International Baccalaureate
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Diploma Programme

# Environmental systems and societies guide

First examinations 2010

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**Diploma Programme**
**Environmental systems and societies guide**

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The International Baccalaureate (IB) offers three high quality and challenging educational programmes for a worldwide community of schools, aiming to create a better, more peaceful world.



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# IB mission statement

The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.

# IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

IB learners strive to be:

| | |
|---|---|
| **Inquirers** | They develop their natural curiosity. They acquire the skills necessary to conduct inquiry and research and show independence in learning. They actively enjoy learning and this love of learning will be sustained throughout their lives. |
| **Knowledgeable** | They explore concepts, ideas and issues that have local and global significance. In so doing, they acquire in-depth knowledge and develop understanding across a broad and balanced range of disciplines. |
| **Thinkers** | They exercise initiative in applying thinking skills critically and creatively to recognize and approach complex problems, and make reasoned, ethical decisions. |
| **Communicators** | They understand and express ideas and information confidently and creatively in more than one language and in a variety of modes of communication. They work effectively and willingly in collaboration with others. |
| **Principled** | They act with integrity and honesty, with a strong sense of fairness, justice and respect for the dignity of the individual, groups and communities. They take responsibility for their own actions and the consequences that accompany them. |
| **Open-minded** | They understand and appreciate their own cultures and personal histories, and are open to the perspectives, values and traditions of other individuals and communities. They are accustomed to seeking and evaluating a range of points of view, and are willing to grow from the experience. |
| **Caring** | They show empathy, compassion and respect towards the needs and feelings of others. They have a personal commitment to service, and act to make a positive difference to the lives of others and to the environment. |
| **Risk-takers** | They approach unfamiliar situations and uncertainty with courage and forethought, and have the independence of spirit to explore new roles, ideas and strategies. They are brave and articulate in defending their beliefs. |
| **Balanced** | They understand the importance of intellectual, physical and emotional balance to achieve personal well-being for themselves and others. |
| **Reflective** | They give thoughtful consideration to their own learning and experience. They are able to assess and understand their strengths and limitations in order to support their learning and personal development. |

# Contents

# Purpose of this document

This publication is intended to guide the planning, teaching and assessment of the subject in schools. Subject teachers are the primary audience, although it is expected that teachers will use the guide to inform students and parents about the subject.

This guide can be found on the subject page of the online curriculum centre (OCC) at http://occ.ibo.org, a password-protected IB website designed to support IB teachers. It can also be purchased from the IB store at http://store.ibo.org.

## Additional resources

Additional publications such as teacher support materials, subject reports, internal assessment guidance and grade descriptors can also be found on the OCC. Specimen and past examination papers as well as markschemes can be purchased from the IB store.

Teachers are encouraged to check the OCC for additional resources created or used by other teachers. Teachers can provide details of useful resources, for example: websites, books, videos, journals or teaching ideas.

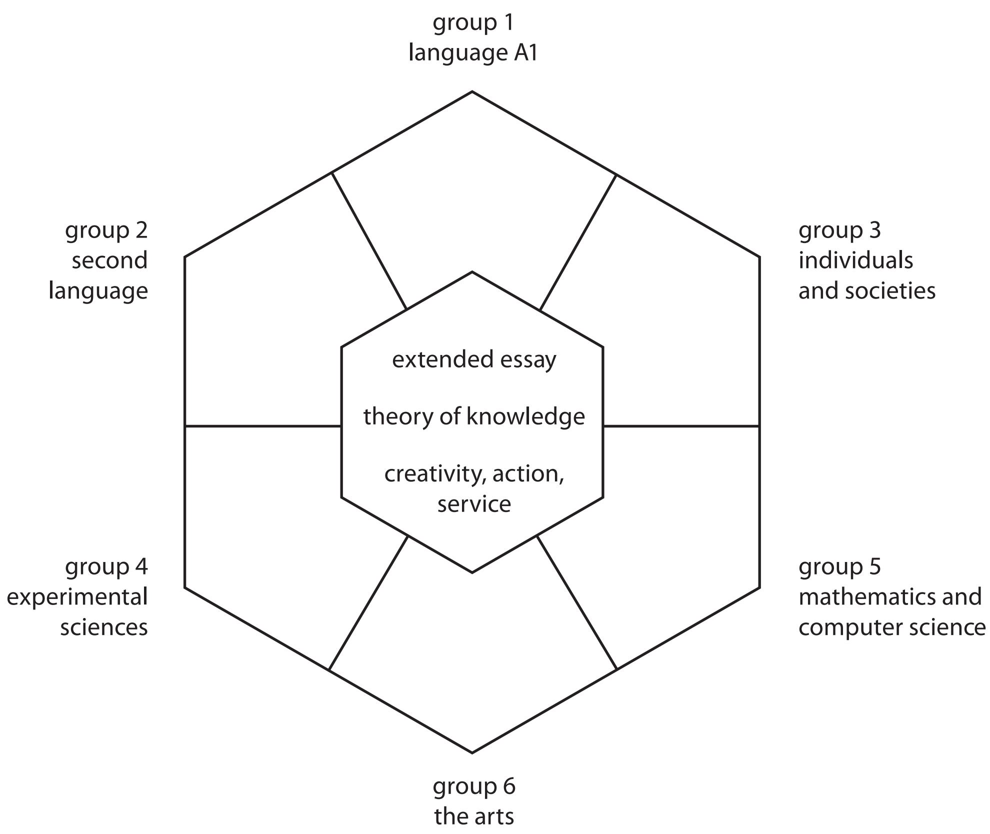
**First examinations 2010**

# The Diploma Programme

The Diploma Programme is a rigorous pre-university course of study designed for students in the 16 to 19 age range. It is a broad-based two-year course that aims to encourage students to be knowledgeable and inquiring, but also caring and compassionate. There is a strong emphasis on encouraging students to develop intercultural understanding, open-mindedness, and the attitudes necessary for them to respect and evaluate a range of points of view.

## The Diploma Programme hexagon

The course is presented as six academic areas enclosing a central core. It encourages the concurrent study of a broad range of academic areas. Students study: two modern languages (or a modern language and a classical language); a humanities or social science subject; an experimental science; mathematics; one of the creative arts. It is this comprehensive range of subjects that makes the Diploma Programme a demanding course of study designed to prepare students effectively for university entrance. In each of the academic areas students have flexibility in making their choices, which means they can choose subjects that particularly interest them and that they may wish to study further at university.



## Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can choose a second subject from groups 1 to 5 instead of a group 6 subject. Normally, three subjects (and not more than four) are taken at higher level (HL), and the others are taken at standard level (SL). The IB recommends 240 teaching hours for HL subjects and 150 hours for SL. Subjects at HL are studied in greater depth and breadth than at SL.

At both levels, many skills are developed, especially those of critical thinking and analysis. At the end of the course, students' abilities are measured by means of external assessment. Many subjects contain some element of coursework assessed by teachers. The course is available for examinations in English, French and Spanish.

## The core of the hexagon

All Diploma Programme students participate in the three course requirements that make up the core of the hexagon. Reflection on all these activities is a principle that lies at the heart of the thinking behind the Diploma Programme.

The theory of knowledge course encourages students to think about the nature of knowledge, to reflect on the process of learning in all the subjects they study as part of their Diploma Programme course, and to make connections across the academic areas. The extended essay, a substantial piece of writing of up to 4,000 words, enables students to investigate a topic of special interest that they have chosen themselves. It also encourages them to develop the skills of independent research that will be expected at university. Creativity, action, service involves students in experiential learning through a range of artistic, sporting, physical and service activities.

## The IB mission statement and the IB learner profile

The Diploma Programme aims to develop in students the knowledge, skills and attitudes they will need to fulfill the aims of the IB, as expressed in the organization's mission statement and the learner profile. Teaching and learning in the Diploma Programme represent the reality in daily practice of the organization's educational philosophy.

# Nature of the subject

As a transdisciplinary subject, environmental systems and societies is designed to combine the techniques and knowledge associated with group 4 (the experimental sciences) with those associated with group 3 (individuals and societies). By choosing to study a transdisciplinary course such as this as part of their diploma, students are able to satisfy the requirements for both groups 3 and 4 of the hexagon, thus allowing them to choose another subject from any hexagon group (including another group 3 or 4 subject). Transdisciplinary subjects therefore introduce more flexibility into the IB Diploma Programme. The environmental systems and societies course is offered at SL only.

The prime intent of this course is to provide students with a coherent perspective of the interrelationships between environmental systems and societies; one that enables them to adopt an informed personal response to the wide range of pressing environmental issues that they will inevitably come to face. Students' attention can be constantly drawn to their own relationship with their environment and the significance of choices and decisions that they make in their own lives. It is intended that students develop a sound understanding of the interrelationships between environmental systems and societies, rather than a purely journalistic appreciation of environmental issues. The teaching approach therefore needs to be conducive to students evaluating the scientific, ethical and socio-political aspects of issues.

## The international dimension

Environmental issues are both local and global in their extent. This course reflects the international element throughout but, where it may be drawn particularly to the attention of the students, this is highlighted alongside some assessment statements (Int).

We all live on one planet Earth, yet use much more than one planet Earth's worth of resources. This is obviously not sustainable and this course attempts to discuss the issues surrounding resource use at various scales—from that of the individual (for example, attitudes to recycling) to that of the global community (aims 1, 2, 6 and 8 in particular).

Internationally, both governmental and non-governmental environmental organizations are considered in the course, from the United Nations Environment Programme (UNEP) to Greenpeace and the World Wide Fund for Nature (WWF).

Environmental scientists work internationally at all levels. In this course, students may share data collected with those in other IB Diploma Programme schools on other continents just as professional scientists pool their data. Students taking this course should thus become more aware of the diversity of cultural perspectives on the environment (aim 4) and appreciate that environmental issues may be controversial as they cross geographical and cultural boundaries (aim 7).

# Prior learning

Students will be able to study this course successfully with no specific previous knowledge of science or geography. However, as the course aims to foster an international perspective, awareness of local and global environmental concerns and an understanding of the scientific method, a course that shares these aims would be good preparation.

## Mathematical requirements

All Diploma Programme environmental systems and societies students should be able to:

- perform the basic arithmetic functions: addition, subtraction, multiplication and division
- use simple descriptive statistics: mean, median, mode, range, frequency, percentages, ratios, approximations and reciprocals
- use standard notation (for example, $3.6 \times 10^6$)
- use direct and inverse proportion
- interpret frequency data in the form of bar charts, column graphs and histograms, and interpret pie charts
- understand the significance of the standard deviation of a set of data
- plot and sketch graphs (with suitable scales and axes)
- interpret graphs, including the significance of gradients, changes in gradients, intercepts and areas
- demonstrate sufficient knowledge of probability (for example, in assessing risks in environmental impact).

# Links to the Middle Years Programme

Students who have undertaken the IB Middle Years Programme (MYP) sciences, humanities and mathematics courses will be well prepared for environmental systems and societies. Holistic learning and intercultural awareness (fundamental concepts to the MYP) are particularly important to the transdisciplinary and global nature of the subject. The areas of interaction, in particular *homo faber* and environment, provide an excellent foundation to the study of human activity and its effects on the quality of people's lives both locally and globally. The MYP humanities course also emphasizes time, place and space, change, systems and global awareness—all fundamental concepts in environmental systems and societies. This course, however, also focuses on the natural environment, including its organic and inorganic components, its processes and feedback mechanisms, and how these interact with human behaviour. The MYP framework for sciences provides the basis on which all of this knowledge can be built.

The approach chosen for the environmental systems and societies internal assessment draws upon skills developed in the practical and investigative elements of the MYP sciences and humanities courses.

# Environmental systems and societies and theory of knowledge

This course offers some excellent opportunities for approaching issues of knowledge in immediate and practical contexts. The systems approach itself, which is employed throughout the syllabus, raises some interesting points of comparison and contrast with conventional models of the scientific method. It is essentially holistic rather than reductionist. While this approach is frequently quantitative in its representation of data, it also addresses the challenge of handling a wide range of qualitative data. There are many checks and guidelines to ensure objectivity in data handling and interpretation but the standards of objectivity may not always be so rigorously controlled as they are in the purely physical sciences. Furthermore, as a transdisciplinary subject, the material addressed frequently lies astride the interface of what are perceived as clear subject boundaries. In exploring and understanding an environmental issue, one must be able to integrate the hard, scientific, quantitative "facts" with the qualitative value judgments of politics, sociology and ethics. All this makes particularly fertile ground for discussions related to theory of knowledge (TOK). Some examples of how TOK may be brought to the attention of students are included in the "Syllabus content" section.

# Aims

## Environmental systems and societies aims

The systems approach provides the core methodology of this course. It is amplified by other sources, such as economic, historical, cultural, socio-political and scientific, to provide a holistic perspective on environmental issues.

The aims of the **environmental systems and societies** course are to:

1. promote understanding of environmental processes at a variety of scales, from local to global
2. provide a body of knowledge, methodologies and skills that can be used in the analysis of environmental issues at local and global levels
3. enable students to apply the knowledge, methodologies and skills gained
4. promote critical awareness of a diversity of cultural perspectives
5. recognize the extent to which technology plays a role in both causing and solving environmental problems
6. appreciate the value of local as well as international collaboration in resolving environmental problems
7. appreciate that environmental issues may be controversial, and may provoke a variety of responses
8. appreciate that human society is both directly and indirectly linked to the environment at a number of levels and at a variety of scales.

# Assessment objectives

The objectives reflect those parts of the aims that will be assessed. It is the intention of the **environmental systems and societies** course that students should achieve the following objectives.

1. Demonstrate an understanding of information, terminology, concepts, methodologies and skills with regard to environmental issues.
2. Apply and use information, terminology, concepts, methodologies and skills with regard to environmental issues.
3. Synthesize, analyse and evaluate research questions, hypotheses, methods and scientific explanations with regard to environmental issues.
4. Using a holistic approach, make reasoned and balanced judgments using appropriate economic, historical, cultural, socio-political and scientific sources.
5. Articulate and justify a personal viewpoint on environmental issues with reasoned argument while appreciating alternative viewpoints, including the perceptions of different cultures.
6. Demonstrate the personal skills of cooperation and responsibility appropriate for effective investigation and problem solving.
7. Select and demonstrate the appropriate practical and research skills necessary to carry out investigations with due regard to precision.

For a list of command terms for objectives 1–5, see the "Glossary of command terms" section in the appendices.

# Assessment objectives in practice

| Assessment objective | Which component addresses this assessment objective? | How is the assessment objective addressed? |
| --- | --- | --- |
| 1–3 | Paper 1 | Short-answer and data-based questions |
| 1–5 | Paper 2 | Section A: case study<br>Section B: two structured essay questions (from a choice of four) |
| 1–7 | Internal assessment | Practical work with some activities selected and marked against the internal assessment criteria |

## Assessment statements

Assessment statements, which are numbered, are expressed in terms of the outcomes that are expected of students at the end of the course (for example, “2.1.1 Distinguish between biotic and abiotic (physical) components of an ecosystem”). These are intended to prescribe to examiners what can be assessed by means of the written examinations. Each one is classified as objective 1, 2 or 3 according to the command terms used (see the “Glossary of command terms” section). The objective levels are relevant for the examinations and for balance within the syllabus, while the command terms indicate the depth of treatment required for a given assessment statement.

