Zane Stiles, Justin Beiriger, and Alec DiVito
AP Biology
November 29, 2012
Mr. Krotec

Energy Dynamics Lab

Introduction:

The purpose of this experiment was to follow energy input through an ecosystem. In any ecosystem, complex abiotic and biotic interactions involve the exchange of free energy and matter. A constant input of energy is required to maintain a system. In most systems, the constant input of energy is the sun. The radiation of the sun is converted to biomass by primary producers, which provides the energy input for primary consumer, who provide the energy input for secondary consumers, and so on. The primary consumers, which are represented by larvae in this experiment, are herbivores, as they eat primary producers, which are plants, represented by the plants in this experiment. In this experiment, the light over the plant provides the constant energy input while the food which is continually added to butterfly larvae provides for constant energy. The interactions between the species are measured by weighing the biomass at each trophic level. This biomass is measured by taking the weight of each item (food, larvae, plants, frass, etc.) and estimating their dry weight or drying them and measuring the dry weight, in order to compensate for the water found in almost all organic material. This water does not contain chemical energy to be used by the organism, so is not included in the calculation from biomass to kilocalories. The butterfly food is assumed to be 77% water by mass, meaning 33% of the wet weight is the dry weight. Likewise, 38% of the frass wet weight is assumed to be dry weight, or biomass, and 40% of the larvae wet weight is considered to be dry weight, or biomass. In order to convert this to energy, in order to follow energy in the system, food is considered to be 4.35 kcal/g (dry weight), larvae 5.5 kcal/g (dry weight) and frass 4.76kcal/g (dry weight).

Gross primary productivity is the total amount of energy produced by the primary producers in an observed ecosystem. Net primary productivity is the total amount of energy produced minus the amount of energy that went to respiration, keeping the primary producers alive. Therefore net primary productivity is gross primary productivity minus respiration. Net primary productivity was measured in this experiment, as the plants and larvae respirated throughout.

In an ecosystem, however, there is not a perfect transfer of energy. General wisdom suggests that only 10% of the energy from each trophic level is transferred to the next. The rest is lost to heat and imperfect energy transfer as well as respiration. This experiment will test this purported 10% by measuring the energy transfer from primary producers (food) to primary consumers (butterfly larvae). Thus the null hypothesis is that there will not be significant variance from this 10% energy transfer and the observed energy transfer efficiency percentage.

Procedure:

See packet

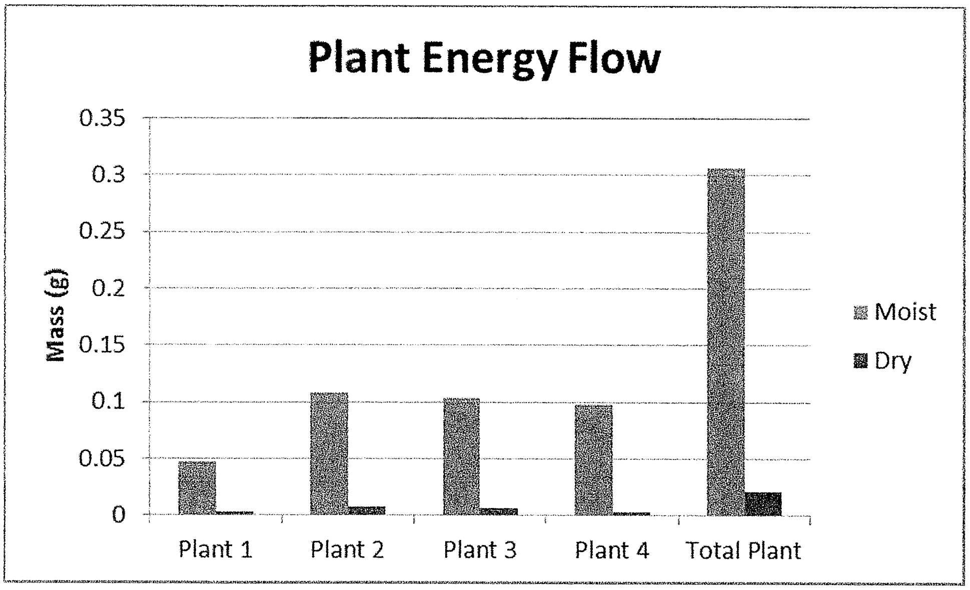
Results:

energy flow of plants

Calories of light energy → Plant Biomass/Energy → biomass
→ Respiration
→ Waste/lost as heat

