

MARINE SCIENCE 9693
GCE A/AS Level
For AS Level examination in 2008 and 2009
For A Level examination in 2009

You can find syllabuses and information about CIE teacher training events on the CIE Website (www.cie.org.uk).

Marine Science

GCE Advanced Subsidiary Level and GCE Advanced Level 9693

For AS Level examination in 2008 and 2009
For A Level examination in 2009

(Available in the June examination only)

CONTENTS

	<i>Page</i>
Introduction	1
Aims	1
Assessment Objectives	2
Scheme of Assessment	3
Weighting of Assessment Objectives	4
Structure of the Syllabus	4
Subject Content	5
Mathematical Requirements	15
Glossary of Terms	16

NOTE

Copies of syllabuses, past papers and Examiners' reports are available on CD-ROM and can be ordered using the Publications Catalogue, which is available on CIE Online at <http://www.cie.org.uk/CIE/WebSite/qualificationsandawardshub/orderpublications/orderpublications.jsp>.

INTRODUCTION

This syllabus is designed to give flexibility both to teachers and to candidates and to place greater emphasis on the understanding and application of concepts and principles than on the recall of factual material, whilst still giving a thorough introduction to the study of Marine Science.

Centres and candidates may choose:

- to take all Advanced Level components in the same examination session leading to the full A Level;
- to follow a **staged** assessment route to the Advanced Level by taking the Advanced Subsidiary qualification in an earlier examination session. Subject to satisfactory performance such candidates are then only required to take the final part of the assessment (referred to in this syllabus as A2) leading to the full A Level;
- to take the Advanced Subsidiary qualification only.

AIMS

The syllabus aims to:

1. provide, through well designed studies of Marine Science, a worthwhile educational experience for all students, whether or not they go on to study a related subject beyond this level and, in particular, to enable them to acquire sufficient understanding and knowledge to:
 - become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific import;
 - recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life;
 - be suitably prepared for studies beyond A Level in subjects relating to the marine environment, in further or higher education, and for professional courses.
2. stimulate students, create and sustain their interest in Marine Science, and enhance their understanding of its relevance to society.
3. develop abilities and skills that:
 - are relevant to the study and practice of Marine Science;
 - are useful in everyday life;
 - encourage effective communication.
4. assist the development of
 - objectivity;
 - integrity;
 - initiative;
 - the skills of scientific inquiry.
5. stimulate interest in and care for the local and global environment, and understand the need for conservation.
6. promote an awareness:
 - that scientific theories and methods have developed, and continue to do so, as a result of co-operative activities of groups and individuals;
 - that the study and practice of science is subject to social, economic, technological, ethical and cultural influences and limitations;
 - that science transcends national boundaries and that the language of science, correctly and rigorously applied, is universal;
 - of the importance of the use of IT for communication, as an aid to experiments and as a tool for the interpretation of experimental and theoretical results.

ASSESSMENT OBJECTIVES

These describe the knowledge, skills and abilities that candidates are expected to demonstrate at the end of the course. They reflect those aspects of the aims that will be assessed.

A Knowledge with understanding

Students should be able to demonstrate knowledge and understanding in relation to:

1. scientific phenomena, facts, laws, definitions, concepts, theories;
2. scientific vocabulary, terminology, conventions (including symbols, quantities and units);
3. scientific quantities and their determination;
4. human activities that impact on the marine environment, including the needs and interests of those involved.

The syllabus content defines the factual material that candidates need to recall and explain. Questions testing the objectives above will often begin with one of the following words: *define*, *name*, *describe*, *explain* or *outline*.

B Handling information and solving problems

Students should be able, using oral, written, symbolic, graphical and numerical forms of presentation, to:

1. locate, select, organise and present information from a variety of sources;
2. translate information from one form to another;
3. manipulate numerical and other data;
4. use information to identify patterns, report trends and draw inferences;
5. interpret and evaluate observations and experimental data;
6. present reasoned explanation for phenomena, patterns and relationships;
7. make predictions and propose hypotheses;
8. devise and plan investigations;
9. evaluate investigative methods and techniques, and suggest possible improvements;
10. apply knowledge, including principles, to novel situations;
11. solve problems.

