



Cambridge International AS & A Level

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MARINE SCIENCE

9693/41

Paper 4 A Level Data-handling and Investigative Skills

May/June 2026

1 hour 45 minutes

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen. Do **not** use correction fluid or tape.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION

- The total mark for this paper is 75.
- The number of marks for each question or part question is shown in brackets [].

This document has **24** pages. Any blank pages are indicated.

Answer **all** questions.

- 1 (a) Figure 1.1 is a photomicrograph of a marine diatom called *Ditylium brightwelli*.

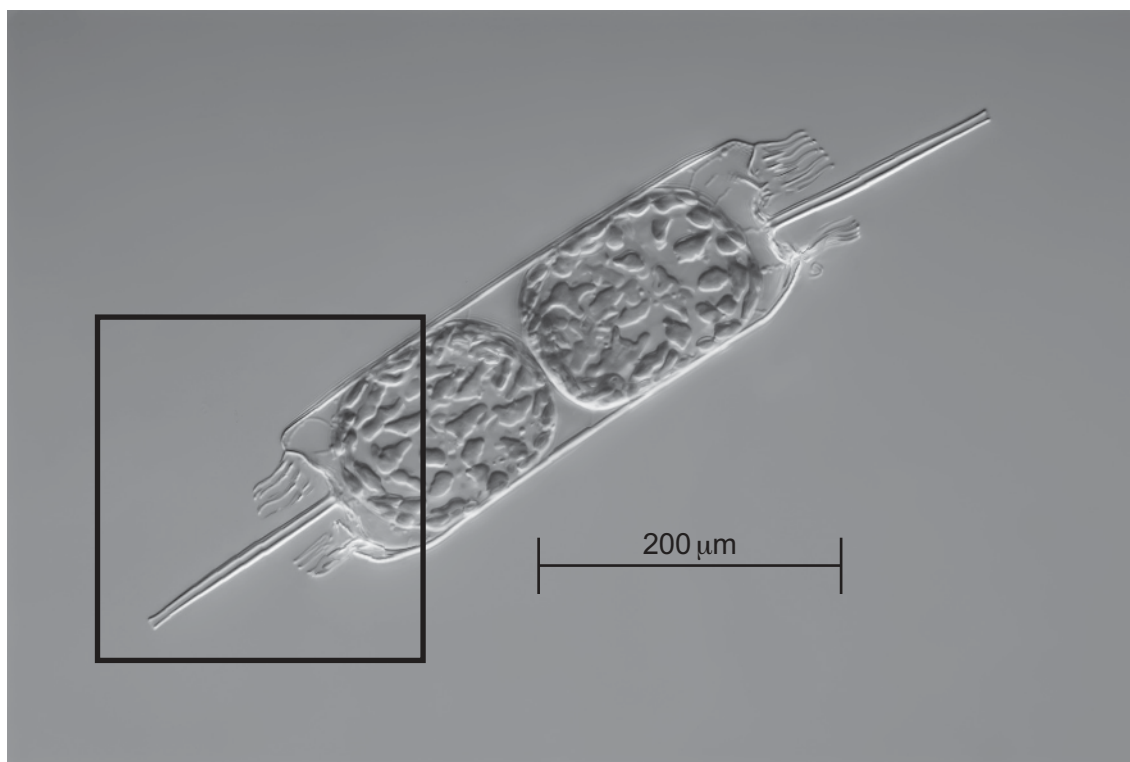


Figure 1.1

- (i) Make a large drawing of the part of *Ditylium brightwelli* inside the black box shown in Figure 1.1.

Do **not** label your drawing.

(ii) Use the scale bar to calculate the magnification of the photomicrograph in Figure 1.1.

× [3]

(iii) *Ditylimum brightwelli* fixes carbon by photosynthesis.

Outline how the light-independent stage of photosynthesis fixes carbon.

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..... [3]



(b) Carbon can also be fixed in marine ecosystems by chemosynthesis.

Scientists investigated the proportion of carbon fixed by photosynthesis and chemosynthesis in different areas of ocean.

This is the scientists' method.