# Syllabus outline

| Syllabus component | Teaching hours |
|---|---|
| **Topic 1: Systems and models** | **5** |
| **Topic 2: The ecosystem** | **31** |
| 2.1 Structure | 4 |
| 2.2 Measuring abiotic components of the system | 1 |
| 2.3 Measuring biotic components of the system | 4 |
| 2.4 Biomes | 3 |
| 2.5 Function | 7 |
| 2.6 Changes | 7 |
| 2.7 Measuring changes in the system | 5 |
| **Topic 3: Human population, carrying capacity and resource use** | **39** |
| 3.1 Population dynamics | 5 |
| 3.2 Resources—natural capital | 8 |
| 3.3 Energy resources | 4 |
| 3.4 The soil system | 4 |
| 3.5 Food resources | 6 |
| 3.6 Water resources | 3 |
| 3.7 Limits to growth | 2.5 |
| 3.8 Environmental demands of human populations | 6.5 |
| **Topic 4: Conservation and biodiversity** | **15** |
| 4.1 Biodiversity in ecosystems | 3 |
| 4.2 Evaluating biodiversity and vulnerability | 6 |
| 4.3 Conservation of biodiversity | 6 |

| Syllabus component | Teaching hours |
|---|---|
| **Topic 5: Pollution management** | **18** |
| 5.1 Nature of pollution | 1 |
| 5.2 Detection and monitoring of pollution | 3 |
| 5.3 Approaches to pollution management | 2 |
| 5.4 Eutrophication | 3 |
| 5.5 Solid domestic waste | 2 |
| 5.6 Depletion of stratospheric ozone | 3 |
| 5.7 Urban air pollution | 2 |
| 5.8 Acid deposition | 2 |
| **Topic 6: The issue of global warming** | **6** |
| **Topic 7: Environmental value systems** | **6** |
| **Total teaching hours** | **120** |

# Approaches to the teaching of environmental systems and societies

## Systems approach

The systems approach is central to the course and has been employed for a number of reasons. The very nature of environmental issues demands a holistic treatment. In reality, an environmental system functions as a whole and the traditional reductionist approach of science inevitably tends to overlook or, at least, understate this important quality. Furthermore, the systems approach is common to many disciplines (for example, economics, geography, politics, ecology). It emphasizes the similarities between the ways in which matter, energy and information flow (not only in biological systems but in, for example, transport and communication systems). This approach therefore integrates the perspectives of different disciplines. Given the integrated nature of this subject, stressing the links between areas of the syllabus is critical and should be considered when planning the delivery of the course.

## Sustainability

The concept of sustainability is central to an understanding of the nature of interactions between environmental systems and societies. Resource management issues are essentially issues of sustainability, and students' attention should be drawn to this throughout the course.

## Holistic evaluation

It is important that students develop a holistic appreciation of the complexities of environmental issues, in which the interaction between environmental systems and societies is central. The course requires that students consider the costs and the benefits of human activities, both to the environment and to societies, over the short and long term. In doing so, students will arrive at informed personal viewpoints. They should be aware of and be able to justify their own position and to appreciate the views of others along the continuum of environmental philosophies. Their viewpoints may vary according to the issues being considered.

## Local and global material

This course requires the study of environmental systems and societies at a range of scales from local to global, but the teaching of the course should be firmly rooted in the local environment. There are many references throughout the syllabus to "local examples", and fieldwork will inevitably be based on local ecosystems. A national or regional perspective is appropriate for the study of certain issues such as resource management and pollution management. Many environmental issues are international in nature, such as climate change and management of the oceans. On a broader scale, the course naturally leads students to an appreciation of the nature of the international dimension, since the resolution of the major environmental issues rests heavily upon international relationships and agreements.

# Use of information and communication technology

Although the use of information and communication technology (ICT) is not an assessment requirement in this subject, it is strongly encouraged throughout the course in both practical and theory work. The application of ICT is integral to the practice, understanding and development of the subject, and teachers should attempt to expose students to a variety of ICT media, resources, software and hardware, ranging in format and complexity. In terms of hardware, this can range from the use of scientific calculators as data collection devices (data loggers) to the deployment of both laboratory- and field-based electronic data measuring and recording equipment. Hand-held global positioning systems (GPS) allow for the exploration of ideas of space and relative location. Within the classroom, geographical information systems (GIS) and remote sensing packages allow for the exploration of a great range of themes within the environmental systems and societies syllabus.

Students should also be allowed to explore and utilize the wealth of data, information and software available on the World Wide Web. It is important, however, that students are encouraged to develop the skills necessary to evaluate this data and information critically.

# Practical work

The most important aspect of the environmental systems and societies course is hands-on work in the laboratory and/or out in the field. The syllabus not only directly requires the use of field techniques, but many components can only be covered effectively through this approach. Practical work in this subject is an opportunity to gain and develop skills and techniques beyond the requirements of the assessment model and should be fully integrated with the teaching of the course.

In line with the poster *Ethical practice in the Diploma Programme*, the following guidelines exist for all practical work undertaken as part of the Diploma Programme.

- No experiments involving other people will be undertaken without their written consent and their understanding of the nature of the experiment.
- No experiment will be undertaken that inflicts pain on, or causes distress to, humans or live animals.
- No experiment or fieldwork will be undertaken that damages the environment.

# Syllabus content

## Topic 1: Systems and models (5 hours)

It is essential that the systems approach is used throughout this course. This approach identifies the elements of the systems, and examines the relationships and processes that link these elements into a functioning entity. This topic may be best viewed therefore as a theme to be used in the delivery of the other topics, rather than as an isolated teaching topic.

The topic identifies some of the underlying principles that can be applied to living systems, from the level of the individual up to that of the whole biosphere. It would therefore be helpful to describe and analyse the systems addressed in the terms laid out in this topic (wherever possible). The systems approach also emphasizes the similarities between environmental systems, biological systems and artificial entities such as transport and communication systems. This approach stresses that there are concepts, techniques and terms that can be transferred from one discipline (such as ecology) to another (such as engineering).

**TOK:** How does a systems approach compare to the reductionist approach of conventional science? How does methodology compare between these two approaches? What are the benefits of using an approach that is common to other disciplines such as economics and sociology?

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 1.1.1 | Outline the concept and characteristics of systems. | 2 | The emphasis will be on ecosystems but some mention should be made of economic, social and value systems. |
| 1.1.2 | Apply the systems concept on a range of scales. | 2 | The range must include a small-scale local ecosystem, a large ecosystem such as a biome, and Gaia as an example of a global ecosystem. |
| 1.1.3 | Define the terms *open system*, *closed system* and *isolated system*. | 1 | These terms should be applied when characterizing real systems.<br>• An open system exchanges matter and energy with its surroundings (for example, an ecosystem).<br>• A closed system exchanges energy but not matter; the "Biosphere II" experiment was an attempt to model this. Strictly, closed systems do not occur naturally on Earth, but all the global cycles of matter, for example, the water and nitrogen cycles, approximate to closed systems.<br>• An isolated system exchanges neither matter nor energy. No such systems exist (with the possible exception of the entire cosmos). |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 1.1.4 | Describe how the first and second laws of thermodynamics are relevant to environmental systems. | 2 | The first law concerns the conservation of energy. The second law explains the dissipation of energy that is then not available to do work, bringing about disorder. The second law is most simply stated as: "In any isolated system entropy tends to increase spontaneously." This means that energy and materials go from a concentrated into a dispersed form (the availability of energy to do work diminishes) and the system becomes increasingly disordered.<br><br>Both laws should be examined in relation to the energy transformations and maintenance of order in living systems. |
| 1.1.5 | Explain the nature of equilibria. | 3 | A steady-state equilibrium should be understood as the common property of most open systems in nature. A static equilibrium, in which there is no change, should be appreciated as a condition to which natural systems can be compared. (Since there is disagreement in the literature regarding the definition of dynamic equilibrium, this term should be avoided.) Students should appreciate, however, that some systems may undergo long-term changes to their equilibrium while retaining an integrity to the system (for example, succession). The relative stability of an equilibrium—the tendency of the system to return to that original equilibrium following disturbance, rather than adopting a new one—should also be understood. |
| 1.1.6 | Define and explain the principles of *positive feedback* and *negative feedback*. | 3 | The self-regulation of natural systems is achieved by the attainment of equilibrium through feedback systems.<br><br>• Negative feedback is a self-regulating method of control leading to the maintenance of a steady-state equilibrium—it counteracts deviation, for example, predator–prey relationships.<br>• Positive feedback leads to increasing change in a system—it accelerates deviation, for example, the exponential phase of population growth.<br><br>Feedback links involve time lags. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 1.1.7 | Describe transfer and transformation processes. | 2 | Transfers normally flow through a system and involve a change in location.<br><br>Transformations lead to an interaction within a system in the formation of a new end product, or involve a change of state. Using water as an example, run-off is a transfer process and evaporation is a transformation process. Dead organic matter entering a lake is an example of a transfer process; decomposition of this material is a transformation process. |
| 1.1.8 | Distinguish between flows (inputs and outputs) and storages (stock) in relation to systems. | 2 | Identify flows through systems and describe their direction and magnitude. |
| 1.1.9 | Construct and analyse quantitative models involving flows and storages in a system. | 3 | Storages, yields and outputs should be included in the form of clearly constructed diagrammatic and graphical models. |
| 1.1.10 | Evaluate the strengths and limitations of models. | 3 | A model is a simplified description designed to show the structure or workings of an object, system or concept. In practice, some models require approximation techniques to be used. For example, predictive models of climate change may give very different results. In contrast, an aquarium may be a relatively simple ecosystem but demonstrates many ecological concepts. |

# Topic 2: The ecosystem (31 hours)

The techniques required in this topic may be exemplified through practical work in marine, terrestrial, freshwater or urban ecosystems, or any combination of these. The selection of environments can be made according to the local systems available to the students, and the most convenient systems for demonstrating the techniques in question. However, there is an advantage in using the various practical measurements to quantify different aspects of the same ecosystem, where possible. In this way, the techniques are not simply rehearsed in isolation, but can be used to build up a holistic model of that system.

**TOK:** How does the role of instrumentation circumvent the limitations of perception? Can environmental investigations and measurements be as precise or reliable as those in the physical sciences? Why is this, and how does this affect the validity of the knowledge? Applying similarly rigorous standards as are used in physics, for example, would leave environmentalists with very little they could claim as knowledge. But, by insisting on high degrees of objectivity, would we miss out on a useful understanding of the environment? Is a pragmatic or correspondence test of truth most appropriate in this subject area?

## 2.1 Structure

**4 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 2.1.1 | Distinguish between biotic and abiotic (physical) components of an ecosystem. | 2 | |
| 2.1.2 | Define the term *trophic level*. | 1 | |
| 2.1.3 | Identify and explain trophic levels in food chains and food webs selected from the local environment. | 3 | Relevant terms (for example, producers, consumers, decomposers, herbivores, carnivores, top carnivores) should be applied to local, named examples and other food chains and food webs. |
| 2.1.4 | Explain the principles of pyramids of numbers, pyramids of biomass, and pyramids of productivity, and construct such pyramids from given data. | 3 | Pyramids are graphical models of the quantitative differences that exist between the trophic levels of a single ecosystem. A pyramid of biomass represents the standing stock of each trophic level measured in units such as grams of biomass per square metre (g $m^{-2}$). Biomass may also be measured in units of energy, such as J $m^{-2}$.<br><br>In accordance with the second law of thermodynamics, there is a tendency for numbers and quantities of biomass and energy to decrease along food chains; therefore the pyramids become narrower as one ascends. Pyramids of numbers can sometimes display different patterns, for example, when individuals at lower trophic levels are relatively large. Similarly, pyramids of biomass can show greater quantities at higher trophic levels because they represent the biomass present at a given time (there may be marked seasonal variations). Both pyramids of numbers and pyramids of biomass represent storages.<br><br>Pyramids of productivity refer to the flow of energy through a trophic level and invariably show a decrease along the food chain. For example, the turnover of two retail outlets cannot be compared by simply comparing the goods displayed on the shelves; the rates at which the shelves are being stocked and the goods sold also need to be known. Similarly, a business may have substantial assets but cash flow may be very limited. In the same way, pyramids of biomass simply represent the momentary stock, whereas pyramids of productivity show the rate at which that stock is being generated. Biomass, measured in units of mass or energy (for example, g $m^{-2}$ or J $m^{-2}$), should be distinguished from productivity measured in units of flow (for example, g $m^{-2}$ $yr^{-1}$ or J $m^{-2}$ $yr^{-1}$). |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| | | | A pyramid of energy may be represented either as the standing stock (biomass) measured in units of energy ($J\ m^{-2}$) or as productivity measured in units of flow of energy ($J\ m^{-2}\ yr^{-1}$), depending on the text consulted. As this is confusing, this syllabus avoids the term pyramid of energy. |
| 2.1.5 | Discuss how the pyramid structure affects the functioning of an ecosystem. | 3 | This should include concentration of non-biodegradable toxins in food chains, limited length of food chains, and vulnerability of top carnivores. Definitions of the terms biomagnification, bioaccumulation and bioconcentration are not required. |
| 2.1.6 | Define the terms *species*, *population*, *habitat*, *niche*, *community* and *ecosystem* with reference to local examples. | 1 | |
| 2.1.7 | Describe and explain population interactions using examples of named species. | 3 | Include competition, parasitism, mutualism, predation and herbivory.<br><br>Mutualism is an interaction in which both species derive benefit. Interactions should be understood in terms of the influences each species has on the population dynamics of others, and upon the carrying capacity of the others' environment. Graphical representations of these influences should be interpreted. |

## 2.2 Measuring abiotic components of the system

**1 hour**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 2.2.1 | List the significant abiotic (physical) factors of an ecosystem. | 1 | |
| 2.2.2 | Describe and evaluate methods for measuring at least three abiotic (physical) factors within an ecosystem. | 3 | Students should know methods for measuring any three significant abiotic factors and how these may vary in a given ecosystem with depth, time or distance. For example:<br>• marine—salinity, pH, temperature, dissolved oxygen, wave action<br>• freshwater—turbidity, flow velocity, pH, temperature, dissolved oxygen<br>• terrestrial—temperature, light intensity, wind speed, particle size, slope, soil moisture, drainage, mineral content.<br>This activity may be carried out effectively in conjunction with an examination of related biotic components. |

## 2.3 Measuring biotic components of the system

**4 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 2.3.1 | Construct simple keys and use published keys for the identification of organisms. | 3 | Students could practise with keys supplied and then construct their own keys for up to eight species. |
| 2.3.2 | Describe and evaluate methods for estimating abundance of organisms. | 3 | Methods should include capture–mark–release–recapture (Lincoln index) and quadrats for measuring population density, percentage frequency and percentage cover. |
| 2.3.3 | Describe and evaluate methods for estimating the biomass of trophic levels in a community. | 3 | Dry weight measurements of quantitative samples could be extrapolated to estimate total biomass. |
| 2.3.4 | Define the term *diversity*. | 1 | Diversity is often considered as a function of two components: the number of different species and the relative numbers of individuals of each species. |
| 2.3.5 | Apply Simpson's diversity index and outline its significance. | 2 | $D = \frac{N(N-1)}{\sum n(n-1)}$<br><br>Students are not required to memorize this formula but must know the meaning of the symbols:<br><br>$D$ = diversity index<br><br>$N$ = total number of organisms of all species found<br><br>$n$ = number of individuals of a particular species<br><br>$D$ is a measure of species richness. A high value of $D$ suggests a stable and ancient site, and a low value of $D$ could suggest pollution, recent colonization or agricultural management. The index is normally used in studies of vegetation but can also be applied to comparisons of animal (or even all species) diversity. |

## 2.4 Biomes

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 2.4.1 | Define the term *biome*. | 1 | **Int:** Biomes usually cross national boundaries (biomes do not stop at a border; for example, the Sahara, tundra, tropical rainforests). |
| 2.4.2 | Explain the distribution, structure and relative productivity of tropical rainforests, deserts, tundra and any other biome. | 3 | Refer to prevailing climate and limiting factors. For example, tropical rainforests are found close to the equator where there is high insolation and rainfall and where light and temperature are not limiting. The other biome may be, for example, temperate grassland or a local example. Limit climate to temperature, precipitation and insolation. |

