

Scheme of work

This scheme of work illustrates one approach to cover the topics in our A-level Environmental Science (7447) specification.

The order in which the topics are taught is up to the teacher and should be planned to match your students’ needs and schedules for fieldwork.

The scientific principles are clearly stated in the specification, but specific examples to be used are left to the discretion of individual teachers and students.

In addition to the factual content expanded below, opportunities should be taken to incorporate:

* opportunities for skills development and independent thinking
* research methods
* methodologies
* sampling techniques
* maths skills
* Working scientifically.

Prior knowledge: GCSE Combined Science or equivalent.

The living environment

Conditions for life on Earth

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| How the main conditions that allowed early life to develop on planet Earth came about. | Students should understand that the conditions that allowed life to develop on Earth were controlled by features such as position, rotation and mass of the earth. | Induction questions – discussion on such things as: why does the rock you live on support life?/so much life?/such diverse life?  It is important to reject the changes that will be covered in ‘How the presence of life on Earth has brought about change’, eg ‘oxygen to breathe’. Oxygen is the product of life, not a precursor of life.  Discussion:   * How did scientists monitor the conditions on Earth in the past? * How have these methods changed? * How have these methods changed the confidence in our conclusions? |  |
| How the presence of life on Earth has brought about change. | Students should understand that many of the features of Earth that support life now have been produced or controlled by life, especially oxygen, ozone, temperature control by CO2 and biogeochemical cycles. | Students could compare data for Earth with other planets to discuss why Earth is suitable for the development and continued support of life.  Students could construct a timeline to emphasise the changes that have occurred. | Cards of major events in Earth's history: formation, first life, oxygen in the atmosphere, first life on land, dinosaurs, humans etc. |