- Collect water from an area of sea over the continental shelf and from an area of open ocean.
- Place five samples of water from each area into test-tubes.
- Measure carbon fixation by photosynthesis.
- Measure carbon fixation by chemosynthesis.
- Calculate the mean rates of carbon fixation from photosynthesis and chemosynthesis for both areas.

The results are shown in Figure 1.2.

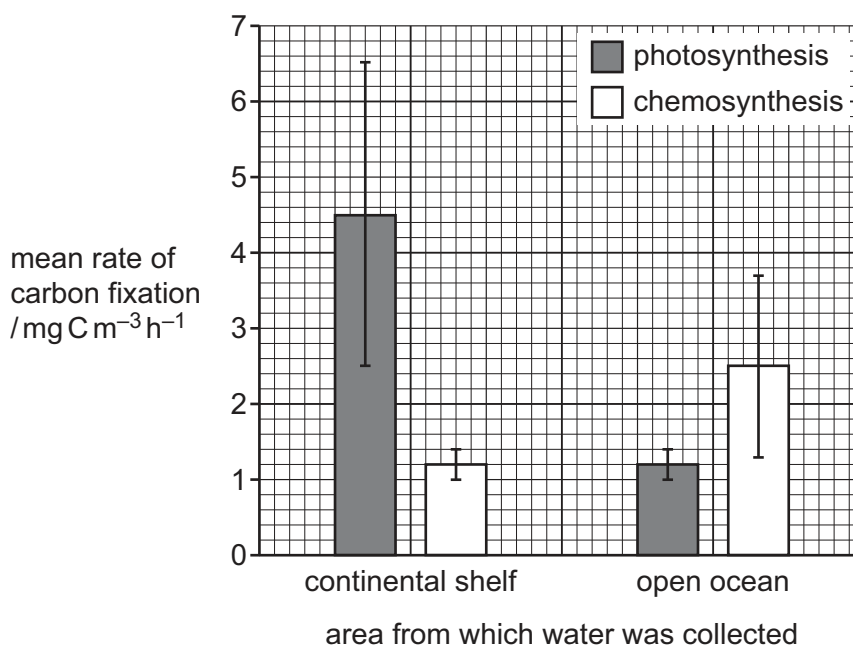


Figure 1.2

- (i) Give **one** variable that the scientists should standardise to compare the rate of photosynthesis and the rate of chemosynthesis.

..... [1]



- (ii) Calculate the percentage of the total mean rate of carbon fixation in water from the continental shelf that is due to photosynthesis.

..... % [2]

- (iii) The error bars in Figure 1.2 are ± 2 standard deviations.

Explain what the error bars show about the difference between the mean rate of carbon fixation by photosynthesis and by chemosynthesis in water from the continental shelf.

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..... [2]

- (iv) Describe **and** explain the results of the investigation shown in Figure 1.2.

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- (v) In a further experiment, the scientists compared the mean rate of carbon fixation by chemosynthesis from two different locations of seabed within the open ocean area.

The results are shown in Table 1.1.

Table 1.1

location	mean rate of carbon fixation by chemosynthesis /mg C m ⁻³ h ⁻¹
P	0.2
Q	2.8

Suggest why there is a difference in the mean rate of carbon fixation by chemosynthesis in the two areas shown in Table 1.1.

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..... [2]

[Total: 21]



- 2 Ocean acidification from increased atmospheric carbon dioxide could have negative impacts on hard corals and shelled organisms.

(a) (i) Describe how carbon dioxide reacts with sea water.

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..... [2]

(ii) Explain why ocean acidification could have negative impacts on hard corals and shelled organisms.

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..... [2]

(b) Ocean acidification may have less impact on species of soft corals.

Figure 2.1 is a photograph of a soft coral.