## 2.5 Function

**7 hours**

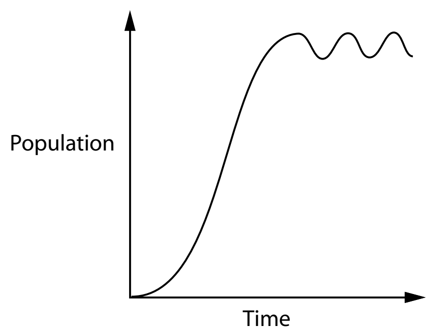
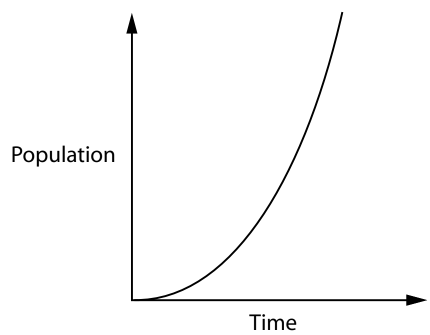
| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 2.5.1 | Explain the role of producers, consumers and decomposers in the ecosystem. | 3 | |
| 2.5.2 | Describe photosynthesis and respiration in terms of inputs, outputs and energy transformations. | 2 | Biochemical details are not required. Details of chloroplasts, light-dependent and light-independent reactions, mitochondria, carrier systems, ATP and specific intermediate biochemicals are not expected.<br><br>Photosynthesis should be understood as requiring carbon dioxide, water, chlorophyll and certain visible wavelengths of light to produce organic matter and oxygen. The transformation of light energy into the chemical energy of organic matter should be appreciated.<br><br>Respiration should be recognized as requiring organic matter and oxygen to produce carbon dioxide and water. Without oxygen, carbon dioxide and other waste products are formed. Energy is released in a form available for use by living organisms, but is ultimately lost as heat. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 2.5.3 | Describe and explain the transfer and transformation of energy as it flows through an ecosystem. | 3 | Explain pathways of incoming solar radiation incident on the ecosystem including:<br>• loss of radiation through reflection and absorption<br>• conversion of light to chemical energy<br>• loss of chemical energy from one trophic level to another<br>• efficiencies of transfer<br>• overall conversion of light to heat energy by an ecosystem<br>• re-radiation of heat energy to the atmosphere.<br>Construct and analyse simple energy-flow diagrams illustrating the movement of energy through ecosystems, including the productivity of the various trophic levels.<br>The distinction between storages of energy illustrated by boxes in energy-flow diagrams (representing the various trophic levels), and the flows of energy or productivity often shown as arrows (sometimes of varying widths) needs to be emphasized. The former are measured as the amount of energy or biomass per unit area and the latter are given as rates, for example, $J\ m^{-2}\ day^{-1}$. |
| 2.5.4 | Describe and explain the transfer and transformation of materials as they cycle within an ecosystem. | 3 | Processes involving the transfer and transformation of carbon, nitrogen and water as they cycle within an ecosystem should be described, and the conversion of organic and inorganic storage noted where appropriate.<br>Construct and analyse flow diagrams of these cycles. |
| 2.5.5 | Define the terms *gross productivity*, *net productivity*, *primary productivity* and *secondary productivity*. | 1 | Productivity is production per unit time. |
| 2.5.6 | Define the terms and calculate the values of both *gross primary productivity* (GPP) and *net primary productivity* (NPP) from given data. | 2 | Use the equation<br>NPP = GPP – R<br>where R = respiratory loss |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 2.5.7 | Define the terms and calculate the values of both *gross secondary productivity* (GSP) and *net secondary productivity* (NSP) from given data. | 2 | Use the equations<br>NSP = GSP – R<br>GSP = food eaten – fecal loss<br>where R = respiratory loss<br>The term "assimilation" is sometimes used instead of "secondary productivity". |

## 2.6 Changes

**7 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 2.6.1 | Explain the concepts of limiting factors and carrying capacity in the context of population growth. | 3 | |
| 2.6.2 | Describe and explain S and J population curves. | 3 | Explain changes in both numbers and rates of growth in standard S and J population growth curves.<br>Population curves should be sketched, described, interpreted and constructed from given data.<br>**S curve**<br><br>**J curve**<br> |

| | Assessment statement | Obj | Teacher’s notes |
|---|---|---|---|
| 2.6.3 | Describe the role of density-dependent and density-independent factors, and internal and external factors, in the regulation of populations. | 2 | According to theory, density-dependent factors operate as negative feedback mechanisms leading to stability or regulation of the population.<br><br>Both types of factors may operate on a population. Many species, particularly *r*-strategists, are probably regulated by density-independent factors, of which weather is the most important. Internal factors might include density-dependent fertility or size of breeding territory, and external factors might include predation or disease. |
| 2.6.4 | Describe the principles associated with survivorship curves including, *K*- and *r*-strategists. | 2 | *K*- and *r*-strategists represent idealized categories and many organisms occupy a place on the continuum.<br><br>Students should be familiar with interpreting features of survivorship curves including logarithmic scales. |
| 2.6.5 | Describe the concept and processes of succession in a named habitat. | 2 | Students should study named examples of organisms from a pioneer community, seral stages and climax community.<br><br>The concept of succession, occurring over time, should be carefully distinguished from the concept of zonation, which refers to a spatial pattern. |
| 2.6.6 | Explain the changes in energy flow, gross and net productivity, diversity and mineral cycling in different stages of succession. | 3 | In early stages, gross productivity is low due to the initial conditions and low density of producers. The proportion of energy lost through community respiration is relatively low too, so net productivity is high, that is, the system is growing and biomass is accumulating.<br><br>In later stages, with an increased consumer community, gross productivity may be high in a climax community. However, this is balanced by respiration, so net productivity approaches zero and the production:respiration (P:R) ratio approaches one. |
| 2.6.7 | Describe factors affecting the nature of climax communities. | 2 | Climatic and edaphic factors determine the nature of a climax community. Human factors frequently affect this process through, for example, fire, agriculture, grazing and/or habitat destruction. |

## 2.7 Measuring changes in the system

**5 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 2.7.1 | Describe and evaluate methods for measuring changes in abiotic and biotic components of an ecosystem along an environmental gradient. | 3 | |
| 2.7.2 | Describe and evaluate methods for measuring changes in abiotic and biotic components of an ecosystem due to a specific human activity. | 3 | Methods and changes should be selected appropriately for the human activity chosen. Suitable human impacts for study might include toxins from mining activity, landfills, eutrophication, effluent, oil spills and overexploitation. This could include repeated measurements on the ground, satellite images and maps. |
| 2.7.3 | Describe and evaluate the use of environmental impact assessments (EIAs). | 3 | Students should have the opportunity to see an actual EIA study. They should realize that an EIA involves production of a baseline study before any environmental development, assessment of possible impacts, and monitoring of change during and after the development. |

# Topic 3: Human population, carrying capacity and resource use (39 hours)

**TOK:** What do the models of "natural capital/income" and the "ecological footprint" add to the earlier concepts of "resources" and "carrying capacity"? Is one model any more objective than the other? Is this a good thing? With regard to the terms used, how does the **language** affect our understanding of the concepts? (For example, there is perhaps a sense that "natural capital" is something to be preserved, while "resources" are specifically there for human utilization. Similarly, "ecological footprint" conjures an image of environmental threat from any growing population, whereas "carrying capacity" focuses on the maximum number that a population can reach.)

## 3.1 Population dynamics

**5 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.1.1 | Describe the nature and explain the implications of exponential growth in human populations. | 3 | |
| 3.1.2 | Calculate and explain, from given data, the values of crude birth rate, crude death rate, fertility, doubling time and natural increase rate. | 3 | |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.1.3 | Analyse age/sex pyramids and diagrams showing demographic transition models. | 3 | **Int:** While many of the more economically developed countries (MEDCs) have a declining population size, that of many of the less economically developed countries (LEDCs) is rising rapidly. The position of various countries on the demographic transition model reflects their development stages. |
| 3.1.4 | Discuss the use of models in predicting the growth of human populations. | 3 | This might include computer simulations, statistical and/or demographic tables for LEDCs and MEDCs, age/sex pyramids and graphical extrapolation of population curves. |

## 3.2 Resources—natural capital

**8 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.2.1 | Explain the concept of resources in terms of natural income. | 3 | Ecologically minded economists describe resources as "natural capital". If properly managed, renewable and replenishable resources are forms of wealth that can produce "natural income" indefinitely in the form of valuable goods and services.<br><br>This income may consist of marketable commodities such as timber and grain (goods) or may be in the form of ecological services such as the flood and erosion protection provided by forests (services). Similarly, non-renewable resources can be considered in parallel to those forms of economic capital that cannot generate wealth without liquidation of the estate. |
| 3.2.2 | Define the terms *renewable*, *replenishable* and *non-renewable natural capital*. | 1 | There are three broad classes of natural capital.<br>• Renewable natural capital, such as living species and ecosystems, is self-producing and self-maintaining and uses solar energy and photosynthesis. This natural capital can yield marketable goods such as wood fibre, but may also provide unaccounted essential services when left in place, for example, climate regulation.<br>• Replenishable natural capital, such as groundwater and the ozone layer, is non-living but is also often dependent on the solar "engine" for renewal.<br>• Non-renewable (except on a geological timescale) forms of natural capital, such as fossil fuel and minerals, are analogous to inventories: any use implies liquidating part of the stock. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.2.3 | Explain the dynamic nature of the concept of a resource. | 3 | Consider how cultural, economic, technological and other factors influence the status of a resource over time and space. For example, uranium, due to the development of nuclear technology, has only recently become a valuable resource. |
| 3.2.4 | Discuss the view that the environment can have its own intrinsic value. | 3 | Organisms or ecosystems that are valued on aesthetic or intrinsic grounds may not provide commodities identifiable as either goods or services, and so remain unpriced or undervalued from an economic viewpoint. Organisms or ecosystems regarded as having intrinsic value, for instance from an ethical, spiritual or philosophical perspective, are valued regardless of their potential use to humans. Therefore, diverse perspectives may underlie the evaluation of natural capital.<br><br>Attempts are being made to acknowledge diverse valuations of nature (for example, biodiversity, rate of depletion of natural resources) so that they may be weighed more rigorously against more common economic values (for example, gross national product (GNP)). However, some argue that these valuations are impossible to quantify and price realistically. Not surprisingly, much of the sustainability debate centres on the problem of how to weigh conflicting values in our treatment of natural capital.<br><br>**TOK:** How can we quantify values such as aesthetic value, which are inherently qualitative? |
| 3.2.5 | Explain the concept of sustainability in terms of natural capital and natural income. | 3 | The term "sustainability" has been given a precise meaning in this syllabus. Students should understand that any society that supports itself in part by depleting essential forms of natural capital is unsustainable. If human well-being is dependent on the goods and services provided by certain forms of natural capital, then long-term harvest (or pollution) rates should not exceed rates of capital renewal. Sustainability means living, within the means of nature, on the "interest" or sustainable income generated by natural capital. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.2.6 | Discuss the concept of sustainable development. | 3 | The term "sustainable development" was first used in 1987 in *Our Common Future* (The Brundtland Report) and was defined as "development that meets current needs without compromising the ability of future generations to meet their own needs." The value of this approach is a matter of considerable debate and there is now no single definition for sustainable development. For example, some economists may view sustainable development as a stable annual return on investment regardless of the environmental impact, whereas some environmentalists may view it as a stable return without environmental degradation.<br><br>Consider the development of changing attitudes to sustainability and economic growth, since the Rio Earth Summit (1992) leading to Agenda 21.<br><br>**Int:** International summits on sustainable development have highlighted the issues involved in economic development across the globe, yet the viewpoints of environmentalists and economists may be very different. |
| 3.2.7 | Calculate and explain sustainable yield from given data. | 3 | Sustainable yield (SY) may be calculated as the rate of increase in natural capital, that is, that which can be exploited without depleting the original stock or its potential for replenishment. For example, the annual sustainable yield for a given crop may be estimated simply as the annual gain in biomass or energy through growth and recruitment. See figures 1 and 2. |

**Figure 1**

$$SY = \left( \frac{\text{total biomass}}{\text{energy}} \text{ at time } t+1 \right) - \left( \frac{\text{total biomass}}{\text{energy}} \text{ at time } t \right)$$

**Figure 2**

SY = (annual growth and recruitment) – (annual death and emigration)

## 3.3 Energy resources

**4 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.3.1 | Outline the range of energy resources available to society. | 2 | |
| 3.3.2 | Evaluate the advantages and disadvantages of two contrasting energy sources. | 3 | Consider one non-renewable (fossil fuels or nuclear) and one renewable energy source. |
| 3.3.3 | Discuss the factors that affect the choice of energy sources adopted by different societies. | 3 | This may include availability, economic, cultural, environmental and technological factors. |

## 3.4 The soil system

**4 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.4.1 | Outline how soil systems integrate aspects of living systems. | 2 | Emphasize a systems approach. Students should draw diagrams that show links between the soil, lithosphere, atmosphere and living organisms. The soil as a living system should be considered with reference to a generalized soil profile. Studies of specific soil profiles, for example, podsol, are not required.<br><br>Transfers of material (including deposition) result in reorganization of the soil. There are inputs of organic and parent material, precipitation, infiltration and energy. Outputs include leaching, uptake by plants and mass movement. Transformations include decomposition, weathering and nutrient cycling. |
| 3.4.2 | Compare and contrast the structure and properties of sand, clay and loam soils, including their effect on primary productivity. | 3 | Consider mineral content, drainage, water-holding capacity, air spaces, biota and potential to hold organic matter, and link these to primary productivity. |
| 3.4.3 | Outline the processes and consequences of soil degradation. | 2 | Human activities such as overgrazing, deforestation, unsustainable agriculture and irrigation cause processes of degradation. These include soil erosion, toxification and salinization. Desertification (enlargement of deserts through human activities) can be associated with this degradation. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.4.4 | Outline soil conservation measures. | 2 | Consider:<br>• soil conditioners (for example, use of lime and organic materials)<br>• wind reduction techniques (wind breaks, shelter belts, strip cultivation)<br>• cultivation techniques (terracing, contour plowing)<br>• efforts to stop plowing of marginal lands. |
| 3.4.5 | Evaluate soil management strategies in a named commercial farming system and in a named subsistence farming system. | 3 | |

## 3.5 Food resources

**6 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.5.1 | Outline the issues involved in the imbalance in global food supply. | 2 | Students should appreciate the differences in food production and distribution around the world, including the socio-political, economic and ecological influences on these. |
| 3.5.2 | Compare and contrast the efficiency of terrestrial and aquatic food production systems. | 3 | Compare and contrast these in terms of their trophic levels and efficiency of energy conversion. There is no need to consider individual production systems in detail. In terrestrial systems, most food is harvested from relatively low trophic levels (producers and herbivores). However, in aquatic systems, perhaps largely due to human tastes, most food is harvested from higher trophic levels where the total storages are much smaller. Although energy conversions along the food chain may be more efficient in aquatic systems, the initial fixing of available solar energy by primary producers tends to be less efficient due to the absorption and reflection of light by water. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.5.3 | Compare and contrast the inputs and outputs of materials and energy (energy efficiency), the system characteristics, and evaluate the relative environmental impacts for two named food production systems. | 3 | The systems selected should be both terrestrial or both aquatic. In addition, the inputs and outputs of the two systems should differ qualitatively and quantitatively (not all systems will be different in all aspects). The pair of examples could be North American cereal farming and subsistence farming in some parts of South-East Asia, intensive beef production in the developed world and the Maasai tribal use of livestock, or commercial salmon farming in Norway/Scotland and rice-fish farming in Thailand. Other local or global examples are equally valid.<br>Factors to be considered should include:<br>• inputs—for example, fertilizers (artificial and natural), irrigation water, pesticides, fossil fuels, food distribution, human labour, seed, breeding stock<br>• system characteristics—for example, selective breeding, genetically engineered organisms, monoculture versus polyculture, sustainability<br>• socio-cultural—for example, for the Maasai, cattle equals wealth and quantity is more important than quality<br>• environmental impact—for example, pollution, habitat loss, reduction in biodiversity, soil erosion<br>• outputs—for example, food quality and quantity, pollutants, soil erosion. |
| 3.5.4 | Discuss the links that exist between social systems and food production systems. | 3 | This could be illustrated through the use of examples, such as:<br>• the way in which the low population densities and belief systems of shifting cultivators links with the ecosystem of "slash and burn" agriculture<br>• the relationship between high population densities, culture, soil fertility and the wet-rice ecosystem of South-East Asia<br>• the link between the political economy of modern urban society, corporate capitalism and agro-ecosystems. |

