**Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Lab: Energy Dynamics in an Ecosystem**

**■BACKGROUND** Almost all life on this planet is powered, either directly or indirectly, by sunlight. Energy captured from sunlight drives the production of energy-rich organic compounds  during the process of photosynthesis. These organic compounds are the **biomass** of the ecosystem. This biomass is equivalent to the net amount of energy captured and stored by the **producers** in a system and is called the system’s **net primary productivity**. The net primary productivity is also the amount of energy available to the next trophic level. **Gross primary productivity** is a measure of the total energy captured and turned into chemical energy during photosynthesis. To obtain the net primary productivity, you must subtract all the energy that was used in cellular respiration and ultimately released as heat, from the gross productivity.

In terrestrial systems, plants play the role of producers. Plants allocate that biomass (energy) to power their life processes or to store energy. Different plants have different strategies of energy allocation that reflect their role in various ecosystems. For example, annual weedy  plants allocate a larger percentage of their biomass production to reproductive processes and seeds than do slower growing perennials. As plants, the producers are consumed  or decomposed, and their stored chemical energy powers additional individuals, the consumers, or trophic levels of the biotic community. Biotic systems run on energy much as economic systems run on money. Energy is generally in limited supply in most communities. Energy dynamics in a biotic community is fundamental to understanding ecological interactions.

Learning Objectives:

-To explain community/ecosystem energy dynamics, including energy transfer between different trophic levels.

-To calculate biomass, net primary productivity (NPP), secondary productivity, and respiration.

**There are two parts to this lab:**

Part 1- Estimate the net primary productivity (NPP) of Wisconsin Fast Plants over several weeks.

Part 2 - You will calculate the flow of energy from plants (producers) to butterfly larvae (primary consumers). These calculations will include an estimate of secondary productivity, which would be the amount of biomass added to the larvae and therefore to the next trophic level, and the amount of energy lost to cellular respiration.

**Part 1: Estimating Net Productivity (NPP) of Fast Plants**

Primary productivity is a rate — energy captured by photosynthetic organisms in a given area per unit of time. Based on the second law of thermodynamics, when energy is converted from one form to another, some energy will be lost as heat. When light energy is converted to chemical energy in photosynthesis or transferred from one organism (a plant or producer) to its consumer (e.g., an herbivorous insect), some energy will be lost as heat during each transfer.

In terrestrial ecosystems, productivity (or energy capture) is generally estimated by the change in biomass of plants produced over a specific time period. Measuring biomass or changes in biomass is relatively straightforward: simply mass the organism(s) on an appropriate scale and record the mass over various time intervals. The complicating factor is that a large percentage of the mass of a living organism is water — not the energy-rich organic compounds of biomass. Therefore, to determine the biomass at a particular point in time accurately, you must dry the organism. Obviously, this creates  a problem if you wish to take multiple measurements on the same living organism. Another issue is that different organic compounds store different amounts of energy;  in proteins and carbohydrates it is about 4 kcal/g dry weight and in fats it is 9 kcal/g of dry weight).

**Define the following terms, and then fill in the diagram below showing energy transfer in plants.**

1. Gross Primary Productivity - \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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2. Net primary Productivity - \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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3. Secondary Net Productivity - \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**Review the energy transfer in plants by filling in the arrows below:**



**Procedure (For each section, show ALL CALCULATIONS in the spaces provided)**

**Step 1:** Plant 40 Wisconsin Fast Plants in the same manner you planted them for the artificial selection lab. Plant 4 per container. Grow them for 7 days in controlled conditions.

**Step 2**: on day 7, randomly select 10 of the 40 plants and carefully remove them from the soil with their roots intact. Gently wash the soil from the roots and blot the roots dry. Measure the wet mass of the 10 plants collectively.

**Wet Mass of 10 Plants (Day 7) = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Step 3:** Place the 10 plants in the drying oven at 200°C for 24 hours. After 24 hours, remove the plants from the drying oven and record the mass of the dry plants.

**Dry mass of 10 Plants (Day 8) = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Step 4:** Use the following equation to calculate percent biomass:

% biomass = mass of dry plants x 100

mass of wet plants

**Percent Biomass = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**\*Note how much of the plants’ total mass is actually biomass (organic compounds) and how much is made up of water.**

Each gram of a Fast Plant’s **dry biomass** is equivalent to **4.35 kcal of energy.**

To calculate the amount of energy in kcal in the plants, multiply

4.35 kcal/g x the dry biomass

**-Amount of energy in kcal of the 10 plants (8 days) = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**-Amount of energy in kcal of 1 plant (at 8 days) = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Net Primary Productivity (NPP)** is the amount of energy stored (added) as biomass **per day** by autotrophs in an ecosystem and is expressed in **kcal/day.**

**In the following section, you will calculate NPP per plant per day.**

**Organize your data in the following table:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Age in Days | Wet mass/10 plants | Dry mass/10 plants | Percent biomass | Energy in kcal per 10 plants | Energy in kcal per plant | Net Primary Productivity per day per plant |
| **7** |  |  |  |  |  |  |

**Step 5:** On day 14, randomly select 10 plants and carefully remove them from the soil with their roots intact. Gently wash the soil from the roots and blot the roots dry. Measure the wet mass of the 10 plants collectively. After recording the wet mass, place the plants in the drying oven to obtain the dry mass as before.

