4.2 Productivity and energy transfer

Name: _____ Class: _____ Date: _____ **Total: 19 marks**

KEY WORDS gross primary productivity • net primary productivity • trophic level • transfer efficiency

Objective

Practise statements 5.9-5.10: gross and net primary productivity, the units of productivity, and the efficiency of energy and biomass transfers between trophic levels.

1 Key knowledge and worked examples

■ The productivity equation

$$\text{NPP} = \text{GPP} - R$$

Gross primary productivity : energy fixed by photosynthesis, per unit area per time (kJ m^{-2} yr^{-1}). **Net primary productivity** : what remains after the producers' own respiration – the energy actually available to herbivores.

■ Ten per cent, four losses

Each transfer upward keeps about 10 %: losses to respiration (heat), egestion (faeces), excretion and uneaten parts. Biomass transfer efficiency:

$$\text{efficiency} = \frac{\text{energy or biomass at next level}}{\text{energy or biomass at this level}} \times 100\%$$

■ Worked example: the arithmetic of eating lower

Plankton fix 12 000 kJ m^{-2} yr^{-1}, respiring 7 200. NPP = 4 800. Fish eating plankton keep 10 % = 480; humans eating the fish keep 48. Humans eating the plankton directly (seaweed farm) would access 480 – ten times more energy per unit area.

2 Practice

2.1 Define net primary productivity and give its units. [2]

2.2 State two reasons energy is lost between a rabbit and the fox that eats it. [2]

2.3 Producers fix 80 000 kJ m^{-2} yr^{-1} and respire 30 000. Calculate the energy reaching second-order consumers if each transfer is 10 % efficient. [2]

3 Exam-style questions

3.1 The table shows the energy entering and leaving each trophic level of a lake (kJ m^{-2} yr^{-1}).

Level	Energy in	Respiration	Egestion + excretion	Eaten by next level
Algae	55 000 (fixed)	22 000	3 000	?
Zooplankton	?	2 400	900	470
Fish	470	210	60	44

Calculate the algae's NPP, the transfer efficiency from algae to zooplankton, and the efficiency from zooplankton to fish. [5]

3.2 Explain why a vegetarian human population can be larger than a meat-eating one on the same land, referring to the energy losses at each transfer. [4]

3.3 A farmer measures biomass transfer from grass to cattle at 8 % in a cold winter and 15 % in summer. Suggest why the winter percentage falls, referring to respiration, and state one management change that would raise it. [4]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 The energy fixed by photosynthesis minus the producers' own respiration; units kJ m^{-2} yr^{-1}.

2.2 Any two: rabbit respiration lost as heat; egestion of cellulose; excretion; parts of the rabbit never eaten by the fox.

2.3 NPP = 50 000; herbivores keep 5 000; second-order consumers keep 500 kJ m^{-2} yr^{-1}.

3.1 Algae NPP = 55 000 − 22 000 = 33 000. Zooplankton intake = algae's passed-on energy: 33 000 − 3 000 egestion = 30 000; transfer efficiency 2 400 + 900 + 470 = 3 770... consistent intake is 3 770: efficiency = 3 770/30 000 ≈ 12.6%. Zooplankton to fish: 470/3 770 × 100 = 12.5%. Allowing for zooplankton production only (470 + respiration + losses): full credit for consistent ratios.

3.2 Each transfer loses ~90 % of the energy to respiration and waste; eating plants directly removes one whole transfer, so the same land supports roughly ten times the human energy intake.

3.3 In cold conditions the cattle respire more to maintain body temperature, so a larger share of intake leaves as heat instead of biomass. Management: housing or windbreaks to reduce heat loss; or higher-energy feed so more intake remains after maintenance.