Diploma Programme

Environmental systems and societies guide

First assessment 2017

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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.

As IB learners we strive to be:

INQUIRERS
We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life.

KNOWLEDGEABLE
We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance.

THINKERS
We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned, ethical decisions.

COMMUNICATORS
We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups.

PRINCIPLED
We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences.

OPEN-MINDED
We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience.

CARING
We show empathy, compassion and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us.

RISK-TAKERS
We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change.

BALANCED
We understand the importance of balancing different aspects of our lives—intellectual, physical, and emotional—to achieve well-being for ourselves and others. We recognize our interdependence with other people and with the world in which we live.

REFLECTIVE
We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development.

The IB learner profile represents 10 attributes valued by IB World Schools. We believe these attributes, and others like them, can help individuals and groups become responsible members of local, national and global communities.

Contents

Purpose of this document

This publication is intended to guide the planning, teaching and assessment of environmental systems and societies (ESS) in schools. ESS 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 ESS page of the online curriculum centre (OCC) at occ.ibo.org, a password-protected IB website designed to support IB teachers. It can also be purchased from the IB store at store.ibo.org.

Additional resources

Additional publications such as specimen papers and markschemes, teacher support materials (TSMs), subject reports and grade descriptors can also be found on the OCC. 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.

Acknowledgment

The IB wishes to thank the educators and associated schools for generously contributing time and resources to the production of this guide.

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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 model

The course is presented as six academic areas enclosing a central core (see figure 1). 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.

Figure 1

Diploma Programme model

Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can, instead of an arts subject, choose two subjects from another area. 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 core of the Diploma Programme model

All Diploma Programme students participate in the three elements that make up the core of the model.

Theory of knowledge (TOK) is a course that is fundamentally about critical thinking and inquiry into the process of knowing rather than about learning a specific body of knowledge. The TOK course examines the nature of knowledge and how we know what we claim to know. It does this by encouraging students to analyse knowledge claims and explore questions about the construction of knowledge. The task of TOK is to emphasize connections between areas of shared knowledge and link them to personal knowledge in such a way that an individual becomes more aware of his or her own perspectives and how they might differ from others.

Creativity, activity, service (CAS) is at the heart of the Diploma Programme. The emphasis in CAS is on helping students to develop their own identities, in accordance with the ethical principles embodied in the IB mission statement and the IB learner profile. It involves students in a range of activities alongside their academic studies throughout the Diploma Programme. The three strands of CAS are:

Creativity—arts, and other experiences that involve creative thinking

Activity—physical exertion contributing to a healthy lifestyle

Service—an unpaid and voluntary exchange that has a learning benefit for the student. Possibly, more than any other component in the Diploma Programme, CAS contributes to the IB's mission to create a better and more peaceful world through intercultural understanding and respect.

The extended essay, including the world studies extended essay, offers the opportunity for IB students to investigate a topic of special interest, in the form of a 4,000-word piece of independent research. The area of research undertaken is chosen from one of the students' six Diploma Programme subjects, or in the case of the interdisciplinary world studies essay, two subjects, and acquaints them with the independent research and writing skills expected at university. This leads to a major piece of formally presented, structured writing, in which ideas and findings are communicated in a reasoned and coherent manner, appropriate to the subject or subjects chosen. It is intended to promote high-level research and writing skills, intellectual discovery and creativity. An authentic learning experience, it provides students with an opportunity to engage in personal research on a topic of choice, under the guidance of a supervisor.

Prior learning

Past experience shows that students will be able to study ESS successfully with no background in, or previous knowledge of, environmental studies. Their approach to learning, characterized by the IB learner profile attributes, will be significant here.

Links to the Middle Years Programme

Students who have undertaken Middle Years Programme (MYP) courses in sciences and in individuals and societies will be well prepared for Diploma Programme ESS. The alignment between MYP and Diploma Programme courses allows for a smooth transition for students between programmes.

In the MYP students develop cognitive and procedural skills as well as strong conceptual understandings that support teaching and learning in the Diploma Programme. The 16 key concepts are the big ideas of the MYP that are broad, organizing and powerful. They have relevance within each specific course but also transcend it, having relevance in other subject groups. These key concepts facilitate both disciplinary and interdisciplinary learning by making connections with other subjects. For MYP sciences and MYP individuals and societies, the relevant key concepts are identified in tables 1 and 2.

Aesthetics	**Change**	Communication	Communities
Connections	Creativity	Culture	Development
Form	Global interactions	Identity	Logic
Perspective	**Relationships**	**Systems**	Time, place and space

Table 1

MYP key concepts for the sciences

Aesthetics	**Change**	Communication	Communities
Connections	Creativity	Culture	Development
Form	**Global interactions**	Identity	Logic
Perspective	Relationships	**Systems**	**Time, place and space**

Table 2

MYP key concepts for individuals and societies

The overlap between some key concepts in these two subject groups in MYP reinforces the position of ESS as an interdisciplinary subject in the Diploma Programme, making the MYP a good foundation for ESS.

Courses in the MYP individuals and societies group encompass experimentation and observation, reasoning and argumentation, the use of primary sources, and data that can be used to propose knowledge claims about human existence and behaviour. In this subject group, MYP students begin to evaluate these knowledge claims by assessing validity, reliability, credibility, certainty and individual, as well as cultural, perspectives.

There is focus on the development of critical and creative thinking skills that students can apply in a wide variety of areas of interest and careers. The knowledge, skills and attitudes that students develop in individuals and societies provide a meaningful foundation for further study and help to prepare students for work in academia, in non-governmental and governmental organizations, non-profit organizations, and business and industry.

Courses in the MYP sciences are focused on inquiry-based learning. A holistic sciences programme thus allows students to develop and utilize a mixture of cognitive abilities, social skills, personal motivation, conceptual knowledge and problem-solving competencies (Rhoton 2010). Inquiry aims to support students' understanding by providing them with opportunities to independently and collaboratively investigate relevant issues through both research and experimentation. This forms a firm base of scientific understanding with deep conceptual understanding for students entering the Diploma Programme.

Links to the IB Career-related Programme (CP)

The IB Career-related Programme (CP) incorporates the vision and educational principles of the IB into a unique programme specifically developed for students who wish to engage in career-related learning.

The CP's flexible educational framework allows schools to meet the needs, backgrounds and context of their students. Each school creates its own distinctive version of the CP. The aim of the CP is to provide students with an excellent foundation to support their further studies and specialized training, as well as ensuring their success in the workforce.

An important element of the CP framework is that students are required to study a minimum of two Diploma Programme subjects. ESS is a good choice for one of the Diploma Programme courses. By providing insight into environmental issues and their impact on societies in a broad sense, it can contribute to the appreciation of concepts such as sustainability when applied to careers ranging from construction to agriculture to the food industry and hospitality. An understanding of issues such as energy security and ecological footprints is also increasingly important in all spheres of industry and commerce. ESS can also contribute to a greater understanding of an individual or organization's role in responding to environmental challenges from a local to a global context, through the career opportunities and choices they make.

Academic honesty

Academic honesty in the Diploma Programme is a set of values and behaviours informed by the attributes of the learner profile. In teaching, learning and assessment, academic honesty serves to promote personal integrity, engender respect for the integrity of others and their work, and ensure that all students have an equal opportunity to demonstrate the knowledge and skills they acquire during their studies.

All coursework—including work submitted for assessment—is to be authentic, based on the student's individual and original ideas with the ideas and work of others fully acknowledged. Assessment tasks that require teachers to provide guidance to students or that require students to work collaboratively must be completed in full compliance with the detailed guidelines provided by the IB for the relevant subjects.

For further information on academic honesty in the IB and the Diploma Programme, please consult the IB publications *Academic honesty*, *The Diploma Programme: From principles into practice* and *General regulations: Diploma Programme*. Specific information regarding academic honesty as it pertains to external and internal assessment components of this Diploma Programme subject can be found in this guide.

Learning diversity and learning support requirements

Schools must ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Candidates with assessment access requirements* and *Learning diversity within the International Baccalaureate programmes: Special educational needs within the International Baccalaureate programmes*.

The nature of environmental systems and societies

ESS is an interdisciplinary group 3 and 4 course that is offered only at standard level (SL). As an interdisciplinary course, ESS is designed to combine the methodology, techniques and knowledge associated with group 4 (sciences) with those associated with group 3 (individuals and societies). Because it is an interdisciplinary course, students can study ESS and have it count as either a group 3 or a group 4 course, or as both. If students choose the latter option, this leaves the opportunity to study an additional subject from any other group, including an additional group 3 or group 4 subject.

ESS is a complex course, requiring a diverse set of skills from its students. It is firmly grounded in both a scientific exploration of environmental systems in their structure and function and in the exploration of cultural, economic, ethical, political, and social interactions of societies with the environment. As a result of studying this course, students will become equipped with the ability to recognize and evaluate the impact of our complex system of societies on the natural world. The interdisciplinary nature of the course requires a broad skill set from students and includes the ability to perform research and investigations and to participate in philosophical discussion. The course requires a systems approach to environmental understanding and problem-solving, and promotes holistic thinking about environmental issues. It is recognized that to understand the environmental issues of the 21st century and suggest suitable management solutions, both the human and environmental aspects must be understood. Students should be encouraged to develop solutions from a personal to a community and to a global scale.

Through the exploration of cause and effect, the course investigates how values interact with choices and actions, resulting in a range of environmental impacts. Students develop an understanding that the connections between environmental systems and societies are diverse, varied and dynamic. The complexity of these interactions challenges those working towards understanding the actions required for effective guardianship of the planet and sustainable and equitable use of shared resources.

Environmental systems and societies and the core

Environmental systems and societies and creativity, activity and service

CAS enables students to embody the attributes of the IB learner profile in real and practical ways, to grow as unique individuals and to recognize their role in relation to others. Students develop skills, attitudes and dispositions through a variety of individual and group experiences that provide them with opportunities to explore their interests and express their passions, personalities and perspectives. CAS complements a challenging academic programme in a holistic way, providing opportunities for self-determination, collaboration, accomplishment and enjoyment.

The three strands of CAS are:

- creativity—exploring and extending ideas leading to an original or interpretive product or performance
- activity—physical exertion contributing to a healthy lifestyle
- service—collaborative and reciprocal engagement with the community in response to an authentic need.

There are strong links between ESS and CAS that both teachers and students can explore. In ESS students actively engage with environmental issues and create innovative solutions where possible. Students could extend their classroom activities into CAS experiences using their learning in purposeful and meaningful ways. All three strands of CAS can be incorporated into experiences that relate to ESS within local, national and global communities.

Examples include:

- creating a campaign to support an initiative within the school that addresses an environmental issue such as reduction of food waste
- taking part in voluntary work that engages with an environmental initiative such as a project to preserve the environment of an endangered species
- working alongside a community organization to tackle the problem of air pollution by promoting and supporting the use of bicycles and access to public transport.

Environmental systems and societies and theory of knowledge

The TOK course (first assessment 2015) engages students in reflection on the nature of knowledge and on how we know what we claim to know. The course identifies eight ways of knowing: language, sense perception, emotion, reason, imagination, faith, intuition and memory. Students explore these means of producing knowledge within the context of various areas of knowledge: mathematics, natural sciences, human sciences, history, the arts, ethics, religious knowledge systems and indigenous knowledge systems. The course also requires students to make comparisons between the different areas of knowledge, reflecting on how knowledge is arrived at in the various disciplines, what the disciplines have in common, and the differences between them.

TOK lessons can support students in their study of ESS, just as the study of ESS can support students in their TOK studies. TOK provides a space for students to engage in stimulating, wider discussions about questions such as what it means for a discipline to be a natural science or a human science, or whether there should be ethical constraints on the pursuit of this knowledge. It also provides an opportunity for students to reflect on the methodologies of ESS as an interdisciplinary subject, and how these compare to the methodologies of other areas of knowledge. It is now widely accepted that researchers utilize not only scientific methods, but a variety of approaches, in order to enhance understanding of the interaction between environmental systems and societies. Scientific disciplines share a common focus on utilizing inductive and deductive reasoning, on the importance of evidence, and so on; but in the ESS course students are also required to use other methods traditionally associated with the human sciences.

In this way there are rich opportunities for students to create links between their ESS and TOK courses. One way in which teachers can help students to make these links to TOK is by drawing students' attention to knowledge questions that arise from their subject content. Knowledge questions are open-ended questions about knowledge, and can include the following.

- How do we distinguish science from pseudoscience?
- How does a systems approach enhance our understanding of environmental issues?
- How does knowledge of environmental systems progress?
- What is the role of imagination and intuition in a systems approach?
- What are the similarities and differences in the methods of gaining knowledge in the natural sciences and in the human sciences?
- How does emotion impact on our perception and understanding of environmental issues?

Examples of relevant knowledge questions are provided within the sub-topics in the "Syllabus content" section of this guide. Teachers can also find suggestions of interesting knowledge questions for discussion in the "Areas of knowledge" chapter of the *Theory of knowledge guide*. Students should be encouraged to raise and discuss such knowledge questions in both their ESS and TOK classes.

Environmental systems and societies and international-mindedness

Although the ESS course requires the study of environmental systems and societies at a range of scales, from local to global, the teaching of the course should be firmly grounded in the local environment. The syllabus contains many references to "local examples", and fieldwork may be based on local ecosystems.

On a broader scale, the course also leads students to an appreciation of the nature of the international dimension of ESS, since the resolution of the major environmental issues rests heavily upon international relationships and agreements. On an organizational level, many international bodies exist, such as the United Nations Educational, Scientific and Cultural Organization (UNESCO); the United Nations Environment Programme (UNEP); and the World Meteorological Organization (WMO). In addition, there are many international bodies representing every branch of environmental science. ESS teachers and students are encouraged to access the extensive websites and databases of these international organizations and bodies to enhance their appreciation of the international dimension.

It is widely accepted that many environmental problems are international in nature and this has led to a global approach to research in many areas such as climate change, biodiversity and population dynamics. The data from such research is shared worldwide and much of this is freely available to students.

The power of scientific knowledge to transform societies is unparalleled. It has the potential to produce great universal benefits, or to reinforce inequalities and cause harm to people and the environment. In line with the IB mission statement, ESS students need to be aware of the moral responsibility to ensure that scientific knowledge and data are available to all countries on an equitable basis, and that countries have the capacity to use this for developing sustainable societies.

Students' attention should be drawn to sections of the syllabus with links to international-mindedness. Examples of issues relating to international-mindedness are given within sub-topics in the "Syllabus content" section of the guide. Teachers could also use resources found on the teacher resource exchange.

Engaging with sensitive topics

A cornerstone of the ESS course is the idea of environmental value systems (EVSs). Each individual, or group of individuals, will have his or her own EVS arising from his or her beliefs and circumstances. One's perception of the importance and impact of environmental threats varies according to individual circumstances, cultures and traditions, and is subject to change over time.

Studying this course will lead students to critically examine and develop their own value systems. They should also become acquainted with the diverse range of EVSs of people from different cultures and backgrounds. These too can be critically examined, but this should be done in an atmosphere of tolerance and respect towards others.

Approaches to teaching and learning in environmental systems and societies

Approaches to Teaching and Learning

Approaches to teaching and learning (ATL) across the Diploma Programme refers to deliberate strategies, skills and attitudes that permeate the teaching and learning environments. These approaches and tools, intrinsically linked with the IB learner profile attributes, enhance student learning and assist student preparation for the Diploma Programme assessment and beyond. The aims of approaches to teaching and learning in the Diploma Programme are to:

- empower teachers as "teachers of learners" as well as "teachers of content"
- empower teachers to create clearer strategies for facilitating learning experiences in which students are more meaningfully engaged in structured inquiry and greater critical and creative thinking
- promote both the aims of individual subjects (making them more than course aspirations) and linking previously isolated knowledge (concurrency of learning)
- encourage students to develop an explicit variety of skills that will equip them to continue to be actively engaged in learning after they leave school, and to help them not only to obtain university admission through better grades, but also to prepare for success during tertiary education and beyond
- enhance further the coherence and relevance of the students' Diploma Programme experience
- allow schools to identify the distinctive nature of an IB Diploma Programme education, with its blend of idealism and practicality.

The five categories of ATL skills (thinking skills, communication skills, social skills, self-management skills and research skills) along with the six approaches to teaching principles (teaching based on inquiry, teaching focused on conceptual understanding, teaching developed in local and global contexts, teaching focused on effective teamwork and collaboration, teaching differentiated to meet the needs of all learners, and teaching informed by assessment) encompass the key values that underpin IB pedagogy.

The order in which the ESS syllabus is arranged in the "Syllabus content" section of this guide is **not** the order in which it should be taught, and it is up to teachers to decide on an approach that best incorporates strategies for learning and teaching that suits their individual circumstances. Figure 2 may assist teachers in designing the scheme of work as it illustrates how the ESS course is concept-based and focuses on interactions and impacts.

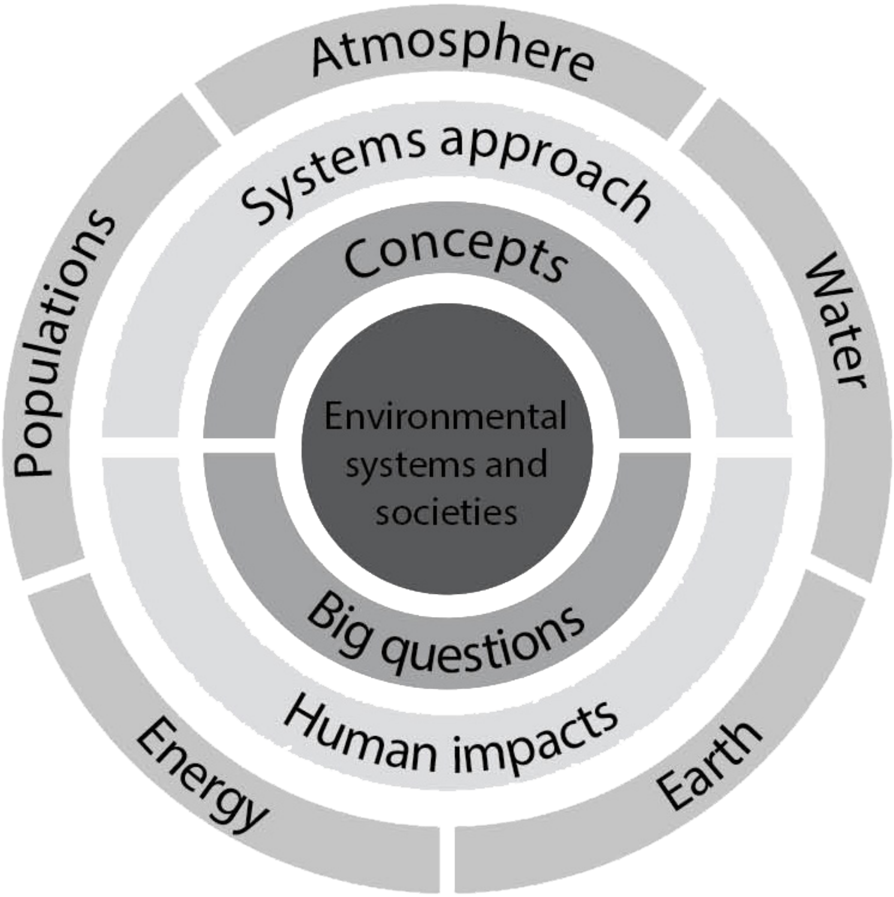

Figure 2

Structure of the ESS course

Concepts and big questions

The central concepts of the ESS course include sustainability, equilibrium, strategy, biodiversity and EVSs. Many of the issues encountered in the course and beyond, such as resource management, pollution, globalization and energy security, are linked to these concepts and so it is important that these issues are emphasized in each context. The big questions, listed at the end of this section, provide a focus for re-examining these concepts in a variety of ways as the course progresses. They can be:

- used to introduce topics
- integrated as the basis for classroom discussions and student assignments
- examined retrospectively to review a topic
- used as a revision exercise at the end of the course.