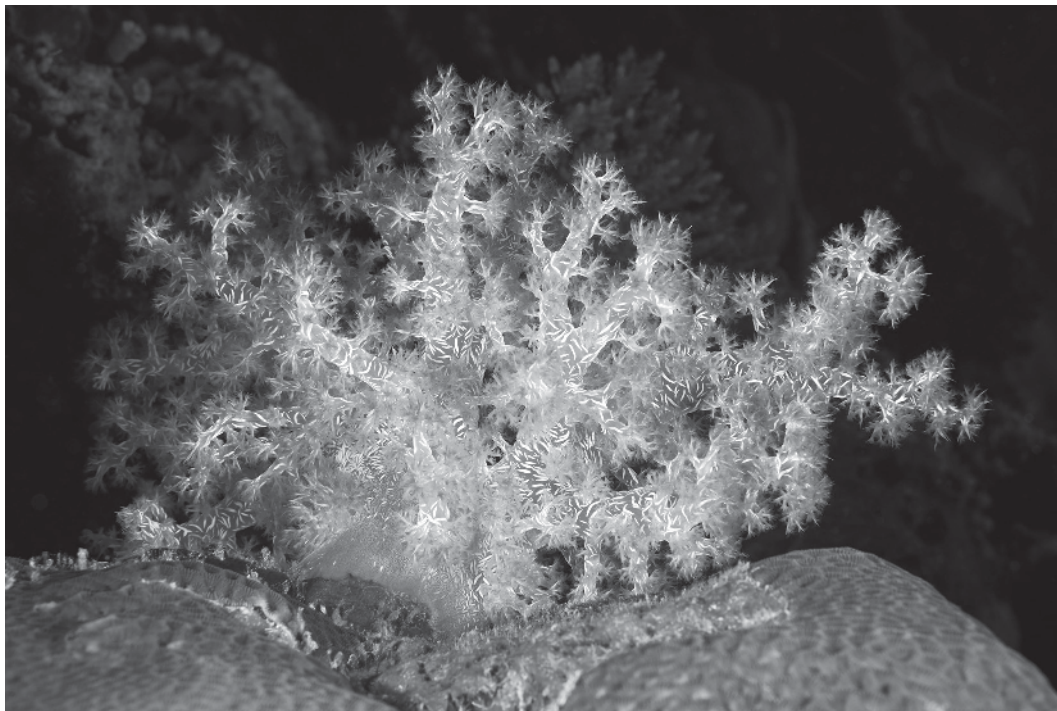


Figure 2.1



Soft corals move their tentacles in rhythmic pulses and can change the rate of pulses depending on the water conditions.

Scientists compared the effects of sea water and acidified sea water on the rate of tentacle movement and rate of growth of a soft coral, over 3 weeks.

The soft coral species has a symbiotic relationship with photosynthetic zooxanthellae.

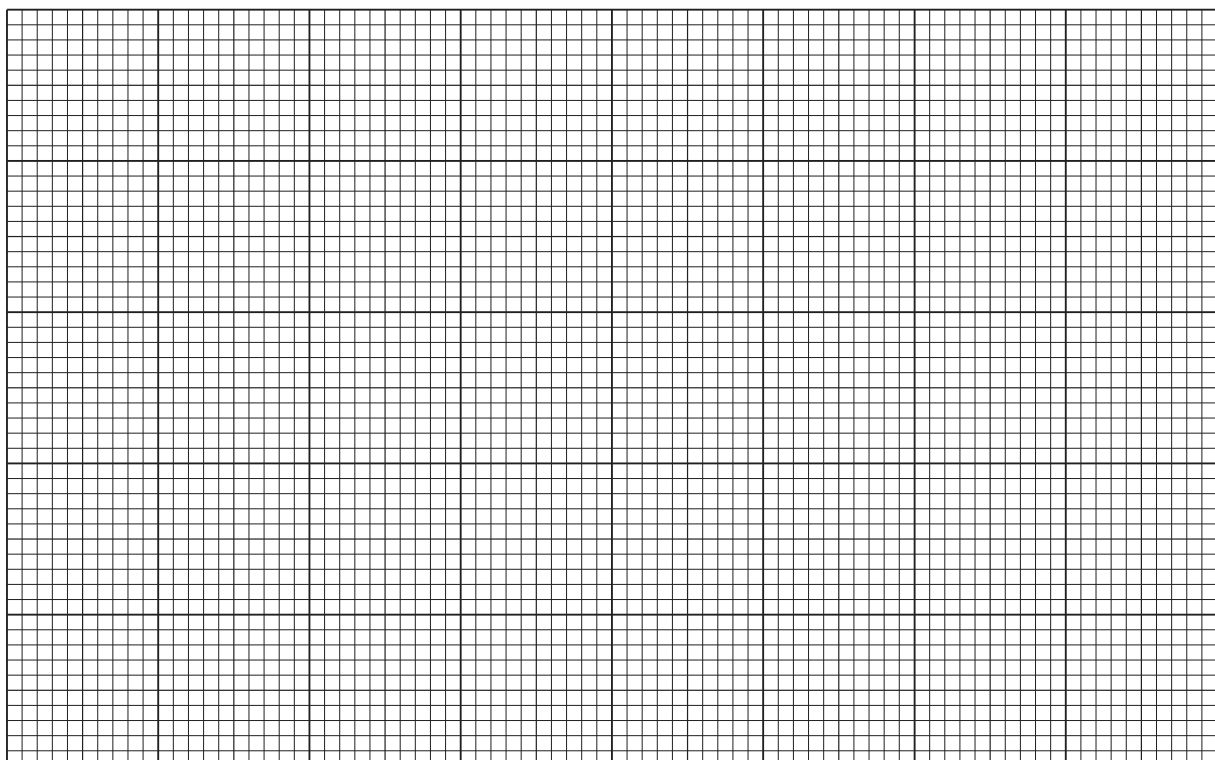
Table 2.1 shows the scientists' results.

