Lab 2: Miscellaneous Calculations

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> Date
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> - **Lab Date:** 23 September 2024 (Monday)
> - **Due Date:** 7:00, 30 September 2024 (Monday)

1 Background

Students will work as individuals; assignments are per individual. This lab is due on Monday 30 September 2024 at 7:00 on iKamva.

1.1 Pre-Lab

Read this lab and contextualise within the pertinent material in your text.

1.2 Post-Lab

Upon completion of this lab:

- transcribe all tables and questions (Exercises A-E) to an electronic document and submit on iKamva. To submit online on Monday 30 September 2024 at 7:00.

2 Questions

2.1 Question 1: Dilutions (10 marks)

A 1.5% (mass:volume) carrageenan gel consists of 0.75g of carrageenan dissolved in 50 ml of 1% KCl. You accidentally added 0.87g to the 50 ml.

i. What percentage gel have you inadvertently prepared?
ii. How much additional water must be added to the 50 ml to achieve the desired 1.5% gel?
iii. Carrageenan is a polysaccharide. Identify its biological origin: which photoautotrophs synthesise it?
iv. Explain its ecological role in those organisms.
v. Describe how humans exploit carrageenan's properties in food or industry.

2.2 Question 2: Quantum Light Measurements (4 marks)

monochromatic blue light source (420 nm) provides a photon flux density of 120 μmol photons.m^{-2}.s^{-1}.

How many photons will fall on an area of 25 cm^2 over a 2-hour period?

(Be sure to convert the area into square metres, and assume flux density remains constant.)

2.3 Question 3: Plant Growth Rates (9 marks)

For each scenario below:

- Identify the biological process the measurements represent;
- Write down a suitable equation for calculating the process;
- Calculate the rate;
- State the resulting units.

Scenario i (4 marks)	Scenario ii (5 marks)
• Day 1: Plant biomass of 99 g	• Time, 0 minutes: 7.95 mg/L O_2
• Day 100: Plant biomass of 149 g	• Time, 20 minutes: 11.39 mg/L O_2
	• Algal biomass: 2.3 g fresh mass

(In Scenario ii, calculate the oxygen production rate per gram of algal fresh mass.)

2.4 Question 4: Light Attenuation (15 marks)

You are a marine scientist assessing light penetration in the water column off Richards Bay, KZN. Measurements are taken in 5 m increments down to 50 m. Two stations are sampled:

- 1 km from shore (incident radiation at surface, 8:00: 1,213 μmol photons.m^{-2}.s^{-1})
- 20 km from shore (incident radiation at surface, 9:35: 2,166 μmol photons.m^{-2}.s^{-1})

Unfortunately, your submersible light meter was left in the lab; only surface values are available.

1. Using the Beer–Lambert law $I_z = I_0 e^{-kz}$, construct vertical light intensity curves for each site (surface to 50 m). State any assumptions made about the attenuation coefficient k.

2. Justify why these theoretical curves are a reasonable approximation of reality.
3. Identify physical and methodological factors that would cause deviation from the actual in situ profiles.

2.5 Question 5: Photosynthetic Rate Calculation (10 marks)

A leaf in full sunlight absorbs 10 mol of photons per square meter per second (mol m^{-2} s^{-1}). Its quantum yield is 0.05 mol of CO_2 fixed per mol of photons absorbed.

Calculate the photosynthetic rate (in µmol CO_2 m^{-2} s^{-1}) of the leaf under these conditions.

2.6 Question 6: Relative Growth Rate (RGR) (5 marks)

The biomass of a plant at time t_0 is 50 g. After 10 days (time t_1), the biomass is 80 g.

Calculate the relative growth rate (RGR) in g g^{-1} day^{-1} using the equation:

$$RGR = \frac{\ln(W_1) - \ln(W_0)}{t_1 - t_0}$$

Where:

- (W_1) is the biomass at time (t_1)
- (W_0) is the biomass at time (t_0)

Explain why logarithmic growth is used instead of simple arithmetic increase.

2.7 Question 7: Respiration Rate and Plant Carbon Balance (5 marks)

A plant in darkness consumes 5 mg CO_2 per hour for respiration. During the day, its photosynthetic rate is 15 mg CO_2 per hour. Assume 12 hours light and 12 hours dark.

Calculate the net carbon balance of the plant over a 24-hour period. Is it positive or negative?

(Clarify whether the rates refer to whole-plant values or per unit biomass in your calculation.)

2.8 Question 8: Additive Light Intensity at Different Depths in Water (10 marks)

In an aquatic experiment, photon flux density at 2 m depth arises from multiple sources:

- Direct sunlight = 400 µmol photons m^{-2} s^{-1}
- Diffuse underwater reflections = 120 µmol photons m^{-2} s^{-1}
- Scattered light from particles = 50 µmol photons m^{-2} s^{-1}

1. Calculate the total photon flux density at a depth of 2 meters.
2. If a plant requires ≥500 µmol photons m^{-2} s^{-1} for photosynthesis, is the requirement met?
3. Briefly discuss how turbidity or scattering would affect these additive contributions in natural waters.

2.9 Question 9: Spectrally resolved attenuation and the euphotic boundary (12 marks)

At noon the surface PAR is $I_0 = 1,800\ \mu\text{mol photons m}^{-2}\text{s}^{-1}$. Treat the incident spectrum as two quasi-monochromatic bands:

- "Blue–green" centred at 490 nm, comprising 45% of I_0, with diffuse attenuation $k_{BG} = 0.040\ \mathrm{m}^{-1}$.
- "Red–yellow" centred at 620 nm, comprising 55% of I_0, with diffuse attenuation $k_{RY} = 0.25\ \mathrm{m}^{-1}$.

Assume independent exponential loss with depth and no internal sources.

1. Write an explicit expression for total PAR at depth z as the sum of the two bands, $I(z) = I_{BG}(z) + I_{RY}(z)$. State the units at each step.
2. Compute the 1% light level $z_{1\%}$ defined by $I(z_{1\%}) = 0.01\, I_0$. Because the sum of two exponentials lacks a closed-form inverse, determine $z_{1\%}$ to the nearest metre by a transparent numerical bracketing (show at least three evaluated depths and your final interpolation).
3. At $z = 30$ m and $z = 60$ m, calculate the fractional contribution of the blue–green band to total PAR, i.e., $f_{BG}(z) = I_{BG}(z)/I(z)$. Interpret the change in f_{BG} with depth in one or two sentences.

(Note. Answers that hide the unit conversions or skip the bracketing will be penalised.)

Bibliography