Systems approach

The systems approach is central to the course and should be employed for a number of reasons.

- It facilitates disciplinary and interdisciplinary learning allowing for connections to be made with other subjects.
- It deepens students' understanding of complex and dynamic ecosystems.
- It allows students to integrate new content into existing knowledge.

The very nature of the environment and how we relate to it demands a holistic treatment. Environmental systems do not function in isolation, but show deep complexity and interaction with other systems to which they connect in a physical and temporal sense. Systems can also be examined at different levels depending on the issue under investigation. For example, an individual lake can be thought of as a system with its own flows and storages, but in a larger context, this lake is one element of a much larger ecosystem that impacts on the environment and communities around it.

The concept of systems has been used in the natural sciences since the 1940s, especially in biology—for example, in the understanding of living organisms in terms of the interactions of the endocrine, nervous and other systems. It is recognized that a reductionist approach of some areas of traditional science inevitably tends to overlook or understate the interactions between such systems, meaning that the "big picture" is missed. A systems approach (which is common to many other disciplines, such as economics, geography, ecology and engineering) emphasizes the ways in which matter, energy and information flow, and integrates the perspectives of different disciplines to better represent the complex nature of the environment. Wherever possible, students should be encouraged to represent the systems they study with models that show the storages and flows, or be given these diagrams to interpret as part of the learning process. Given the nature of the ESS course, stressing the links between syllabus sub-topics in this way is critical and should be considered when planning the delivery of the course. An appreciation of the systems approach can also be transplanted by students from one discipline to another.

In the "Syllabus content" section of this guide, the topics are arranged so that the underlying principles of the systems approach to ESS are addressed in topics 1, 2 and 3. The contexts in which these principles have relevance for the purpose of this course are described in topics 4 to 8. The first three topics are critical in showing the basis of the systems approach to the subject, but it would be advisable to draw on the examples of the later topics from the outset to allow students to develop genuine understanding of this approach.

Holistic evaluation and human impact

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 ESS course requires that students consider the costs and the benefits of human activities, both to the environment and to societies, on a local and global scale and over the short and long terms. In doing so, students will arrive at informed but 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.

Contexts

A genuine appreciation of the overarching concepts and principles of environmental systems is only achievable when the big ideas are set in context. This course therefore requires that students explore the application of these concepts and principles in a wide range of situations. Contexts, founded in atmospheric, terrestrial and aquatic systems, along with the issues of energy and population, have been selected to offer a broad range that may be approached from local to global perspectives. While the guide organizes these contexts into a given framework of sub-topics, teachers are not required to use this structure in their teaching, since these contexts all interact with each other. Depending on each local situation, a different approach to the sub-topics may be more appropriate.

Please refer to the "Structuring a course" section of the *Environmental systems and societies teacher support material* for further ideas of possible teaching models.

Big questions

The following big questions are intended as a guide to shape an overall concept-based approach to the delivery of this subject, and to encourage a holistic perspective on the relationship between human societies and natural systems. They have been designed to engender a vision of the overarching principles that are central to the course, and to encourage students to revisit central ideas in different contexts.

A. Which strengths and weaknesses of the systems approach and of the use of models have been revealed through this topic?

B. To what extent have the solutions emerging from this topic been directed at **preventing** environmental impacts, **limiting** the extent of the environmental impacts or **restoring** systems in which environmental impacts have already occurred?

C. What value systems are at play in the causes and approaches to resolving the issues addressed in this topic?

D. How does your personal value system compare with the others you have encountered in the context of issues raised in this topic?

E. How are the issues addressed in this topic relevant to sustainability or sustainable development?

F. In which ways might the solutions explored in this topic alter your predictions for the state of human societies and the biosphere decades from now?

While these big questions do not in themselves add to the required syllabus content, they identify an approach that will be reflected in more open-ended examination questions. Table 3 shows which big questions have been identified as having particular relevance to each of the topics. This table is not intended to be comprehensive and teachers may find other selections more appropriate.

Big question	Possible relevant topics
A	1, 2, 4, 5, 7, 8
B	3, 4, 5, 6, 7, 8
C	1, 3, 7, 8
D	1, 3, 7, 8
E	1, 2, 3, 4, 5, 6, 7, 8
F	3, 4, 5, 6, 7, 8

Table 3
Big questions

Aims

Environmental systems and societies aims

The systems approach provides the core methodology of the ESS course. It is complemented by other influences, such as economic, historical, cultural, sociopolitical and scientific factors, to provide a holistic perspective on environmental issues. During the course, students will look at examples on a variety of scales, from local to global, and in an international context.

The aims of the ESS course are to enable students to:

1. acquire the knowledge and understandings of environmental systems at a variety of scales
2. apply the knowledge, methodologies and skills to analyse environmental systems and issues at a variety of scales
3. appreciate the dynamic interconnectedness between environmental systems and societies
4. value the combination of personal, local and global perspectives in making informed decisions and taking responsible actions on environmental issues
5. be critically aware that resources are finite, and that these could be inequitably distributed and exploited, and that management of these inequities is the key to sustainability
6. develop awareness of the diversity of environmental value systems
7. develop critical awareness that environmental problems are caused and solved by decisions made by individuals and societies that are based on different areas of knowledge
8. engage with the controversies that surround a variety of environmental issues
9. create innovative solutions to environmental issues by engaging actively in local and global contexts.

Assessment objectives

These objectives reflect how the aims of the ESS course will be assessed. It is the intention of this course that students, in the context of environmental systems and related issues, are able to fulfill the following assessment objectives.

1. Demonstrate knowledge and understanding of relevant:
   - facts and concepts
   - methodologies and techniques
   - values and attitudes.
2. Apply this knowledge and understanding in the analysis of:
   - explanations, concepts and theories
   - data and models
   - case studies in unfamiliar contexts
   - arguments and value systems.
3. Evaluate, justify and synthesize, as appropriate:
   - explanations, theories and models
   - arguments and proposed solutions
   - methods of fieldwork and investigation
   - cultural viewpoints and value systems.
4. Engage with investigations of environmental and societal issues at the local and global level through:
   - evaluating the political, economic and social contexts of issues
   - selecting and applying the appropriate research and practical skills necessary to carry out investigations
   - suggesting collaborative and innovative solutions that demonstrate awareness and respect for the cultural differences and value systems of others.

Assessment objectives in practice

Assessment components	Assessment objectives	How are the assessment objectives addressed?
Paper 1	Objectives 1–3	Case study
Paper 2	Objectives 1–3	Section A: short answer questions Section B: two essays from a choice of four
Internal assessment	Objectives 1–4	Individual investigation assessed using markbands

The objectives will be tested in the examinations through the use of the command terms (given in the "Glossary of command terms" section of the guide).

Syllabus outline

Syllabus component	Recommended teaching hours
Core content	**120**
Topic 1—Foundations of environmental systems and societies	16
Topic 2—Ecosystems and ecology	25
Topic 3—Biodiversity and conservation	13
Topic 4—Water and aquatic food production systems and societies	15
Topic 5—Soil systems and terrestrial food production systems and societies	12
Topic 6—Atmospheric systems and societies	10
Topic 7—Climate change and energy production	13
Topic 8—Human systems and resource use	16
Practical scheme of work	**30**
Practical activities	20
Individual investigation	10
Total teaching hours	**150**

The recommended teaching time is 150 hours to complete SL courses as stated in article 8.2 of the document *General regulations: Diploma Programme*.

Practical work

Practical work is an important aspect of the ESS course, whether in the laboratory, classroom, 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 ESS is an opportunity for students 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 *IB animal experimentation policy* (see the *Environmental systems and societies teacher support material* for full details), 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.

Mathematical requirements

All Diploma Programme ESS students should be able to:

- perform the basic arithmetic functions: addition, subtraction, multiplication and division
- carry out calculations involving means, decimals, fractions, percentages, ratios, approximations and reciprocals
- use standard notation (for example, 3.6×10^6)
- use direct and inverse proportion
- solve simple algebraic equations
- plot graphs (with suitable scales and axes) including two variables that show linear and non-linear relationships
- interpret graphs, including the significance of gradients, changes in gradients, intercepts and areas
- interpret data presented in various forms (for example, bar charts, histograms and pie charts).

Use of information communication technology

The use of information communication technology (ICT) is encouraged throughout all aspects of the course in relation to both the practical programme and day-to-day classroom activities.

Planning the course

The syllabus as provided in this subject guide is not intended to be in teaching order. Instead it provides detail of what must be covered by the end of the course. A school should develop a scheme of work that best works for its students. For example, the scheme of work could be developed to match available resources, to take into account student prior learning and experience, or in conjunction with other local requirements.

However the course is planned, adequate time must be provided for examination revision. Time must also be given for students to reflect on their learning experience and their growth as learners.

Format of the guide

The format of the "Syllabus content" of the guide has been designed to give prominence and focus to teaching and learning in the context of the IB Diploma Programme.

Topics

Topics are numbered—for example, "Topic 6: Atmospheric systems and societies". With each topic, the relevant big questions (see the section "Approaches to teaching and learning in environmental systems and societies") are given.

Sub-topics

Sub-topics are numbered as well—for example, "6.1 Introduction to the atmosphere". Further information and guidance are contained in the *Environmental systems and societies teacher support material*.

Each sub-topic begins with "Significant ideas", which are the overarching principles that define and encapsulate the learning within the sub-topic.

Underneath the "Significant ideas" there are two columns. The first column lists:

- "Knowledge and understanding", which are the main ideas to be addressed
- "Applications and skills", which outline how the knowledge and understandings can be applied and some of the specific skills that should be developed in relation to the sub-topic.

The contents of the "Significant ideas" section and the contents of the left-hand column are all legitimate items for assessment. In addition, some assessment of international-mindedness, from the content of the right-hand column, will take place as in the previous course.

The second column lists:

- "Guidance", which gives information about the limits and constraints and the depth of treatment required for teachers
- "International-mindedness", which, where appropriate, suggests to teachers relevant references to international-mindedness
- "Theory of knowledge", which provides examples of TOK knowledge questions (see the *Theory of knowledge guide*) that can be used to focus students' thoughts on the preparation of the TOK prescribed essay
- "Connections", which identify the links between the sub-topic, other parts of the syllabus and the Diploma Programme in general.

Topic 1: <Title>

<table>
<tr><th colspan="2">1.1 Sub-topic</th></tr>
<tr><td colspan="2">Significant ideas: A description of the overarching principles and concepts of the sub-topic.</td></tr>
<tr><td>Knowledge and understanding:
• Specifics of the content requirements for each sub-topic.
Applications and skills:
• Details of how students can apply the understandings. For example, these applications could involve discussions of viewpoints or an evaluation of issues and impacts.</td><td>Guidance:
• Specifics of, and constraints to, the requirements for the knowledge, understandings, applications and skills.
International-mindedness:
• Ideas that teachers can easily integrate into the delivery of their lessons.
Theory of knowledge:
• Examples of TOK knowledge questions.
Connections:
• Syllabus and cross-curricular links.</td></tr>
</table>

Environmental systems and societies and the IB learner profile

The ESS course contributes to the development of the IB learner profile. By following the course, students will have engaged with the attributes of the IB learner profile. For example, the requirements of the internal assessment provide students with opportunities to develop every aspect of the IB learner profile. For each attribute of the learner profile, a number of references from the course are given below.

Learner profile attribute	Environmental systems and societies
Inquirers	Aims 1, 2, 5 and 6 Practical work and internal assessment
Knowledgeable	Aims 1, 2, 3, 5 and 6 International-mindedness links, practical work and internal assessment
Thinkers	Aims 3, 5, 7 and 8 TOK links, practical work and internal assessment
Communicators	Aims 2, 8 and 9 External assessment, practical work and internal assessment
Principled	Aims 4, 7, 8 and 9 Practical work and internal assessment, ethical behaviour/practice (*Ethical practice in the Diploma Programme* poster, *IB animal experimentation policy*), academic honesty
Open-minded	Aims 3, 4, 6, 7 and 8 International-mindedness links, practical work and internal assessment
Caring	Aims 4, 8 and 9 Practical work and internal assessment, ethical behaviour/practice (*Ethical practice in the Diploma Programme* poster, *IB animal experimentation policy*)
Risk-takers	Aims 4, 8 and 9 Practical work and internal assessment
Balanced	Aims 4, 5, 6 and 7 Practical work and internal assessment
Reflective	Aims 3, 4, 5, 6, and 7 Practical work and internal assessment

Syllabus content

Syllabus component	Teaching hours
Topic 1: Foundations of environmental systems and societies 1.1 Environmental value systems 1.2 Systems and models 1.3 Energy and equilibria 1.4 Sustainability 1.5 Humans and pollution	**16**
Topic 2: Ecosystems and ecology 2.1 Species and populations 2.2 Communities and ecosystems 2.3 Flows of energy and matter 2.4 Biomes, zonation and succession 2.5 Investigating ecosystems	**25**
Topic 3: Biodiversity and conservation 3.1 An introduction to biodiversity 3.2 Origins of biodiversity 3.3 Threats to biodiversity 3.4 Conservation of biodiversity	**13**
Topic 4: Water and aquatic food production systems and societies 4.1 Introduction to water systems 4.2 Access to fresh water 4.3 Aquatic food production systems 4.4 Water pollution	**15**
Topic 5: Soil systems and terrestrial food production systems and societies 5.1 Introduction to soil systems 5.2 Terrestrial food production systems and food choices 5.3 Soil degradation and conservation	**12**

Syllabus component	Teaching hours
Topic 6: Atmospheric systems and societies 6.1 Introduction to the atmosphere 6.2 Stratospheric ozone 6.3 Photochemical smog 6.4 Acid deposition	**10**
Topic 7: Climate change and energy production 7.1 Energy choices and security 7.2 Climate change—causes and impacts 7.3 Climate change—mitigation and adaptation	**13**
Topic 8: Human systems and resource use 8.1 Human population dynamics 8.2 Resource use in society 8.3 Solid domestic waste 8.4 Human population carrying capacity	**16**
Total teaching hours	**120**

Syllabus

Topic 1: Foundations of environmental systems and societies (16 hours)

Big questions: This topic may be particularly appropriate for considering big questions A, C, D and E.

1.1: Environmental value systems	
Significant ideas: • Historical events, among other influences, affect the development of environmental value systems (EVSs) and environmental movements. • There is a wide spectrum of EVSs, each with its own premises and implications.	
Knowledge and understanding:	**Guidance:**
• Significant historical influences on the development of the environmental movement have come from literature, the media, major environmental disasters, international agreements and technological developments. • An EVS is a worldview or paradigm that shapes the way an individual, or group of people, perceives and evaluates environmental issues, influenced by cultural, religious, economic and sociopolitical contexts. • An EVS might be considered as a system in the sense that it may be influenced by education, experience, culture and media (inputs), and involves a set of interrelated premises, values and arguments that can generate consistent decisions and evaluations (outputs). • There is a spectrum of EVSs, from ecocentric through anthropocentric to technocentric value systems.	• A society is an arbitrary group of individuals who share some common characteristics, such as geographical location, cultural background, historical time frame, religious perspective, value system and so on. • A variety of significant historical influences could be covered, but with a minimum of three in-depth examples. Possible examples could include: James Lovelock's development of the Gaia hypothesis; Minamata disaster; Rachel Carson's book *Silent Spring* (1962); Davis Guggenheim's documentary *An Inconvenient Truth* (2006); Chernobyl disaster of 1986; Fukushima Daiihi nuclear disaster of 2011; whaling; Bhopal disaster of 1984; Gulf of Mexico oil spill of 2010; Chipko movement; Rio Earth Summit 2012 (Rio+20); Earth Day; Green Revolution; Copenhagen Accord; recent or local events of student interest. • In the range of historical influences selected, it is beneficial to have both local and global examples.

1.1: Environmental value systems

- An ecocentric viewpoint integrates social, spiritual and environmental dimensions into a holistic ideal. It puts ecology and nature as central to humanity and emphasizes a less materialistic approach to life with greater self-sufficiency of societies. An ecocentric viewpoint prioritizes biorights, emphasizes the importance of education and encourages self-restraint in human behaviour.
- An anthropocentric viewpoint argues that humans must sustainably manage the global system. This might be through the use of taxes, environmental regulation and legislation. Debate would be encouraged to reach a consensual, pragmatic approach to solving environmental problems.
- A technocentric viewpoint argues that technological developments can provide solutions to environmental problems. This is a consequence of a largely optimistic view of the role humans can play in improving the lot of humanity. Scientific research is encouraged in order to form policies and to understand how systems can be controlled, manipulated or changed to solve resource depletion. A pro-growth agenda is deemed necessary for society’s improvement.
- There are extremes at either end of this spectrum (for example, deep ecologists–ecocentric to cornucopian–technocentric), but in practice, EVSs vary greatly depending on cultures and time periods, and they rarely fit simply or perfectly into any classification.
- Different EVSs ascribe different intrinsic value to components of the biosphere.