Table 2.1

week	rate of tentacle movement /pulses min ⁻¹		rate of growth of soft coral /a.u.	
	sea water	acidified sea water	sea water	acidified sea water
1	46	36	0.5	0.3
2	40	30	0.4	0.1
3	38	26	0.3	0.1

- (i) Draw a bar chart to display the data shown in Table 2.1.

Include a key to identify the bars.



week

[5]



- (ii) The growth of the coral polyps was measured by calculating the total surface areas of the coral polyp tentacles.

The surface area of a tentacle is calculated using this formula:

$$\text{surface area of one tentacle} = 2\pi rl$$

r = radius of the tentacle

l = length of the tentacle

$\pi = 3.14$

A soft coral polyp has eight tentacles.

Each tentacle has a radius of 1.5 mm and a length of 4 mm.

Calculate the total surface area of the eight tentacles of the coral polyp.

Give your answer to **two** significant figures.

State the unit.

[3]

- (iii) Suggest explanations for the effect of acidified sea water on the growth of the soft coral shown in Table 2.1.

[4]

[Total: 16]



- 3 The Baltic Sea is an area of ocean in the northern hemisphere between latitudes of 53°N and 66°N . The Baltic Sea has areas of low-salinity sea water.

Figure 3.1 is a map of the Baltic Sea.