Conservation of biodiversity

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| The importance of the conservation of biodiversity. | Students should understand that the other species on Earth are vital for human survival in providing resources, maintaining life-support systems and supporting each other through inter-species relationships. | Group discussion:  How could you convince someone that the conservation of biodiversity is important?  Balloon debate:   * Allocate taxa to student groups eg giant panda, tiger, spiders, blue whale, sharks, wasps, golden eagle. * Not every taxon can survive. After group discussions, each group has to argue why their taxon should survive.   Quiz:   * Why has (taxon) proved to be important? * Where does (substance) come from?   Research activity:  Completion of table of examples of reasons why different taxa should be conserved eg:   * species/chemical/disease treated * species/physiological feature/medical knowledge gained * species/anatomical adaptation/biomimetics application.   Students could study a map of the distribution of Centres of diversity/CWR species and consider the current level of threat. | [General information](http://www.countrysideinfo.co.uk/biodvy.htm)  [Zoological Society of London – field Conservation](https://www.zsl.org/conservation)  [Bullfrog research and MRSA](http://news.bbc.co.uk/1/hi/scotland/edinburgh_and_east/6607531.stm)  [Squid nerve function research](https://www.sciencedaily.com/releases/2000/03/000302070536.htm)  [Wildlife farming](http://www.fao.org/docrep/W7540E/w7540e0h.htm)  [Biomimetics](https://news.mongabay.com/2005/07/biomimetics-technology-that-mimcs-nature/)  [Bionics](http://www.bionik.tu-berlin.de/institut/xstart.htm)  [Crop wild relatives](http://www.cwrdiversity.org/)  [New species](http://www.abc.net.au/science/news/stories/s143723.htm) |
| How humans influence biodiversity, with examples in a range of different contexts. | Students should understand that many human activities threaten the survival of wildlife on different spatial and temporal scales. | Class discussion on the different ways that wildlife is threatened:   * direct/indirect * deliberate/unintentional.   Emphasis should be placed on the impacts of consumer demand on indirect impacts: energy use, food production, consumer products, transport, waste disposal etc.  These issues are revisited throughout the other topics of the specification. | [Introduced species in the UK](http://www.introduced-species.co.uk/)  [Introduced species in the USA](https://www.invasive.org/) |
| Methods of conserving biodiversity: setting conservation priorities. | Students should understand how priorities are set, based on assessments of importance and threats. | Discussion/group research on IUCN categorisation of species into threat levels based on population status and changes.  The basic principles scientific research can be considered with reference to the collection of the data for selected species/taxa eg estimating the population of tigers/blue whales/elephants/bluefin tuna.  The criteria used for assessing importance should be considered, eg endemism, EDGE species, keystone species.  Completion of glossary of terms.  Completion of examples table.  Mindmap construction. | [World Conservation Union - IUCN](http://www.iucn.org/)  [Redlists of endangered species](http://www.iucnredlist.org/)  [IUCN area categories](https://www.iucn.org/theme/protected-areas/about/protected-areas-categories)  [UNEP World conservation monitoring centre](http://www.unep-wcmc.org/)  [WWF threatened species](http://www.worldwildlife.org/endangered/)  [EDGE species](http://www.edgeofexistence.org/species/) |
| Methods of conserving biodiversity: legislation/protocols. | Students should understand that different types of legislation and protocols protect wildlife and habitats in different ways:   * protection of species * protection of habitats * restrictions on damaging activities * control of trade * organisations/ agreements to enable exploitation but regulate it at a sustainable level. | The main features of the Wildlife and Countryside Act (1981) should be considered, such as brief details of:   * designation of protected areas eg SSSIs * protection of most bird species and their nests * protection of many mammal species * prohibition of uprooting wild plants * control of selected activities eg pesticide use in bat roosts.   Selected designated protected areas should be used to demonstrate how the restriction of activities and management agreements protect species and habitats, eg details/examples of SSSIs and Operations likely to disrupt.  The role of CITES should be considered, especially where in-situ conservation is difficult but the threat is caused by international trade.  The reasons for categorisation should be emphasised:   * appendix I – no trade * appendix II – trade restricted to areas where exploitation is not a threat.   The IWC, EU CFP and ITTO should be considered to identify procedures/problems and conflicting interests in organisations/agreements that aim to achieve sustainable exploitation. | [IWC](http://iwc.int/)  [ITTO](http://www.itto.int/)  [EU CFP](https://ec.europa.eu/fisheries/cfp_en)  [Map of protected areas](http://magic.defra.gov.uk/MagicMap.aspx)  [Protected species in woodlands](http://www.forestry.gov.uk/england-protectedspecies)  [SPAs in the UK](http://www.jncc.gov.uk/page-162)  [SACs](http://www.jncc.gov.uk/page-23)  [Ramsar](http://www.ramsar.org)  [Ramsar sites](http://www.jncc.gov.uk/page-161)  [UK habitats](http://jncc.defra.gov.uk/page-2)  [UK designated areas](http://www.naturalengland.org.uk/conservation/designated-areas/default.htm) |