Applications and skills:

- **Discuss** the view that the environment can have its own intrinsic value.
- **Evaluate** the implications of two contrasting EVSs in the context of given environmental issues.
- **Justify,** using examples and evidence, how historical influences have shaped the development of the modern environmental movement

- EVSs are individual; there is no “wrong” EVS.
- During the ESS course students should be encouraged to develop their own EVS and to be able to justify their decisions on environmental issues based on their EVSs.

International-mindedness:

- Ecosystems may often cross national boundaries and conflict may arise from the clash of different value systems about exploitation of resources (for example, migration of wildlife across borders in southern Africa).
- Differences in cultures and societies may influence the development of environmental value systems.

Theory of knowledge:

- EVSs shape the way we perceive the environment—which other value systems shape the way we view the world?

Connections:

- ESS: Conservation of biodiversity (3.4); soil degradation and conservation (5.3); photochemical smog (6.3), acid deposition (6.4); climate change—causes and impacts (7.2); resource use in society (8.2)
- Diploma Programme: Social and cultural anthropology, geography (HL)

1.2: Systems and models

Significant ideas:

- A systems approach can help in the study of complex environmental issues.
- The use of systems and models simplifies interactions but may provide a more holistic view without reducing issues to single processes.

Knowledge and understanding:

- A systems approach is a way of visualizing a complex set of interactions which may be ecological or societal.
- These interactions produce the emergent properties of the system.
- The concept of a system can be applied at a range of scales.
- A system is comprised of storages and flows.
- The flows provide inputs and outputs of energy and matter.
- The flows are processes that may be either transfers (a change in location) or transformations (a change in the chemical nature, a change in state or a change in energy).
- In system diagrams, storages are usually represented as rectangular boxes and flows as arrows, with the direction of each arrow indicating the direction of each flow. The size of the boxes and the arrows may be representative of the size/magnitude of the storage or flow.
- An open system exchanges both energy and matter across its boundary while a closed system exchanges only energy across its boundary.
- An isolated system is a hypothetical concept in which neither energy nor matter is exchanged across the boundary.
- Ecosystems are open systems; closed systems only exist experimentally, although the global geochemical cycles approximate to closed systems.

Guidance:

- A systems approach should be taken for all the topics covered in the ESS course.
- Biosphere refers to the part of the Earth inhabited by organisms that extends from the upper parts of the atmosphere to deep within the Earth's crust.
- Students should interpret given system diagrams and use data to produce their own for a variety of examples, such as carbon cycling, food production and soil systems.
- Students are **not** expected to know any particular system diagram symbols such as those of Odum or Sankey.

International-mindedness:

- The use of models facilitates international collaboration in science by removing language barriers that may exist.

Theory of knowledge:

- Models are simplified constructions of reality—in the construction of a model, how can we know which aspects of the world to include and which to ignore?

<table>
<tr><th colspan="2">1.2: Systems and models</th></tr>
<tr><td>

- A model is a simplified version of reality and can be used to understand how a system works and to predict how it will respond to change.
- A model inevitably involves some approximation and therefore loss of accuracy.

Applications and skills:

- **Construct** a system diagram or a model from a given set of information.
- **Evaluate** the use of models as a tool in a given situation, for example, climate change predictions.

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Connections:

- ESS: Introduction to water systems (4.1); introduction to soil systems (5.1); terrestrial food production systems and food choices (5.2); introduction to the atmosphere (6.1)
- Diploma Programme: Design technology (topic 3), geography (option G), biology (topic 4)

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</table>

1.3: Energy and equilibria

Significant ideas:

- The laws of thermodynamics govern the flow of energy in a system and the ability to do work.
- Systems can exist in alternative stable states or as equilibria between which there are tipping points.
- Destabilizing positive feedback mechanisms will drive systems towards these tipping points, whereas stabilizing negative feedback mechanisms will resist such changes.

Knowledge and understanding:	Guidance:
• The first law of thermodynamics is the principle of conservation of energy, which states that energy in an isolated system can be transformed but cannot be created or destroyed. • The principle of conservation of energy can be modelled by the energy transformations along food chains and energy production systems. • The second law of thermodynamics states that the entropy of a system increases over time. Entropy is a measure of the amount of disorder in a system. An increase in entropy arising from energy transformations reduces the energy available to do work.	• The use of examples in this sub-topic is particularly important so that the abstract concepts have a context in which to be understood. • Emphasis should be placed on the relationships between resilience, stability, equilibria and diversity. • A stable equilibrium is the condition of a system in which there is a tendency for it to return to the previous equilibrium following disturbance. • A steady-state equilibrium is 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.

1.3: Energy and equilibria

- The second law of thermodynamics explains the inefficiency and decrease in available energy along a food chain and energy generation systems.
- As an open system, an ecosystem will normally exist in a stable equilibrium, either in a steady-state equilibrium or in one developing over time (for example, succession), and maintained by stabilizing negative feedback loops.
- Negative feedback loops (stabilizing) occur when the output of a process inhibits or reverses the operation of the same process in such a way as to reduce change—it counteracts deviation.
- Positive feedback loops (destabilizing) will tend to amplify changes and drive the system towards a tipping point where a new equilibrium is adopted.
- The resilience of a system, ecological or social, refers to its tendency to avoid such tipping points and maintain stability.
- Diversity and the size of storages within systems can contribute to their resilience and affect their speed of response to change (time lags).
- Humans can affect the resilience of systems through reducing these storages and diversity.
- The delays involved in feedback loops make it difficult to predict tipping points and add to the complexity of modelling systems.

Applications and skills:

- **Explain** the implications of the laws of thermodynamics to ecological systems.
- **Discuss** resilience in a variety of systems.
- **Evaluate** the possible consequences of tipping points.

- A tipping point is the minimum amount of change within a system that will destabilize it, causing it to reach a new equilibrium or stable state.
- Examples of human impacts and possible tipping points should be explored.

International-mindedness:

- The use of energy in one part of the globe may lead to a tipping point or time lag that influences the entire planet's ecological equilibrium.

Theory of knowledge:

- The laws of thermodynamics are examples of scientific laws—in which ways do scientific laws differ from the laws of human science subjects, such as economics?

Connections:

- ESS: Systems and models (1.2); communities and ecosystems (2.2); terrestrial food production systems and food choices (5.2); energy choices and security (7.1)
- DP: Physics (topic 2 and option B); chemistry (topics 5, 7 and 15; option C); biology (topic 6); design technology (topic 2)

1.4: Sustainability

Significant ideas:

- All systems can be viewed through the lens of sustainability.
- Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.
- Environmental indicators and ecological footprints can be used to assess sustainability.
- Environmental impact assessments (EIAs) play an important role in sustainable development.

Knowledge and understanding:

- Sustainability is the use and management of resources that allows full natural replacement of the resources exploited and full recovery of the ecosystems affected by their extraction and use.
- Natural capital is a term used for natural resources that can produce a sustainable natural income of goods or services.
- Natural income is the yield obtained from natural resources.
- Ecosystems may provide life-supporting services such as water replenishment, flood and erosion protection, and goods such as timber, fisheries, and agricultural crops.
- Factors such as biodiversity, pollution, population or climate may be used quantitatively as environmental indicators of sustainability. These factors can be applied on a range of scales, from local to global. The Millennium Ecosystem Assessment (MA) gave a scientific appraisal of the condition and trends in the world's ecosystems and the services they provide using environmental indicators, as well as the scientific basis for action to conserve and use them sustainably.
- EIAs incorporate baseline studies before a development project is undertaken. They assess the environmental, social and economic impacts of the project, predicting and evaluating possible impacts and suggesting mitigation strategies for the project. They are usually followed by an audit and continued monitoring. Each country or region has different guidance on the use of EIAs.

Guidance:

- A sustainability lens should be used throughout the course, where appropriate.
- EFs can be used to give students a sense of their own impact at the start of the course and are addressed in more detail in topic 8.
- There is no expectation to explore an EIA in depth, but rather to focus on the principles of their use.

International-mindedness:

- International summits and conferences aim to produce international tools (bodies, treaties, agreements) that address environmental issues.
- EIAs vary across national borders.

Theory of knowledge:

- EIAs incorporate baseline studies before a development project is undertaken—to what extent should environmental concerns limit our pursuit of knowledge?

Connections:

- ESS: Human systems and resource use (topic 8)
- Diploma Programme: Social and cultural anthropology; design technology (topics 2 and 8); geography (topic 3, options C and G); economics

<table>
<tr><th colspan="2">1.4: Sustainability</th></tr>
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- EIAs provide decision-makers with information in order to consider the environmental impact of a project. There is not necessarily a requirement to implement an EIA’s proposals, and many socio-economic factors may influence the decisions made.
- Criticisms of EIAs include: the lack of a standard practice or training for practitioners, the lack of a clear definition of system boundaries and the lack of inclusion of indirect impacts.
- An ecological footprint (EF) is the area of land and water required to sustainably provide all resources at the rate at which they are being consumed by a given population. If the EF is greater than the area available to the population, this is an indication of unsustainability.

Applications and skills:

- **Explain** the relationship between natural capital, natural income and sustainability.
- **Discuss** the value of ecosystem services to a society.
- **Discuss** how environmental indicators such as MA can be used to evaluate the progress of a project to increase sustainability.
- **Evaluate** the use of EIAs**.**
- **Explain** the relationship between EFs and sustainability.

</td><td></td></tr>
</table>

1.5: Humans and pollution

Significant ideas:

- Pollution is a highly diverse phenomenon of human disturbance in ecosystems.
- Pollution management strategies can be applied at different levels.

Knowledge and understanding:

- Pollution is the addition of a substance or an agent to an environment through 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 in the environment.
- Pollutants may be in the form of organic or inorganic substances, light, sound or thermal energy, biological agents or invasive species, and may derive from a wide range of human activities including the combustion of fossil fuels.
- Pollution may be non-point or point source, persistent or biodegradable, acute or chronic.
- Pollutants may be primary (active on emission) or secondary (arising from primary pollutants undergoing physical or chemical change).
- Dichlorodiphenyltrichloroethane (DDT) exemplifies a conflict between the utility of a "pollutant" and its effect on the environment.

Applications and skills:

- **Construct** systems diagrams to show the impact of pollutants.
- **Evaluate** the effectiveness of each of the three different levels of intervention, with reference to figure 3.
- **Evaluate** the uses of DDT.

Guidance:

- The terms "pollutant" and "contaminant" in environmental chemistry are considered more or less synonymous.
- Pollution that arises from numerous widely dispersed origins is described as non-point source. Point source pollution arises from a single clearly identifiable site.
- "Biodegradable" means capable of being broken down by natural biological processes
- The principles of this sub-topic, particularly figure 3, should be used throughout the course when addressing issues of pollution.
- Students should be aware that for some pollutants there may be a time lag before an appreciable effect on organisms is evident.
- With reference to figure 3, students should appreciate the advantages of employing the earlier strategies of pollution management over the later ones, and the importance of collaboration.
- Students might demonstrate knowledge of both the anti-malarial and agricultural use of DDT.

International-mindedness:

- Pollution cannot be contained by national boundaries and therefore can act either locally, regionally or globally.

1.5: Humans and pollution	
	Theory of knowledge: • Experts sometimes disagree about pollution management strategies—on what basis might we decide between the judgments of the experts if they disagree? **Connections:** • ESS: Stratospheric ozone (6.2); photochemical smog (6.3); water pollution (4.4); terrestrial food production systems and food choices (5.2); human population carrying capacity (8.4); biodiversity and conservation (topic 3) • Diploma Programme: Social and cultural anthropology; chemistry (options A, B, C and D); design technology (topic 2), geography (option G); economics

Process of pollution	Level of pollution management
Human activity producing pollutant ↓	**Altering human activity** The most fundamental level of pollution management is to change the human activity that leads to the production of the pollutant in the first place, by promoting alternative technologies, lifestyles and values through: • campaigns • education • community groups • governmental legislation • economic incentives/disincentives.
Release pollutant into environment ↓	**Controlling release of pollutant** Where the activity/production is not completely stopped, strategies can be applied at the level of regulating or preventing the release of pollutants by: • legislating and regulating standards of emission • developing/applying technologies for extracting pollutant from emissions.
Impact of pollutant on ecosystems	**Clean-up and restoration of damaged systems** Where both the above levels of management have failed, strategies may be introduced to recover damaged ecosystems by: • extracting and removing pollutant from ecosystem • replanting/restocking lost or depleted populations and communities.

Figure 3

Pollution management targeted at three different levels

Syllabus

Topic 2: Ecosystems and ecology (25 hours)

Big questions: This topic may be particularly appropriate for considering big questions A and E.

2.1: Species and populations

Significant ideas:

- A species interacts with its abiotic and biotic environments, and its niche is described by these interactions.
- Populations change and respond to interactions with the environment.
- Any system has a carrying capacity for a given species.

Knowledge and understanding:	Guidance:
• A species is a group of organisms that share common characteristics and that interbreed to produce fertile offspring. • A habitat is the environment in which a species normally lives. • A niche describes the particular set of abiotic and biotic conditions and resources to which an organism or population responds. • The fundamental niche describes the full range of conditions and resources in which a species could survive and reproduce. The realized niche describes the actual conditions and resources in which a species exists due to biotic interactions. • The non-living, physical factors that influence the organisms and ecosystem—such as temperature, sunlight, pH, salinity, and precipitation—are termed abiotic factors. • The interactions between the organisms—such as predation, herbivory, parasitism, mutualism, disease, and competition—are termed biotic factors.	• Students should address this topic in the context of valid named species, for example, use "Atlantic salmon" rather than "fish", "Kentucky bluegrass" rather than "grass" and "silver birch" rather than "tree". • It is useful to be aware that for some organisms, habitats can change over time as a result of migration. • This sub-topic provides lots of opportunities for use of simulations and data analysis. **International-mindedness:** • The change in one community can impact on other communities (butterfly effect). **Theory of knowledge:** • Through the use of specialized vocabulary, is the shaping of knowledge more dramatic in some areas of knowledge compared to others?

2.1: Species and populations	
• 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. • A population is a group of organisms of the same species living in the same area at the same time, and which are capable of interbreeding. • S and J population curves describe a generalized response of populations to a particular set of conditions (abiotic and biotic factors). • Limiting factors will slow population growth as it approaches the carrying capacity of the system. **Applications and skills:** • **Interpret** graphical representations or models of factors that affect an organism's niche. Examples include predator–prey relationships, competition, and organism abundance over time. • **Explain** population growth curves in terms of numbers and rates.	**Connections:** • ESS: Human population carrying capacity (8.4) • Diploma Programme: Social and cultural anthropology; biology (topic 4)

2.2: Communities and ecosystems

Significant ideas:

- The interactions of species with their environment result in energy and nutrient flows.
- Photosynthesis and respiration play a significant role in the flow of energy in communities.
- The feeding relationships of species in a system can be modelled using food chains, food webs and ecological pyramids.

Knowledge and understanding:	Guidance:
• A community is a group of populations living and interacting with each other in a common habitat. • An ecosystem is a community and the physical environment with which it interacts.	• 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.

2.2: Communities and ecosystems

- Respiration and photosynthesis can be described as processes with inputs, outputs and transformations of energy and matter.
- Respiration is the conversion of organic matter into carbon dioxide and water in all living organisms, releasing energy. Aerobic respiration can be represented by the following word equation.

  glucose + oxygen → carbon dioxide + water

- During respiration, large amounts of energy are dissipated as heat, increasing the entropy in the ecosystem while enabling organisms to maintain relatively low entropy and so high organization.
- Primary producers in most ecosystems convert light energy into chemical energy in the process of photosynthesis.
- The photosynthesis reaction is can be represented by the following word equation.

  carbon dioxide + water →glucose + oxygen

- Photosynthesis produces the raw material for producing biomass.
- The trophic level is the position that an organism occupies in a food chain, or the position of a group of organisms in a community that occupy the same position in food chains.
- Producers (autotrophs) are typically plants or algae that produce their own food using photosynthesis and form the first trophic level in a food chain. Exceptions include chemosynthetic organisms that produce food without sunlight.
- Feeding relationships involve producers, consumers and decomposers. These can be modelled using food chains, food webs and ecological pyramids.
- Ecological pyramids include pyramids of numbers, biomass and productivity and are quantitative models that are usually measured for a given area and time.

- Details of chloroplasts, light-dependent and light-independent reactions, mitochondria, carrier systems, adenosine triphosphate (ATP) and specific intermediate biochemicals are not expected.
- This topic should be actively linked with sub-topic 1.3, as questions will arise requiring students to use their knowledge of thermodynamics with energy flow in ecosystems.
- Biomass, measured in units of mass (for example, $g\ m^{-2}$), should be distinguished from productivity, measured in units of flow (for example, $g\ m^{-2}\ yr^{-1}$ or $J\ m^{-2}\ yr^{-1}$).
- Although there is variation in the literature, for this syllabus "pyramids of biomass" refers to a standing crop (a fixed point in time) and "pyramids of productivity" refer to the rate of flow of biomass or energy.

Pyramid	Units
Biomass (standing crop)	$g\ m^{-2}$
Productivity (flow of biomass/energy)	$g\ m^{-2}yr^{-1}$ $J\ m^{-2}yr^{-1}$

International-mindedness:

- Ecosystems such as lakes and forests can exist across political boundaries.

Theory of knowledge:

- Feeding relationships can be represented by different models—how can we decide when one model is better than another?

<table>
<tr><th colspan="2">2.2: Communities and ecosystems</th></tr>
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- 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 towards the apex.
- Bioaccumulation is the build-up of persistent or non-biodegradable pollutants within an organism or trophic level because they cannot be broken down.
- Biomagnification is the increase in concentration of persistent or non-biodegradable pollutants along a food chain.
- Toxins such as DDT and mercury accumulate along food chains due to the decrease of biomass and energy.
- Pyramids of numbers can sometimes display different patterns; for example, when individuals at lower trophic levels are relatively large (inverted pyramids).
- A pyramid of biomass represents the standing stock or storage of each trophic level, measured in units such as grams of biomass per square metre ($g\ m^{-2}$) or Joules per square metre ($J\ m^{-2}$) (units of biomass or energy).
- Pyramids of biomass can show greater quantities at higher trophic levels because they represent the biomass present at a fixed point in time, although seasonal variations may be marked.
- Pyramids of productivity refer to the flow of energy through a trophic level, indicating the rate at which that stock/storage is being generated.
- Pyramids of productivity for entire ecosystems over a year always show a decrease along the food chain.

Applications and skills:

- **Construct** models of feeding relationships—such as food chains, food webs and ecological pyramids—from given data.
- **Explain** the transfer and transformation of energy as it flows through an ecosystem.