The assessment objectives above cannot be precisely specified in the syllabus content because questions testing such skills are often based on information that is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, deductive manner. Questions testing these objectives may begin with one of the following words: *discuss*, *predict*, *suggest*, *explain*, *calculate* or *determine*.

SCHEME OF ASSESSMENT

AS candidates are required to enter for Papers 1 and 2.

A2 candidates are required to enter for Papers 3 and 4.

A Level candidates are required to enter for Papers 1, 2, 3 and 4.

Paper	Type of Paper	Duration	Marks	Weighting %	
				AS	A
1	Structured questions on AS topics	1 h 30 min	75	60	30
2	Data-handling and longer written questions on AS topics	1 h 15 min	50	40	20
3	Structured questions on A2 topics	1 h 30 min	75	-	30
4	Data-handling and longer written questions on A2 topics	1 h 15 min	50	-	20

PAPER 1 (1 h 30 min, 75 marks) (available in June 2008 and June 2009)

This paper will consist of a variable number of structured questions based on the AS syllabus. All questions will be compulsory.

PAPER 2 (1 h 15 min, 50 marks) (available in June 2008 and June 2009)

This paper will consist of:

- A variable number of questions requiring data handling (20 marks). The data may be provided in written, numerical, diagrammatic or graphical forms, or a mixture of these.
- Two free-response questions (15 marks each). These questions will require candidates to demonstrate aspects of assessment objectives A and B.

All questions will be compulsory and will be based on the AS syllabus.

PAPER 3 (1 h 30 min, 75 marks) (available in June 2009)

This paper will consist of a variable number of structured questions based on the A2 syllabus, making links where appropriate with the AS syllabus. All questions will be compulsory.

PAPER 4 (1 h 15 min, 50 marks) (available in June 2009)

This paper will consist of:

- A variable number of questions requiring data handling (20 marks). The data may be provided in written, numerical, diagrammatic or graphical forms, or a mixture of these.
- Two free-response questions (15 marks each). These questions will require candidates to demonstrate aspects of assessment objectives A and B.

All questions will be compulsory and will be based on the A2 syllabus, making links where appropriate with the AS syllabus.

WEIGHTING OF ASSESSMENT OBJECTIVES

Assessment Objective	AS Level	A Level
A	50%	45%
B	50%	55%

The table above gives the overall allocation of marks to assessment objectives A and B in the whole examination. The balance on individual papers may vary slightly.

STRUCTURE OF THE SYLLABUS

The Subject Content of the syllabus is divided into 16 sections. Sections 1 – 7 are to be studied by AS candidates and sections 8 – 15 contain the additional material to be studied by A level candidates. This structure is shown in the table below.

Section		AS	A2
1	Scientific method	✓	
2	Marine ecosystems and biodiversity	✓	
3	Energetics of marine ecosystems	✓	
4	Nutrient cycles in marine ecosystems	✓	
5	Coral reefs and lagoons	✓	
6	The ocean floor and the coast	✓	
7	Physical and chemical oceanography	✓	
8	Physiology of marine primary producers		✓
9	Aspects of marine animal physiology		✓
10	Marine animal reproductive behaviour		✓
11	Fisheries management		✓
12	Aquaculture		✓
13	Human impact on marine ecosystems		✓
14	Marine conservation and ecotourism		✓
15	Marine biotechnology		✓

The content of the AS level course concentrates on the scientific study of the sea and its ecosystems. The A2 part of the course concentrates on human activities that depend on the sea and have an impact on it.

In order to specify the syllabus as precisely as possible and also to emphasise the importance of skills other than recall, learning outcomes have been used throughout. Each part of the syllabus is specified by a brief Contents section followed by detailed learning outcomes. It is hoped that this format will be helpful to teachers and students.

It must be emphasised that the syllabus is not intended to be a teaching syllabus, nor is it intended to represent a teaching order.