## 3.6 Water resources

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.6.1 | Describe the Earth's water budget. | 2 | Only a small fraction (2.6% by volume) of the Earth's water supply is fresh water. Of this, over 80% is in the form of ice caps and glaciers, 0.6% is groundwater and the rest is made up of lakes, soil water, atmospheric water vapour, rivers and biota in decreasing order of storage size. Precise figures are not required. |
| 3.6.2 | Describe and evaluate the sustainability of freshwater resource usage with reference to a case study. | 3 | Irrigation, industrialization and population increase all make demands on the supplies of fresh water. Global warming may disrupt rainfall patterns and water supplies. The hydrological cycle supplies humans with fresh water but we are withdrawing water from underground aquifers and degrading it with wastes at a greater rate than it can be replenished. Consider the increased demand for fresh water, inequity of usage and political consequences, methods of reducing use and increasing supplies. A case study must be explored that covers some of these issues and demonstrates either sustainable or unsustainable water use. |

## 3.7 Limits to growth

**2.5 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.7.1 | Explain the difficulties in applying the concept of carrying capacity to local human populations. | 3 | By examining carefully the requirements of a given species and the resources available, it might be possible to estimate the carrying capacity of that environment for the species. This is problematic in the case of human populations for a number of reasons. The range of resources used by humans is usually much greater than for any other species. Furthermore, when one resource becomes limiting, humans show great ingenuity in substituting one resource for another. Resource requirements vary according to lifestyles, which differ from time to time and from population to population. Technological developments give rise to continual changes in the resources required and available for consumption. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| | | | Human populations also regularly import resources from outside their immediate environment, which enables them to grow beyond the boundaries set by their local resources and increases their carrying capacity. While importing resources in this way increases the carrying capacity for the local population, it has no influence on global carrying capacity. All these variables make it practically impossible to make reliable estimates of carrying capacities for human populations. |
| 3.7.2 | Explain how absolute reductions in energy and material use, reuse and recycling can affect human carrying capacity. | 3 | Human carrying capacity is determined by the rate of energy and material consumption, the level of pollution and the extent of human interference in global life-support systems. While reuse and recycling reduce these impacts, they can also increase human carrying capacity. |

## 3.8 Environmental demands of human populations

**6.5 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.8.1 | Explain the concept of an ecological footprint as a model for assessing the demands that human populations make on their environment. | 3 | The ecological footprint of a population is the area of land, in the same vicinity as the population, that would be required to provide all the population's resources and assimilate all its wastes. As a model, it is able to provide a quantitative estimate of human carrying capacity. It is, in fact, the inverse of carrying capacity. It refers to the area required to sustainably support a given population rather than the population that a given area can sustainably support. |
| 3.8.2 | Calculate from appropriate data the ecological footprint of a given population, stating the approximations and assumptions involved. | 2 | Although the accurate calculation of an ecological footprint might be very complex, an approximation can be achieved through the steps outlined in figures 3 and 4.<br><br>The total land requirement (ecological footprint) can then be calculated as the sum of these two *per capita* requirements, multiplied by the total population.<br><br>This calculation clearly ignores the land or water required to provide any aquatic and atmospheric resources, assimilate wastes other than carbon dioxide ($CO_2$), produce the energy and material subsidies imported to the arable land for increasing yields, replace loss of productive land through urbanization, and so on. |

**Figure 3**

$$\text{\textit{per capita} land requirement for food production (ha)} = \frac{\text{\textit{per capita} food consumption (kg yr}^{-1}\text{)}}{\text{mean food production per hectare of local arable land (kg ha}^{-1}\text{ yr}^{-1}\text{)}}$$

**Figure 4**

$$\text{\textit{per capita} land requirement for absorbing waste } CO_2 \text{ from fossil fuels (ha)} = \frac{\text{\textit{per capita} } CO_2 \text{ emission (kg C yr}^{-1}\text{)}}{\text{net carbon fixation per hectare of local natural vegetation (kg C ha}^{-1}\text{ yr}^{-1}\text{)}}$$

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 3.8.3 | Describe and explain the differences between the ecological footprints of two human populations, one from an LEDC and one from an MEDC. | 3 | Data for food consumption are often given in grain equivalents, so that a population with a meat-rich diet would tend to consume a higher grain equivalent than a population that feeds directly on grain.<br>Students should be aware that in MEDCs, about twice as much energy in the diet is provided by animal products than in LEDCs. Grain production will be higher with intensive farming strategies. Populations more dependent on fossil fuels will have higher $CO_2$ emissions. Fixation of $CO_2$ is clearly dependent on climatic region and vegetation type. These and other factors will often explain the differences in the ecological footprints of populations in LEDCs and MEDCs. |
| 3.8.4 | Discuss how national and international development policies and cultural influences can affect human population dynamics and growth. | 3 | Many policy factors influence human population growth. Domestic and international development policies (which target the death rate through agricultural development, improved public health and sanitation, and better service infrastructure) may stimulate rapid population growth by lowering mortality without significantly affecting fertility.<br>Some analysts believe that birth rates will come down by themselves as economic welfare improves and that the population problem is therefore better solved through policies to stimulate economic growth.<br>Education about birth control encourages family planning.<br>Parents may be dependent on their children for support in their later years and this may create an incentive to have many children. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| | | | Urbanization may also be a factor in reducing crude birth rates.<br><br>Policies directed towards the education of women, enabling women to have greater personal and economic independence, may be the most effective method for reducing population pressure. |
| 3.8.5 | Describe and explain the relationship between population, resource consumption and technological development, and their influence on carrying capacity and material economic growth. | 3 | Because technology plays such a large role in human life, many economists argue that human carrying capacity can be expanded continuously through technological innovation. For example, if we learn to use energy and material twice as efficiently, we can double the population or the use of energy without necessarily increasing the impact (load) imposed on the environment. However, to compensate for foreseeable population growth and the economic growth that is deemed necessary, especially in developing countries, it is suggested that efficiency would have to be raised by a factor of 4 to 10 to remain within global carrying capacity. |

# Topic 4: Conservation and biodiversity (15 hours)

**TOK:** This topic raises some engaging issues of debate concerning the moral justification for exploiting species and the moral imperative for conserving them. Do other organisms have a right to moral consideration? How is this justified? Do panda bears have a greater right than lichens? What about the rights of "pest" or pathogenic organisms? To what extent are these arguments based upon emotion and to what extent upon reason? And how does this affect their validity?

## 4.1 Biodiversity in ecosystems

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 4.1.1 | Define the terms *biodiversity*, *genetic diversity*, *species diversity* and *habitat diversity*. | 1 | |
| 4.1.2 | Outline the mechanism of natural selection as a possible driving force for speciation. | 2 | Speciation occurs as a result of the isolation (geographical or reproductive) of populations. The concept of fitness should be understood. The history of the development of the modern theory of evolution is not expected, nor is a detailed knowledge of genetics (including allele frequency). |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 4.1.3 | State that isolation can lead to different species being produced that are unable to interbreed to yield fertile offspring. | 1 | Isolation of populations, behavioural differences that preclude reproduction and the inability to produce fertile offspring (leading to speciation) should all be examined, with examples. |
| 4.1.4 | Explain how plate activity has influenced evolution and biodiversity. | 3 | The consequences of plate tectonics on speciation should be understood (that is, the separation of gene pools, formation of physical barriers and land bridges) together with the implications these consequences have for evolution. The role of plate activity in generating new and diverse habitats, thus promoting biodiversity, should also be considered. Detailed understanding of the mechanism of plate tectonics is not required. |
| 4.1.5 | Explain the relationships among ecosystem stability, diversity, succession and habitat. | 3 | Consider how:<br>• diversity changes through succession<br>• greater habitat diversity leads to greater species and genetic diversity<br>• a complex ecosystem, with its variety of nutrient and energy pathways, provides stability<br>• human activities modify succession, for example, logging, grazing, burning<br>• human activities often simplify ecosystems, rendering them unstable, for example, North America wheat farming versus tall grass prairie<br>• an ecosystem's capacity to survive change may depend on diversity, resilience and inertia. |

## 4.2 Evaluating biodiversity and vulnerability

**6 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 4.2.1 | Identify factors that lead to loss of diversity. | 2 | These include:<br>• natural hazard events (for example, volcanoes, drought, ice age, meteor impact)<br>• habitat degradation, fragmentation and loss<br>• agricultural practices (for example, monoculture, use of pesticides, use of genetically modified species)<br>• introduction and/or escape of non-native species<br>• pollution<br>• hunting, collecting and harvesting.<br>**Int:** Rate of loss of biodiversity may vary from country to country depending on the ecosystems present, protection policies and monitoring, environmental viewpoints and stage of economic development. |
| 4.2.2 | Discuss the perceived vulnerability of tropical rainforests and their relative value in contributing to global biodiversity. | 3 | Consider:<br>• the vulnerability of other systems<br>• the regeneration rate of tropical rainforests<br>• total area and species diversity<br>• rainforest and "green politics". |
| 4.2.3 | Discuss current estimates of numbers of species and past and present rates of species extinction. | 3 | Examine the fossil record for evidence of mass extinctions in the past, and compare and contrast the possible causes of these to present-day extinctions. The time frame of these periods of extinction should be considered. |
| 4.2.4 | Describe and explain the factors that may make species more or less prone to extinction. | 3 | The following factors (among others) will affect the risk of extinction: numbers, degree of specialization, distribution, reproductive potential and behaviour, and trophic level. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 4.2.5 | Outline the factors used to determine a species' Red List conservation status. | 2 | Students should be aware of the factors used to determine a species' conservation status, and that a sliding scale operates. Students should appreciate that a range of factors are used to determine conservation status, such as:<br>• population size<br>• reduction in population size<br>• numbers of mature individuals<br>• geographic range and degree of fragmentation<br>• quality of habitat<br>• area of occupancy<br>• probability of extinction.<br>Definitions of the conservation status categories are not required and the term "criteria" has been avoided due to the complexity of the Red List classification system. |
| 4.2.6 | Describe the case histories of three different species: one that has become extinct, another that is critically endangered, and a third species whose conservation status has been improved by intervention. | 2 | Students should know the ecological, socio-political and economic pressures that caused or are causing the chosen species' extinction. The species' ecological roles and the possible consequences of their disappearance should be understood. |
| 4.2.7 | Describe the case history of a natural area of biological significance that is threatened by human activities. | 2 | Students should know the ecological, socio-political and economic pressures that caused or are causing the degradation of the chosen area, and the consequent threat to biodiversity. |

## 4.3 Conservation of biodiversity

**6 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 4.3.1 | State the arguments for preserving species and habitats. | 1 | Students should appreciate arguments based on ethical, aesthetic, genetic resource and commercial (including opportunity cost) considerations. They should also appreciate life-support and ecosystem-support functions. |
| 4.3.2 | Compare and contrast the role and activities of intergovernmental and non-governmental organizations in preserving and restoring ecosystems and biodiversity. | 3 | Consider the United Nations Environment Programme (UNEP) as an intergovernmental organization and the World Wide Fund for Nature (WWF) and Greenpeace as non-governmental organizations. Compare and contrast UNEP and WWF in terms of use of the media, speed of response, diplomatic constraints and political influence. Consider also recent international conventions on biodiversity (for example, conventions signed at the Rio Earth Summit (1992) and subsequent updates). |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 4.3.3 | State and explain the criteria used to design protected areas. | 3 | In effect, protected areas may become "islands" within a country and will normally lose some of their diversity. The principles of island biogeography might be applied to the design of reserves. Appropriate criteria should include size, shape, edge effects, corridors and proximity. |
| 4.3.4 | Evaluate the success of a named protected area. | 3 | The granting of protected status to a species or ecosystem is no guarantee of protection without community support, adequate funding and proper research. Consider a specific local example. |
| 4.3.5 | Discuss and evaluate the strengths and weaknesses of the species-based approach to conservation. | 3 | Students should consider the relative strengths and weaknesses of:<br>• the Convention on International Trade in Endangered Species (CITES)<br>• captive breeding and reintroduction programmes, and zoos<br>• aesthetic versus ecological value. |

# Topic 5: Pollution management (18 hours)

The purpose of this topic is to give a broad overview of pollution and its management with reference to examples from aquatic, terrestrial and atmospheric systems.

**TOK:** Most cases of non-point source pollution exemplify well the intractable ethical problem of the "tragedy of the commons". That is to say, an individual polluting a common resource suffers little themselves from their own pollution and yet may benefit considerably in other ways. Therefore, those that do not pollute are doubly penalized—they suffer the pollution, and yet gain no benefit from polluting the resource themselves. There is thus a net advantage for any individual who does pollute. Ultimately, as many individuals adopt the most advantageous attitude, this leads to a great deal of suffering for all. It is exactly this conundrum that underlies much of the difficulty in managing non-point source pollution of shared resources on both a local (for example, a river) and an international (for example, the atmosphere) scale. Indeed, that one nation may gain considerably from non-compliance, especially while others comply, underlies much of the hesitancy in reaching international agreements on pollution strategies. Consideration and comparison of how both deontological and utilitarian approaches to ethics address this issue may make for interesting debate. In addition, the role of international legislation compared to increasing public awareness in tackling the problem could arguably be seen as a directly parallel debate. That is, is a system of rules, or appealing to the general good, the most effective way forward?