</td><td>

Connections:

- ESS: Energy and equilibria (1.3); sustainability (1.4); climate change—causes and impacts (7.2); water pollutiion (4.4); terrestrial food production systems and food choices (5.2); biodiversity and conservation (topic 3)
- Diploma Programme: Biology (topics 4 and 9; option C)

</td></tr>
</table>

2.2: Communities and ecosystems	
• **Analyse** the efficiency of energy transfers through a system. • **Construct** system diagrams representing photosynthesis and respiration. • **Explain** the relevance of the laws of thermodynamics to the flow of energy through ecosystems. • **Explain** the impact of a persistent or non-biodegradable pollutant in an ecosystem.	

2.3: Flows of energy and matter

Significant ideas:

- Ecosystems are linked together by energy and matter flows.
- The Sun's energy drives these flows, and humans are impacting the flows of energy and matter both locally and globally.

Knowledge and understanding:	Guidance:
• As solar radiation (insolation) enters the Earth's atmosphere, some energy becomes unavailable for ecosystems as this energy is absorbed by inorganic matter or reflected back into the atmosphere. • Pathways of radiation through the atmosphere involve a loss of radiation through reflection and absorption as shown in figure 4.	• Students should have the opportunity to measure productivity and biomass experimentally. • Students could design experiments to compare productivity in different systems. • 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, $J\ m^{-2}\ yr^{-1}$.

2.3: Flows of energy and matter

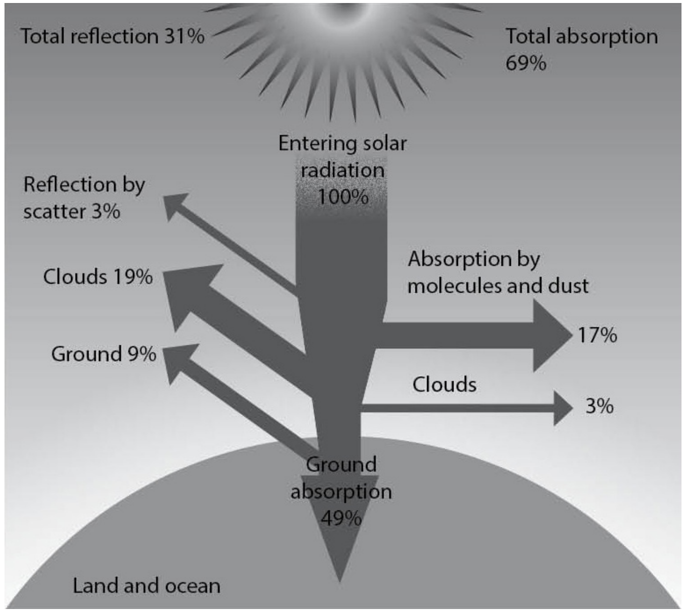

Figure 4

Pathways of radiation

- Pathways of energy through an ecosystem include:
  - conversion of light energy to chemical energy
  - transfer of chemical energy from one trophic level to another with varying efficiencies
  - overall conversion of ultraviolet and visible light to heat energy by an ecosystem
  - re-radiation of heat energy to the atmosphere.
- The conversion of energy into biomass for a given period of time is measured as productivity.

- Students should understand the link between sustainable yields and productivity.
- Values for GPP and NPP should be compared from various biomes.
- The term "assimilation" is sometimes used instead of "secondary productivity".
- The roles of calcification, sedimentation, lithification, weathering and volcanoes in the carbon cycle are **not** required.
- Detailed knowledge of the role of bacteria in nitrogen fixation, nitrification and ammonificaction is **not** required.

International-mindedness:

- Human impacts on the flows of energy and matter occur on a global scale**.**

Theory of knowledge:

- The Sun's energy drives energy flows, and throughout history there have been "myths" about the importance of the Sun—what role can mythology and anecdotes play in the passing on of scientific knowledge?

Connections:

- ESS: Introduction to the atmosphere (6.1); introduction to water systems (4.1); introduction to soil systems (5.1); human population carrying capacity (8.4)
- Diploma Programme: Biology (topics 4 and 9; option C); chemistry (option C); geography (topic 3); physics (sub-topic 2.8)

2.3: Flows of energy and matter	
• Net primary productivity (NPP) is calculated by subtracting respiratory losses (R) from gross primary productivity (GPP). NPP = GPP – R • Gross secondary productivity (GSP) is the total energy or biomass assimilated by consumers and is calculated by subtracting the mass of fecal loss from the mass of food consumed. GSP = food eaten – fecal loss • Net secondary productivity (NSP) is calculated by subtracting respiratory losses (R) from GSP. NSP = GSP – R • Maximum sustainable yields are equivalent to the net primary or net secondary productivity of a system. • Matter also flows through ecosystems linking them together. This flow of matter involves transfers and transformations. • The carbon and nitrogen cycles are used to illustrate this flow of matter using flow diagrams. These cycles contain storages (sometimes referred to as sinks) and flows, which move matter between storages. • Storages in the carbon cycle include organisms and forests (both organic), or the atmosphere, soil, fossil fuels and oceans (all inorganic). • Flows in the carbon cycle include consumption (feeding), death and decomposition, photosynthesis, respiration, dissolving and fossilization. • Storages in the nitrogen cycle include organisms (organic), soil, fossil fuels, atmosphere and water bodies (all inorganic). • Flows in the nitrogen cycle include nitrogen fixation by bacteria and lightning, absorption, assimilation, consumption (feeding), excretion, death and decomposition, and denitrification by bacteria in water-logged soils.	

2.3: Flows of energy and matter	
• Human activities such as burning fossil fuels, deforestation, urbanization and agriculture impact energy flows as well as the carbon and nitrogen cycles. **Applications and skills:** • **Analyse** quantitative models of flows of energy and matter. • **Construct** a quantitative model of the flows of energy or matter for given data. • **Analyse** the efficiency of energy transfers through a system. • **Calculate** the values of both GPP and NPP from given data. • **Calculate** the values of both GSP and NSP from given data. • **Discuss** human impacts on energy flows, and on the carbon and nitrogen cycles.	

<table>
<tr><th colspan="2">2.4: Biomes, zonation and succession</th></tr>
<tr><td colspan="2">Significant ideas:
• Climate determines the type of biome in a given area, although individual ecosystems may vary due to many local abiotic and biotic factors.
• Succession leads to climax communities that may vary due to random events and interactions over time. This leads to a pattern of alternative stable states for a given ecosystem.
• Ecosystem stability, succession and biodiversity are intrinsically linked.</td></tr>
<tr><td>Knowledge and understanding:
• Biomes are collections of ecosystems sharing similar climatic conditions that can be grouped into five major classes: aquatic, forest, grassland, desert and tundra. Each of these classes has characteristic limiting factors, productivity and biodiversity.
• Insolation, precipitation and temperature are the main factors governing the distribution of biomes.</td><td>Guidance:
• Students should be encouraged to study at least four contrasting pairs of biomes of interest to them, such as temperate forests and tropical seasonal forests; or tundras and deserts; or tropical coral reefs and hydrothermal vents; or temperate bogs and tropical mangrove forests.</td></tr>
</table>

2.4: Biomes, zonation and succession

- The tricellular model of atmospheric circulation explains the distribution of precipitation and temperature and how they influence structure and relative productivity of different terrestrial biomes.
- Climate change is altering the distribution of biomes and causing biome shifts.
- Zonation refers to changes in community along an environmental gradient due to factors such as changes in altitude, latitude, tidal level or distance from shore (coverage by water).
- Succession is the process of change over time in an ecosystem involving pioneer, intermediate and climax communities.
- During succession, the patterns of energy flow, gross and net productivity, diversity, and mineral cycling change over time.
- Greater habitat diversity leads to greater species and genetic diversity.
- *r*- and *K*-strategist species have reproductive strategies that are better adapted to pioneer and climax communities, respectively.
- In early stages of succession, gross productivity is low due to the unfavourable 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.
- In later stages of succession, with an increased consumer community, gross productivity may be high in a climax community. However, this is balanced by respiration, so net productivity approaches 0 and the productivity–respiration (P:R) ratio approaches 1.
- In a complex ecosystem, the variety of nutrient and energy pathways contributes to its stability.

- Examples of zonation may be studied as part of sub-topic 2.5.
- It is important to distinguish zonation (a spatial phenomenon) from succession (a temporal phenomenon).
- Named examples of organisms from the pioneer, intermediate and climax communities should be provided.
- Ecosystems demonstrating zonation or undergoing succession are appropriate for ecological fieldwork.
- *r*-strategist species are those that produce large numbers of offspring so they can colonize new habitats quickly and make use of short-lived resources, whereas *K*-strategist species tend to produce a small number of offspring, which increases their survival rate and enables them to survive in long-term climax communities.

International-mindedness:

- Zonation occurs on different scales that can be both local and global.

Theory of knowledge:

- Ecosystems are studied by measuring biotic and abiotic factors—how can you know in advance which of these factors are significant to the study?

Connections:

- ESS: Energy and equilibria (1.3): investigating ecosystems (2.5); climate change—causes and impacts (7.2); terrestrial food production systems and food choices (5.2); soil degradation and conservation (5.3)
- Diploma Programme: Geography (topic 3); biology (topic 4)

2.4: Biomes, zonation and succession	
• There is no one climax community, but rather a set of alternative stable states for a given ecosystem. These depend on the climatic factors, the properties of the local soil and a range of random events that can occur over time. • Human activity is one factor that can divert the progression of succession to an alternative stable state by modifying the ecosystem; for example, the use of fire in an ecosystem, the use of agriculture, grazing pressure, or resource use (such as deforestation). This diversion may be more or less permanent depending upon the resilience of the ecosystem. • An ecosystem's capacity to survive change may depend on its diversity and resilience. **Applications and skills:** • **Explain** the distributions, structure, biodiversity and relative productivity of contrasting biomes. • **Analyse** data for a range of biomes. • **Discuss** the impact of climate change on biomes. • **Describe** the process of succession in a given example. • **Explain** the general patterns of change in communities undergoing succession. • **Discuss** the factors that could lead to alternative stable states in an ecosystem. • **Discuss** the link between ecosystem stability, succession, diversity and human activity. • **Distinguish** the roles of *r* and *K* selected species in succession. • **Interpret** models or graphs related to succession and zonation.	

2.5: Investigating ecosystems

Significant ideas:

- The description and investigation of ecosystems allows for comparisons to be made between different ecosystems and for them to be monitored, modelled and evaluated over time, measuring both natural change and human impacts.
- Ecosystems can be better understood through the investigation and quantification of their components.

Knowledge and understanding:

- The study of an ecosystem requires that it be named and located; for example, Deinikerwald in Baar, Switzerland—a mixed deciduous–coniferous managed woodland.
- Organisms in an ecosystem can be identified using a variety of tools including keys, comparison to herbarium or specimen collections, technologies and scientific expertise.
- Sampling strategies may be used to measure biotic and abiotic factors and their change in space, along an environmental gradient, over time, through succession, or before and after a human impact (for example, as part of an EIA).
- Measurements should be repeated to increase reliability of data. The number of repetitions required depends on the factor being measured.
- Methods for estimating the biomass and energy of trophic levels in a community include measurement of dry mass, controlled combustion and extrapolation from samples. Data from these methods can be used to construct ecological pyramids.
- Methods for estimating the abundance of non-motile organisms include the use of quadrats for making actual counts, measuring population density, percentage cover and percentage frequency.
- Direct and indirect methods for estimating the abundance of motile organisms can be described and evaluated. Direct methods include actual counts and sampling. Indirect methods include the use of capture–mark–recapture with the application of the Lincoln index.

$$\text{Lincoln index} = \frac{n_1 \times n_2}{n_m}$$

Guidance:

- When constructing identification keys, students should be reminded that generic terms such as "big" or "small" are not useful. Comparative, quantitative descriptors and simple identification of the presence or absence of external features are most useful in keys.
- The design of sampling strategies needs to be appropriate for its purpose and provide a valid representation of the system being investigated. Suitable sampling techniques include random or systematic in a uniform environment, or transects over an environmental gradient.
- Students should be familiar with the measurement of at least three abiotic factors. These could come from different ecosystems, such as:
  - marine—salinity, pH, temperature, dissolved oxygen, wave action
  - freshwater—turbidity, flow velocity, pH, temperature, dissolved oxygen
  - terrestrial—temperature, light intensity, wind speed, particle size, slope, soil moisture, drainage, mineral content.

2.5: Investigating ecosystems

- n_1 is the number caught in the first sample.
- n_2 is the number caught in the second sample.
- n_m is the number caught in the second sample that were marked.

- Species richness is the number of species in a community and is a useful comparative measure.
- Species diversity is a function of the number of species and their relative abundance and can be compared using an index. There are many versions of diversity indices, but students are only expected to be able to apply and evaluate the result of the Simpson diversity index as shown below. Using this formula, the higher the result (D), the greater the species diversity. This indication of diversity is only useful when comparing two similar habitats, or the same habitat over time.

$$D = \frac{N(N-1)}{\sum^{n}(n-1)}$$

- D is the Simpson diversity index.
- N is the total number of organisms of all species found.
- n is the number of individuals of a particular species.

Applications and skills:

- **Design** and carry out ecological investigations.
- **Construct** simple identification keys for up to eight species.
- **Evaluate** sampling strategies.

- Suitable human impacts might include toxins from mining activity, landfills, eutrophication, effluent, oil spills, overexploitation and change of land use (for example, deforestation, development or use for tourism activities).
- Interesting studies can be made using historic maps or geographic information system (GIS) data to track land use change.
- Formulae do not need to be memorized but should be applied to given data.
- Percentage cover is an estimate of the area in a given frame size (quadrat) covered by the plant in question. Percentage frequency is the number of occurrences divided by the number of possible occurrences; for example, if a plant occurs in 5 out of 100 squares in a grid quadrat, then the percentage frequency is 5%.
- Similar habitats can be compared using D; a lower value in one habitat may indicate human impact. Low values of D in the Arctic tundra, however, may represent stable and ancient sites.
- All ecosystem investigations should follow the guidelines in the *IB animal experimentation policy*.

International-mindedness:

- The use of internationally standardized methods of ecological study are necessary when making comparisons across international boundaries.

Theory of knowledge:

- When is quantitative data superior to qualitative data in giving us knowledge about the world?
- Controlled laboratory experiments are often seen as the hallmark of the scientific method, but are not possible in fieldwork—to what extent is the knowledge obtained by observational natural experiment less scientific than the manipulated laboratory experiment?

2.5: Investigating ecosystems	
• **Evaluate** methods to measure at least three abiotic factors in an ecosystem. • **Evaluate** methods to investigate the change along an environmental gradient and the effect of a human impact in an ecosystem. • **Evaluate** methods for estimating biomass at different trophic levels in an ecosystem. • **Evaluate** methods for measuring or estimating populations of motile and non-motile organisms. • **Calculate** and interpret data for species richness and diversity. • **Draw** graphs to illustrate species diversity in a community over time, or between communities.	**Connections:** • ESS: Sustainability (1.4); biodiversity and conservation (topic 3) • Diploma Programme: Biology (topic 4): chemistry (topic 11)

Topic 3: Biodiversity and conservation (13 hours)

Big questions: This topic may be particularly appropriate for considering big questions B, C, D, E and F.

3.1: An introduction to biodiversity

Significant ideas:

- Biodiversity can be identified in a variety of forms, including species diversity, habitat diversity and genetic diversity.
- The ability to both understand and quantify biodiversity is important to conservation efforts.

Knowledge and understanding:	Guidance:
• Biodiversity is a broad concept encompassing the total diversity of living systems, which includes the diversity of species, habitat diversity and genetic diversity. • Species diversity in communities is a product of two variables: the number of species (richness) and their relative proportions (evenness). • Communities can be described and compared through the use of diversity indices. When comparing communities that are similar, low diversity could be indicative of pollution, eutrophication or recent colonization of a site. The number of species present in an area is often indicative of general patterns of biodiversity. • Habitat diversity refers to the range of different habitats in an ecosystem or biome. • Genetic diversity refers to the range of genetic material present in a population of a species.	• Interpreting diversity is complex; low diversity can be present in natural, ancient and unpolluted sites (for example, in Arctic ecosystems). • Species diversity within a community is a component of the broader description of the biodiversity of an entire ecosystem. **International-mindedness:** • International scientific collaboration is important in the conservation of biodiverse regions. **Theory of knowledge:** • The term "biodiversity" has replaced the term "nature" in much literature on conservation issues—does this represent a paradigm shift? • Diversity index is not a measure in the true sense of a word, but merely a number (index), as it involves a subjective judgment on the combination of two measures: proportion and richness. Are there examples in other areas of knowledge of the subjective use of numbers?

3.1: An introduction to biodiversity	
• Quantification of biodiversity is important to conservation efforts so that areas of high biodiversity may be identified, explored, and appropriate conservation put in place where possible. • The ability to assess changes to biodiversity in a given community over time is important in assessing the impact of human activity in the community. **Applications and skills:** • **Distinguish** between biodiversity, diversity of species, habitat diversity and genetic diversity. • **Comment** on the relative values of biodiversity data. • **Discuss** the usefulness of providing numerical values of species diversity to understanding the nature of biological communities and the conservation of biodiversity.	**Connections:** • ESS: Foundations of ESS (topic 1); investigating ecosystems (2.5); water pollution (4.4); acid deposition (6.4); climate change—causes and impacts (7.2) • Diploma Programme: Biology (topics 5 and 10)

<table>
<tr><th colspan="2">3.2: Origins of biodiversity</th></tr>
<tr><td colspan="2">Significant ideas:
• Evolution is a gradual change in the genetic character of populations over many generations, achieved largely through the mechanism of natural selection.
• Environmental change gives new challenges to species, which drives the evolution of diversity.
• There have been major mass extinction events in the geological past.</td></tr>
<tr><td>Knowledge and understanding:
• Biodiversity arises from evolutionary processes.
• Biological variation arises randomly and can either be beneficial to, damaging to, or have no impact on, the survival of the individual.
• Natural selection occurs through the following mechanism.
1. Within a population of one species, there is genetic diversity, which is called variation.</td><td>Guidance:
• Natural selection is an evolutionary driving force, sometimes called “survival of the fittest”. In this context, the meaning of “fittest” is understood to be “best-suited to the niche”.</td></tr>
</table>

3.2: Origins of biodiversity

2. Due to natural variation, some individuals will be fitter than others.
3. Fitter individuals have an advantage and will reproduce more successfully than individuals who are less fit.
4. The offspring of fitter individuals may inherit the genes that give that advantage.