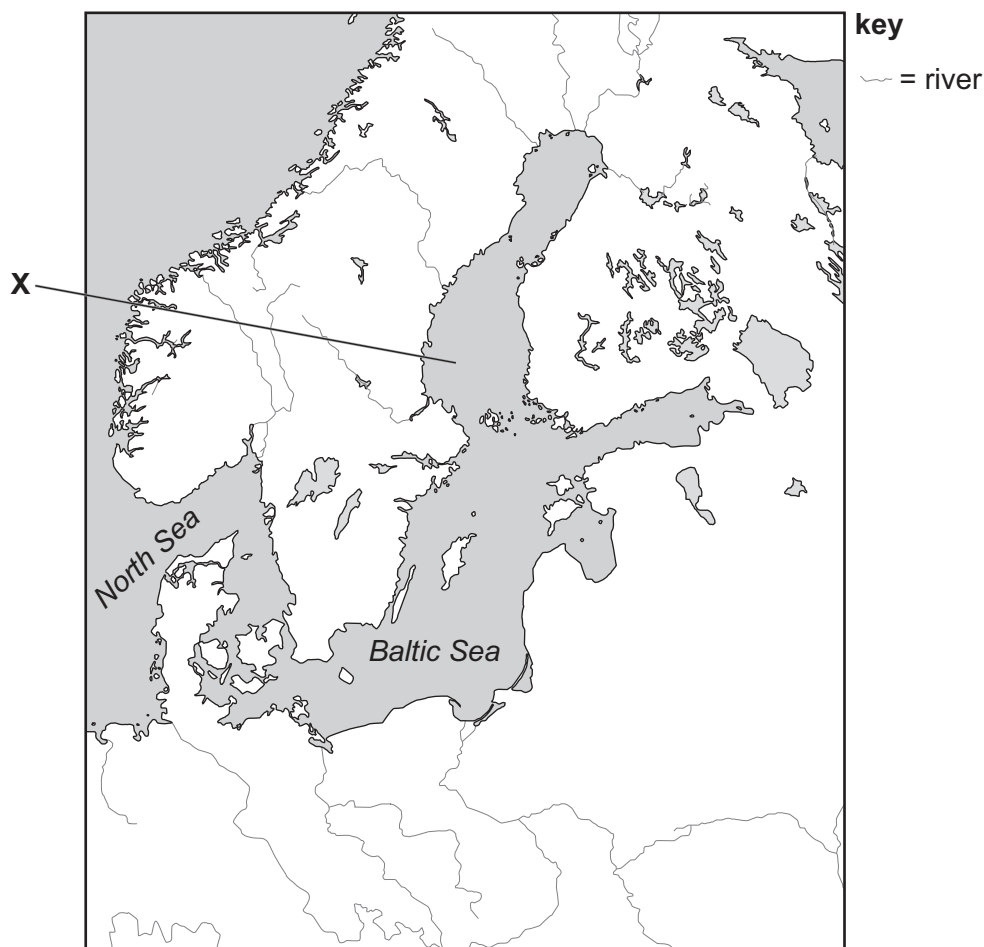


Figure 3.1

- (a) Suggest why the area labelled **X** in Figure 3.1 has water with low salinity.

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..... [2]

- (b) Blue mussels are a species of mussel that lives in the Baltic Sea.

Scientists investigated the effect of placing blue mussels into water of different salinities for two weeks.

After two weeks in the different salinities, the scientists measured the percentage water content of the mussel body fluid and the osmolarity of the mussel body fluid.

The osmolarity of a solution is a measure of the number of solute particles dissolved in a fixed volume. The unit for osmolarity is mOsmol dm^{-3} .

Figure 3.2 and Figure 3.3 show the results.