## 5.1 Nature of pollution

1 hour

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 5.1.1 | Define the term *pollution*. | 1 | |
| 5.1.2 | Distinguish between the terms point source pollution and non-point source pollution, and outline the challenges they present for management. | 2 | Point source pollution is generally more easily managed because its impact is more localized, making it easier to control emission, attribute responsibility and take legal action. |
| 5.1.3 | State the major sources of pollutants. | 1 | Sources of pollutants are combustion of fossil fuels, domestic and industrial waste, manufacturing and agricultural systems. |

## 5.2 Detection and monitoring of pollution

3 hours

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 5.2.1 | Describe two direct methods of monitoring pollution. | 2 | Students should describe one method for air and one for soil or water. |
| 5.2.2 | Define the term *biochemical oxygen demand* (BOD) and explain how this indirect method is used to assess pollution levels in water. | 3 | |
| 5.2.3 | Describe and explain an indirect method of measuring pollution levels using a biotic index. | 3 | This will involve levels of tolerance, diversity and abundance of organisms. The concept of indicator species should be understood. A polluted and an unpolluted site (for example, upstream and downstream of a point source) should be compared. |

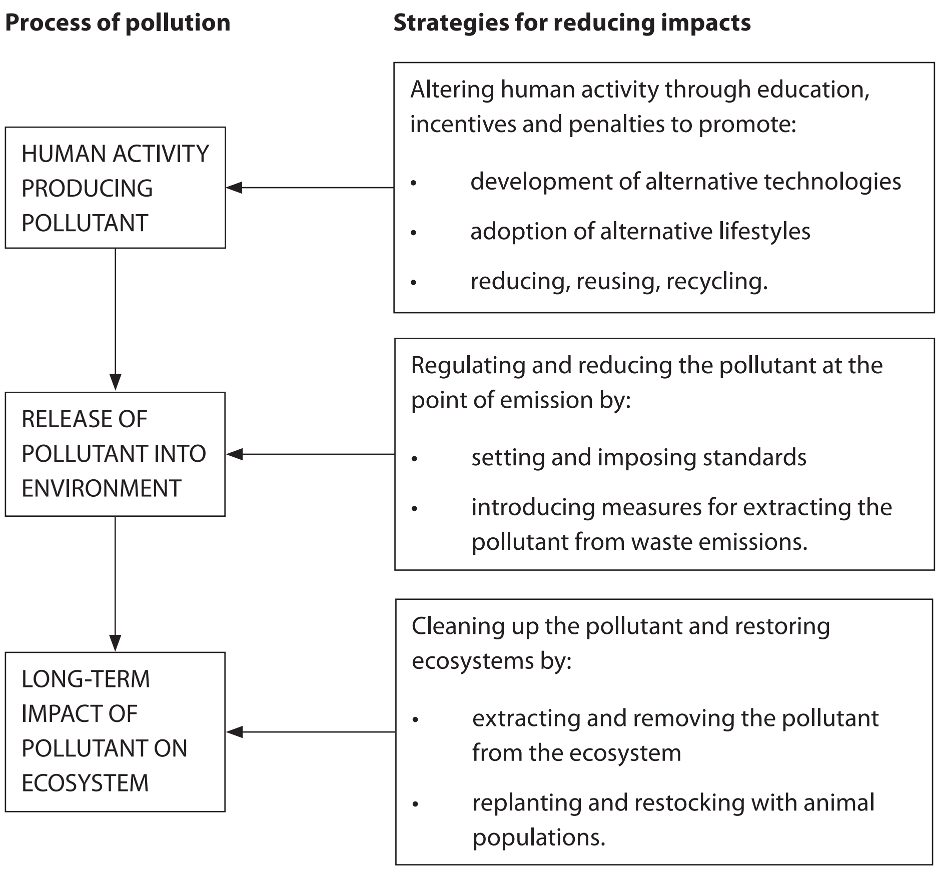
## 5.3 Approaches to pollution management

2 hours

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 5.3.1 | Outline approaches to pollution management with respect to figure 5. | 2 | Pollutants are produced through human activities and create long-term effects when released into ecosystems. Strategies for reducing these impacts can be directed at three different levels in the process: altering the human activity, regulating and reducing quantities of pollutant released at the point of emission, and cleaning up the pollutant and restoring ecosystems after pollution has occurred. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| | | | Using figure 5, students should be able to show the value and limitations of each of the three different levels of intervention. In addition, students should appreciate the advantages of employing the earlier strategies over the later ones and the importance of collaboration in the effective management of pollution. |
| 5.3.2 | Discuss the human factors that affect the approaches to pollution management. | 3 | Cultural values, political systems and economic systems will influence the choice of pollution management strategies and their effective implementation. Real examples should be considered. |
| 5.3.3 | Evaluate the costs and benefits to society of the World Health Organization's ban on the use of the pesticide DDT. | 3 | |

**Figure 5**



## 5.4 Eutrophication

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 5.4.1 | Outline the processes of eutrophication. | 2 | Include increase in nitrates and phosphates leading to rapid growth of algae, accumulation of dead organic matter, high rate of decomposition and lack of oxygen. The role of positive feedback should be noted in these processes. |
| 5.4.2 | Evaluate the impacts of eutrophication. | 3 | Include death of aerobic organisms, increased turbidity, loss of macrophytes, reduction in length of food chains and loss of species diversity. |
| 5.4.3 | Describe and evaluate pollution management strategies with respect to eutrophication. | 3 | Students should apply the model in 5.3.1 in the evaluation of the strategies. For example:<br>• Altering the human activity producing pollution can be exemplified by alternative methods of enhancing crop growth, alternative detergents, and so on.<br>• Regulating and reducing pollutants at the point of emission can be illustrated by sewage treatment processes that remove nitrates and phosphates from the waste.<br>• Clean-up and restoration can be exemplified by pumping mud from eutrophic lakes and reintroducing plant and fish species. |

## 5.5 Solid domestic waste

**2 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 5.5.1 | Outline the types of solid domestic waste. | 2 | Students should consider their own and their community's generation of waste. Consider the different types of material, for example, paper, glass, metal, plastics, organic waste (kitchen or garden), packaging, as well as their total volume. |
| 5.5.2 | Describe and evaluate pollution management strategies for solid domestic (municipal) waste. | 3 | Consider recycling, incineration, composting and landfill. |

## 5.6 Depletion of stratospheric ozone

**3 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 5.6.1 | Outline the overall structure and composition of the atmosphere. | 2 | |
| 5.6.2 | Describe the role of ozone in the absorption of ultraviolet radiation. | 2 | Ultraviolet radiation is absorbed during the formation and destruction of ozone from oxygen. Memorization of chemical equations is not required. |
| 5.6.3 | Explain the interaction between ozone and halogenated organic gases. | 3 | Halogenated organic gases are very stable under normal conditions but can liberate halogen atoms when exposed to ultraviolet radiation in the stratosphere. These atoms react with monatomic oxygen and slow the rate of ozone re-formation. Pollutants enhance the destruction of ozone, thereby disturbing the equilibrium of the ozone production system (see 1.1.5). |
| 5.6.4 | State the effects of ultraviolet radiation on living tissues and biological productivity. | 1 | The effects include mutation and subsequent effects on health and damage to photosynthetic organisms, especially phytoplankton and their consumers such as zooplankton. |
| 5.6.5 | Describe three methods of reducing the manufacture and release of ozone-depleting substances. | 2 | For example, recycling refrigerants, alternatives to gas-blown plastics, alternative propellants and alternatives to methyl bromide (bromomethane). |
| 5.6.6 | Describe and evaluate the role of national and international organizations in reducing the emissions of ozone-depleting substances. | 3 | Examine the role of the United Nations Environment Programme (UNEP) in forging international agreements (for example, the Montreal Protocol and subsequent updates) on the use of ozone-depleting substances, and study the relative effectiveness of these agreements and the difficulties in implementing and enforcing them. In addition, students should be familiar with what steps national governments are taking to comply with these agreements. |

## 5.7 Urban air pollution

**2 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 5.7.1 | State the source and outline the effect of tropospheric ozone. | 2 | When fossil fuels are burned, two of the pollutants emitted are hydrocarbons (from unburned fuel) and nitrogen monoxide (nitric oxide, NO). Nitrogen monoxide reacts with oxygen to form nitrogen dioxide ($NO_2$), a brown gas that contributes to urban haze. Nitrogen dioxide can also absorb sunlight and break up to release oxygen atoms that combine with oxygen in the air to form ozone.<br><br>Ozone is a toxic gas and an oxidizing agent. It damages crops and forests, irritates eyes, can cause breathing difficulties in humans and may increase susceptibility to infection. It is highly reactive and can attack fabrics and rubber materials. |
| 5.7.2 | Outline the formation of photochemical smog. | 2 | Photochemical smog is a mixture of about one hundred primary and secondary pollutants formed under the influence of sunlight. Ozone is the main pollutant.<br><br>The frequency and severity of photochemical smogs in an area depend on local topography, climate, population density and fossil fuel use. Precipitation cleans the air and winds disperse the smog. Thermal inversions trap the smogs in valleys (for example, Los Angeles, Santiago, Mexico City, Rio de Janeiro, São Paulo, Beijing) and concentrations of air pollutants can build to harmful and even lethal levels. |
| 5.7.3 | Describe and evaluate pollution management strategies for urban air pollution. | 3 | Measures to reduce fossil fuel combustion should be considered, for example, reducing demand for electricity and private cars and switching to renewable energy. Refer to clean-up measures, for example, catalytic converters. |

## 5.8 Acid deposition

**2 hours**

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 5.8.1 | Outline the chemistry leading to the formation of acidified precipitations. | 2 | Refer to the conversion of sulfur dioxide and oxides of nitrogen ($NO_x$) into the sulfates and nitrates of dry deposition and the sulfuric and nitric acids of wet deposition. Knowledge of chemical equations is not required. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 5.8.2 | Describe three possible effects of acid deposition on soil, water and living organisms. | 2 | Include:<br>• one direct effect, for example, acid on aquatic organisms and coniferous forests<br>• one toxic effect, for example, aluminium ions on fish<br>• one nutrient effect, for example, leaching of calcium. |
| 5.8.3 | Explain why the effect of acid deposition is regional rather than global. | 3 | Refer to areas downwind of major industrial regions that are adversely affected by acid rain and link them to sources of sulfur dioxide and nitrogen dioxide emissions. Consider the effect of geology (rocks and soils) on water acidity through buffering. |
| 5.8.4 | Describe and evaluate pollution management strategies for acid deposition. | 3 | Measures to reduce fossil fuel combustion should be considered, for example, reducing demand for electricity and private cars and switching to renewable energy. Refer to clean-up measures at "end of pipe" locations (points of emission). Consider the role of international agreements in effecting change.<br><br>The cost-effectiveness of spreading ground limestone in Swedish lakes in the early 1980s provides a good case study. |

# Topic 6: The issue of global warming (6 hours)

This topic allows the study of a controversial global issue in more depth. Opinion within scientific and political communities is divided on this issue, and students should be encouraged to develop a personal viewpoint having considered the arguments.

**TOK:** This topic directly and usefully challenges popular views of certainty within the sciences. If the scientific community has access to such certainty, how can it be as publicly divided as it has been in this case? What effect does a highly sensitive political context have on objectivity? Can politicians exploit the ambiguity of conclusions coming from the scientific community to their own ends?

**Int:** This issue involves the international community working together to research and reduce the effects of global warming.

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 6.1.1 | Describe the role of greenhouse gases in maintaining mean global temperature. | 2 | The greenhouse effect is a normal and necessary condition for life on Earth. Consider carbon dioxide ($CO_2$) levels in geological times. |
| 6.1.2 | Describe how human activities add to greenhouse gases. | 2 | Water, $CO_2$, methane and chlorofluorocarbons (CFCs) are the main greenhouse gases. Human activities are increasing levels of $CO_2$, methane and CFCs in the atmosphere, which may lead to global warming. |

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 6.1.3 | Discuss qualitatively the potential effects of increased mean global temperature. | 3 | Consider the potential effects on the distribution of biomes, global agriculture and human societies. Students should appreciate that effects might be adverse or beneficial, for example:<br>• biomes shifting<br>• change in location of crop growing areas<br>• changed weather patterns<br>• coastal inundation (due to thermal expansion of the oceans and melting of the polar ice caps)<br>• human health (spread of tropical diseases). |
| 6.1.4 | Discuss the feedback mechanisms that would be associated with an increase in mean global temperature. | 3 | For example:<br>• negative feedback—increased evaporation in tropical latitudes leading to increased snowfall on the polar ice caps, which reduces the mean global temperature<br>• positive feedback—increased thawing of permafrost, leading to an increase in methane levels, which increases the mean global temperature.<br>Any feedback mechanisms associated with global warming may involve very long time lags. |
| 6.1.5 | Describe and evaluate pollution management strategies to address the issue of global warming. | 3 | Students should consider the following strategies:<br>• global—intergovernmental and international agreements (for example, Kyoto Agreement and subsequent updates), carbon tax and carbon trading, alternative energy sources<br>• local—allow students to explore their own lifestyle in the context of local greenhouse gas emissions<br>• preventive and reactive.<br>Students should evaluate these strategies with regard to their effectiveness and the implications for MEDCs and LEDCs of reducing $CO_2$ emissions in terms of economic growth and national development. |
| 6.1.6 | Outline the arguments surrounding global warming. | 2 | Students should appreciate the variety of sometimes conflicting arguments surrounding this issue. Note the complexity of the problem and the uncertainty of global climate models. Students should be aware of the concept of global dimming due to increased levels of atmospheric pollution. |
| 6.1.7 | Evaluate contrasting human perceptions of the issue of global warming. | 3 | Students should explore different viewpoints in relation to their own. |

# Topic 7: Environmental value systems (6 hours)

Understanding environmental value systems is a central theme in this course. Therefore, this topic should be used in the analysis of environmental issues throughout the course, as well as being taught as a discrete unit.

**TOK:** This topic, in its entirety, could be considered a component of a theory of knowledge course, and particularly directs students to evaluate their own personal standpoints. Any knowledge, including all that gained from this course, once it is put to use in either intellectual argument or practical application, tends to carry with it a value-laden context. Even where the data itself is highly objective, the selection of the data is rarely value-free. Besides, valuing objectivity over subjectivity can be seen as a value in itself.

**Int:** There are frameworks of axioms and assumptions, values and beliefs, perspectives and world views that colour our knowledge. This topic explores a range of just such frameworks, and invites students to identify, evaluate and justify their own position within that spectrum.

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 7.1.1 | State what is meant by an environmental value system. | 1 | This is a particular world view or set of paradigms that shapes the way an individual or group of people perceive and evaluate environmental issues. This will be influenced by cultural (including religious), economic and socio-political context.<br><br>An environmental value system is a system in the sense that it has inputs (for example, education, cultural influences, religious doctrine, media) and outputs (for example, decisions, perspectives, courses of action) determined by processing these inputs.<br><br>**Int:** Ecosystems may often cross national boundaries and this may lead to conflict arising from the clash of different value systems about exploitation of resources (for example, ocean fishing and whaling). |
| 7.1.2 | Outline the range of environmental philosophies with reference to figure 6. | 2 | |

**Figure 6**

ENVIRONMENTAL

← →

ECOCENTRISM (nature centred)

Holistic world view. Minimum disturbance of natural processes. Integration of spiritual, social and environmental dimensions. Sustainability for the whole Earth. Self-reliant communities within a framework of global citizenship. Self-imposed restraint on resource use.

ANTHROPOCENTRISM (people centred)

People as environmental managers of sustainable global systems. Population control given equal weight to resource use. Strong regulation by independent authorities required.

TECHNOCENTRISM (technology centred)

Technology can keep pace with and provide solutions to environmental problems. Resource replacement solves resource depletion. Need to understand natural processes in order to control them. Strong emphasis on scientific analysis and prediction prior to policy-making. Importance of market, and economic growth.

*Deep ecologists*

1. Intrinsic importance of nature for the humanity of man.
2. Ecological (and other natural) laws dictate human morality.
3. Biorights—the right of endangered species or unique landscapes to remain unmolested.

*Self-reliance soft ecologists*

1. Emphasis on smallness of scale and hence community identity in settlement, work and leisure.
2. Integration of concepts of work and leisure through a process of personal and communal improvement.
3. Importance of participation in community affairs, and of guarantees of the rights of minority interests. Participation seen as both a continuing education and a political function.

*(Deep ecologists and self-reliance soft ecologists)*

4. Lack of faith in modern large-scale technology and its associated demands on elitist expertise, central state authority and inherently anti-democratic institutions.
5. Implication that materialism for its own sake is wrong and that economic growth can be geared to providing for the basic needs of those below subsistence levels.

*Environmental managers*

1. Belief that economic growth and resource exploitation can continue assuming:
   - **a** suitable economic adjustments to taxes, fees, etc
   - **b** improvements in the legal rights to a minimum level of environmental quality
   - **c** compensation arrangements satisfactory to those who experience adverse environmental and/or social effects.
2. Acceptance of new project appraisal techniques and decision review arrangements to allow for wider discussion or genuine search for consensus among representative groups of interested parties.

*Cornucopians*

1. Belief that man can always find a way out of any difficulties, either political, scientific or technological.
2. Acceptance that pro-growth goals define the rationality of project appraisal and policy formulation.
3. Optimism about the ability of man to improve the lot of the world's people.
4. Faith that scientific and technological expertise provides the basic foundation for advice on matters pertaining to economic growth, public health and safety.
5. Suspicion of attempts to widen basis for participation and lengthy discussion in project appraisal and policy review.
6. Belief that all impediments can be overcome given a will, ingenuity and sufficient resources arising out of growth.