- This natural selection will contribute to the evolution of biodiversity over time.
- Environmental change gives new challenges to species: those that are suited will survive, and those that are not suited will not survive.
- Speciation is the formation of new species when populations of a species become isolated and evolve differently from other populations.
- Isolation of populations can be caused by environmental changes forming barriers such as mountain formation, changes in rivers, sea level change, climatic change or plate movements. The surface of the Earth is divided into crustal, tectonic plates that have moved throughout geological time. This has led to the creation of both land bridges and physical barriers with evolutionary consequences.
- The distribution of continents has also caused climatic variations and variation in food supply, both contributing to evolution.
- Mass extinctions of the past have been caused by various factors, such as tectonic plate movements, super-volcanic eruption, climatic changes (including drought and ice ages), and meteorite impact—all of which resulted in new directions in evolution and therefore increased biodiversity.

Applications and skills:

- **Explain** how plate activity has influenced evolution and biodiversity.
- **Discuss** the causes of mass extinctions.

International-mindedness:

- Within the human population, distinct characteristics have evolved within different populations through natural selection and exposure to the environmental conditions that were unique to the regions of those populations. How has globalization altered some of the environmental factors that were formerly unique to different human populations?
- Human impact has increased the rate at which some mass extinctions have occurred on a global scale.

Theory of knowledge:

- The theory of evolution by natural selection tells us that change in populations is achieved through the process of natural selection—is there a difference between a convincing theory and a correct one?

Connections:

- ESS: Biomes, zonation and succession (2.4); climate change—causes and impacts (7.2)
- Diploma Programme: Biology (topic 5)

3.3: Threats to biodiversity

Significant idea:

- While global biodiversity is difficult to quantify, it is decreasing rapidly due to human activity. Classification of species conservation status can provide a useful tool in the conservation of biodiversity.

Knowledge and understanding:

- Estimates of the total number of species on Earth vary considerably. They are based on mathematical models, which are influenced by classification issues and a lack of finance for scientific research, resulting in many habitats and groups being significantly under-recorded.
- The current rates of species loss are far greater now than in the recent past, due to increased human influence. The human activities that cause species extinctions include habitat destruction, introduction of invasive species, pollution, overharvesting and hunting.
- The International Union of Conservation of Nature (IUCN) publishes data in the "Red List of Threatened Species" in several categories. Factors used to determine the conservation status of a species include: population size, degree of specialization, distribution, reproductive potential and behaviour, geographic range and degree of fragmentation, quality of habitat, trophic level, and the probability of extinction.
- Tropical biomes contain some of the most globally biodiverse areas and their unsustainable exploitation results in massive losses in biodiversity and their ability to perform globally important ecological services.
- Most tropical biomes occur in less economically developed countries (LEDCs) and therefore there is conflict between exploitation, sustainable development and conservation.

Guidance:

- The total number of classified species is a small fraction of the estimated total of species, and it continues to rise. Estimates of extinction rates as a consequence are also varied, but current extinction rates are thought to be between 100 and 10,000 times greater than background rates.
- Case studies of three species should be carried out. In each case, the ecological, sociopolitical or economic pressures that are impacting on the species should be explored. The species' ecological roles and the possible consequences of their disappearance should be considered.

International-mindedness:

- Conservation needs to work at the local grass roots level to create meaningful change in the communities that live alongside conservation areas. International organizations are important for enforcing the Convention on International Trade in Endangered Species (CITES) agreement, assessing global status of species' numbers and influencing governments.
- The science of taxonomy is important to understand species extinction. Major surveys are carried out using international teams of specialists.

Theory of knowledge:

- There may be long-term consequences when biodiversity is lost—should people be held morally responsible for the long-term consequences of their actions?

3.3: Threats to biodiversity	
Applications and skills: • **Discuss** the case histories of three different species: one that has become extinct due to human activity, another that is critically endangered, and a third species whose conservation status has been improved by intervention. • **Describe** the threats to biodiversity from human activity in a given natural area of biological significance or conservation area. • **Evaluate** the impact of human activity on the biodiversity of tropical biomes. • **Discuss** the conflict between exploitation, sustainable development and conservation in tropical biomes.	**Connections:** • ESS: Sustainability (1.4); communities and ecosystems (2.2); water pollution (4.4); soil degradation and conservation (5.3); resource use in society (8.2) • Diploma Programme: Geography (topic 3); biology (topic 5 and option C)

3.4: Conservation of biodiversity	
Significant ideas: • The impact of losing biodiversity drives conservation efforts. • The variety of arguments given for the conservation of biodiversity will depend on EVSs. • There are various approaches to the conservation of biodiversity, each with associated strengths and limitations.	
Knowledge and understanding: • Arguments about species and habitat preservation can be based on aesthetic, ecological, economic, ethical and social justifications. • International, governmental and non-governmental organizations (NGOs) are involved in conserving and restoring ecosystems and biodiversity, with varying levels of effectiveness due to their use of media, speed of response, diplomatic constraints, financial resources and political influence. • Recent international conventions on biodiversity work to create collaboration between nations for biodiversity conservation.	**Guidance:** • Economic arguments for preservation often involve valuation of ecotourism, of the genetic resource, and commercial considerations of the natural capital. Ecological reasons may be related to the ecosystem. Ethical arguments are very broad, and can include the intrinsic value of the species or the utilitarian value. • International conventions on conservation and biodiversity have been adopted over the past decades. • A specific example of a protected area and the success it has achieved should be studied.

<table>
<tr><th colspan="2">3.4: Conservation of biodiversity</th></tr>
<tr>
<td>
• Conservation approaches include habitat conservation, species-based conservation and a mixed approach.
• Criteria for consideration when designing protected areas include size, shape, edge effects, corridors, and proximity to potential human influence.
• Alternative approaches to the development of protected areas are species-based conservation strategies including:
– CITES
– captive breeding and reintroduction programmes, and zoos
– selection of "charismatic" species to help protect others in an area (flagship species)
– selection of keystone species to protect the integrity of the food web.
• Community support, adequate funding and proper research influence the success of conservation efforts.
• The location of a conservation area in a country is a significant factor in the success of the conservation effort. Surrounding land use for the conservation area and distance from urban centres are important factors for consideration in conservation area design.

Applications and skills:
• Explain the criteria used to design and manage protected areas.
• Evaluate the success of a given protected area.
• Evaluate different approaches to protecting biodiversity.
</td>
<td>
International-mindedness:
• International organizations such as the World Wildlife Fund (WWF), Greenpeace, Friends of the Earth International (FoEI) and Earth First! undertake global programmes in terms of conservation of biodiversity.

Theory of knowledge:
• There are various approaches to the conservation of biodiversity—how can we determine when we should be disposed to act on what we know?

Connections:
• ESS: Environmental value systems (1.1); communities and ecosystems (2.2); resource use in society (8.2)
• Diploma Programme: Geography (topic 3); biology (option C)
</td>
</tr>
</table>

Topic 4: Water and aquatic food production systems and societies (15 hours)

Big questions: This topic may be particularly appropriate for considering big questions A, B, E and F.

<table>
<tr><th colspan="2">4.1: Introduction to water systems</th></tr>
<tr><td colspan="2">Significant ideas:
The hydrological cycle is a system of water flows and storages that may be disrupted by human activity.
The ocean circulatory system (ocean conveyor belt) influences the climate and global distribution of water (matter and energy).</td></tr>
<tr><td>Knowledge and understanding:
Solar radiation drives the hydrological cycle.
Fresh water makes up only a small fraction (approximately 2.6% by volume) of the Earth’s water storages.
Storages in the hydrological cycle include organisms, soil and various water bodies, including oceans, groundwater (aquifers), lakes, rivers, atmosphere, glaciers and ice caps.
Flows in the hydrological cycle include evapotranspiration, sublimation, evaporation, condensation, advection (wind-blown movement), precipitation, melting, freezing, flooding, surface runoff, infiltration, percolation, and stream-flow or currents.
Human activities such as agriculture, deforestation and urbanization have a significant impact on surface runoff and infiltration.
Ocean circulation systems are driven by differences in temperature and salinity. The resulting difference in water density drives the ocean conveyor belt, which distributes heat around the world, and thus affects climate.</td>
<td>Guidance:
The effect of urbanization on water flows and potential of flash floods should be covered.
International-mindedness:
Many hydrological cycles are shared by various nations. This can lead to international disputes.
Theory of knowledge:
The hydrological cycle is represented as a systems model—to what extent can systems diagrams effectively model reality, given that they are only based on limited observable features?
Connections:
ESS: Climate change—causes and impacts (7.2); terrestrial food production systems and food choices (5.2); aquatic food production systems (4.3); resource use in society (8.2); sustainability (1.4)</td></tr>
</table>

4.1: Introduction to water systems	
Applications and skills: • **Discuss** human impact on the hydrological cycle. • **Construct** and **analyse** a hydrological cycle diagram.	• Diploma Programme: Social and cultural anthropology; geography (options A and D)

4.2: Access to fresh water

Significant ideas:

- The supplies of freshwater resources are inequitably available and unevenly distributed, which can lead to conflict and concerns over water security.
- Freshwater resources can be sustainably managed using a variety of different approaches.

Knowledge and understanding:

- Access to an adequate freshwater supply varies widely.
- Climate change may disrupt rainfall patterns and further affect this access.
- As populations, irrigation and industrialization increase, the demand for fresh water increases.
- Freshwater supplies may become limited through contamination and unsustainable abstraction.
- Water supplies can be enhanced through reservoirs, redistribution, desalination, artificial recharge of aquifers and rainwater harvesting schemes. Water conservation (including grey-water recycling) can help to reduce demand but often requires a change in attitude by the water consumers.
- The scarcity of water resources can lead to conflict between human populations, particularly where sources are shared.

Applications and skills:

- **Evaluate** the strategies that can be used to meet an increasing demand for fresh water.
- **Discuss**, with reference to a case study, how shared freshwater resources have given rise to international conflict.

Guidance:

- Consider examples of unequal distribution and inequitable supply.

International-mindedness:

- Unequal access to fresh water can cause conflict between countries that have an abundance of fresh water and those that do not.

Theory of knowledge:

- Aid agencies often use emotive advertisements around the water security issue—to what extent can emotion be used to manipulate knowledge and actions?

Connections:

- ESS: Climate change—causes and impacts (7.2); terrestrial food production systems and food choices (5.2) and aquatic food production systems (4.3); resource use in society (8.2) and sustainability (1.4).
- Diploma Programme: Social and cultural anthropology; geography (topic 3; options A, B and F); economics

4.3: Aquatic food production systems

Significant ideas:

- Aquatic systems provide a source of food production.
- Unsustainable use of aquatic ecosystems can lead to environmental degradation and collapse of wild fisheries.
- Aquaculture provides potential for increased food production.

Knowledge and understanding:

- Demand for aquatic food resources continues to increase as human population grows and diet changes.
- Photosynthesis by phytoplankton supports a highly diverse range of food webs.
- Aquatic (freshwater and marine) flora and fauna are harvested by humans.
- The highest rates of productivity are found near coastlines or in shallow seas, where upwellings and nutrient enrichment of surface waters occurs.
- Harvesting some species, such as seals and whales, can be controversial. Ethical issues arise over biorights, rights of indigenous cultures and international conservation legislation.
- Developments in fishing equipment and changes to fishing methods have led to dwindling fish stocks and damage to habitats.
- Unsustainable exploitation of aquatic systems can be mitigated at a variety of levels (international, national, local and individual) through policy, legislation and changes in consumer behaviour.
- Aquaculture has grown to provide additional food resources and support economic development and is expected to continue to rise.
- Issues around aquaculture include: loss of habitats, pollution (with feed, antifouling agents, antibiotics and other medicines added to fish pens), spread of diseases and escaped species (some involving genetically modified organisms).

Guidance:

- Wild fisheries are also known as "capture fisheries".
- Aquaculture is the farming of aquatic organisms in both coastal and inland areas that involves intervention in the rearing process to enhance production.
- Examine different points of view regarding harvesting of a controversial species; for example, the historical Inuit tradition of whaling versus modern international conventions.
- When looking at the increase in demand for food resources, consideration should be given to changes in attitude towards "health foods" and food fashions.
- Consider how two contrasting fisheries have been managed and relate to the concept of sustainability; for example, cod fisheries in Newfoundland and Iceland. Issues that should be covered include: improvements to boats, fishing gear (trawler bags), and detection of fisheries and boats via satellites. Management aspects should include: use of quotas, designation of marine protected areas (exclusion zones), and restriction on types and size of fishing gear (including mesh size of nets).
- Students should understand maximum sustainable yield (MSY) as applied to fish stocks.

International-mindedness:

- Successful management of marine and some freshwater fisheries requires partnership between different nations.

4.3: Aquatic food production systems	
Applications and skills: • **Discuss**, with reference to a case study, the controversial harvesting of a named species. • **Evaluate** strategies that can be used to avoid unsustainable fishing. • **Explain** the potential value of aquaculture for providing food for future generations. • **Discuss** a case study that demonstrates the impact of aquaculture.	**Theory of knowledge:** • The Inuit people have an historical tradition of whaling—to what extent does our culture determine or shape our ethical judgments? **Connections:** • ESS: Biodiversity and conservation (topic 3); terrestrial food production systems and food choices (5.2); human population carrying capacity (8.4); resource use in society (8.2); sustainability (1.4) • Diploma Programme: Geography (option B); economics

4.4: Water pollution

Significant idea:

- Water pollution, both to groundwater and surface water, is a major global problem, the effects of which influence human and other biological systems.

<table>
<tr><th>Knowledge and understanding:</th><th>Guidance:</th></tr>
<tr><td>
• There are a variety of freshwater and marine pollution sources.
• Types of aquatic pollutants include floating debris, organic material, inorganic plant nutrients (nitrates and phosphates), toxic metals, synthetic compounds, suspended solids, hot water, oil, radioactive pollution, pathogens, light, noise and biological pollutants (invasive species).
• A wide range of parameters can be used to directly test the quality of aquatic systems, including pH, temperature, suspended solids (turbidity), metals, nitrates and phosphates.
• Biodegradation of organic material utilizes oxygen, which can lead to anoxic conditions and subsequent anaerobic decomposition, which in turn leads to formation of methane, hydrogen sulfide and ammonia (toxic gases).
</td><td>
• Sources of freshwater pollution should include runoff, sewage, industrial discharge and solid domestic waste.
• Sources of marine pollution should include rivers, pipelines, atmosphere and activities at sea (operational and accidental discharges).
• The role of positive and negative feedback in the process of eutrophication should be covered. Coastal eutrophication can lead to red tide blooms.
• With respect to measuring aquatic pollution, a polluted and an unpolluted site (for example, upstream and downstream of a point source) should be compared.
</td></tr>
</table>

4.4: Water pollution

- Biochemical oxygen demand (BOD) is 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. BOD is used to indirectly measure the amount of organic matter within a sample.
- Some species can be indicative of polluted waters and can be used as indicator species.
- A biotic index indirectly measures pollution by assaying the impact on species within the community according to their tolerance, diversity and relative abundance.
- Eutrophication can occur when lakes, estuaries and coastal waters receive inputs of nutrients (nitrates and phosphates), which results in an excess growth of plants and phytoplankton.
- Dead zones in both oceans and fresh water can occur when there is not enough oxygen to support marine life.
- Application of figure 3 to water pollution management strategies includes:
  1. reducing human activities that produce pollutants (for example, alternatives to current fertilizers and detergents)
  2. reducing release of pollution into the environment (for example, treatment of waste water to remove nitrates and phosphates)
  3. removing pollutants from the environment and restoring ecosystems (for example, removal of mud from eutrophic lakes and reintroduction of plant and fish species).

Applications and skills:

- **Analyse** water pollution data.
- **Explain** the process and impacts of eutrophication.
- **Evaluate** the uses of indicator species and biotic indices in measuring aquatic pollution.
- **Evaluate** pollution management strategies with respect to water pollution.

International-mindedness:

- Countries with limited access to clean water often have higher incidences of water-borne illnesses.

Theory of knowledge:

- A wide range of parameters are used to test the quality of water and judgments are made about causes and effects of water quality—how can we effectively identify cause–effect relationships, given that we can only ever observe correlation?

Connections:

- ESS: Terrestrial food production systems and food choices (5.2); climate change—causes and impacts (7.2); sustainability (1.4); resource use in society (8.2); biodiversity and conservation (topic 3); solid domestic waste (8.3)
- Diploma Programme: Social and cultural anthropology; chemistry (topic 9; options B and D)

Topic 5: Soil systems and terrestrial food production systems and societies (12 hours)

Big questions: This topic may be particularly appropriate for considering big questions A, B, E and F.

<table>
<tr><th colspan="2">5.1: Introduction to soil systems</th></tr>
<tr><td colspan="2">Significant ideas:
The soil system is a dynamic ecosystem that has inputs, outputs, storages and flows.
The quality of soil influences the primary productivity of an area.</td></tr>
<tr><td>Knowledge and understanding:
The soil system may be illustrated by a soil profile that has a layered structure (horizons).
Soil system storages include organic matter, organisms, nutrients, minerals, air and water.
Transfers of material within the soil, including biological mixing and leaching (minerals dissolved in water moving through soil), contribute to the organization of the soil.
There are inputs of organic material including leaf litter and inorganic matter from parent material, precipitation and energy. Outputs include uptake by plants and soil erosion.
Transformations include decomposition, weathering and nutrient cycling.</td><td>Guidance:
Studies of specific soil profiles, such as podsol, are not required.
Familiarity with the soil texture triangle diagram used for soil type classification based on the percentage of sand, silt, and clay in the soil is required.
International-mindedness:
Significant differences exist in arable (potential to promote primary productivity) soil availability around the world. These differences have sociopolitical, economic and ecological influences.
Theory of knowledge:
The soil system may be represented by a soil profile—since a model is, strictly speaking, not real, how can it lead to knowledge?</td></tr>
</table>

5.1: Introduction to soil systems	
• The structure and properties of sand, clay and loam soils differ in many ways, including mineral and nutrient content, drainage, water-holding capacity, air spaces, biota and potential to hold organic matter. Each of these variables is linked to the ability of the soil to promote primary productivity. • A soil texture triangle illustrates the differences in composition of soils. **Applications and skills:** • **Outline** the transfers, transformations, inputs, outputs, flows and storages within soil systems. • **Explain** how soil can be viewed as an ecosystem. • **Compare and contrast** the structure and properties of sand, clay and loam soils, with reference to a soil texture diagram, including their effect on primary productivity.	**Connections:** • ESS: Communities and ecosystems (2.2); flows of energy and matter (2.3); investigating ecosystems (2.5); biomes, zonation and succession (2.4); introduction to water systems (4.1); terrestrial food production systems and food choices (5.2); soil degradation and conservation (5.3); acid deposition (6.4); climate change (7.1 and 7.2); resource use in society (8.2); solid domestic waste (8.3) • Diploma Programme: Geography (topic 3)

5.2: Terrestrial food production systems and food choices

Significant ideas:

- The sustainability of terrestrial food production systems is influenced by sociopolitical, economic and ecological factors.
- Consumers have a role to play through their support of different terrestrial food production systems.
- The supply of food is inequitably available and land suitable for food production is unevenly distributed among societies, and this can lead to conflict and concerns.