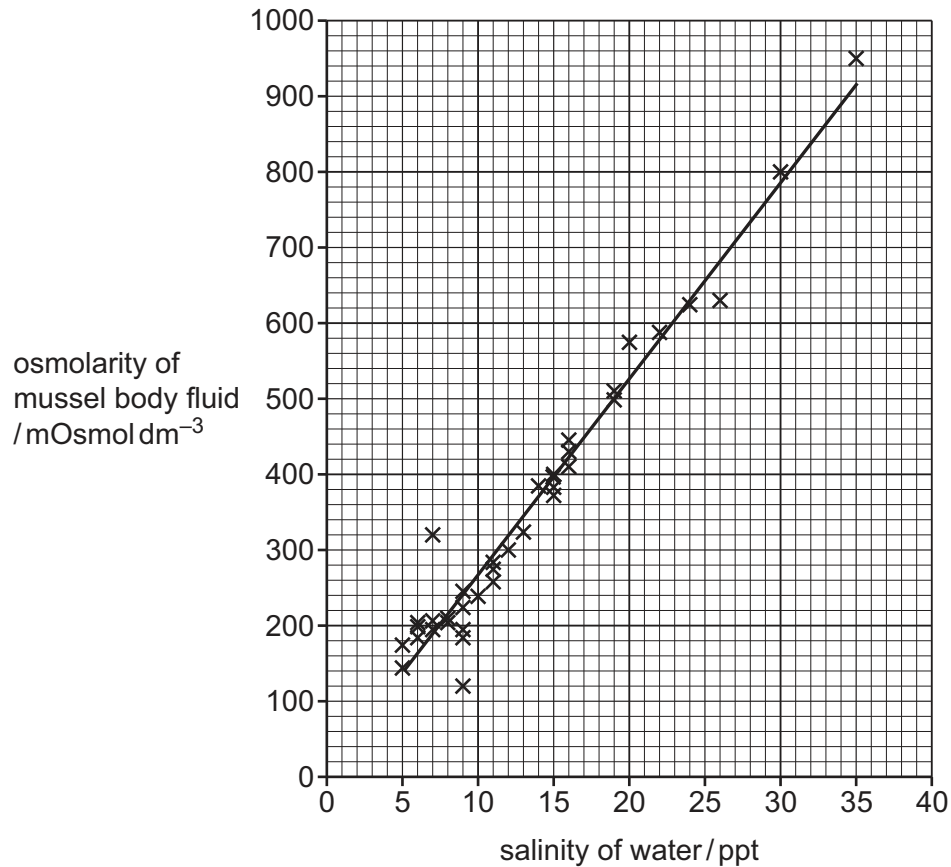


Figure 3.2

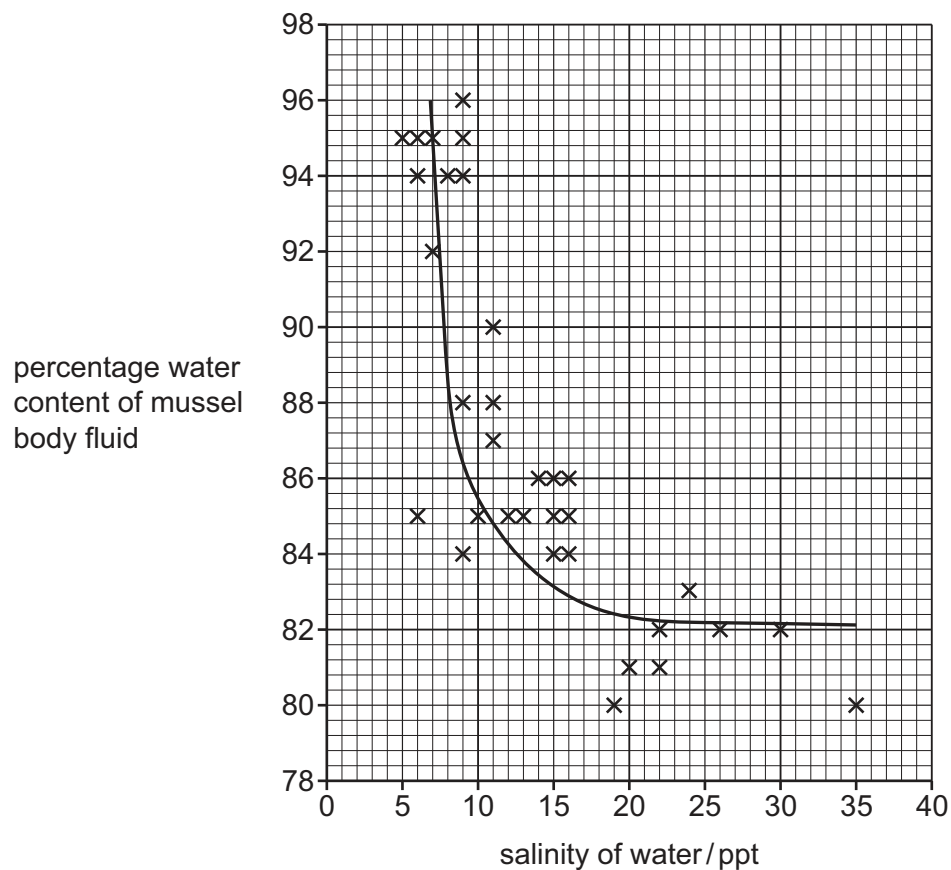


Figure 3.3



- (i) Use the line of best fit in Figure 3.2 to calculate the mean increase of osmolarity per increase in salinity of water.

Give your answer to the nearest whole number.