Age of plant (days)	Wet weight (g)	Dry weight (g)	Percent of wet weight that represents biomass	Energy represented in biomass (4.35 kcal/g)	Net primary productivity/day
0 days old, 10 seeds	N/A	0.1110g	N/A	0.4829 kcal starting fuel	N/A
Average wt/seed	N/A	0.0111	N/A	0.0483 kcal starting fuel	N/A
Plant #1: 14 days old	0.0474g	0.0032g	6.75%	0.013 kcal	0.00093 kcal/day
Plant #2: 14 days old	0.1076g	0.0073g	6.78%	0.032 kcal	0.0023 kcal/day
Plant #3: 14 days old	0.1034g	0.0070g	6.77%	0.030 kcal	0.0021 kcal/day
Plant #4: 14 days old	0.0978g	0.0033g	3.37%	0.014 kcal	0.0010 kcal/day
14 day total	0.3062g	0.0208g	6.79%	0.091 kcal	0.0065 kcal/day
Average per plant	0.0766g	0.0052g	6.79%	0.023 kcal	0.0016 kcal/day

	Plant 1	Plant 2	Plant 3	Plant 4	Total Plant
Moist	0.0474	0.1076	0.1034	0.0978	0.3062
Dry	0.0032	0.0073	0.007	0.0033	0.0208



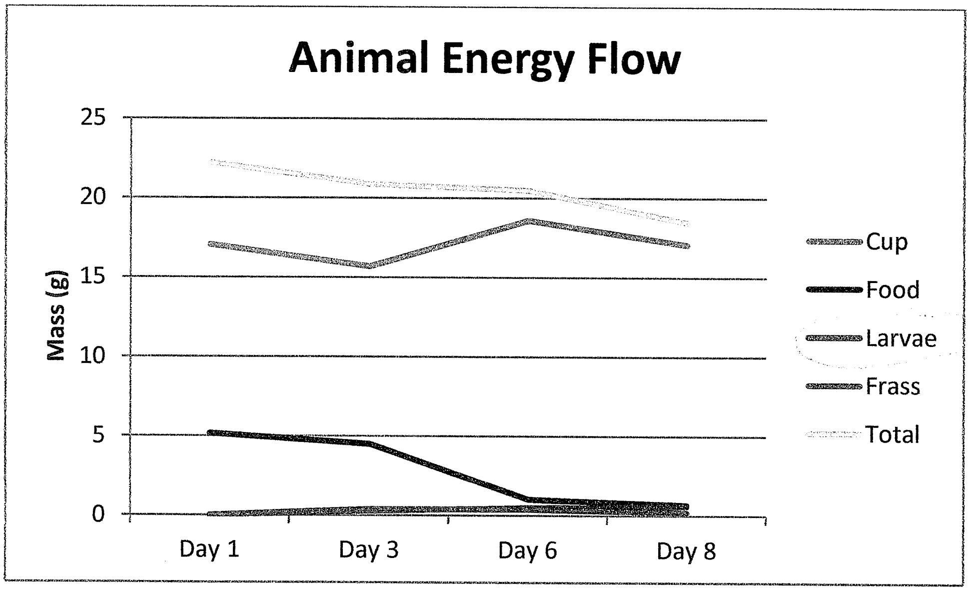
energy flow for butterfly larvae

Calories of food energy **(6.4767 kcal)** → Energy/Biomass in butterfly larvae → biomass **0.8008 kcal**
→ Respiration **1.7479 kcal**
→ Waste/lost as heat **3.9280 kcal**

Age of larvae (days)	Wet weight of larvae (g)	Dry weight of larvae (assumed to be 40% of wet weight) (g)	Weight of waste (fecal and molts) (g)	Wet Weight of consumed food (original food [5.1729]-remaining food) (g)	Dry weight of food consumed (assumed to be 33% of wet weight) (g)	Wet weight of frass produced (g)	Dry weight of frass produced (assumed to be 38% of wet weight) (g)
1	0.0052	0.0021	0	0	0	0	0
3	0.2806	0.1122 (0.1101 produced)	0.3970	1.6351	0.5455	0.3970	0.1509
6	0.4982	0.1993 (0.1972 produced)	0.3808	2.4965 (4.1316 total)	0.8238 (1.3634 total)	0.3808 (0.7778 total)	0.1447 (0.2956 total)
8	0.3692	0.1477 (0.1456 produced)	0.1885	0.3803 (4.5119 total)	0.1255 (1.4889 total)	0.1885 (0.9663 total)	0.0716 (0.3672 total)