Knowledge and understanding:	Guidance:
• The sustainability of terrestrial food production systems is influenced by factors such as scale; industrialization; mechanization; fossil fuel use; seed, crop and livestock choices; water use; fertilizers; pest control; pollinators; antibiotics; legislation; and levels of commercial versus subsistence food production. • Inequalities exist in food production and distribution around the world.	• Possible examples for contrasting terrestrial food production systems include North American cereal farming and subsistence farming in Southeast Asia, or intensive beef production in South America and the Maasai tribal use of livestock. These examples are not meant to be prescriptive and appropriate local examples are also encouraged.

5.2: Terrestrial food production systems and food choices

- Food waste is prevalent in both LEDCs and more economically developed countries (MEDCs), but for different reasons.
- Socio-economic, cultural, ecological, political and economic factors can be seen to influence societies in their choices of food production systems.
- As the human population grows, along with urbanization and degradation of soil resources, the availability of land for food production per capita decreases.
- The yield of food per unit area from lower trophic levels is greater in quantity, lower in cost and may require fewer resources.
- Cultural choices my influence societies to harvest food from higher trophic levels.
- Terrestrial food production systems can be compared and contrasted according to inputs, outputs, system characteristics, environmental impact and socio-economic factors.
- Increased sustainability may be achieved through:
  - altering human activity to reduce meat consumption and increase consumption of organically grown and locally produced terrestrial food products
  - improving the accuracy of food labels to assist consumers in making informed food choices
  - monitoring and control of the standards and practices of multinational and national food corporations by governmental and intergovernmental bodies
  - planting of buffer zones around land suitable for food production to absorb nutrient runoff.

- Factors to be used in comparing and contrasting food production systems include:
  - inputs, such as fertilizers (artificial or organic); water (irrigation or rainfall); pest control (pesticides or natural predators); labour (mechanized and fossil-fuel dependent or physical labour); seed (genetically modified organisms—GMOs—or conventional); breeding stock (domestic or wild); livestock growth promoters (antibiotics or hormones versus organic or none)
  - outputs, such as food quality, food quantity, pollutants (air, soil, water), consumer health, soil quality (erosion, degradation, fertility); common pollutants released from food production systems include fertilizers, pesticides, fungicides, antibiotics, hormones and gases from the use of fossil fuels; transportation, processing and packaging of food may also lead to further pollution from fossil fuels
  - system characteristics, such as diversity (monoculture versus polyculture); sustainability; indigenous versus introduced crop species
  - environmental impacts, such as pollution (air, soil, water); habitat loss; biodiversity loss; soil erosion or degradation; desertification; disease epidemics from high-density livestock farming
  - socio-economic factors, such as farming for profit or subsistence, for export or local consumption, for quantity or quality; traditional or commercial farming.
- Food waste is an issue arising in MEDCs, where regulatory standards may be set according to commercial preferences so that consumable food is discarded. It can also be an issue in LEDCs, where the necessary refrigeration and transport infrastructure is insufficient to avoid food spoilage.

<table>
<tr><th colspan="2">5.2: Terrestrial food production systems and food choices</th></tr>
<tr>
<td>
Applications and skills:

Analyse tables and graphs that illustrate the differences in inputs and outputs associated with food production systems.
Compare and contrast the inputs, outputs and system characteristics for two given food production systems.
Evaluate the relative environmental impacts of two given food production systems.
Discuss the links that exist between sociocultural systems and food production systems.
Evaluate strategies to increase sustainability in terrestrial food production systems.

</td>
<td>
International-mindedness:

Food choices can be influenced by culture, religion or regional food production differences.

Theory of knowledge:

Consumer behaviour plays an important role in food production systems—are there general laws that can describe human behaviour?

Connections:

ESS: Environmental value systems (1.1); flows of energy and matter (2.3); communities and ecosystems (2.2); investigating ecosystems (2.5); threats to biodiversity (3.3); water pollution (4.4); introduction to soil systems (5.1); soil degradation and conservation (5.3); resource use in society (8.2); solid domestic waste (8.3); human population carrying capacity (8.4)
Diploma Programme: Biology (options B and C); chemistry (options B and C); geography (option F); economics

</td>
</tr>
</table>

<table>
<tr><th colspan="2">5.3 Soil degradation and conservation</th></tr>
<tr><td colspan="2">Significant Ideas:
• Fertile soils require significant time to develop through the process of succession.
• Human activities may reduce soil fertility and increase soil erosion.
• Soil conservation strategies exist and may be used to preserve soil fertility and reduce soil erosion.</td></tr>
<tr><td>Knowledge and understanding:
• Soil ecosystems change through succession. Fertile soil contains a community of organisms that work to maintain functioning nutrient cycles and that are resistant to soil erosion.</td><td>Guidance:
• Applying knowledge of specific food production systems to their associated soil degradation and consequent soil conservation management strategies is recommended.</td></tr>
<tr><td>• Human activities that can reduce soil fertility include deforestation, intensive grazing, urbanization and certain agricultural practices (such as irrigation and monoculture).
• Commercial, industrialized food production systems generally tend to reduce soil fertility more than small-scale subsistence farming methods.
• Reduced soil fertility may result in soil erosion, toxification, salination and desertification.
• Soil conservation measures include soil conditioners (such as organic materials and lime), wind reduction techniques (wind breaks, shelter belts), cultivation techniques (terracing, contour ploughing, strip cultivation) and avoiding the use of marginal lands.
Applications and skills:
• Explain the relationship between soil ecosystem succession and soil fertility.
• Discuss the influences of human activities on soil fertility and soil erosion.
• Evaluate the soil management strategies of a given commercial farming system and of a given subsistence farming system.</td><td>International-mindedness:
• Variant use of soil systems can lead to different degradation and conservation.
Theory of knowledge:
• Our understanding of soil conservation has progressed in recent years—what constitutes progress in different areas of knowledge?
• Fertile soil can be considered as a non-renewable resource because once depleted, it can take significant time to restore the fertility—how does our perception of time influence our understanding of change?
Connections:
• ESS: Communities and ecosystems (2.2); investigating ecosystems (2.5); introduction to soil systems (5.1); terrestrial food production systems and food choices (5.2); biomes, zonation and succession (2.4); climate change—causes and impacts (7.2); resource use in society (8.2)
• Diploma Programme: Chemistry (options A and C); geography (topic 3)</td></tr>
</table>

Syllabus

Topic 6: Atmospheric systems and societies (10 hours)

Big questions: This topic may be particularly appropriate for considering big questions B, E and F.

6.1: Introduction to the atmosphere	
Significant ideas: • The atmosphere is a dynamic system that is essential to life on Earth. • The behaviour, structure and composition of the atmosphere influence variations in all ecosystems.	
Knowledge and understanding: • The atmosphere is a dynamic system (with inputs, outputs, flows and storages) that has undergone changes throughout geological time. • The atmosphere is predominantly a mixture of nitrogen and oxygen, with smaller amounts of carbon dioxide, argon, water vapour and other trace gases. • Human activities impact atmospheric composition through altering inputs and outputs of the system. Changes in the concentrations of atmospheric gases—such as ozone, carbon dioxide, and water vapour—have significant effects on ecosystems. • Most reactions connected to living systems occur in the inner layers of the atmosphere, which are the troposphere (0–10 km above sea level) and the stratosphere (10–50 km above sea level). • Most clouds form in the troposphere and play an important role in the albedo effect of the planet. • The greenhouse effect of the atmosphere is a natural and necessary phenomenon maintaining suitable temperatures for living systems.	**Guidance:** • Students should recognize the atmosphere as a dynamic system. The composition of the atmosphere has changed throughout geological history. Living organisms (biotic components) have transformed the atmospheric composition of the Earth and vice versa throughout history. • The use of chemical symbols or chemical formulae for atmospheric gases is **not** required. **International-mindedness:** • Impact to the atmosphere from pollutants can be localized, as evidenced by the destruction of the ozone layer over the poles of the Earth. • Pollutants released to the atmosphere are carried by currents in the atmosphere and may create damage in a location other than where they are produced. **Theory of knowledge:** • The atmosphere is a dynamic system—how should we react when we have evidence that does not fit with an existing theory?

6.1: Introduction to the atmosphere	
Applications and skills: • **Discuss** the role of the albedo effect from clouds in regulating global average temperature. • **Outline** the role of the greenhouse effect in regulating temperature on Earth.	**Connections:** • ESS: Climate change—causes and impacts (7.2); systems and models (1.2); introduction to water systems (4.1); introduction to soil systems (5.1); biomes, zonation and succession (2.4); acid deposition (6.4) climate change—causes and impacts (7.2) • Diploma Programme: Geography (topic 3); physics (sub-topic 8.2)

<table>
<tr><th colspan="2">6.2: Stratospheric ozone</th></tr>
<tr><td colspan="2">Significant ideas:
Stratospheric ozone is a key component of the atmospheric system because it protects living systems from the negative effects of ultraviolet radiation from the Sun.
Human activities have disturbed the dynamic equilibrium of stratospheric ozone formation.
Pollution management strategies are being employed to conserve stratospheric ozone.</td></tr>
<tr><td>Knowledge and understanding:
Some ultraviolet radiation from the Sun is absorbed by stratospheric ozone causing the ozone molecule to break apart. Under normal conditions the ozone molecule will reform. This ozone destruction and reformation is an example of a dynamic equilibrium.
Ozone depleting substances (including halogenated organic gases such as chlorofluorocarbons—CFCs) are used in aerosols, gas-blown plastics, pesticides, flame retardants and refrigerants. Halogen atoms (such as chlorine) from these pollutants increase destruction of ozone in a repetitive cycle, allowing more ultraviolet radiation to reach the Earth.
Ultraviolet radiation reaching the surface of the Earth damages human living tissues, increasing the incidence of cataracts, mutation during cell division, skin cancer and other subsequent effects on health.</td>
<td>Guidance:
The use of chemical symbols, formulae or equations for the destruction of ozone is not required.
Relate to figure 3.
International-mindedness:
The depletion of ozone has global implications to ocean productivity and oxygen production.
National economic approaches may have an impact on international environmental discussions.
Theory of knowledge:
The Montreal Protocol was an international agreement created by the UN—can one group or organization decide what is best for the rest of the world?</td></tr>
</table>

<table>
<tr><th colspan="2">6.2: Stratospheric ozone</th></tr>
<tr><td>

- The effects of increased ultraviolet radiation on biological productivity include damage to photosynthetic organisms, especially phytoplankton, which form the basis of aquatic food webs.
- Pollution management may be achieved by reducing the manufacture and release of ozone-depleting substances. Methods for this reduction include:
  - recycling refrigerants
  - developing alternatives to gas-blown plastics, halogenated pesticides, propellants and aerosols
  - developing non-propellant alternatives.

  UNEP has had a key role in providing information, and creating and evaluating international agreements, for the protection of stratospheric ozone.
- An illegal market for ozone-depleting substances persists and requires consistent monitoring.
- The *Montreal Protocol on Substances that Deplete the Ozone Layer* (1987) and subsequent updates is an international agreement for the reduction of use of ozone-depleting substances signed under the direction of UNEP. National governments complying with the agreement made national laws and regulations to decrease the consumption and production of halogenated organic gases such as chlorofluorocarbons (CFCs).

Applications and skills:

- **Evaluate** the role of national and international organizations in reducing the emissions of ozone-depleting substances.

</td><td>

Connections:

- ESS: Energy and equilibria (1.3); humans and pollution (1.5); resource use in society (8.2); communities and ecosystems (2.2); investigating ecosystems (2.5)
- Diploma Programme: Chemistry (topics 5 and 14); geography (option G); economics.

</td></tr>
</table>

6.3: Photochemical smog

Significant ideas:

- The combustion of fossil fuels produces primary pollutants that may generate secondary pollutants and lead to photochemical smog, the levels of which can vary by topography, population density and climate.
- Photochemical smog has significant impacts on societies and living systems.
- Photochemical smog can be reduced by decreasing human reliance on fossil fuels.

Knowledge and understanding:

- Primary pollutants from the combustion of fossil fuels include carbon monoxide, carbon dioxide, black carbon or soot, unburned hydrocarbons, oxides of nitrogen, and oxides of sulfur.
- In the presence of sunlight, secondary pollutants are formed when primary pollutants undergo a variety of reactions with other chemicals already present in the atmosphere.
- Tropospheric ozone is an example of a secondary pollutant, formed when oxygen molecules react with oxygen atoms that are released from nitrogen dioxide in the presence of sunlight.
- Tropospheric ozone is highly reactive and damages plants (crops and forests), irritates eyes, creates respiratory illnesses and damages fabrics and rubber materials. Smog is a complex mixture of primary and secondary pollutants, of which tropospheric ozone is the main pollutant.
- The frequency and severity of smog in an area depends on local topography, climate, population density, and fossil fuel use.
- Thermal inversions occur due to a lack of air movement when a layer of dense, cool air is trapped beneath a layer of less dense, warm air. This causes concentrations of air pollutants to build up near the ground instead of being dissipated by "normal" air movements.
- Deforestation and burning may also contribute to smog.
- Economic losses caused by urban air pollution can be significant.

Guidance:

- The use of chemical symbols, formulae or equations is **not** required.
- Relate to figure 3.

International-mindedness:

- The global rise of urbanization and industrialization has led to an increase in urban air pollution.

Theory of knowledge:

- Environmental problems are often emotive—under what circumstances should we maintain a detached relationship with the subject matter under investigation?

Connections:

- ESS: Climate change—causes and impacts (7.2); acid deposition (6.4); stratospheric ozone (6.2); humans and pollution (1.5); investigating ecosystems (2.5)
- Diploma Programme: Chemistry (topic 5); geography (option G), economics

6.3: Photochemical smog	
• Pollution management strategies include: – altering human activity to consume less fossil fuels—example activities include the purchase of energy-efficient technologies, the use of public or shared transit, and walking or cycling – regulating and reducing pollutants at the point of emission through government regulation or taxation – using catalytic converters to clean the exhaust of primary pollutants from car exhaust – regulating fuel quality by governments – adopting clean-up measures such as reforestation, regreening, and conservation of areas to sequester carbon dioxide. **Applications and skills:** • **Evaluate** pollution management strategies for reducing photochemical smog.	

6.4: Acid deposition

Significant ideas:

- Acid deposition can impact living systems and the built environment.
- The pollution management of acid deposition often involves cross-border issues.

Knowledge and understanding:	Guidance:
• The combustion of fossil fuels produces sulfur dioxide and oxides of nitrogen as primary pollutants. These gases may be converted into secondary pollutants of dry deposition (such as ash and dry particles) or wet deposition (such as rain and snow).	• The use of chemical symbols or chemical formulae is **not** required. • Possible case studies of intergovernmental situations involving acid deposition to consider include the USA Midwest and Eastern Canada interaction, as well as the impact of industrial Britain, Germany and Poland on Sweden.

6.4: Acid deposition

- The possible effects of acid deposition on soil, water and living organisms include:
  - direct effect—for example, acid on aquatic organisms and coniferous forests
  - indirect toxic effect—for example, increased solubility of metal (such as aluminium ions) on fish
  - indirect nutrient effect—for example, leaching of plant nutrients.
- The impacts of acid deposition may be limited to areas downwind of major industrial regions but these areas may not be in the same country as the source of emissions.
- Pollution management strategies for acid deposition could include:
  - altering human activity—for example, through reducing use, or using alternatives to, fossil fuels; international agreements and national governments may work to reduce pollutant production through lobbying
  - regulating and monitoring the release of pollutants—for example, through the use of scrubbers or catalytic converters that may remove sulfur dioxide and oxides of nitrogen from coal-burning powerplants and cars.
- Clean-up and restoration measures may include spreading ground limestone in acidified lakes or recolonization of damaged systems—but the scope of these measures is limited.

Applications and skills:

- **Evaluate** pollution management strategies for acid deposition.

International-mindedness:

- The polluting country and the polluted country are often not the same: acid deposition affects regions far from its source. Therefore, solving this issue requires international cooperation.

Theory of knowledge:

- To what extent does the recognition of the ethical responsibility of knowledge influence the further production or acquisition of knowledge?

Connections:

- ESS: Photochemical smog (6.3); humans and pollution (1.5); investigating ecosystems (2.5)
- Diploma Programme: Chemistry (topic 8); economics

Topic 7: Climate change and energy production (13 hours)

Big questions: This topic may be particularly appropriate for considering big questions A, B, C, D, E and F.

7.1: Energy choices and security	
Significant ideas: • There is a range of different energy sources available to societies that vary in their sustainability, availability, cost and sociopolitical implications. • The choice of energy sources is controversial and complex. Energy security is an important factor in making energy choices.	
Knowledge and understanding: • Fossil fuels contribute to the majority of humankind's energy supply, and they vary widely in the impacts of their production and their emissions; their use is expected to increase to meet global energy demand. • Sources of energy with lower carbon dioxide emissions than fossil fuels include renewable energy (solar, biomass, hydropower, wind, wave, tidal and geothermal) and their use is expected to increase. Nuclear power is a low-carbon low-emission non-renewable resource but is controversial due to the radioactive waste it produces and the potential scale of any accident. • Energy security depends on adequate, reliable and affordable supply of energy that provides a degree of independence. An inequitable availability and uneven distributions of energy sources may lead to conflict. • The energy choices adopted by a society may be influenced by availability; sustainability; scientific and technological developments; cultural attitudes; and political, economic and environmental factors. These in turn affect energy security and independence. • Improvements in energy efficiencies and energy conservation can limit growth in energy demand and contribute to energy security.	**Guidance:** • Strengths and weaknesses of the use of a fossil fuel, of a renewable source of energy, and of nuclear power should be considered. • Use case studies to highlight the energy choices of different countries. **International-mindedness:** • Choice of energy sources can have impacts at both local and global level as emissions of greenhouse gases can contribute to global climatic change. • Political and economic situations around the world can affect energy security and choice of options. **Theory of knowledge:** • The choice of energy sources is controversial and complex—how can we distinguish between a scientific claim and a pseudoscience claim when making choices?