..... mOsmol dm⁻³ ppt⁻¹ [3]

- (ii) Discuss how the results in Figure 3.2 **and** Figure 3.3 show how the blue mussel survives in sea water of different salinities.

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- (c) Outline how salmon survive when they swim from areas with low salinity into areas with high salinity.

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..... [3]

[Total: 12]



- 4 There are several restrictions that can be placed on fishing to ensure that fisheries are exploited sustainably.

Setting up marine protected areas (MPAs) is one type of restriction.

- (a) (i) Give **two** other restrictions that can be placed on fishing to ensure sustainable exploitation of fisheries.

1

2 [2]

- (ii) Describe the short-term sociological effects of placing fishing restrictions on an area that local people have fished for many years.

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..... [2]

- (b) Scientists investigated the effect of setting up an MPA on the stocks of high-trophic-level fish in the Mediterranean Sea.

The scientists sampled high-trophic-level fish species for one week in five 25 m² quadrat areas in each of two locations.

Location **A** was inside an MPA where all fishing had been banned for two years.

Location **B** was in a region where fishing was carried out continuously.

The scientists compared the following factors:

- the mean number of high-trophic-level fish
- the mean biomass of high-trophic-level fish
- the mean number of different high-trophic-level fish species.

Table 4.1 shows the results.

Table 4.1

location	mean number of high-trophic-level fish per quadrat	mean biomass of high-trophic-level fish per quadrat/kg	mean number of different high-trophic-level fish species per quadrat
A (inside MPA)	75.5	24.0	14.5
B	50.0	9.0	9.0



- (i) The scientists used a statistical test to investigate the difference in the mean number of high-trophic-level fish per quadrat between location **A** and location **B**.

Five quadrats were sampled within location **A**.

The standard deviation for location **A** was 4.5.

Calculate the standard error (SE) for the mean number of high-trophic-level fish per quadrat in location **A**.

$$SE = \frac{s}{\sqrt{n}}$$

SE = standard error

s = standard deviation

n = sample size (number of observations)

..... [1]

- (ii) Use Table 4.1 **and** your calculated value for standard error in **4(b)(i)** to calculate the 95% confidence intervals (CI) for mean number of high-trophic-level fish per quadrat in location **A**.

$$95\% \text{ CI} = \bar{x} \pm (2 \times SE)$$

$\bar{x}$ = mean

95% CI = ... to

[1]

- (iii) The 95% confidence intervals for the mean number of high-trophic-level fish per quadrat in location **B** are 44.2 to 55.8.

Use this information **and** your answer to **4(b)(ii)** to comment on the mean number of high-trophic-level fish per quadrat in location **A** compared with location **B**.

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 [2]



- (iv) The scientists also compared the number of high-trophic-level fish with different body lengths in the quadrats in both locations.

Figure 4.1 shows the results.