Adapted from Figure 10.1: The evolution of environmentalist objectives and strategies in the seventies, page 372. First published in O'Riordan, T. 1981. *Environmentalism*. London, UK. Pion Limited.

| | Assessment statement | Obj | Teacher's notes |
|---|---|---|---|
| 7.1.3 | Discuss how these philosophies influence the decision-making process with respect to environmental issues covered in this course. | 3 | |
| 7.1.4 | Outline key historical influences on the development of the modern environmental movement. | 2 | Consider major landmarks, for example, Minamata, Rachel Carson's *Silent Spring*, Bhopal, whaling (Save the Whale), Chernobyl, leading to environmental pressure groups, both local and global, the concept of stewardship and increased media coverage raising public awareness. |
| 7.1.5 | Compare and contrast the environmental value systems of two named societies. | 3 | The societies chosen should demonstrate significant differences, for example:<br>• First Nation Americans and European pioneers operating frontier economics, which involved exploitation of seemingly unlimited resources<br>• Buddhist and Judaeo-Christian societies<br>• Communist and capitalist societies. |
| 7.1.6 | Justify your personal viewpoint on environmental issues. | 3 | Students should be encouraged to reflect upon where they stand on the continuum of environmental philosophies with regard to specific issues arising throughout the syllabus, for example, population control, resource exploitation, sustainable development, and so on.<br>**Int:** The environmental philosophy of an individual, as with that of a community (see 7.1.1), will inevitably be shaped by cultural, economic and socio-political context. Students should recognize this and appreciate that others may have equally valid viewpoints (aims 4 and 7). |

# Assessment in the Diploma Programme

## General

Assessment is an integral part of teaching and learning. The most important aims of assessment in the Diploma Programme are that it should support curricular goals and encourage appropriate student learning. Both external and internal assessment are used in the Diploma Programme. IB examiners mark work produced for external assessment, while work produced for internal assessment is marked by teachers and externally moderated by the IB.

There are two types of assessment identified by the IB.

- Formative assessment informs both teaching and learning. It is concerned with providing accurate and helpful feedback to students and teachers on the kind of learning taking place and the nature of students' strengths and weaknesses in order to help develop students' understanding and capabilities. Formative assessment can also help to improve teaching quality, as it can provide information to monitor progress towards meeting the course aims and objectives.
- Summative assessment gives an overview of previous learning and is concerned with measuring student achievement.

The Diploma Programme primarily focuses on summative assessment designed to record student achievement at, or towards the end of, the course of study. However, many of the assessment instruments can also be used formatively during the course of teaching and learning, and teachers are encouraged to do this. A comprehensive assessment plan is viewed as being integral with teaching, learning and course organization. For further information, see the IB *Programme standards and practices* document.

The approach to assessment used by the IB is criterion-related, not norm-referenced. This approach to assessment judges students' work by their performance in relation to identified levels of attainment, and not in relation to the work of other students. For further information on assessment within the Diploma Programme please refer to the publication *Diploma Programme assessment: Principles and practice*.

To support teachers in the planning, delivery and assessment of the Diploma Programme courses a variety of resources can be found on the OCC or purchased from the IB store (http://store.ibo.org). Teacher support materials, subject reports, internal assessment guidance, grade descriptors, as well as resources from other teachers, can be found on the OCC. Specimen and past examination papers as well as markschemes can be purchased from the IB store.

## Methods of assessment

The IB uses several methods to assess work produced by students.

### Assessment criteria

Assessment criteria are used when the assessment task is open-ended. Each criterion concentrates on a particular skill that students are expected to demonstrate. An assessment objective describes what students should be able to do and assessment criteria describe how well they should be able to do it. Using assessment criteria allows discrimination between different answers and encourages a variety of responses.

Each criterion comprises a set of hierarchically ordered level descriptors. Each level descriptor is worth one or more marks. Each criterion is applied independently using a best-fit model. The maximum marks for each criterion may differ according to the criterion's importance. The marks awarded for each criterion are added together to give the total mark for the piece of work.

## Markbands

Markbands are a comprehensive statement of expected performance against which responses are judged. They represent a single holistic criterion divided into level descriptors. Each level descriptor corresponds to a range of marks to differentiate student performance. A best-fit approach is used to ascertain which particular mark to use from the possible range for each level descriptor.

## Markschemes

This generic term is used to describe analytic markschemes that are prepared for specific examination papers. Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from the students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response. A markscheme may include the content expected in the responses to questions or may be a series of marking notes giving guidance on how to apply criteria.

# Assessment outline

First examinations 2010

| Assessment component | Weighting |
|---|---|
| **External assessment (written papers, 3 hours)** | **80%** |
| **Paper 1—1 hour**<br>45 marks | **30%** |
| **Paper 2—2 hours**<br>65 marks | **50%** |
| **Internal assessment—30 hours**<br>42 marks | **20%** |

Note: The environmental systems and societies course is only offered at SL. There is no HL option available.

# External assessment

Two different methods are used to assess students.

- Detailed markschemes specific to each examination paper
- Markbands

The markbands are not published in this guide.

The markbands are related to the assessment objectives and the grade descriptors established for the environmental systems and societies course. The grade descriptors are available on the online curriculum centre and describe the extent to which the assessment objectives should be met for each grade level. The markschemes are specific to each examination.

## External assessment details

The external assessment consists of two written papers and is worth 80% of the final assessment.

A calculator is required for both papers. Programmable graphic display calculators (GDCs) are permitted.

### Paper 1

Paper 1 is made up of short-answer and data-based questions.

### Paper 2

Paper 2 consists of two sections, A and B.

In section A, students will be provided with a range of data in a variety of forms relating to a specific case study. Students are required to make reasoned and balanced judgments by analysing this data.

In section B, students are required to answer two structured essay questions from a choice of four.

> Note: Wherever possible, teachers should use, and encourage students to use, the Système International d'Unités (International System of Units—SI units).

# Practical work and internal assessment

## Purpose of internal assessment

Internal assessment is an integral part of the course and is compulsory for all students. It enables students to demonstrate the application of their skills and knowledge, and to pursue their personal interests, without the time limitations and other constraints that are associated with written examinations. The internal assessment should, as far as possible, be woven into normal classroom teaching and not be a separate activity conducted after a course has been taught.

Internal assessment in environmental systems and societies comprises a series of practical and fieldwork activities that are undertaken as part of the practical scheme of work. The performance in internal assessment is judged against four assessment criteria. The internal assessment model addresses objectives 6 and 7 in particular, but also objectives 1 to 5 of the course objectives

## Rationale for practical work

Although the requirements for internal assessment are mainly centred on the assessment of research and practical skills, the different types of experimental work that a student may engage in serve other purposes, including:

- illustrating, teaching and reinforcing theoretical concepts
- developing an appreciation of the essential hands-on nature of fieldwork
- developing an appreciation of the benefits and limitations of a range of investigative methodologies.

Therefore, there may be good justification for teachers to conduct further experimental work beyond that required for the internal assessment scheme.

## Practical scheme of work

The practical scheme of work (PSOW) is the practical course planned by the teacher and acts as a summary of all the investigative activities carried out by a student. The better practical scheme of work will be one that moves towards the holistic modelling of particular environments rather than using a series of isolated ecological exercises. If several techniques are employed to measure various components of a single ecosystem, the interrelatedness of these components can be examined and the final result may be a more integrated and holistic model.

### Syllabus coverage

The range of investigations carried out should reflect the breadth and depth of the subject syllabus, but it is not necessary to carry out an investigation for every syllabus topic. However, practical activities should ideally include a spread of content material from the course. A minimum number of investigations to be carried out is not specified.

## Choosing investigations

Teachers are free to formulate their own practical schemes of work by choosing fieldwork and investigations according to the requirements outlined. Their choices should be based on:

- the needs of their students
- available resources
- teaching styles.

Each scheme of work must include some complex investigations that make greater conceptual demands on the students. Given the aims and objectives of this course, students should be provided with the opportunity to carry out investigations that demonstrate the interrelationships between environmental and social systems. A scheme made up entirely of simple experiments, such as ticking boxes or exercises involving filling in tables, will not provide an adequate range of experience for students.

Teachers are encouraged to use the online curriculum centre to share ideas about possible investigations by joining in the discussion forums and adding resources to the environmental systems and societies home page.

> Note: Any investigation or part investigation that is to be used to assess students should be specifically designed to match the relevant assessment criteria.

## Flexibility

The internal assessment model is flexible enough to allow a wide variety of investigations to be carried out. These could include:

- short laboratory practicals over one or two lessons and long-term practicals or projects extending over several weeks
- computer simulations
- data-gathering exercises such as questionnaires and surveys
- data-analysis exercises
- general laboratory work and fieldwork.

It is vital, however, that the range of tasks undertaken by students reflects the transdisciplinary nature of this course. Through a balanced and varied practical scheme of work, students should be able to experience tasks that focus on laboratory work and/or fieldwork, as well as more value-based investigations.

# Practical work documentation

Details of an individual student's practical scheme of work are recorded on **form ES/PSOW** provided in the *Handbook of procedures for the Diploma Programme*. Electronic versions may be used as long as they include all necessary information. In addition, the investigations corresponding to the best two marks achieved by each student when assessed using the three internal assessment criteria (planning, data collection and processing, and discussion, evaluation and conclusion) and the instructions given by the teacher for the investigations must be retained for possible inclusion in the sample work sent to the internal assessment moderator.

# Group work

Group work is an essential element of practical work and is required in order to develop and assess the personal skills criterion. However, work used for the assessment of the other criteria must be the work of the individual. This may raise logistical problems for teachers. Please see the section "Guidance on the criteria" for further advice on the assessment of work carried out in groups.

# Time allocation for practical work

Internal assessment is an integral part of the environmental systems and societies course, contributing 20% to the final assessment. This weighting should be reflected in the time that is allocated to teaching the knowledge, skills and understanding required to undertake work as well as the total time allocated to carry out the work.

It is recommended that a total of approximately 30 hours should be allocated to practical work (excluding time spent writing up work). This should include:

- time for the teacher to explain to students the requirements of the internal assessment
- the course ethical guidelines
- class time for students to work on the internal assessment component
- time for consultation between the teacher and each student
- time to review and monitor progress, and to check authenticity.

The time allocated should be spread throughout most of the course and not confined to just a few weeks at the beginning, middle or end.

Only some of the 30 hours of practical work need to be allocated to the practical work that is assessed using the internal assessment criteria. This will normally be done during the latter part of the course when students have become more familiar with the criteria and can be assessed in complex practical work.

# Guidance and authenticity

The practical work submitted for internal assessment must be the student's own work. However, it is not the intention that students should decide upon a title or topic and be left to work on the internal assessment component without any further support from the teacher. The teacher should play an important role during both the planning stage and the period when the student is working on the internally assessed work. It is the responsibility of the teacher to ensure that students are familiar with:

- the requirements of the type of work to be internally assessed
- the environmental systems and societies course ethical guidelines
- the assessment criteria; students must understand that the work submitted for assessment must address these criteria effectively.

Teachers and students must discuss the internally assessed work. Students should be encouraged to initiate discussions with the teacher to obtain advice and information, and students must not be penalized for seeking guidance. However, if a student could not have completed the work without substantial support from the teacher, this should be recorded on the appropriate form from the *Handbook of procedures for the Diploma Programme*.

It is the responsibility of teachers to ensure that all students understand the basic meaning and significance of concepts that relate to academic honesty, especially authenticity and intellectual property. Teachers must ensure that all student work for assessment is prepared according to the requirements and must explain clearly to students that the internally assessed work must be entirely their own.

As part of the learning process, teachers can give advice to students on a first draft of the internally assessed work. This advice should be in terms of the way the work could be improved, but this first draft must not be heavily annotated or edited by the teacher. The next version handed to the teacher after the first draft must be the final one.

All work submitted to the IB for moderation or assessment must be authenticated by a teacher, and must not include any known instances of suspected or confirmed malpractice. Each student must sign the coversheet for internal assessment to confirm that the work is his or her authentic work and constitutes the final version of that work. Once a student has officially submitted the final version of the work to a teacher (or the coordinator) for internal assessment, together with the signed coversheet, it cannot be retracted.

Authenticity may be checked by discussion with the student on the content of the work, and scrutiny of one or more of the following:

- the student's initial proposal
- the first draft of the written work
- the references cited
- the style of writing compared with work known to be that of the student.

The requirement for teachers and students to sign the coversheet for internal assessment applies to the work of all students, not just the sample work that will be submitted to an examiner for the purpose of moderation. If the teacher and student sign a coversheet, but there is a comment to the effect that the work may not be authentic, the student will not be eligible for a mark in that component and no grade will be awarded. For further details refer to the IB publication *Academic honesty* and the relevant articles in the *General regulations: Diploma Programme*.

The same piece of work cannot be submitted to meet the requirements of both the internal assessment and the extended essay.

# Safety

While teachers are responsible for following national or local guidelines, which may differ from country to country, attention should be given to the following mission statement, which was developed by the International Council of Associations for Science Education (ICASE) Safety Committee.

## ICASE Safety Committee

### Mission statement

> The mission of the ICASE Safety Committee is to promote good quality, exciting practical science, which will stimulate students and motivate their teachers, in a safe and healthy learning environment. In this way, all individuals (teachers, students, laboratory assistants, supervisors, visitors) involved in science education are entitled to work under the safest possible practicable conditions in science classrooms and laboratories. Every reasonable effort needs to be made by administrators to provide and maintain a safe and healthy learning environment and to establish and require safe methods and practices at all times. Safety rules and regulations need to be developed and enforced for the protection of those individuals carrying out their activities in science classrooms and laboratories, and experiences in the field. Alternative science activities are encouraged in the absence of sufficiently safe conditions.
>
> It is a basic responsibility of everyone involved to make safety and health an ongoing commitment. Any advice given will acknowledge the need to respect the local context, the varying educational and cultural traditions, the financial constraints and the legal systems of differing countries.

# Internal assessment criteria

## Using assessment criteria for internal assessment

For internal assessment, a number of assessment criteria have been identified. Each assessment criterion has level descriptors describing specific levels of achievement together with an appropriate range of marks. The level descriptors concentrate on positive achievement, although for the lower levels failure to achieve may be included in the description.

Teachers must judge the internally assessed work against the criteria using the level descriptors.

- The aim is to find, for each criterion, the descriptor that conveys most accurately the level attained by the student, using the best-fit model. A best-fit approach means that compensation should be made when a piece of work matches different aspects of a criterion at different levels. The mark awarded should be one that most fairly reflects the balance of achievement against the criterion. It is not necessary for every single aspect of a level descriptor to be met for that mark to be awarded.
- When assessing a student's work, teachers should read the level descriptors for each criterion until they reach a descriptor that most appropriately describes the level of the work being assessed. If a piece of work seems to fall between two descriptors, both descriptors should be read again and the one that more appropriately describes the student's work should be chosen.
- Where there are two or more marks available within a level, teachers should award the upper marks if the student's work demonstrates the qualities described to a great extent. Teachers should award the lower marks if the student's work demonstrates the qualities described to a lesser extent.
- Only whole numbers should be recorded; partial marks, such as fractions and decimals, are not acceptable.
- Teachers should not think in terms of a pass or fail boundary, but should concentrate on identifying the appropriate descriptor for each assessment criterion.
- The highest level descriptors do not imply faultless performance but should be achievable by a student. Teachers should not hesitate to use the extremes if they are appropriate descriptions of the work being assessed.
- A student who attains a high level of achievement in relation to one criterion will not necessarily attain high levels of achievement in relation to the other criteria. Similarly, a student who attains a low level of achievement for one criterion will not necessarily attain low achievement levels for the other criteria. Teachers should not assume that the overall assessment of the students will produce any particular distribution of marks.
- It is recommended that the assessment criteria be made available to students.