<table>
<tr><th colspan="2">7.1: Energy choices and security</th></tr>
<tr><td>Applications and skills:
Evaluate the advantages and disadvantages of different energy sources.
Discuss the factors that affect the choice of energy sources adopted by different societies.
Discuss the factors that affect energy security.
Evaluate the energy strategy of a given society.</td><td>Connections:
ESS: Energy and equilibria (1.3); sustainability (1.4); resource use in society (8.2); human population carrying capacity (8.4).
Diploma Programme: Social and cultural anthropology; chemistry (option C); design technology (topic 2); physics (topics 8 and 11); geography (topics 3 and 4); economics</td></tr>
</table>

7.2: Climate change—causes and impacts

Significant ideas:

- Climate change has been a normal feature of the Earth's history, but human activity has contributed to recent changes.
- There has been significant debate about the causes of climate change.
- Climate change causes widespread and significant impacts on a global scale.

Knowledge and understanding:

- Climate describes how the atmosphere behaves over relatively long periods of time, whereas weather describes the conditions in the atmosphere over a short period of time.
- Weather and climate are affected by oceanic and atmospheric circulatory systems.
- Human activities are increasing levels of greenhouse gases (GHGs, such as carbon dioxide, methane and water vapour) in the atmosphere, which leads to:
  - an increase in the mean global temperature
  - increased frequency and intensity of extreme weather events
  - the potential for long-term changes in climate and weather patterns
  - rise in sea level.

Guidance:

- GHGs are those atmospheric gases that absorb infrared radiation, causing global temperatures to be higher than they would otherwise be.
- Students should be able to distinguish between the natural and the enhanced greenhouse effect and to identify a variety of human activities that contribute to GHG emissions. Students must understand the concept of tipping points and how it might be applied to climate change.
- A minimum of two different viewpoints should be considered.

International-mindedness:

- The impacts of the climate change are global and require coordinated international action.

<table>
<tr><th colspan="2">7.2: Climate change—causes and impacts</th></tr>
<tr><td>
• The potential impacts of climate change may vary from one location to another and may be perceived as either adverse or beneficial. These impacts may include changes in water availability, distribution of biomes and crop growing areas, loss of biodiversity and ecosystem services, coastal inundation, ocean acidification, and damage to human health.
• Both negative and positive feedback mechanisms are associated with climate change and may involve very long time lags.
• There has been significant debate due to conflicting EVSs surrounding the issue of climate change.
• Global climate models are complex and there is a degree of uncertainty regarding the accuracy of their predictions.
Applications and skills:
• Discuss the feedback mechanisms that would be associated with a change in mean global temperature.
• Evaluate contrasting viewpoints on the issue of climate change.
</td><td>
Theory of knowledge:
• There has been considerable debate about the causes of climate change—does our interpretation of knowledge from the past allow us to reliably predict the future?
Connections:
• ESS: Systems and models (1.2); energy and equilibria (1.3); threats to biodiversity (3.3); access to fresh water (4.2); aquatic food production systems (4.3); terrestrial food production systems and food choices (5.2); introduction to the atmosphere (6.1); stratospheric ozone (6.2); human population carrying capacity (8.4)
• Diploma Programme: Social and cultural anthropology; chemistry (option C); physics (topic 8); geography (topics 3 and 4); economics; biology (topic 4)
</td></tr>
</table>

<table>
<tr><th colspan="2">7.3: Climate change—mitigation and adaptation</th></tr>
<tr><td colspan="2">Significant ideas:
• Mitigation attempts to reduce the causes of climate change.
• Adaptation attempts to manage the impacts of climate change.</td></tr>
<tr><td>Knowledge and understanding:
• Mitigation involves reduction and/or stabilization of GHG emissions and their removal from the atmosphere.
• Mitigation strategies to reduce GHGs in general may include:
– reduction of energy consumption</td><td>Guidance:
• CCS is carried out by carbon dioxide being compressed, transported and stored permanently underground (geological sites used as repositories) or chemically fixed to form a carbonate.</td></tr>
</table>

7.3: Climate change—mitigation and adaptation

- reduction of emissions of oxides of nitrogen and methane from agriculture
- use of alternatives to fossil fuels
- geo-engineering.

- Mitigation strategies for carbon dioxide removal (CDR techniques) include:
  - protecting and enhancing carbon sinks through land management; for example, through the UN collaborative programme on reducing emissions from deforestation and forest degradation in developing countries (UN-REDD)
  - using biomass as a fuel source
  - using carbon capture and storage (CCS)
  - enhancing carbon dioxide absorption by the oceans through either fertilizing oceans with compounds of nitrogen, phosphorus and iron to encourage the biological pump, or increasing upwellings to release nutrients to the surface.
- Even if mitigation strategies drastically reduce future emissions of GHGs, past emissions will continue to have an effect for decades to come.
- Adaptation strategies can be used to reduce adverse affects and maximize any positive effects. Examples of adaptations include flood defences, vaccination programmes, desalinization plants and planting of crops in previously unsuitable climates.
- Adaptive capacity varies from place to place and can be dependent on financial and technological resources. MEDCs can provide economic and technological support to LEDCs.

- Mitigation is the use of technology and substitution to reduce resource inputs and emissions per unit of output.
- Adaptation is the adjustment of natural or human systems in response to actual or expected climatic stimuli or their effects, which either moderates harm or exploits beneficial opportunities.
- Two mitigation and two adaptation strategies should be considered.

International-mindedness:

- The impacts of climate change are global and require global mitigation.

Theory of knowledge:

- There is a degree of uncertainty in the extent and effect of climate change—how can we be confident of the ethical responsibilities that may arise from knowledge when that knowledge is often provisional or incomplete?

Connections:

- ESS: Humans and pollution (1.5); access to fresh water (4.2); photochemical smog (6.3)
- Diploma Programme: Physics (topic 8); economics

7.3: Climate change—mitigation and adaptation	
• There are international efforts and conferences to address mitigation and adaptation strategies for climate change; for example, the Intergovernmental Panel on Climate Change (IPCC), National Adaptation Programmes of Action (NAPAs) and the United Nations Framework Convention on Climate Change (UNFCCC). **Applications and skills:** • **Discuss** mitigation and adaptation strategies to deal with impacts of climate change. • **Evaluate** the effectiveness of international climate change talks.	

Topic 8: Human systems and resource use (16 hours)

Big questions: This topic may be particularly appropriate for considering big questions A, B, C, D, E and F.

8.1: Human population dynamics
Significant ideas: • A variety of models and indicators are employed to quantify human population dynamics. • Human population growth rates are impacted by a complex range of changing factors.

8.1: Human population dynamics

Knowledge and understanding:

- Demographic tools for quantifying human population include crude birth rate (CBR), crude death rate (CDR), total fertility rate (TFR), doubling time (DT) and natural increase rate (NIR).
- Global human population has followed a rapid growth curve, but there is uncertainty as to how this may be changing.
- As the human population grows, increased stress is placed on all of the Earth's systems.
- Age–gender pyramids and demographic transition models (DTM) can be useful in the prediction of human population growth. The DTM is a model that shows how a population transitions from a pre-industrial stage with high CBRs and CDRs to an economically advanced stage with low or declining CBRs and low CDRs.
- Influences on human population dynamics include cultural, historical, religious, social, political and economic factors.
- National and international development policies may also have an impact on human population dynamics.

Guidance:

- A variety of predictive models could be included, such as computer simulations, statistical and/or demographic tables for LEDCs and MEDCs, age–gender pyramids, and graphical extrapolation of population curves.
- Development policies may increase or decrease population growth.
  - CBRs and growth rates are reduced through educating of women for greater independence (economic and reproductive), stimulation of economic growth to improve economic welfare and give greater economic independence, mechanization of the agricultural sector and subsequent urbanization.
  - Growth rates may increase if CDRs fall as a result of improved public health, sanitation, and service infrastructure.

International-mindedness:

- A country's development depends on its economy and its demographics. It also depends on the policies of other countries and international organizations such as the World Bank, the International Monetary Fund (IMF) and the World Trade Organization (WTO).

Applications and skills:

- **Calculate** values of CBR, CDR, TFR, DT and NIR.
- **Explain** the relative values of CBR, CDR, TFR, DT and NIR.
- **Analyse** age–gender pyramids and diagrams showing demographic transition models.
- **Discuss** the use of models in predicting the growth of human populations.
- **Explain** the nature and implications of growth in human populations.
- **Analyse** the impact that national and international development policies can have on human population dynamics and growth.
- **Discuss** the cultural, historical, religious, social, political and economic factors that influence human population dynamics.

Theory of knowledge:

- A variety of models and indicators are employed to quantify human population dynamics—to what extent are the methods of the human sciences "scientific"?

Connections:

- ESS: Sustainability (1.4); humans and pollution (1.5); species and populations (2.1); water pollution (4.4); soil degradation and conservation (5.3); climate change—causes and impacts (7.2); human population carrying capacity (8.4)
- Diploma Programme: Biology (option C); social and cultural anthropology; sports, exercise and health science (option C); geography (topic 1); economics

<table>
<tr><th colspan="2">8.2: Resource use in society</th></tr>
<tr><td colspan="2">Significant ideas:
• The renewability of natural capital has implications for its sustainable use.
• The status and economic value of natural capital is dynamic.</td></tr>
<tr><td>Knowledge and understanding:
• Renewable natural capital can be generated and/or replaced as fast as it is being used. It includes living species and ecosystems that use solar energy and photosynthesis, as well as non-living items, such as groundwater and the ozone layer.
• Non-renewable natural capital is either irreplaceable or can only be replaced over geological timescales; for example, fossil fuels, soil and minerals.
• Renewable natural capital can be utilized sustainably or unsustainably. If renewable natural capital is used beyond its natural income this use becomes unsustainable.</td><td>Guidance:
• The valuation of natural capital can be divided into the following two main categories.
– Use of valuation: resources that have a price—marketable goods, ecological functions, recreational function
– Non-use of valuation: resources that have intrinsic value (the right to exist), future uses (medicines, potential gene pool), existence value (Amazon rainforest), present for future generations
• Consider at least two examples of how the status of natural capital can vary.</td></tr>
<tr><td>• The impacts of extraction, transport and processing of a renewable natural capital may cause damage, making this natural capital unsustainable.
• Natural capital provides goods (such as tangible products) and services (such as climate regulation) that have value. This value may be aesthetic, cultural, economic, environmental, ethical, intrinsic, social, spiritual or technological.
• The concept of a natural capital is dynamic. Whether or not something has the status of natural capital, and the marketable value of that capital varies regionally and over time and is influenced by cultural, social, economic, environmental, technological and political factors. Examples include cork, uranium and lithium.
Applications and skills:
• Outline an example of how renewable and non-renewable natural capital has been mismanaged.
• Explain the dynamic nature of the concept of natural capital.</td><td>• “Natural capital” is often used interchangeably with the term “resource”, and the rate of its replacement is referred to as “natural income”.
International-mindedness:
• There are marked cultural differences in attitudes to the management of natural capital.
Theory of knowledge:
• As resources become scarce, we have to make decisions about how to use them—to what extent should potential damage to the environment limit our pursuit of knowledge?
Connections:
• ESS: Environmental values systems (1.1); sustainability (1.4)
• Diploma Programme: Social and cultural anthropology; design technology (topics 2 and 8); physics (topic 8); geography (topic 4); economics</td></tr>
</table>

8.3: Solid domestic waste

Significant ideas:

- Solid domestic waste (SDW) is increasing as a result of growing human populations and consumption.
- Both the production and management of SDW can have significant influence on sustainability.

Knowledge and understanding:

- There are different types of SDW, the volume and composition of which changes over time.
- The abundance and prevalence of non-biodegradable pollution (such as plastic, batteries or e-waste) in particular has become a major environmental issue.
- Waste disposal options include landfills, incineration, recycling and composting.
- There are a variety of strategies that can be used to manage SDW (refer to figure 3) influenced by cultural, economic, technological and political barriers. These strategies include:
  - altering human activity—for example, through a reduction of consumption and composting of food waste.
  - controlling the release of pollutant—governments create legislation to encourage recycling and reuse initiatives and impose taxes for SDW collection and on disposable items
  - reclaiming landfills, using SDW for waste-to-energy programmes, implementing initiatives to remove plastics from the Great Pacific garbage patch (clean-up and restoration).

Applications and skills:

- **Evaluate** SDW disposal options.
- **Compare and contrast** pollution management strategies for SDW.
- **Evaluate**, with reference to figure 3, pollution management strategies for SDW by considering recycling, incineration, composting and landfills.

Guidance:

- SDW includes household waste such as paper, glass, metal, plastics, organic (kitchen or garden), packaging, construction debris, and clothing.
- Students should consider the amount and source of non-biodegradable pollution generated within a chosen locality and how it is managed.
- The adoption of the circular economy provides an alternative approach to waste and sustainability.

International-mindedness:

- Pollution can be transborder; the pollution from one country may affect another.
- Differences in development level of countries can influence the amount and type of SDW they generate.

Theory of knowledge:

- The circular economy can be seen as a paradigm shift—does knowledge develop through paradigm shifts in all areas of knowledge?

Connections:

- ESS: Sustainability (1.4); humans and pollution (1.5); flows of energy and matter (2.3); water pollution (4.4); soil degradation and conservation (5.3); acid deposition (6.4)
- Diploma Programme: Chemistry (option A); geography (topic 4 and option B)

8.4: Human population carrying capacity	
Significant ideas: • Human carrying capacity is difficult to quantify. • The EF is a model that makes it possible to determine whether human populations are living within carrying capacity.	
Knowledge and understanding:	**Guidance:**
• Carrying capacity is the maximum number of a species, or "load", that can be sustainably supported by a given area.	• Discussion of the application of the carrying capacity that allows human populations to grow beyond the boundaries set by their local resources should include:

8.4: Human population carrying capacity

- It is possible to estimate the carrying capacity of an environment for a given species; however, this is problematic in the case of human populations for a number of reasons.
- An EF is the area of land and water required to support a defined human population at a given standard of living. The measure of an EF takes into account the area required to provide all the resources needed by the population, and the assimilation of all wastes.
- EF is a model used to estimate the demands that human populations place on the environment.
- EFs may vary significantly by country and by individual and include aspects such as lifestyle choices (EVS), productivity of food production systems, land use and industry. If the EF of a human population is greater than the land area available to it, this indicates that the population is unsustainable and exceeds the carrying capacity of that area.
- Degradation of the environment, together with the consumption of finite resources, is expected to limit human population growth.
- If human populations do not live sustainably, they will exceed carrying capacity and risk collapse.

Applications and skills:

- **Evaluate** the application of carrying capacity to local and global human populations.
- **Compare and contrast** the differences in the EF of two countries.
- **Evaluate** how EVSs impact the EFs of individuals or populations.

  – the range of resources used
  – human ingenuity, meaning that humans are able to substitute one material for another
  – variations in lifestyles
  – importation of resources
  – technological developments that give rise to continual changes in the resources required and that are available for consumption.

- Because carrying capacity for human populations is difficult to calculate, it is also difficult to estimate the extent to which they are approaching or exceeding carrying capacity, although environmental indicators (see sub-topic 1.4) may help in this respect.
- The EF is a model that provides a way round this dilemma. Instead of focusing on a given environment and trying to calculate the carrying capacity it provides, it focuses on a given population (with its current rate of resource consumption) and estimates the area of environment necessary to sustainably support that particular population. The size of this area is compared with the area available to the population, then gives an indication of whether the population is living sustainably and within the carrying capacity provided.

International-mindedness:

- Sustainability is the responsible use and management of global resources that allows natural regeneration and minimizes environmental damage.

<table>
<tr><th colspan="2">8.4: Human population carrying capacity</th></tr>
<tr><td></td><td>Theory of knowledge:
Human carrying capacity is difficult to quantify and contains elements of subjective judgment. It has been claimed that historians cannot be unbiased—could the same be said of environmental scientists when making knowledge claims?
Connections:
ESS: Sustainability (1.4); humans and pollution (1.5); access to fresh water (4.2); aquatic food production systems (4.3); terrestrial food production systems and food choices (5.2); energy choices and security (7.1); resource use in society (8.2)
Diploma Programme: Geography (topic 4 and option G)</td></tr>
</table>

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 assessments 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 (store.ibo.org). Additional publications such as specimen papers and markschemes, teacher support materials, subject reports and grade descriptors can also be found on the OCC. 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.

Analytic markschemes

Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response.

Marking notes

For some assessment components marked using assessment criteria, marking notes are provided. Marking notes give guidance on how to apply assessment criteria to the particular requirements of a question.

Responsibilities of the school

The school is required to ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Candidates with assessment access requirements* and *Learning diversity within the International Baccalaureate programmes: Special educational needs within the International Baccalaureate programmes*.

Acknowledging the ideas or work of another person

Coordinators and teachers are reminded that candidates must acknowledge all sources used in work submitted for assessment. The following is intended as a clarification of this requirement.

Diploma Programme candidates submit work for assessment in a variety of media that may include audio-visual material, text, graphs, images and/or data published in print or electronic sources. If a candidate uses the work or ideas of another person, the candidate must acknowledge the source using a standard style of referencing in a consistent manner. A candidate's failure to acknowledge a source will be investigated by the IB as a potential breach of regulations that may result in a penalty imposed by the IB final award committee.

The IB does not prescribe which style(s) of referencing or in-text citation should be used by candidates; this is left to the discretion of appropriate faculty/staff in the candidate's school. The wide range of subjects, three response languages and the diversity of referencing styles make it impractical and restrictive to insist on particular styles. In practice, certain styles may prove most commonly used, but schools are free to choose a style that is appropriate for the subject concerned and the language in which candidates' work is written. Regardless of the reference style adopted by the school for a given subject, it is expected that the minimum information given includes: name of author, date of publication, title of source, and page numbers as applicable.

Candidates are expected to use a standard style and use it consistently so that credit is given to all sources used, including sources that have been paraphrased or summarized. When writing text a candidate must clearly distinguish between his or her words and those of others by the use of quotation marks (or other method, such as indentation) followed by an appropriate citation that denotes an entry in the bibliography. If an electronic source is cited, the date of access must be indicated. Candidates are not expected to show faultless expertise in referencing, but are expected to demonstrate that all sources have been acknowledged. Candidates must be advised that audio-visual material, text, graphs, images and/or data published in print or in electronic sources that is not their own must also attribute the source. Again, an appropriate style of referencing/citation must be used.