SUBJECT CONTENT

The content to be studied by AS candidates is shown in normal type.

The additional content to be studied by A Level candidates is shown in **bold** type.

It is assumed that examples to illustrate concepts and content will be drawn from a wide range of marine organisms and environments.

It is expected that practical activities will underpin the teaching of the whole syllabus. In some topics, these practical activities will be primarily laboratory-based, while in other topics the practical activities are more likely to involve field trips.

Candidates may be asked about practical activities in examination questions.

1. Scientific method

Content

The relationship between hypothesis, experiment and theory in science

Uncertainty in experimental results

Learning outcomes

Candidates should be able to:

- (a) describe how scientific method involves interplay between observations and the formation, testing and evaluation of hypotheses
- (b) design experiments to test a given hypothesis, in which variables are controlled and quantitative results are collected
- (c) interpret experimental data to determine whether they support or refute the hypothesis being tested
- (d) formulate a hypothesis on the basis of experimental data
- (e) explain how inherent variations and limitations in the measurement of experimental data lead to uncertainty in the results
- (f) demonstrate an understanding that a hypothesis that is consistently supported by experimental testing and observation can become a theory
- (g) explain the meaning of the term *theory* with reference to examples from the Subject Content
- (h) use the knowledge and understanding gained in this section in new situations or to solve related problems

2. Marine ecosystems and biodiversity

Content

The relationships between organisms within ecosystems

Predator-prey relationships

The connection between environment, biodiversity and ecological niches

Learning outcomes

Candidates should be able to:

- (a) explain the meaning of the terms *ecosystem*, *habitat*, *population*, *community*, *species*, *biodiversity*, *ecological niche*

- (b) describe each of the following types of interrelationship within a marine ecosystem:
 - symbiosis, with examples including coral and zooxanthellae, cleaner fish and grouper, and chemosynthetic bacteria and tube worms
 - parasitism, with examples including tuna and nematodes
- (c) explain the meanings of the terms *producer*, *consumer*, *predator*, *prey* and *trophic level* in the context of food chains and food webs
- (d) explain how populations of predator and prey may be interrelated
- (e) describe shoaling and explain why shoaling may be a successful strategy for feeding, reproduction and predator avoidance, with reference to tuna and sardines
- (f) explain the meaning of the term *succession* and describe examples including the tube worms *Tevnia* and *Riftia*
- (g) understand why extreme and unstable environments tend to have relatively low biodiversity, giving examples including coral reefs (stable and not extreme), sand on a reef slope (unstable), and hydrothermal vents (extreme)
- (h) give examples of organisms that occupy specialised and general ecological niches, including coral-eating butterfly fish and tuna
- (i) explain why habitats with high biodiversity tend to contain narrow ecological niches
- (j) use the knowledge and understanding gained in this section in new situations or to solve related problems

3. Energetics of marine ecosystems

Content

Photosynthesis and chemosynthesis as means of energy capture

Productivity and energy flow along food chains

Learning outcomes

Candidates should be able to:

- (a) explain that photosynthesis captures the energy of sunlight and makes the energy available to the food chain
- (b) explain that chemosynthesis captures the chemical energy of dissolved minerals and that chemosynthetic bacteria at hydrothermal vents make energy available to the food chain
- (c) explain the meaning of the term *productivity* and how high productivity may influence the food chain
- (d) calculate and explain the energy losses along food chains due to respiration and wastage
- (e) calculate and account for the efficiency of energy transfer between trophic levels
- (f) represent food chains as pyramids of energy, numbers and biomass
- (g) use the knowledge and understanding gained in this section in new situations or to solve related problems

4. Nutrient cycles in marine ecosystems

Content

Inputs and outputs to the reservoir of dissolved nutrients

The biological uses of nutrients

Nutrient availability and productivity

Learning outcomes

Candidates should be able to:

- (a) demonstrate an understanding that there is a reservoir of nutrients dissolved in the surface layer of the ocean
- (b) explain the processes by which the reservoir of dissolved nutrients is replenished, including upwelling, runoff from the land and dissolving of atmospheric gases
- (c) demonstrate an understanding that the reservoir of dissolved nutrients is depleted by uptake into organisms in food chains
- (d) explain how productivity may be limited by the availability of dissolved nutrients
- (e) demonstrate an understanding that the nutrients taken up by organisms in food chains may sink to the sea floor in faeces or after death, may be incorporated into coral reefs, or may be removed by harvesting
- (f) show that each of the nutrient cycles listed below can be summarised as shown in Fig. 4.1, and state the biological use of each nutrient:
 - nitrogen, which is used to make proteins;
 - carbon, which is used to make all organic materials;
 - magnesium, which is used to make chlorophyll;
 - calcium, which is used to make bones, corals and shells;
 - phosphorus, which is used to make DNA and bone

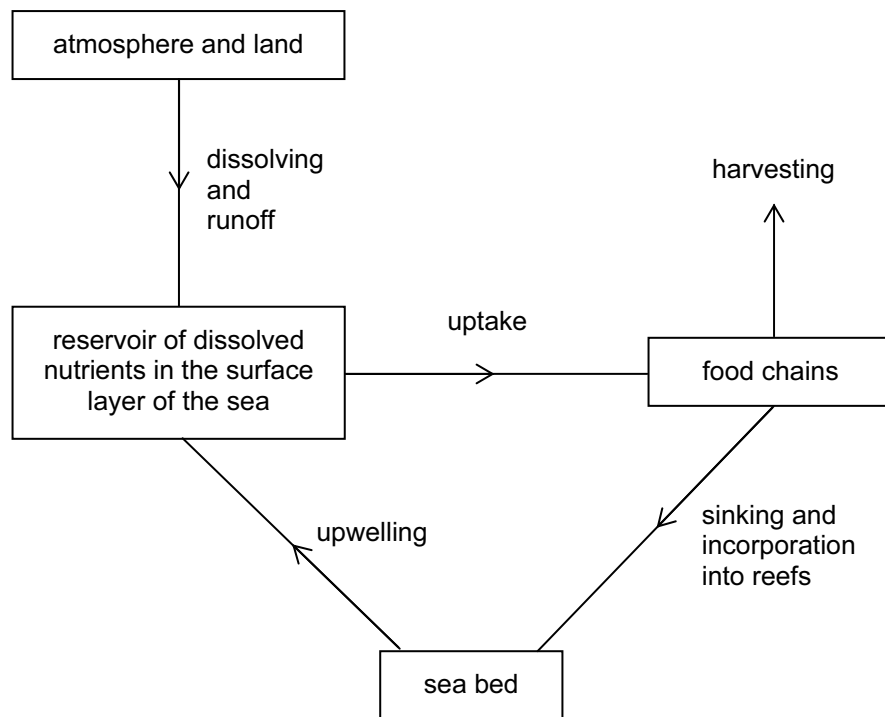


Fig. 4.1

- (g) use the knowledge and understanding gained in this section in new situations or to solve related problems

5. Coral reefs and lagoons

Content

The Darwin-Dana-Daly theory of atoll formation

The protective role of reefs and the causes and effects of reef erosion

Reconstructing the history of reefs

Learning outcomes

Candidates should be able to:

- (a) demonstrate an understanding of the Darwin-Dana-Daly theory of atoll formation and the evidence supporting the theory
- (b) relate the Darwin-Dana-Daly theory to the physiology of coral
- (c) discuss the role of reefs in dissipating the energy of waves and in providing protection for shores and anchorages
- (d) discuss the factors that can lead to a transition from reef growth to reef erosion
- (e) discuss the impact of reef erosion and the use of artificial reefs on the protection of shores and anchorages
- (f) describe the methods used for reconstructing the history of reefs including drilling, geomorphologic analysis and carbon dating
- (g) explain how these methods may be used to investigate the effect of sea level changes on coral reefs
- (h) use the knowledge and understanding gained in this section in new situations or to solve related problems