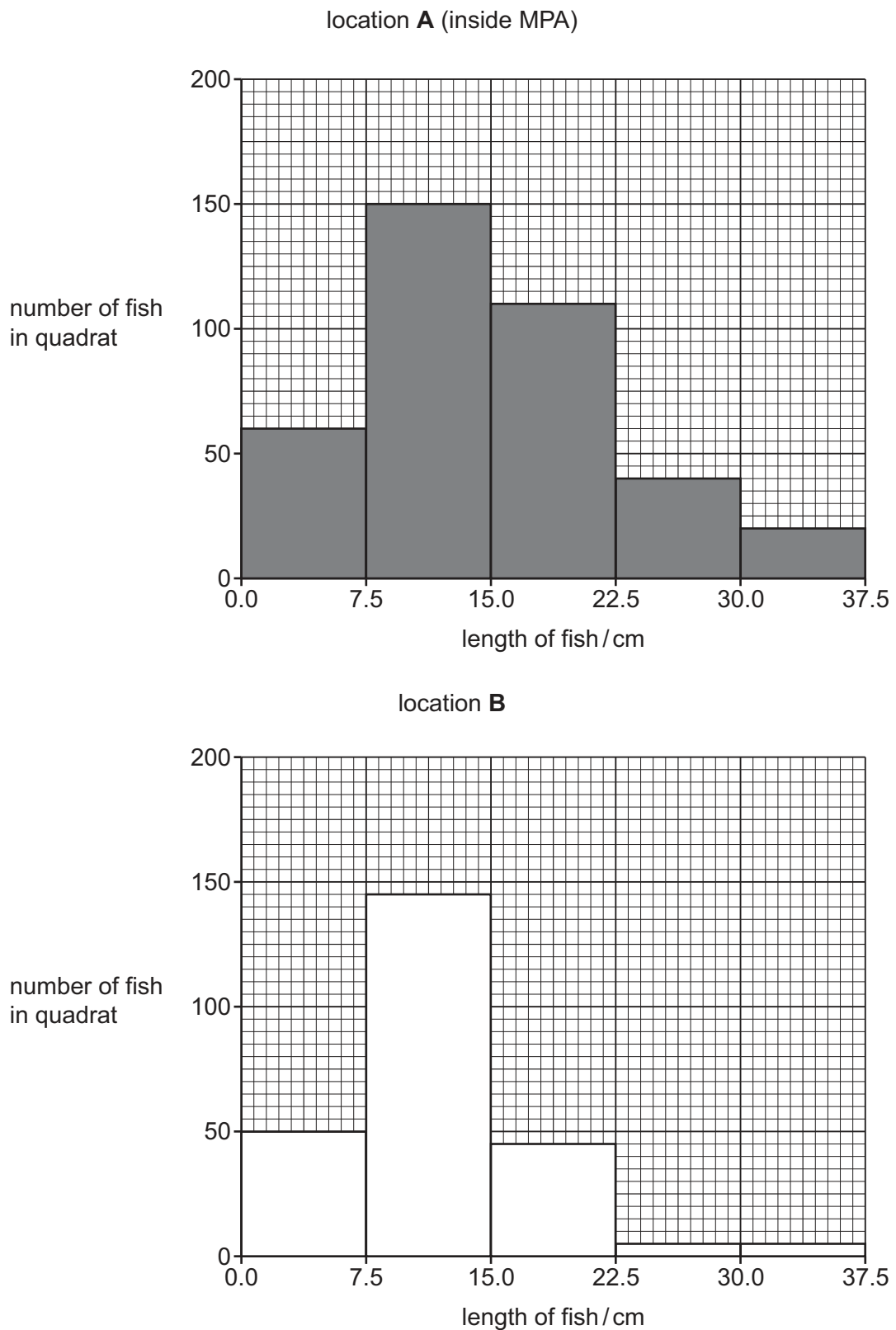


Figure 4.1



The scientists concluded that the MPA successfully increases the number of trophic levels within food chains.

Discuss the scientists' conclusion.

Use information from Table 4.1 **and** Figure 4.1 to support your answer.

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..... [4]

[Total: 12]





- 5 Some heavy metals are toxic substances that can affect marine organisms.

Table 5.1 shows the concentrations of two heavy metal ions, mercury and arsenic, in different species of marine organism from an area of the Atlantic Ocean.

The organisms shown are the first three levels of a food chain.

Table 5.1

organism	mean concentration of heavy metal ions in body tissue/ $\mu\text{g g}^{-1}$	
	mercury	arsenic
phytoplankton	0.12	5.40
shrimp	0.39	7.10
fish	1.70	2.50

- (a) Suggest explanations for the differences in the concentrations of mercury ions and arsenic ions in the tissues of the organisms.

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..... [3]





(b) Marine plants and phytoplankton require iron ions in the water to synthesise chlorophyll.

Plan a laboratory investigation that you could do to investigate the effect of increasing the concentration of iron ions on the rate of photosynthesis of an aquatic plant.

You would be provided with a 10 mg dm^{-3} stock solution of iron sulfate.

Iron sulfate may be an irritant and is an environmental hazard.

Your plan should:

- include a clear statement of the hypothesis
- identify the independent, dependent, and standardised variables
- include full details of the method so that another person can follow it
- describe how you would analyse your results
- be safe and ethical.

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[Total: 14]









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