_2 (IU/kg)	<40[a]	<40[a]	531	<40[a]
Vitamin D_3 (IU/kg)	<40[a,c]	<40[a,c]	<40[a,c]	<40[a,c]
Vitamin E (IU/kg)	53.7	36.2	163.0	63.3
Vitamin K (mg/kg)	78.4	<50[a,c]	<50[a,c]	<50[a,c]
Vitamin C (mg/kg)	92.0	99.0	101.0	90.0
Thiamin (mg/kg)	2.0	1.1[b]	1.7[b]	1.2[b,d]
Riboflavin (mg/kg)	16.6	8.7	11.2	9.3
Pantothenic Acid (mg/kg)	20.3	15.6	7.0	32.8
Niacin (mg/kg)	29.5	46.5	35.3	33.6
Pyridoxine (mg/kg)	2.13	6.90	3.55	1.74[a,d]
Folic Acid (mg/kg)	1.07	1.55	0.64	0.61
Biotin (mg/kg)	0.21	0.43	0.38	0.29
Vitamin B_{12} (µg/kg)	193.0	1.3[a,c]	9.9[a]	<1.2[a,c]
Choline (mg/kg)	1,020	1,410	1,240	1,550
Inositol (mg/kg)	345	267	223	236

[a]Value is <50% of the NRC requirement of rats for growth.
[b]Value is 50–100% of the NRC requirement of rats for growth.
[c]Value is <50% of the NRC requirements of 0–3 week old broiler chickens.
[d]Value is 50–100% of the NRC requirements of 0–3 week old broiler chickens.

TABLE 2. Mineral content (mg/kg) of selected insect species on an as is basis

Mineral	Crickets	Mealworms	Superworms	Waxworms
Calcium	366[a,c]	156[a,c]	262[a,c]	203[a,c]
Phosphorus	2,190	2,640	2,090[d]	1,930[d]
Magnesium	193[d]	620	435	266[b,d]
Sodium	1,110	225[c]	385[c]	<123[a,c]
Potassium	2,850	3,350	2,860	2,310
Chloride	2,210	1,760	1,630	760[d]
Iron	17.5[d]	20.7[d]	19.9[c]	9.6[a,c]
Zinc	54.3	49.5	30.2	25.9[d]
Copper	6.3	8.3	3.6[d]	3.3[d]
Manganese	8.7[c]	3.2[b,c]	3.7[b,c]	2.7[a,c]
Iodine	0.145	<0.10[a,c]	<0.10[a,c]	<0.10[a,c]
Selenium	0.133	0.123	0.103	0.177

[a]Value is <50% of the NRC requirement of rats for growth.
[b]Value is 50–100% of the NRC requirement of rats for growth.
[c]Value is <50% of the NRC requirements of 0–3 week old broiler chickens.
[d]Value is 50–100% of the NRC requirements of 0–3 week old broiler chickens.

Superworms

- Currently, *Zophobas morio* take twice as long to grow as *Tenebrio molitor*.
- However, during the course of their lifetimes, they put on biomass at 4.79 times the rate (Van Broekhoven et al, 2015), yielding a time-weighted average efficiency increase of about 240% over the more common *T. molitor*.
- Given the necessity of large-volume production to supply the aquaculture feed market, among others, it makes sense to focus on the species that produce the highest yield.
- Finally, live Z. *morio* larvae prices are 3.5x higher than *T. molitor* in the United States, making it a more profitable species in the 1-5 year time frame.