6. The ocean floor and the coast

Content

Tectonic processes and the ocean basin

The littoral zone

Learning outcomes

Candidates should be able to:

- (a) describe the theory of plate tectonics and the evidence supporting the theory
- (b) relate tectonic processes to the production of ocean trenches, mid-ocean ridges, hydrothermal vents, abyssal plains, volcanoes, earthquakes and tsunamis
- (c) explain why the water coming from hydrothermal vents is under pressure, hot and rich in minerals
- (d) explain how isostasy may produce shallow seas within or at the edge of continents
- (e) demonstrate an understanding of the processes of erosion and sedimentation that give rise to the morphology of the littoral zone, including rocky shores, sandy shores, muddy shores, estuaries and deltas
- (f) demonstrate an understanding of how environmental factors influence the formation of ecological communities in the littoral zone including mangrove, sandy shore and rocky shore
- (g) use the knowledge and understanding gained in this section in new situations or to solve related problems

7. Physical and chemical oceanography

Content

Factors affecting the chemical composition of seawater

Layering and mixing in the oceans

The tides

Ocean currents

El Niño, monsoon winds and tropical cyclones

Learning outcomes

Candidates should be able to:

- (a) demonstrate an understanding of the effects of volcanic activity, runoff and atmospheric dissolution on the chemical composition of sea water
- (b) outline the effects of evaporation and precipitation on salinity
- (c) describe how temperature and salinity gradients form in water columns to produce ocean layers (including the surface layer, thermocline and deep ocean) and how subsequent mixing of these layers may occur
- (d) demonstrate an understanding of the physical and biological reasons for the variability of the concentration of dissolved oxygen
- (e) describe how tides are produced and how the alignment of Moon and Sun, coastal geomorphology, wind, air pressure and size of water body affect the tidal range
- (f) explain how wind, temperature, density, the Coriolis effect and the shape of the sea bed produce ocean currents and upwelling
- (g) discuss the causes and effects of El Niño events in the Pacific Ocean
- (h) explain the seasonal differences in temperature between the Asian continent and the Indian Ocean, and explain how these differences give rise to the patterns of monsoon winds
- (i) discuss the factors required for a region of low pressure to develop into a tropical cyclone, and explain the role of evaporation, condensation and latent heat in tropical cyclones
- (j) recall that tropical cyclones are also known as hurricanes and typhoons and discuss their impact on coastal communities
- (k) use the knowledge and understanding gained in this section in new situations or to solve related problems

8. Physiology of marine primary producers

Content

The relationship between habitat and the distribution of primary producers

Factors affecting the rate of photosynthesis

Learning outcomes

Candidates should be able to:

- (a) **demonstrate an understanding of the ecological importance of primary producers for carbon fixation and shelter**

- (b) explain why different types of primary producer are found in different habitats, including
 - the open ocean (containing phytoplankton [confined to diatoms, dinoflagellates and cyanobacteria] and floating macroscopic algae [confined to sargassum])
 - shallow waters (containing zooxanthellae in corals, sea grass such as *Thalassia* and kelp forests)
 - intertidal regions (containing green, red and brown algae)
- (c) demonstrate an understanding that photosynthesis (carbon dioxide + water → glucose + oxygen) is the process that nearly all primary producers use to fix carbon
- (d) demonstrate an understanding that photosynthesis involves the use of light energy from the Sun, pigments including chlorophyll, and a number of enzymes
- (e) explain how and why light intensity, light wavelength and temperature affect the rate of photosynthesis and can act as limiting factors
- (f) describe how light of different wavelengths penetrates to different depths in water, and relate this to the presence of accessory pigments, including xanthophylls and phycobilins, in marine primary producers
- (g) use the knowledge and understanding gained in this section in new situations or to solve related problems

9. Aspects of marine animal physiology

Content

Respiration

Gaseous exchange and transport systems

Osmoregulation

Learning outcomes

Candidates should be able to:

- (a) demonstrate an understanding that respiration (glucose + oxygen → carbon dioxide + water) is the process that organisms use to release the energy they require
- (b) demonstrate an understanding that the raw materials and waste products of respiration must be moved to and from the surface of organisms
- (c) discuss how surface area to volume ratio is dependent on the size and shape of an organism, and relate this to the need for specialised gaseous exchange surfaces in larger animals
- (d) explain the need for transport systems in large, active animals
- (e) demonstrate an understanding that marine animals are adapted to live in water which, in comparison with air, contains low and variable concentrations of oxygen
- (f) describe gaseous exchange by simple diffusion, pumped ventilation and ram ventilation in examples including coral polyps, grouper and tuna
- (g) explain why marine organisms may need to regulate their water content and ion content, with reference to the composition of sea water and of body fluids
- (h) outline the process of osmoregulation in a marine bony fish (limited to drinking and absorbing salty water and then actively excreting salt using energy from respiration)

- (i) explain the meaning of the term *osmoconformer* with reference to mussels
- (j) explain the meaning of the term *euryhaline* with reference to salmon
- (k) use the knowledge and understanding gained in this section in new situations or to solve related problems

10. Marine animal reproductive behaviour

Content

Life cycles of marine animals

Learning outcomes

Candidates should be able to:

- (a) compare and contrast the stages in the life cycle of salmon, tuna, oyster, shrimp, giant clam, and grouper
- (b) state the principal habitats for each stage in these life cycles and discuss why these habitats are advantageous
- (c) compare the advantages and disadvantages of internal and external fertilisation and subsequent investment in the care of offspring with reference to tuna, shark and whale
- (d) use the knowledge and understanding gained in this section in new situations or to solve related problems

11. Fisheries management

Content

The need for sustainable fisheries

Monitoring of fish stocks

Methods of stock management and the enforcement of restrictions

Methods of rehabilitating depleted stocks

Learning outcomes

Candidates should be able to:

- (a) explain the need for sustainable exploitation of fish stocks with reference to North Sea fisheries
- (b) discuss the impact of modern fishing technology, including sonar, purse seine fishing, benthic trawling and factory ships, on fish stocks and habitats
- (c) compare and contrast the long-term and short-term sociological impacts of restrictions on fishing and of unrestricted fishing
- (d) describe the principal information needed to decide how best to exploit fish stocks on a sustainable basis, including recruitment, growth, natural mortality, fishing mortality, age of reproductive maturity, fecundity, and dependency on particular habitats
- (e) outline the principal tools used to ensure that fish stocks are exploited on a sustainable basis, including:
 - restriction by season
 - restriction of location, including refuge zones
 - restriction of method, including minimum mesh sizes and the compulsory use of rod-and-line
 - restrictions on the size of fish that can be retained
 - restriction of fishing intensity, including restrictions on the number of boats, boat and engine size, and the amount of fishing gear
 - market-oriented tools, including the labelling of tuna as dolphin-friendly

- (f) discuss the principal methods of monitoring (including air and sea patrolling, inspection of catch, catch per unit effort, satellite monitoring) and enforcement (including imposition of fines, confiscation of boats and gear, imprisonment)
- (g) discuss the advantages and disadvantages of the tools and methods in (e) and (f), including their effectiveness and their impact on non-target species
- (h) discuss the opportunities for, and advantages and disadvantages of, the rehabilitation of depleted stocks, including replanting mangroves, building artificial reefs, and introducing cultivated stock to the wild
- (i) use the knowledge and understanding gained in this section in new situations or to solve related problems

12. Aquaculture

Content

Processes for intensive and extensive aquaculture

The requirements and impacts of aquaculture

Learning outcomes

Candidates should be able to:

- (a) explain the meaning of the terms *intensive* and *extensive* aquaculture techniques
- (b) outline the process for the aquaculture of grouper, tuna, shrimp and giant clam
- (c) explain the requirements for sustainable aquaculture (availability of stock, availability of clean water, availability of feed, efficiency of use of feed, availability of labour, disease management, availability of location, market demand, access to market, return on investment)
- (d) identify the principal impacts of aquaculture (habitat destruction, overexploitation of feedstocks, pollution, introduction of exotics, spread of disease, competition for resources, social impacts, economic impacts)
- (e) use this knowledge and understanding to assess the suitability of proposed aquaculture projects in terms of requirements and impacts
- (f) suggest how the negative impacts of aquaculture might be minimised
- (g) use the knowledge and understanding gained in this section in new situations or to solve related problems

13. Human impact on marine ecosystems

Content

Ecological impacts of industrial activities

The accumulation of toxins in food chains

Global warming and its impact

The ecological effects of shipwrecks

Learning outcomes

Candidates should be able to:

- (a) explore the ecological impacts of
 - the oil industry
 - desalination plants
 - agriculture
 - sewage and refuse disposal
 - dredgingon marine water quality, habitats, biodiversity and food webs

- (b) explain the reasons for the links between the human activities in (a) and their ecological impacts, making reference to the physical properties and chemical composition of the sea where necessary
- (c) explain the accumulation of toxins in food chains, making reference to antifouling paint and mercury pollution, and explore its impact on human food sources
- (d) demonstrate an understanding of the evidence for global warming
- (e) discuss and evaluate the evidence for and against the hypothesis that global warming is caused by human activity
- (f) describe the possible impact of global warming, including sea level rise and coral bleaching
- (g) compare and contrast the ecological impacts of the wreck of an oil-filled tanker and a vessel deliberately sunk as a wreck dive
- (h) use the knowledge and understanding gained in this section in new situations or to solve related problems

14. Marine conservation and ecotourism

Content

Conservation

Ecotourism

Learning outcomes

Candidates should be able to:

- (a) explain the meaning of the term *conservation*
- (b) explain the arguments for and against the desirability of conserving marine species and ecosystems
- (c) discuss, in the context of human activity on marine species and ecosystems, the need for conservation
- (d) demonstrate an understanding of why, to be successful, conservation must sustain ecological linkages and processes
- (e) demonstrate an understanding that there are competing requirements between the activities of coastal communities, including agriculture, industry, shipping, sewage and refuse disposal, aquaculture, fisheries, tourism and conservation
- (f) in given examples of conservation issues, identify stakeholders, conflicts of interest, causes and possible solutions
- (g) define *ecotourism* as tourism based on the appreciation of the natural environment and identify and assess types of ecotourism that support or undermine conservation
- (h) argue the benefits to conservation of responsible practice in tourism, including energy conservation, recycling, use of sustainable sources of building materials, and sponsorship of conservation
- (i) use the knowledge and understanding gained in this section in new situations or to solve related problems

15. Marine biotechnology

Content

Biotechnology

Genes, promoters and phenotypes

Advantages and dangers of genetic engineering

Learning outcomes:

Candidates should be able to:

- (a) **define *biotechnology* as the industrial application of biological processes**
- (b) **state that some microorganisms digest oil, and that these microorganisms are used to digest oil pollution**
- (c) **define the term *gene* and outline the effect of genotype on phenotype**
- (d) **outline the role of promoters in the control of genes**
- (e) **define *genetic engineering* as the transfer of a gene or genes from one species to another**
- (f) **distinguish genetic engineering from other types of biotechnology and from selective breeding**
- (g) **show an understanding that genes cannot be accurately placed in the genome when transferred, and that a promoter may need to be attached to a gene before transfer**
- (h) **state that salmon has been genetically engineered with a growth-promoting gene from another fish and a promoter to turn this gene on all year round**
- (i) **discuss the advantages of genetic engineering for aquaculture and the possible impact of the escape of genetically engineered species into the wild**
- (j) **demonstrate an understanding of the term *precautionary principle***
- (k) **use the knowledge and understanding gained in this section in new situations or to solve related problems**

MATHEMATICAL REQUIREMENTS

Candidates should be able to:

- (a) recognise and use expressions in decimal and standard form (scientific) notation
- (b) recognise and use percentages and ratios
- (c) use appropriate calculating aids (electronic calculator or tables) for addition, subtraction, multiplication and division
- (d) find arithmetic means, standard deviations and powers (including reciprocals and square roots)
- (e) take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified
- (f) change the subject of an equation
- (g) substitute values into and solve linear equations
- (h) comprehend and use the symbols $<$, $>$, \approx , $/$, $<x>$, Σ , $\sqrt{\quad}$, Δ , ∞
- (i) calculate the perimeters and areas of circles, squares and rectangles
- (j) calculate the surface areas and volumes of spheres, cylinders, cubes and rectangular blocks
- (k) translate information between graphical, numerical, algebraic and verbal forms
- (l) construct and interpret frequency tables and diagrams, pie charts and histograms
- (m) select appropriate variables and scales for graph plotting
- (n) choose, by inspection, a straight line or curve which will serve as the best line through a set of data points presented graphically
- (o) draw the tangent to a curved graph
- (p) for linear graphs, determine the slope and intercept
- (q) use the concept of rate of change and determine the rate of change from a linear or curved graph
- (r) recognise and correctly use SI units
- (s) recognise and use the prefixes tera (T), giga (G), mega (M), kilo (k), milli (m), micro (μ) and nano (n)

GLOSSARY OF TERMS USED IN MARINE SCIENCE PAPERS

It is hoped that the glossary (which is relevant only to Marine Science) will prove helpful to candidates as a guide, i.e. it is neither exhaustive nor definitive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. *Define* (the term(s)...) is intended literally, only a formal statement or equivalent paraphrase being required.
2. *What do you understand by/What is meant by* (the term(s)...) normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.
3. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can readily be obtained 'by inspection'.
4. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified, this should **not** be exceeded.
- 5 (a) *Describe*, the data or information given in a graph, table or diagram, requires the candidate to state the key points that can be seen in the stimulus material. Where possible, reference should be made to numbers drawn from the stimulus material.
 (b) *Describe*, a process, requires the candidate to give a step by step written statement of what happens during the process.
- 6 (a) *Explain* may imply reasoning or some reference to theory, depending on the context. It is another way of asking candidates to give reasons for. The candidate needs to leave the examiner in no doubt **why** something happens.
 (b) *Give a reason/Give reasons* is another way of asking candidates to explain **why** something happens.
Describe and *explain* may be coupled, as may *state* and *explain*.
7. *Discuss* requires the candidate to give a critical account of the points involved in the topic.
8. *Outline* implies brevity, i.e. restricting the answer to giving essentials.
9. *Predict* implies that the candidate is **not** expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question.
Predict also implies a concise answer, with no supporting statement required.
10. *Deduce* is used in a similar way to *predict* except that some supporting statement is required, e.g. reference to a law or principle, or the necessary reasoning is to be included in the answer.
11. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in Chemistry, two or more substances may satisfy the given conditions describing an 'unknown'), or to imply that candidates are expected to apply their knowledge to a 'novel' situation, one that may not be formally 'in the syllabus'.
12. *Find* is a general term that may variously be interpreted as *calculate*, *measure*, *determine*, etc.
13. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved. Suitable units should be given where possible.
14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule. Suitable units should be given where possible.

15. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula.
16. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.
17. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, *but* candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value.
In diagrams, *sketch* implies that a simple, freehand drawing is acceptable; nevertheless, care should be taken over proportions and the clear exposition of important details.
18. *Compare* requires candidates to provide both the similarities and differences between things or concepts.
19. *Recognise* is often used to identify facts, characteristics or concepts that are critical (relevant/appropriate) to the understanding of a situation, event, process or phenomenon.
20. *Classify* requires candidates to group things based on common characteristics.

In all questions, the number of marks allocated are shown on the examination paper and should be used as a guide by candidates to how much detail to give. In describing a process, the mark allocation should guide the candidate about how many steps to include. In explaining why something happens, it guides the candidate how many reasons to give, or how much detail to give for each reason.