Age of larvae (days)	Calories of food energy (4.35 kcal/g of dry weight of food)	Respiration (Kcal of frass dry weight [4.76kcal/g])	Total Net Primary Productivity (biomass of larvae minus the original weight at 5.5 kcal/g)	Energy transfer efficiency percentage (net primary productivity/total calories of food energy*100)	Waste/lost as heat (total food kcal-(total respiration +net primary productivity)
1	0	0	0	0	0
3	2.3729 kcal	0.7183 kcal	0.6056 kcal	25.52%	1.0490 kcal
6	3.5835 kcal (4.7037 kcal total)	0.6888 kcal (1.4071 kcal total)	1.0846 kcal	23.06%	2.212 kcal
8	0.5459 kcal (6.4767 kcal total)	0.3408 kcal (1.7479 kcal total)	0.8008 kcal	12.36%	3.9280 kcal

	Day 1	Day 3	Day 6	Day 8
Cup	17.0509	17.0509	17.0509	17.0509
Remaining Food	5.1729	3.5378	1.0413	0.721
Larvae	0.0052	0.2806	0.4932	0.3692
Frass	0	0.397	0.3808	0.1885
Total	22.229	20.8693	18.5905	18.3296



Conclusion:

Many factors limit the efficiency of energy transformation in plants. The efficiency of photosynthesis may limit energy transformation in the plants. If a large amount of energy from the sun or lights in the lab hits the photoreceptors or chlorophyll in the leaves of the plant, not all of it can be transformed into energy. Firstly, not all of the light hitting the leaves can be entered into the Calvin cycle, as so much light is hitting the leaves. Next, photosynthesis cannot transfer energy with 100% efficiency from light energy to biomass as energy is lost as heat in each step of the Calvin cycle. Respiration of the plants in order to maintain homeostasis also uses some of the energy.

Many factors also limit the efficiency of energy transformation in larvae. The larvae must use energy through respiration in order to stay alive, losing energy in the process. Further, the Krebs cycle does not convert energy with 100% efficiency from food to the larvae. Each step in the Krebs cycle represents an opportunity for energy to be lost to heat as each molecule is transformed into another via enzymes.

The data seems to suggest that the 10% transfer of energy efficiency is close to the observed overall amount in the butterfly larvae, which was observed at 12.36%. This marks a percentage difference of 23.6%. However, only 2 butterfly larvae were used, meaning no statistical analysis could be performed comparing this 12.36% to the 10% hypothesis. In future experiments, more trials should be run with far more larvae in order to use statistical analyses to gain statistically significant results. In addition, the 12.36% is only the final percentage. At different stages of the experiment, the efficiency was much higher, going as high as 25.52%.

There was room for a lot of error in this experiment. Most significantly, from day 6 to day 8 in the larvae experiment, the total mass of the larvae decreased from 0.4982g to 0.3692g. The larvae then died, preventing further data collection. One possible explanation is that the larvae were beginning to form chrysalises. Forming these structures would require energy, which may not have been fully provided by the food, as the butterfly could no longer eat after forming a chrysalis. This would force the butterfly to take energy from its biomass rather that the biomass of the food in order to form the chrysalis. In the experiment, the energy consumed in the formation of the chrysalis was calculated as waste, even though this is an evolutionarily necessary process, and clearly not waste. In addition, very few trials were run. Only 4 plants were use, and only 2 larvae. Adding more trials would decrease room for error. In addition, not all of the frass may have been separated from the remaining food each day. This would have caused the calculated reparation to be smaller than the actual respiration, and the remaining food calculated to be higher than the actual amount of food left. Thus missing frass would cause the calculation to calculate a smaller input of food and a smaller total for respiration than the actual result. Also, the organisms used, the plants and larvae, were so small, the scale which was accurate to 4 decimal places could vary significantly from the actual weight. This caused the dry weights of the plants to only be measured to 2 significant digits. In the future, more accurate scales or larger organisms should be used. Finally, the death of the larvae clearly impacted the results. The energy transfer efficiency may have been much higher had the larvae been living at full capacity and not dying.