Inclusive assessment arrangements

Inclusive assessment arrangements are available for candidates with assessment access requirements. These arrangements enable candidates with diverse needs to access the examinations and demonstrate their knowledge and understanding of the constructs being assessed.

The IB document *Candidates with assessment access requirements* provides details on all the inclusive assessment arrangements available to candidates with learning support requirements. The IB document *Learning diversity within the International Baccalaureate programmes: Special educational needs within the International Baccalaureate programmes* outlines the position of the IB with regard to candidates with diverse learning needs in the IB programmes. For candidates affected by adverse circumstances, the IB documents *General regulations: Diploma Programme* and the *Handbook of procedures for the Diploma Programme* provide details on access consideration.

Assessment outline

First assessment 2017

Assessment component	Weighting (%)	Approximate weighting of objectives in each component (%)		Duration (hours)
		1 and 2	**3**	
Paper 1 (case study)	25	50	50	1
Paper 2 (short answers and structured essays)	50	50	50	2
Internal assessment (individual investigation)	25	Covers objectives 1, 2, 3 and 4		10

External assessment

The following methods are used to assess students.

- Detailed markschemes specific to each examination paper
- Markbands

The markbands are published in this guide.

- For paper 1, there is a markscheme.
- For paper 2, there are markbands and a markscheme.

The markbands are related to the assessment objectives established for the ESS course. The markschemes are specific to each examination.

External assessment details

The external assessment consists of two written papers and is worth 75% of the final assessment.

A calculator is required for both papers. Graphic display calculators (GDCs) are permitted (see the **Calculator** section on the OCC: **Diploma Programme > Mathematics > Calculators**).

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

Paper 1

Duration: 1 hour
Weighting: 25%
Marks: 40

- Students will be provided with a range of data in a variety of forms relating to a specific, previously unseen case study.
- Questions will be based on the analysis and evaluation of the data in the case study.
- All of the questions are compulsory.
- The questions test assessment objectives 1, 2 and 3.

Paper 2

Duration: 2 hours
Weighting 50%
Marks: 65

- Paper 2 consists of two sections, A and B.
- Section A (25 marks) is made up of short-answer and data-based questions.

- Section B (40 marks) requires students to answer two structured essay questions from a choice of four. Each question is worth 20 marks.
- The questions test assessment objectives 1, 2 and 3.

The final part of each essay in section B (9 marks) will be marked using markbands.

The aim is to find the descriptor that conveys most accurately the level attained by the student's work, using the best-fit model. A best-fit approach means that compensation will be made when a piece of work matches different aspects of a markband at different levels. The mark awarded will be one that most fairly reflects the balance of achievement against the markband. It is not necessary for every single aspect of a level descriptor to be met for that mark to be awarded.

It is recommended that the markbands be made available to students. The descriptors of these markbands are given below.

Marks	Level descriptor
0	The response does not reach a standard described by the descriptors below and is not relevant to the question.
1–3	The response contains: • minimal evidence of knowledge and understanding of ESS issues or concepts • fragmented knowledge statements poorly linked to the context of the question • some appropriate use of ESS terminology • no examples where required, or examples with insufficient explanation/relevance • superficial analysis that amounts to no more than a list of facts/ideas • judgments/conclusions that are vague or not supported by evidence/argument.
4–6	The response contains: • some evidence of sound knowledge and understanding of ESS issues and concepts • knowledge statements effectively linked to the context of the question • largely appropriate use of ESS terminology • some use of relevant examples where required, but with limited explanation • clear analysis that shows a degree of balance • some clear judgments/conclusions, supported by limited evidence/arguments.
7–9	The response contains: • substantial evidence of sound knowledge and understanding of ESS issues and concepts • a wide breadth of knowledge statements effectively linked with each other, and to the context of the question • consistently appropriate and precise use of ESS terminology • effective use of pertinent, well-explained examples, where required, showing some originality • thorough, well-balanced, insightful analysis • explicit judgments/conclusions that are well-supported by evidence/arguments and that include some critical reflection.

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.

The internal assessment task involves the completion of an individual investigation of an ESS research question that has been designed and implemented by the student. The investigation is submitted as a written report.

Note: Any investigation that is to be used for internal assessment should be specifically designed by the student to address the assessment criteria. Students must therefore be provided with a copy of the assessment criteria when the requirements of the investigation are explained to them.

If a student undertakes an extended essay, it must not be based on the research question of the ESS internal assessment.

Time allocation

The time allocation for the internal assessment activity is 10 hours.

Internal assessment is an integral part of the ESS course, contributing 25% 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 the work, as well as the total time allocated to carry out the investigation itself.

It is recommended that a total of approximately 10 hours of teaching time should be allocated to the task. This should include:

- time for the teacher to explain to students the requirements of the internal assessment
- time to refer to the *IB animal experimentation policy* if appropriate
- time for students to work on the internal assessment component and ask questions
- time for consultation between the teacher and each student
- time to review and monitor progress, and to check authenticity.

Guidance and authenticity

The report 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 *IB animal experimentation policy* document
- 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. As part of the learning process, teachers should read and give advice to students on one draft of the work. The teacher should provide oral or written advice on how the work could be improved, but not edit the draft. The next version handed to the teacher must be the final version for submission.

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.

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 academic misconduct. Each student must 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 it cannot be retracted. The requirement to confirm the authenticity of work applies to the work of all students, not just the sample work that will be submitted to the IB for the purpose of moderation. For further details refer to the IB publications *Academic honesty*, *The Diploma Programme: From principles into practice* and the relevant articles in *General regulations: Diploma Programme*.

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 analysis of the work by a web-based plagiarism detection service.

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

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 achievement levels, 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; the work may be close to achieving marks in the level above. Teachers should award the lower marks if the student's work demonstrates the qualities described to a lesser extent; the work may be close to achieving marks in the level below.
- Only whole numbers should be recorded; partial marks, (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 achievement level in relation to one criterion will not necessarily attain high achievement levels in relation to the other criteria. Similarly, a student who attains a low achievement level 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.

Internal assessment details

Duration: 10 hours
Weighting: 25%

- Individual investigation
- The investigation covers assessment objectives 1, 2, 3 and 4.

The individual investigation will be a single task taking about 10 hours. This time allocation includes time for consultation with the teacher to discuss the research question before the investigation is implemented, as well as time spent developing methodology and collecting data. It should be noted that during the consultation stage, the teacher provides advice to support the student but does not tell the student what to investigate or how to carry it out. Before the final submission, teachers should also provide feedback to the student on one draft of the written report.

The purpose of the internal assessment investigation is to focus on a particular aspect of an ESS issue and to apply the results to a broader environmental and/or societal context. The investigation is recorded as a written report.

The report should be 1,500 to 2,250 words long. Students should be made aware that external moderators will not read beyond 2,250 words and teachers should only mark up to this limit.

The internal assessment investigation consists of:

- identifying an ESS issue and focusing on one of its specific aspects
- developing methodologies to generate data that are analysed to produce knowledge and understanding of this focused aspect
- applying the outcomes of the focused investigation to provide understanding or solutions in the broader ESS context.

It is important to stress that the focused research question should arise from a broader area of environmental interest (the context), so that in conjunction with evaluating the research process and findings of their study, students will be able to discuss the extent to which their study applies to the environmental issue that interests them at a local, regional or global level (the application). This broader discussion does not have to be in direct relation to their findings, because the quality of data collected is not always good enough to use for this application, and this should not be an expectation. However, it is intended that this discussion will lead students to develop creative thinking and novel solutions, or to inform current political and management decisions relating to the issue. For example, if a student carries out a study on the impact of wind turbines that have been erected in the vicinity of their school, he or she may suggest solutions for the erection of wind turbines in other areas based on their findings.

This style of investigation reflects the interdisciplinary nature of the task.

The investigation produced should be commensurate with the level of the course and may draw on methodologies and analytical techniques used in either experimental or human science studies.

Methodologies

- Values and attitude surveys or questionnaires
- Interviews
- Issues-based inquiries to inform decision-making
- Observational fieldwork (natural experiments)
- Field manipulation experiments
- Ecosystem modelling (including mesocosms or bottle experiments)
- Laboratory work
- Models of sustainability
- Use of systems diagrams or other valid holistic modelling approaches
- Elements of environmental impact assessments
- Secondary demographic, development and environmental data
- Collection of both qualitative and quantitative data

Analytical techniques

- Estimations of NPP/GPP or NSP/GSP
- Application of descriptive statistics (measures of spread and average)
- Application of inferential statistics (testing of null hypotheses)
- Other complex calculations
- Cartographic analysis
- Use of spreadsheets or databases
- Detailed calculations of footprints (including ecological, carbon, water footprints)

Investigations may consist of appropriate qualitative work or quantitative work. In some cases these are descriptive approaches and may involve the collection of considerable qualitative data. In others, establishing cause and effect through inferential statistical analysis (a scientific approach) may be used. Exemplars to further assist teachers are presented in the *Environmental systems and societies teacher support material*.

Internal assessment criteria

For internal assessment, the following assessment criteria will be used.

Indentifying the context (CXT)	Planning (PLA)	Results, analysis and conclusion (RAC)	Discussion and evaluation (DEV)	Applications (APP)	Communication (COM)	Total
6 (20%)	6 (20%)	6 (20%)	6 (20%)	3 (10%)	3 (10%)	30 (100%)

Levels of performance are described using multiple indicators per level. In many cases the indicators occur together in a specific level, but not always. Also, not all indicators are always present. This means that a candidate can demonstrate performances that fit into different levels. To accommodate this, the IB assessment models use markbands and advise examiners and teachers to use a **best-fit approach** in deciding the appropriate mark for a particular criterion.

Teachers should read the guidance on using markbands shown above in the section called "Using assessment criteria for internal assessment" before starting to mark. It is also essential to be fully acquainted with the marking of the exemplars in the teacher support material. The precise meaning of the command terms used in the criteria can be found in the glossary of this subject guide.

Identifying the context (CXT) (6)

This criterion assesses the extent to which the student establishes and explores an environmental issue (either local or global) for an investigation and develops this to state a relevant and focused research question.

Achievement level	Descriptor
0	The student's report does not reach a standard described by any of the descriptors given below.
1–2	The student's report: • **states** a research question, but there is a lack of focus • **outlines** an environmental issue (either local or global) that is linked to the research question • **lists** connections between the environmental issue (either local or global) and the research question but there are significant omissions.
3–4	The student's report: • **states** a relevant research question • **outlines** an environmental issue (either local or global) that provides the context to the research question • **describes** connections between the environmental issue (either local or global) and the research question, but there are omissions.
5–6	The student's report: • **states** a relevant, coherent and focused research question • **discusses** a relevant environmental issue (either local or global) that provides the context for the research question • **explains** the connections between the environmental issue (either local or global) and the research question.

Planning (PLA) (6)

This criterion assesses the extent to which the student has developed appropriate methods to gather data that is relevant to the research question. This data could be primary or secondary, qualitative or quantitative, and may utilize techniques associated with both experimental or social science methods of inquiry. There is an assessment of safety, environmental and ethical considerations where applicable.

Achievement level	Descriptor
0	The student's report does not reach a standard described by any of the descriptors given below.
1–2	The student's report: • **designs** a method that is inappropriate because it will not allow for the collection of relevant data • **outlines** the choice of sampling strategy but with some errors and omissions • **lists** some risks and ethical considerations where applicable.
3–4	The student's report: • **designs** a repeatable* method appropriate to the research question but the method does not allow for the collection of sufficient relevant data • **describes** the choice of sampling strategy • **outlines** the risk assessment and ethical considerations where applicable.
5–6	The student's report: • **designs** a repeatable* method appropriate to the research question that allows for the collection of sufficient relevant data • **justifies** the choice of sampling strategy used • **describes** the risk assessment and ethical considerations where applicable.

*Repeatable, in this context, means that sufficient detail is provided for the reader to be able to replicate the data collection for another environment or society. It does **not** necessarily mean repeatable in the sense of replicating it under laboratory conditions to obtain a number of runs or repeats in which all the control variables are exactly the same.

Results, analysis and conclusion (RAC) (6)

This criterion assesses the extent to which the student has collected, recorded, processed and interpreted the data in ways that are relevant to the research question. The patterns in the data are correctly interpreted to reach a valid conclusion.

Achievement level	Descriptor
0	The student's report does not reach a standard described by any of the descriptors given below.
1–2	The student's report: • **constructs** some diagrams, charts or graphs of quantitative and/or qualitative data, but there are significant errors or omissions • **analyses** some of the data but there are significant errors and/or omissions • **states** a conclusion that is not supported by the data.
3–4	The student's report: • **constructs** diagrams, charts or graphs of quantitative and/or qualitative data that are appropriate but there are some omissions • **analyses** the data correctly but the analysis is incomplete • **interprets** some trends, patterns or relationships in the data so that a conclusion with some validity is deduced.
5–6	The student's report: • **constructs** diagrams, charts or graphs of all relevant quantitative and/or qualitative data appropriately • **analyses** the data correctly and completely so that all relevant patterns are displayed • **interprets** trends, patterns or relationships in the data, so that a valid conclusion to the research question is deduced.

Discussion and evaluation (DEV) (6)

This criterion assesses the extent to which the student discusses the conclusion in the context of the environmental issue, and carries out an evaluation of the investigation.

Achievement level	Descriptor
0	The student's report does not reach a standard described by any of the descriptors given below.
1–2	The student's report: • **describes** how some aspects of the conclusion are related to the environmental issue • **identifies** some strengths and weaknesses and limitations of the method • **suggests** superficial modifications and/or further areas of research.
3–4	The student's report: • **evaluates** the conclusion in the context of the environmental issue but there are omissions • **describes** some strengths, weaknesses and limitations within the method used • **suggests** modifications and further areas of research.
5–6	The student's report: • **evaluates** the conclusion in the context of the environmental issue • **discusses** strengths, weaknesses and limitations within the method used • **suggests** modifications addressing one or more significant weaknesses with large effect and further areas of research.

Applications (APP) (3)

This criterion assesses the extent to which the student identifies and evaluates one way to apply the outcomes of the investigation in relation to the broader environmental issue that was identified at the start of the project.

Achievement level	Descriptor
0	The student's report does not reach a standard described by any of the descriptors given below.
1	The student's report: • **states** one potential application and/or solution to the environmental issue that has been discussed in the context • **describes** some strengths, weaknesses and limitations of this solution.
2	The student's report: • **describes** one potential application and/or solution to the environmental issue that has been discussed in the context, based on the findings of the study, but the justification is weak or missing • **evaluates** some relevant strengths, weaknesses and limitations of this solution.
3	The student's report: • **justifies** one potential application and/or solution to the environmental issue that has been discussed in the context, based on the findings of the study • **evaluates** relevant strengths, weaknesses and limitations of this solution.

Communication (COM) (3)

This criterion assesses whether the report has been presented in a way that supports effective communication in terms of structure, coherence and clarity. The focus, process and outcomes of the report are all well presented.

Achievement level	Descriptor
0	The student's report does not reach a standard described by any of the descriptors given below.
1	• The investigation has limited structure and organization. • The report makes limited use of appropriate terminology and it is not concise. • The presentation of the report limits the reader's understanding.
2	• The report has structure and organization but this is not sustained throughout the report. • The report either makes use of appropriate terminology or is concise. • The report is mainly logical and coherent, but is difficult to follow in parts.
3	• The report is well structured and well organized. • The report makes consistent use of appropriate terminology and is concise. • The report is logical and coherent.

Please note that while the report would be expected to be correctly referenced, students will not be penalized under this criterion for a lack of bibliography or other means of citation. It is likely that such an omission would be treated under the IB Diploma Programme academic honesty policy.

Rationale for practical work

Although the requirements for internal assessment are centred on the investigation, students are required to take part in a practical programme of work that accounts for 20 hours of lesson time in addition to the 10 hours prescribed for the internal assessment task. The different types of practical activities that a student may engage in serve a variety of purposes, including:

- illustrating, teaching and reinforcing theoretical concepts
- developing an appreciation of the essential hands-on nature of laboratory and fieldwork
- developing an appreciation of the use of secondary data from databases
- developing an appreciation of the use of modelling
- developing an appreciation of the benefits and limitations of a range of investigative methodology.

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 class.

Syllabus coverage

The range of practical work 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, all students must participate in the internal assessment investigation.

Planning the practical scheme of work

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

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

Each scheme must include some complex tasks that make greater conceptual demands on 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 OCC to share ideas about possible practical activities by joining in the discussion forums and adding resources in the subject home page.

Flexibility

The practical programme is flexible enough to allow a wide variety of practical activities to be carried out. These could include:

- short labs or projects extending over several weeks
- computer simulations
- using databases for secondary data

- developing and using models
- data-gathering exercises such as questionnaires, user trials and surveys
- data-analysis exercises
- fieldwork.

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

Practical work documentation

Details of the practical scheme of work are recorded on the form *ES&S/PSOW* provided in the "Forms and coversheets" section of the *Handbook of procedures for the Diploma Programme*. A copy of the class *ES&S/PSOW* form must be included with any sample set sent to the IB for moderation. A template of this form is available on the OCC (**Diploma Programme > Sciences > Environmental systems and societies > Sample forms**).

Time allocation for practical work

The recommended teaching time for all Diploma Programme courses is 150 hours at SL. Students of ESS are required to spend a minimum of 30 hours on practical activities (excluding time spent writing up work). This time includes 10 hours for the internal assessment investigation. (Only 2–3 hours of investigative work can be carried out after the deadline for submitting work to the moderator and still be counted in the total number of hours for the practical scheme of work.)

Glossary of command terms

Command terms for environmental systems and societies

Students should be familiar with the following key terms and phrases used in examination questions, which are to be understood as described below. Although these terms will be used frequently in examination questions, other terms may be used to direct students to present an argument in a specific way.

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.
Interpret	Use knowledge and understanding to recognize trends and draw conclusions from given information.
Outline	Give a brief account or summary.

Objectives 3 and 4

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.
Demonstrate	Make clear by reasoning or evidence, illustrating with examples or practical application.
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.
Examine	Consider an argument or concept in a way that uncovers the assumptions and interrelationships of the issue.
Justify	Provide evidence to support or defend a choice, decision, strategy or course of action.
Predict	Give an expected result.
Sketch	Represent by means of a diagram or graph (labelled as appropriate). The sketch should give a general idea of the required shape or relationship, and should include relevant features.
Suggest	Propose a solution, hypothesis or other possible answer.
To what extent	Consider the merits or otherwise of an argument or concept. Opinions and conclusions should be presented clearly and supported with appropriate evidence and sound argument.

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