**Again, organize your new data in the following table:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Age in Days | Wet mass/10 plants | Dry mass/10 plants | Percent biomass | Energy in kcal per 10 plants | Energy in kcal per plant | Net Primary Productivity per day per plant |
| **14** |  |  |  |  |  |  |

**Step 6:** On day 21, randomly select 10 plants and carefully remove them from the soil with their roots intact. Gently wash the soil from the roots and blot the roots dry. Measure the wet mass of the 10 plants collectively. After recording the wet mass, place the plants in the drying oven to obtain the dry mass as before.

**Again, organize your new data in the following table:**

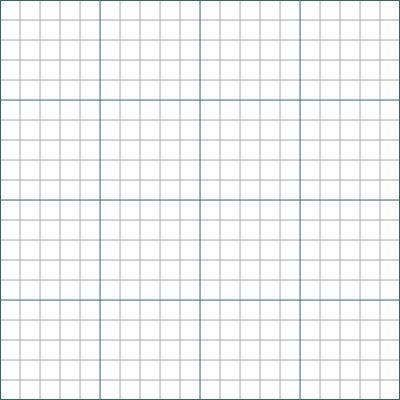
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| --- | --- | --- | --- | --- | --- | --- |
| Age in Days | Wet mass/10 plants | Dry mass/10 plants | Percent biomass | Energy in kcal per 10 plants | Energy in kcal per plant | Net Primary Productivity per day per plant |
| **21** |  |  |  |  |  |  |

**Step 7**: The NPP for a sample class with 7 groups is shown in the table below. Group 1 has been left out. **You should record your data in group 1.**

**Class Data: Net Primary Productivity of Wisconsin Fast Plants**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Time (Days) | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Group 7 | Average |
| 7 |  | .25 | .25 | .27 | .26 | .27 | .26 |  |
| 14 |  | .28 | .29 | .30 | .29 | .30 | .28 |  |
| 21 |  | .31 | .32 | .31 | .32 | .33 | .32 |  |

**Graph the Average Net Primary Productivity for the Fast Plants**



**Why does the NPP increase over time (as the plants grow and mature)?**

**What would you expect the graph of NPP to do at a point when the plants are no longer growing?**

**Part 2: Estimating Energy Transfer from Producers to Primary Consumers**

In this experiment, you will be using a simple two step food chain using Brussels sprouts as the producers and butterfly larvae as the primary consumer.



**Review the energy transfer in primary consumers (butterfly larvae) by filling the arrows below.**



In order to calculate plant, larvae, and frass energy in kcal, you must multiply by known values for the organisms.

**Plant energy = biomass x 4.35 kcal/g**

**Larvae energy = biomass x 5.5 kcal/g**

**Frass energy = biomass x 4.75 kcal/g**

Can you explain why these values differ depending on which organism (or waste) you are measuring?

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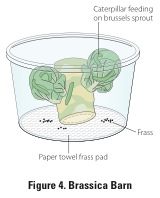
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**Step 1:** Measure the wet mass of the Brussels sprouts and 10 butterfly larvae

**Wet mass of Brussels sprouts \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Wet mass of 10 butterfly larvae (12 days old) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Step 2:** Place Brussels sprouts into an aerated (with air holes) deli container along with 10 butterfly larvae that are 12 days old.

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**Step 3:** After 3 days, disassemble the container and measure the wet mass again.

**Wet mass of Brussels sprouts \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Wet mass of 10 butterfly larvae (15 days old) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Step 4:** Place the Brussels sprouts, butterfly larvae and the frass in the drying oven at 200°C for 24 hours. Then remove the items and measure the dry mass of each.

**Dry mass of Brussels sprouts \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Dry mass of 10 butterfly larvae (15 days old) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Dry mass of frass from 10 larvae \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Tables of Energy/Biomass Flow from Plants to Butterfly Larvae**

You will be using the percent biomass of both the plants and larvae to calculate the energy lost by plants or gained by larvae. **You will assume that the percent biomass is the same on Day 1 and Day 3 because we can’t directly measure this value.**

**Table 1: Brussels Sprouts**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Day 1 | Day 3 |  |
| Wet mass of Brussels sprouts |  |  | Grams consumed = |
| Plant percent biomass  (dry/wet) |  |  |  |
| Plant energy  (wet mass x percent biomass x 4.35kcal/g) |  |  | kcal consumed per 10 larvae = |
| Plant energy consumed per larvae  (energy/10) |  |  | kcal consumed per larvae = |

**Table 2: Butterfly Larvae**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Day 1 | Day 3 |  |
| Wet mass of 10 larvae |  |  | Grams gained = |
| Wet mass per individual |  |  | Grams gained per larvae= |
| Larvae percent biomass (dry/wet) |  |  |  |
| Energy production per individual  (ind. wet mass x percent biomass x 5.5 kcal/g) |  |  | kcal gained per larvae = |

**Table 3: Frass**

|  |  |
| --- | --- |
|  | Day 3 |
| Dry mass of frass from 10 larvae |  |
| Total Frass energy (waste) (frass mass x 4.75 kcal/g) |  |
| Frass energy waste per larvae (frass energy waste/10) |  |

**Table 4: Respiration**

|  |  |
| --- | --- |
| Respiration =  energy consumed/larvae – energy gained/larvae – frass energy waste/ larvae | Day 3 |
| **Show your work here** |  |

**On average 10% of the energy from the producer level is passed onto primary consumers. What percent of energy was passed to the primary consumers in your experiment?**