# Criteria and aspects

There are four assessment criteria that are used to assess the work of students.

- Planning—Pl
- Data collection and processing—DCP
- Discussion, evaluation and conclusion—DEC
- Personal skills—PS

The first three criteria—planning (Pl), data collection and processing (DCP), and discussion, evaluation and conclusion (DEC)—are each assessed at least twice.

Personal skills (PS) is assessed **summatively**, once only, at the end of the course. It should not be the average achieved over the whole practical scheme of work but should reflect any sustained improvement in performance.

Each of the assessment criteria can be separated into three **aspects** as shown in the following sections. Descriptions are provided to indicate what is expected in order to meet the requirements of a given aspect **completely (c)** and **partially (p)**. A description is also given for circumstances in which the requirements are not satisfied, **not at all (n)**.

A **"complete"** is awarded 2 marks, a **"partial"** 1 mark and a **"not at all"** 0 marks.

The maximum mark for each criterion is 6 (representing three "completes").

| | |
|---|---|
| Pl | $\times 2 = 12$ |
| DCP | $\times 2 = 12$ |
| DEC | $\times 2 = 12$ |
| PS | $\times 1 = 6$ |

This makes a total mark out of 42.

The marks for each of the criteria are added together to determine the final mark out of 42 for the internal assessment component. This is then scaled by the IB to give a total out of 20%.

General regulations and procedures relating to internal assessment can be found in the *Handbook of procedures for the Diploma Programme* for the year in which the internal assessment is being submitted.

## Planning

| Levels/marks | Aspect 1 | Aspect 2 | Aspect 3 |
|---|---|---|---|
| | **Defining the problem and selecting variables** | **Controlling variables** | **Developing a method for collection of data** |
| **Complete/2** | States a focused problem/research question and identifies the relevant variables. | Designs a method for the effective control of variables. | Describes a method that allows for the collection of sufficient relevant data. |
| **Partial/1** | States a problem/ research question that is incomplete **or** identifies only some relevant variables. | Designs a method that makes some attempt to control the variables. | Describes a method that does not allow for the collection of sufficient relevant data. |
| **Not at all/0** | Does not state a problem/research question **and** does not identify any relevant variables. | Designs a method that does not allow for the control of the variables. | Describes a method that does not allow for the collection of any relevant data. |

## Data collection and processing

| Levels/marks | Aspect 1 | Aspect 2 | Aspect 3 |
|---|---|---|---|
| | **Recording data** | **Processing data** | **Presenting processed data** |
| **Complete/2** | Systematically records appropriate quantitative and/or qualitative data*, including units. | Processes primary and/or secondary data correctly. | Presents processed data appropriately and effectively to assist analysis. |
| **Partial/1** | Records appropriate quantitative and/or qualitative data but with some mistakes and/or omissions. | Processes primary and/or secondary data but with some mistakes and/or omissions. | Presents processed data appropriately but lacks clarity **or** with some mistakes and/or omissions. |
| **Not at all/0** | Data is not recorded **or** is recorded incomprehensibly. | No processing of data is carried out **or** major mistakes are made in processing. | Presents processed data inappropriately **or** incomprehensibly. |

*This can be raw primary or secondary data

## Discussion, evaluation and conclusion

| Levels/marks | Aspect 1<br>Discussing and reviewing | Aspect 2<br>Evaluating procedure(s) and suggesting improvements | Aspect 3<br>Concluding |
|---|---|---|---|
| **Complete/2** | Discussion is clear and well reasoned, showing a broad understanding of context and the implications of results. | Identifies weaknesses and limitations and suggests realistic improvements. | States a reasonable conclusion, with a correct explanation, based on the data. |
| **Partial/1** | Discussion is adequate, showing some understanding of context and implications of results. | Identifies weaknesses and limitations but misses some obvious faults. Suggests only superficial improvements. | States a reasonable conclusion **or** gives a correct explanation, based on the data. |
| **Not at all/0** | Discussion is inadequate, showing little understanding of context and implications of results. | The weaknesses and limitations are irrelevant **or** missing. Suggests unrealistic improvements. | States an unreasonable conclusion **or** no conclusion at all. |

## Personal skills (assessed summatively)

| Levels/marks | Aspect 1<br>Carrying out techniques | Aspect 2<br>Working in a team | Aspect 3<br>Working safely and ethically |
|---|---|---|---|
| **Complete/2** | Fully competent and methodical in the use of a range of techniques and equipment. | Consistently collaborates and communicates in a group situation and integrates the views of others. | Always pays attention to safety issues and shows due regard for the environmental consequences of his or her actions and academic integrity. |
| **Partial/1** | Usually competent and methodical in the use of a range of techniques and equipment. | Occasionally collaborates and communicates in a group situation. | Usually pays attention to safety issues and shows some regard for the environmental consequences of his or her actions and academic integrity. |
| **Not at all/0** | Rarely competent and methodical in the use of a range of techniques and equipment. | Makes little or no attempt to collaborate in a group situation. | Pays little attention to safety issues and shows little regard for the environmental consequences of his or her actions and academic integrity. |

The assessment can be assisted by the use of a student self-evaluation form, but the use of such a form is not a requirement.

## Assessing an investigation

To illustrate the marking of one criterion, consider the following example. A student's work is assessed against the criterion planning. The teacher feels that the first aspect, defining the problem and selecting variables, is met completely whereas the second and third aspects, controlling variables and developing a method for collection of data, are only achieved partially. This translates to a level of 4.

# Guidance on the criteria

In practical work, the criteria do not need to be used for every investigation. However, when they are used for assessment purposes, it is essential that the teacher does not provide too much guidance that may result in a downward moderation of the students' scores. The following paragraphs indicate how guidance should be limited for such assessment purposes.

## Planning

It is essential in order to assess this criterion that students are given an open-ended problem to investigate. Although the teacher may provide a general aim or context, students must individually identify a problem or research question for themselves. For example, the teacher might suggest that students select and investigate a pattern of distribution in a given ecosystem. Students may decide to investigate a species, identify a particular pattern, formulate a relevant research question, identify those variables that may be responsible for the pattern, and design a method for collecting data.

### Aspect 1: defining the problem and selecting variables

The problem or research question must be clearly stated by the student, possibly in the form of a hypothesis. The student must also clearly state the relevant variables in the investigation, including those to be measured and those to be controlled.

### Aspect 2: controlling variables

It is recognized that, in fieldwork in particular, not all variables can be controlled, but the student should nevertheless clearly identify such variables and attempt to minimize their influence where possible.

### Aspect 3: developing a method for collection of data

The method should allow for the collection of sufficient relevant data to answer the research question. However, what is considered "sufficient" will depend upon the nature of the investigation and the time available to the student.

For the purposes of assessing the planning criterion, it is not necessary that the student actually carries out the investigation, but written accounts should be sufficient to provide evidence of all aspects being assessed. Ideally, however, student-planned investigations should be implemented rather than be treated as a theoretical exercise.

## Data collection and processing

The collection, recording and processing of primary and secondary environmental data is an integral part of enhancing students' understanding of the interaction between society and the environment. Investigations based on either primary or secondary data can be assessed here.

### Aspect 1: recording data

When data collection is carried out in groups, the actual recording and processing of data should be independently undertaken if this criterion is to be assessed. Recording class or group data is only appropriate for assessment if the data-sharing method does not suggest a presentation format for the students.

Data may be quantitative or qualitative and may consist of numerical measurements, observations, drawings, maps, photographs, results of questionnaires or interviews.

Primary data may be generated through fieldwork, laboratory investigations or surveys. Use of secondary data may be the only way to investigate some topics effectively, but in this situation **it is essential that students select the relevant data for themselves** from a range of secondary sources, which may or may not be provided by the teacher. If the data is selected for the students, no credit can be awarded for this aspect of the criterion.

A student who systematically collects relevant data and records it clearly (for example, a well-designed table with correct units and consistent significant figures) would have fulfilled this aspect completely. A student who collects relevant data, but uses incorrect units, omits units or uses inconsistent or inappropriate significant figures, would have partially fulfilled this aspect. A student who collects little or no data, and whose results are difficult or impossible to comprehend because of the way in which they are laid out, would not have fulfilled this aspect at all.

### Aspect 2: processing data

Processing data refers to the manipulation of raw data before it is finally presented. In order to assess this criterion, it is important to use an investigation that requires data processing. This might include grouping elements from raw data, calculation of mean values, percentages, indices or statistical tests. For example, students may collect raw data from communities along a transect and process this data to provide diversity indices for each point, which can subsequently be presented on a graph. Alternatively, the results of an open-ended questionnaire on perceptions of global warming may be grouped into common elements so that percentages for each group can be calculated.

It is important in assessing this criterion that **students are given the opportunity to select their own methods of processing the data**. The written account must include evidence of this processing, for example, calculations for a diversity index, or tabulation of open-ended questionnaire data ready for graphical presentation.

### Aspect 3: presenting processed data

The emphasis is on selection of a method of presentation that displays the processed data to best effect and aids interpretation. Presentation of data may take many forms, including graphical models such as kite diagrams, maps, charts, flow diagrams or annotated drawings.

A high level of neatness and precision, use of scientific conventions and inclusion of unambiguous headings and labels contribute to effective presentation.

Unnecessary repetitive presentation of the same data set in a variety of formats is inappropriate.

## Discussion, evaluation and conclusion

Once the data has been processed and presented in a suitable form, the results are discussed and reviewed, procedures are evaluated and conclusions are drawn. It is intended that this criterion should reflect the holistic approach that is central to the ethos of this course. Thus in the process of reviewing, evaluating and concluding, the student should demonstrate an ability to coherently discuss the broader significance of their findings.

Although teachers may lead class discussions on group projects for example, **students must be able to produce independent discussions, evaluation and conclusions for assessment purposes**.

### Aspect 1: discussing and reviewing

In the discussion, students should review and analyse their results and consider them in the context of relevant literature, accepted scientific understanding/models and class discussions as appropriate. This could include identification of trends, patterns and/or anomalies that may or may not agree with established theory. The assessment of this aspect requires an investigation that allows for discussion within such contexts.

### Aspect 2: evaluating procedure(s) and suggesting improvements

Students should evaluate their investigation in a constructive and reflective way, recognizing strengths but also using weaknesses and limitations to suggest realistic improvements. Students may consider procedures, limitations of equipment, use of equipment, management of time, investigation timing, data quality (accuracy and precision) and relevance of data.

### Aspect 3: concluding

Students are expected to provide a concise and clear conclusion that is supported by the evidence from the data and their discussion.

## Personal skills

This criterion is assessed **summatively** once only at the end of the course.

### Aspect 1: carrying out techniques

The effective student should be able to carry out a range of techniques competently, follow instructions, and assemble and use equipment with precision and accuracy.

### Aspect 2: working in a team

Working in a team is when two or more students work on a task collaboratively. Effective teamwork includes recognizing the contribution of others. There is an expectation that all team members contribute and are encouraged to contribute by the rest of the team. This will be demonstrated in the exchange of ideas, and an ability to integrate ideas into decision-making.

### Aspect 3: working safely and ethically

Students should adhere to safe and ethical working practices, demonstrating academic integrity, for example, properly citing secondary sources, not falsifying data and avoiding plagiarism. Due attention to environmental impact may be demonstrated in various ways, including avoidance of wastage, using safe waste disposal, and minimizing damage to local environments while undertaking an investigation.

# Use of information and communication technology in assessment

The use of information and communication technology is encouraged in practical work throughout the course, whether the investigations are assessed using the internal assessment criteria or otherwise. See the "Approaches to the teaching of environmental systems and societies" section.

Data-logging software may be used in experiments/investigations assessed using the internal assessment criteria provided that the following principle is applied.

The student's contribution to the experiment must be evident so that this alone can be assessed by the teacher. This student's contribution can be in the selection of settings used by the data-logging and graphing equipment, or can be demonstrated in subsequent stages of the experiment.

(When data-logging equipment is used, raw data is defined as any data produced by software and extracted by the student from tables or graphs to be subsequently processed by the student.)

The following categories of experiments exemplify the application of this principle.

## 1. Data logging within a narrowly focused task

Data-logging software may be used to perform a traditional experiment in a new way.

**Use of data-logging software is appropriate with respect to assessment if the student decides on and inputs most of the relevant software settings**. For example, an experiment could be set up to follow the change in dissolved oxygen levels of water samples taken from different sources with varying levels of pollution (and therefore different biochemical oxygen demands) using dissolved oxygen probes linked to a data logger.

Data-logging software that automatically determines the various settings and generates the data tables and graphs would be inappropriate with regard to assessment because the remaining student input required would be minimal.

If the experiment is suitable for assessment, the following guidelines must be followed for the DCP criterion.

### Data collection and processing: aspect 1

Students may present raw data collected using data-logging software, as long as they are responsible for the majority of software settings. The numerical raw data may be presented as a table, or, where a large amount of data has been generated, by graphical means. For example, the student should set the duration and rate of the sampling, and the generated data in the form of lists of measurements from the calculator or computer could be downloaded by the student into a computer spreadsheet. Students must organize the data correctly, for example, by means of table or graph titles, columns or graph axes labelled with units, associated qualitative observations, and so on.

The number of decimal places used in recorded data should not exceed that expressed by the sensitivity of the instrument used. In the case of electronic probes used in data logging, students will be expected to record the sensitivity of the instrument.

### Data collection and processing: aspects 2 and 3

Use of software for graph drawing is appropriate as long as the student is responsible for most of the decisions, such as:

- what to graph
- selection of quantities for axes
- appropriate units
- graph title
- appropriate scale
- how to graph, for example, linear graph line and not scatter.

Note: A computer-calculated gradient is acceptable.

In the example of the investigation to monitor biochemical oxygen demand, the student could process the data by drawing a graph using the graphing function of a spreadsheet. By inspecting the graph or spreadsheet data, the rate of change of dissolved oxygen in the samples could be calculated.

Statistical analysis carried out using calculators or calculations using spreadsheets are acceptable provided that the student selects the data to be processed and chooses the method of processing. In both cases, the student must show one example in the written text. For example, the student must quote the formula used by or entered into a calculator and define the terms used, or the student must write the formula used in a spreadsheet if it is not a standard part of the program's menu of functions (for example, mean, standard deviation).

## 2. Data logging in an open-ended investigation

Data-logging software can enhance data collection and transform the sort of investigations possible. In this case, fully automated data-logging software is appropriate with regard to assessment **if** it is used to enable a broader, complex investigation to be undertaken where students can develop a range of responses involving independent decision-making. For example, a planning task could be set to investigate a factor that affects the rate of transpiration. The student's work could be assessed for planning and DCP as follows.

### Planning: aspect 1

The student must state a focused problem or research question, for example: "What is the difference in the rate of transpiration under different ventilator speeds for *Acacia cavens* and *Lithrea caustica*, two tree species native to central Chile?"

Relevant variables must also be identified, for example:

- independent variable—species of plant
- dependent variable—rate of transpiration
- controlled variables—temperature, mass of plant, leaf surface area, time, wind speed.

### Planning: aspect 2

The student must design a method to monitor and control the variables: use an electronic balance to determine the mass of the plants, and use the same fan to control wind speed.

## Planning: aspect 3

The student must design the method for the appropriate collection of sufficient raw data. The student would select the species of plants to use, and measure transpiration rates using the biological gas pressure probe. The student must also ensure that the tubing is airtight around the stem of the leaf being tested, and select the ventilator speeds and the number of experimental replicates.

## Data collection and processing: aspect 1

Appropriate raw data would consist of the rates of transpiration derived from the graphs of the experimental runs generated by the program using the biological gas pressure probe. These rates of transpiration may be calculated by the student using a function on the program that analyses the graphs, or by hand. This must be done without prompting by the teacher. The derived data for rates of transpiration could be annotated on a series of graphs or presented in a table with an appropriate title, column headings and units.

## Data collection and processing: aspect 2

The graphs showing changes in gas pressure would not be assessed, as these would have been generated automatically by the pre-programmed software on the data logger, without input from the student. However, the rates of transpiration derived from these graphs could be plotted against wind speed for each species using software, provided that the student decides upon the choice of graph type, x and y axis, range and scale.

## Data collection and processing: aspect 3

The student would generate graphs of wind speed versus transpiration rates for each species, which would have clear titles, correctly labelled axes, a legend for the data of the different species of plants, and trend lines.

# Glossary of command terms

## Command terms with definitions

These command terms indicate the depth of treatment required for a given assessment statement and relate to the course objectives in the "Assessment objectives" section. Objectives 1 and 2 are lower-order skills and objectives 3, 4 and 5 relate to higher-order skills. These terms will be used in examination questions, and so it is important that students are familiar with the following definitions.

## Objective 1

| | |
|---|---|
| **Define** | Give the precise meaning of a word, phrase, concept or physical quantity. |
| **Draw** | Represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight line or smooth curve. |
| **Label** | Add labels to a diagram. |
| **List** | Give a sequence of brief answers with no explanation. |
| **Measure** | Obtain a value for a quantity. |
| **State** | Give a specific name, value or other brief answer without explanation or calculation. |

## Objective 2

| | |
|---|---|
| **Annotate** | Add brief notes to a diagram or graph. |
| **Apply** | Use an idea, equation, principle, theory or law in relation to a given problem or issue. |
| **Calculate** | Obtain a numerical answer showing the relevant stages of working. |
| **Describe** | Give a detailed account. |
| **Distinguish** | Make clear the differences between two or more concepts or items. |
| **Estimate** | Obtain an approximate value. |
| **Identify** | Provide an answer from a number of possibilities. |
| **Outline** | Give a brief account or summary. |

# Objectives 3, 4 and 5

| | |
|---|---|
| **Analyse** | Break down in order to bring out the essential elements or structure. |
| **Comment** | Give a judgment based on a given statement or result of a calculation. |
| **Compare and contrast** | Give an account of similarities and differences between two (or more) items or situations, referring to both (all) of them throughout. |
| **Construct** | Display information in a diagrammatic or logical form. |
| **Deduce** | Reach a conclusion from the information given. |
| **Derive** | Manipulate a mathematical relationship to give a new equation or relationship. |
| **Design** | Produce a plan, simulation or model. |
| **Determine** | Obtain the only possible answer. |
| **Discuss** | Offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence. |
| **Evaluate** | Make an appraisal by weighing up the strengths and limitations. |
| **Explain** | Give a detailed account, including reasons or causes. |
| **Justify** | Give valid reasons or evidence to support an answer or conclusion. |
| **Predict** | Give an expected result. |
| **Solve** | Obtain the answer(s) using algebraic and/or numerical methods and/or graphical methods. |
| **Suggest** | Propose a solution, hypothesis or other possible answer. |

# Environmental systems and societies glossary

| | |
|---|---|
| **Abiotic factor** | A non-living, physical factor that may influence an organism or ecosystem; for example, temperature, sunlight, pH, salinity, precipitation. |
| **Biochemical oxygen demand (BOD)** | A measure of the amount of dissolved oxygen required to break down the organic material in a given volume of water through aerobic biological activity. |
| **Biodegradable** | Capable of being broken down by natural biological processes; for example, the activities of decomposer organisms. |
| **Biodiversity** | The amount of biological or living diversity per unit area. It includes the concepts of species diversity, habitat diversity and genetic diversity. |
| **Biomass** | The mass of organic material in organisms or ecosystems, usually per unit area. Sometimes the term "dry weight biomass" is used where mass is measured after the removal of water. Water is not organic material and inorganic material is usually relatively insignificant in terms of mass. |
| **Biome** | A collection of ecosystems sharing similar climatic conditions; for example, tundra, tropical rainforest, desert. |
| **Biosphere** | That part of the Earth inhabited by organisms, that is, the narrow zone (a few kilometres in thickness) in which plants and animals exist. It extends from the upper part of the atmosphere (where birds, insects and wind-blown pollen may be found) down to the deepest part of the Earth's crust to which living organisms venture. |
| **Biotic factor** | A living, biological factor that may influence an organism or ecosystem; for example, predation, parasitism, disease, competition. |
| **Carrying capacity** | The maximum number of a species or "load" that can be sustainably supported by a given environment. |
| **Climax community** | A community of organisms that is more or less stable, and that is in equilibrium with natural environmental conditions such as climate; the end point of ecological succession. |
| **Community** | A group of populations living and interacting with each other in a common habitat. |
| **Competition** | A common demand by two or more organisms upon a limited supply of a resource; for example, food, water, light, space, mates, nesting sites. It may be intraspecific or interspecific. |
| **Correlation** | A measure of the association between two variables. If two variables tend to move up or down together, they are said to be positively correlated. If they tend to move in opposite directions, they are said to be negatively correlated. |
| **Crude birth rate** | The number of births per thousand individuals in a population per year. |
| **Crude death rate** | The number of deaths per thousand individuals in a population per year. |

| | |
|---|---|
| **Demographic transition** | A general model describing the changing levels of fertility and mortality in a human population over time. It was developed with reference to the transition experienced as developed countries (for example, those of North America, Europe, Australasia) passed through the processes of industrialization and urbanization. |
| **Diversity** | A generic term for heterogeneity. The scientific meaning of diversity becomes clear from the context in which it is used; it may refer to heterogeneity of species or habitat, or to genetic heterogeneity. |
| **Diversity, genetic** | The range of genetic material present in a gene pool or population of a species. |
| **Diversity, habitat** | The range of different habitats or number of ecological niches per unit area in an ecosystem, community or biome. Conservation of habitat diversity usually leads to the conservation of species and genetic diversity. |
| **Diversity index** | A numerical measure of species diversity that is derived from both the number of species (variety) and their proportional abundance. |
| **Diversity, species** | The variety of species per unit area. This includes both the number of species present and their relative abundance. |
| **Doubling time** | The number of years it would take a population to double its size at its current growth rate. A natural increase rate of 1% will enable a human population to double in 70 years. Other doubling times can then be calculated proportionately, that is, the doubling time for any human population is equal to 70 divided by the natural increase rate. |
| **Ecological footprint** | The area of land and water required to support a defined human population at a given standard of living. The measure takes account of the area required to provide all the resources needed by the population, and the assimilation of all wastes. (A method of calculation is provided in 3.8.2.) |
| **Ecosystem** | A community of interdependent organisms and the physical environment they inhabit. |
| **Entropy** | A measure of the amount of disorder, chaos or randomness in a system; the greater the disorder, the higher the level of entropy. |
| **Environmental impact assessment (EIA)** | A method of detailed survey required, in many countries, before a major development. Ideally it should be independent of, but paid for by, the developer. Such a survey should include a baseline study to measure environmental conditions before development commences, and to identify areas and species of conservation importance. The report produced is known as an environmental impact statement (EIS) or environmental management review in some countries. The monitoring should continue for some time after the development. |
| **Equilibrium** | A state of balance among the components of a system. |
| **Eutrophication** | The natural or artificial enrichment of a body of water, particularly with respect to nitrates and phosphates, that results in depletion of the oxygen content of the water. Eutrophication is accelerated by human activities that add detergents, sewage or agricultural fertilizers to bodies of water. |

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| **Evolution** | The cumulative, gradual change in the genetic characteristics of successive generations of a species or race of an organism, ultimately giving rise to species or races different from the common ancestor. Evolution reflects changes in the genetic composition of a population over time. |
| **Feedback** | The return of part of the output from a system as input, so as to affect succeeding outputs. |
| **Feedback, negative** | Feedback that tends to damp down, neutralize or counteract any deviation from an equilibrium, and promotes stability. |
| **Feedback, positive** | Feedback that amplifies or increases change; it leads to exponential deviation away from an equilibrium. |
| **Fertility** | In the context of human populations, this refers to the potential for reproduction exhibited in a population. It may be measured as fertility rate, which is the number of births per thousand women of child-bearing age. Alternatively it may be measured as total fertility, which is simply the average number of children a woman has in her lifetime. |
| **Gaia** | The Gaia hypothesis (developed by James Lovelock and named after an ancient Greek Earth goddess) compares the Earth to a living organism in which feedback mechanisms maintain equilibrium. |
| **Global warming** | An increase in average temperature of the Earth's atmosphere. |
| **GNP** | Gross National Product, the current value of all goods and services produced in a country per year. |
| **Greenhouse gases** | Those atmospheric gases which absorb infrared radiation, causing world temperatures to be warmer than they would otherwise be. This process is sometimes known as "radiation trapping". The natural greenhouse effect is caused mainly by water and carbon dioxide. Human activities have led to an increase in the levels of carbon dioxide, methane and nitrous oxide (dinitrogen oxide, $N_2O$) in the atmosphere, and there are fears that this may lead to **global warming**. |
| **Habitat** | The environment in which a species normally lives. |
| **Halogenated organic gases** | Usually known as halocarbons and first identified as depleting the ozone layer in the stratosphere. Now known to be potent greenhouse gases. The most well known are chlorofluorocarbons (CFCs). |
| **Isolation** | The process by which two populations become separated by geographical, behavioural, genetic or reproductive factors. If gene flow between the two subpopulations is prevented, new species may evolve. See **evolution**. |
| ***K*-strategist** | Species that usually concentrate their reproductive investment in a small number of offspring, thus increasing their survival rate and adapting them for living in long-term climax communities. |
| **Latitude** | The angular distance from the equator (that is, north or south of it) as measured from the centre of the Earth (usually in degrees). |
| **LEDC** | Less economically developed country: a country with low to moderate industrialization and low to moderate average GNP *per capita*. |
| **MEDC** | More economically developed country: a highly industrialized country with high average GNP *per capita*. |

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| **Model** | A simplified description designed to show the structure or workings of an object, system or concept. |
| **Mutualism** | A relationship between individuals of two or more species in which all benefit and none suffer. (The term symbiosis will not be used.) |
| **Natural capital** | A term sometimes used by economists for natural resources that, if appropriately managed, can produce a "natural income" of goods and services. The natural capital of a forest might provide a continuing natural income of timber, game, water and recreation. |
| **Natural capital, non-renewable** | Natural resources that cannot be replenished within a timescale of the same order as that at which they are taken from the environment and used; for example, fossil fuels. |
| **Natural capital, renewable** | Natural resources that have a sustainable yield or harvest equal to or less than their natural productivity; for example, food crops, timber. |
| **Natural capital, replenishable** | Non-living natural resources that depend on the energy of the Sun for their replenishment; for example, groundwater. |
| **Natural increase, rate of** | The form in which human population growth rates are usually expressed: $$\frac{\text{crude birth rate} - \text{crude death rate}}{10}$$ Inward and outward migration is ignored. |
| **Niche** | A species' share of a habitat and the resources in it. An organism's ecological niche depends not only on where it lives but also on what it does. |
| **Parasitism** | A relationship between two species in which one species (the parasite) lives in or on another (the host), gaining all or much (in the case of a partial parasite) of its food from it. |
| **Plate tectonics** | The movement of the eight major and several minor internally rigid plates of the Earth's lithosphere in relation to each other and to the partially mobile asthenosphere below. |
| **Pollution** | The addition to an environment of a substance or an agent (such as heat) by human activity, at a rate greater than that at which it can be rendered harmless by the environment, and which has an appreciable effect on the organisms within it. |
| **Pollution, non-point source** | The release of pollutants from numerous, widely dispersed origins; for example, gases from the exhaust systems of vehicles. |
| **Pollution, point source** | The release of pollutants from a single, clearly identifiable site; for example, a factory chimney or the waste disposal pipe of a factory into a river. |
| **Population** | A group of organisms of the same species living in the same area at the same time, and which are capable of interbreeding. |
| **Productivity, gross (GP)** | The total gain in energy or biomass per unit area per unit time, which could be through photosynthesis in primary producers or absorption in consumers. |
| **Productivity, gross primary (GPP)** | The total gain in energy or biomass per unit area per unit time fixed by photosynthesis in green plants. |

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| **Productivity, gross secondary (GSP)** | The total gain by consumers in energy or biomass per unit area per unit time through absorption. |
| **Productivity, net (NP)** | The gain in energy or biomass per unit area per unit time remaining after allowing for respiratory losses (R). Other metabolic losses may take place, but these may be ignored when calculating and defining net productivity for the purpose of this course. |
| **Productivity, net primary (NPP)** | The gain by producers in energy or biomass per unit area per unit time remaining after allowing for respiratory losses (R). This is potentially available to consumers in an ecosystem. |
| **Productivity, net secondary (NSP)** | The gain by consumers in energy or biomass per unit area per unit time remaining after allowing for respiratory losses (R). |
| **Productivity, primary** | The gain by producers in energy or biomass per unit area per unit time. This term could refer to either gross or net primary productivity. |
| **Productivity, secondary** | The biomass gained by heterotrophic organisms, through feeding and absorption, measured in units of mass or energy per unit area per unit time. |
| ***r*-strategist** | Species that tend to spread their reproductive investment among a large number of offspring so that they are well adapted to colonize new habitats rapidly and make opportunistic use of short-lived resources. |
| **Sere** | The set of communities that succeed one another over the course of succession at a given location. |
| **Smog** | The term now used for any haziness in the atmosphere caused by air pollutants. Photochemical smog is produced through the effect of ultraviolet light on the products of internal combustion engines. It may contain ozone and is damaging to the human respiratory system and eyes. |
| **Society** | An arbitrary group of individuals who share some common characteristic such as geographical location, cultural background, historical timeframe, religious perspective, value system, and so on. |
| **Soil** | A mixture of mineral particles and organic material that covers the land, and in which terrestrial plants grow. |
| **Soil profile** | A vertical section through a soil, from the surface down to the parent material, revealing the soil layers or horizons. |
| **Speciation** | The process through which new species form. See also **evolution**. |
| **Species** | A group of organisms that interbreed and produce fertile offspring. |
| **Stable equilibrium** | The condition of a system in which there is a tendency for it to return to a previous equilibrium condition following disturbance. |
| **Standing crop** | See **biomass**. |
| **Steady-state equilibrium** | The condition of an open system in which there are no changes over the longer term, but in which there may be oscillations in the very short term. There are continuing inputs and outputs of matter and energy, but the system as a whole remains in a more or less constant state (for example, a climax ecosystem). |

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| **Succession** | The orderly process of change over time in a community. Changes in the community of organisms frequently cause changes in the physical environment that allow another community to become established and replace the former through competition. Often, but not inevitably, the later communities in such a sequence or sere are more complex than those that appear earlier. |
| **Sustainability** | Use of global resources at a rate that allows natural regeneration and minimizes damage to the environment. For example, a system of harvesting renewable resources at a rate that will be replaced by natural growth might be considered to demonstrate sustainability. |
| **System** | An assemblage of parts and the relationships between them, which together constitute an entity or whole. |
| **System, closed** | A system in which energy, but not matter, is exchanged with its surroundings. |
| **System, isolated** | A system that exchanges neither matter nor energy with its surroundings. |
| **System, open** | A system in which both matter and energy are exchanged with its surroundings (for example, natural ecosystems). |
| **Trophic level** | The position that an organism occupies in a food chain, or a group of organisms in a community that occupy the same position in food chains. |
| **Zonation** | The arrangement or patterning of plant communities or ecosystems into parallel or sub-parallel bands in response to change, over a distance, in some environmental factor. The main biomes display zonation in relation to latitude and climate. Plant communities may also display zonation with altitude on a mountain, or around the edge of a pond in relation to soil moisture. |