| Methods of conserving biodiversity: captive breeding and release. | Students should understand the difference between in-situ and ex-situ conservation and the contribution each makes to the conservation of biodiversity.  Students should understand the role of captive breeding and release programmes in conservation and be able to use examples to illustrate the problems and methods used to increase success. | Research project – selection of examples to illustrate difficulties and methods to increase the success of:   * keeping species in captivity * breeding in captivity * release programmes.   Completion of table of problems, solutions, taxa to illustrate.  Mindmap construction. | [World Association of Zoos and Aquaria](http://www.waza.org/conservation/projects/index.php)  [International Species Information System (zoo species)](http://www.isis.org/CMSHOME/)  [Millennium seedbank](http://www.kew.org/wakehurst/attractions/millennium-seed-bank) |
| Methods of conserving biodiversity: habitat conservation. | Students should understand that habitat protection by legislation/protocols may prevent harm by human activities, but management of natural processes and conditions may be needed to maintain or enhance conditions.  Students should understand the decisions that are made when planning habitat creation. | Students can consider examples of the conservation of existing habitats, including habitat restoration and re-wilding.  Individual/group planning activity:  Planning a new nature reserve.   * The project can be introduced by looking at case-studies of previous habitat creation projects. * Students can be given a context within which to design a nature reserve eg a derelict gravel quarry. They should combine decisions on:   + habitat types   + habitat diversity, area, shape, age structure, biological corridors   + control of abiotic factors   + species to be introduced, encouraged and controlled   + the provision of facilities for humans need not be considered. * The emphasis should be on justifying each decision and explaining how it will achieve its aim. | [Global map of protected areas](https://www.protectedplanet.net/)  [Ramsar](http://www.ramsar.org/)  [Biomes](http://www.blueplanetbiomes.org/)  [Yellowstone park: re-wilding](http://www.yellowstonepark.com/wolf-reintroduction-changes-ecosystem/)  [Rewilding Europe](https://www.rewildingeurope.com/)  [Eradication of invasive species](http://diise.islandconservation.org/)  [Butterfly conservation: habitat creation](http://butterfly-conservation.org/4955/habitat-creation.html)  [BAM Nuttall: habitat creation](http://www.bamnuttall.co.uk/case-study/wallasea-island,17635745)  [Wallasea Wetlands Creation Project: habitat creation](http://www.abpmer.net/wallasea/)  [Example consultancy company: Thomson ecology](http://www.thomsonecology.com/habitat-creation-and-contracting)  [Example consultancy company: Keystone habitats](http://www.keyenv.co.uk/habitats/habitat-creation-and-restoration/) |
| Methods of conserving biodiversity: selected habitats:   * temperate broadleaf woodland * tropical rainforest * coral reefs * deep-water coral reefs * oceanic islands * mangroves * Antarctica. | Students should gain a knowledge of the key features of these selected habitats:   * controlling features * importance * threats * conservation efforts. | The emphasis should be placed on the ecological conditions that the habitats require and the species that are adapted to live there so that human influences can be understood: both positive and negative.  This should be used to consider how the habitats can be conserved.  Emphasis should be placed on the management of human activities to enable conservation to take place where human activities and wildlife habitats co-exist. | Temperate broadleaf woodland:  [The management of semi-natural woodlands](https://www.forestry.gov.uk/PDF/fcpg003.pdf/$FILE/fcpg003.pdf)  [Getting to know your wood and looking after it](https://www.forestry.gov.uk/pdf/so-you-own-a-woodland.pdf/$file/so-you-own-a-woodland.pdf)  [Managing your woodland for wildlife](http://www.woodlands.co.uk/owning-a-wood/managing-your-woodland-for-wildlife/managing-your-woodland-for-wildlife.pdf)  [An introduction to British woodlands and their management](http://www.countrysideinfo.co.uk/woodland_manage/intro.htm)  Tropical rainforests:  [Rainforest relief](http://www.rainforestrelief.org/What_to_Avoid_and_Alternatives.html)  [Rainforest facts](http://www.rain-tree.com/facts.htm)  [World Land Trust](http://www.worldlandtrust.org/)  Coral reefs:  [NOAA](http://www.coralreef.noaa.gov/)  [Marine conservation society](http://www.mcsuk.org/)  [Life-saving products from coral reefs](http://www.issues.org/18.3/p_bruckner.html)  [Great Barrier Reef](http://www.gbrmpa.gov.au/)  [Video: reef creation](https://jamesdysonaward.org/en-GB/projects/mars-modulare-artificial-reef-structure/?cookies=true)  [Deep-sea corals](http://ocean.si.edu/deep-sea-corals)  [Cold-water coral reefs](http://www.snh.gov.uk/about-scotlands-nature/species/invertebrates/marine-invertebrates/cold-water-coral/)  [Marine Reserves Coalition: cold water coral reefs](http://www.marinereservescoalition.org/conservation/uk/uk-marine-life/cold-water-coral-reefs/)  Oceanic islands:  [Native animals](http://www.doc.govt.nz/nature/native-animals/)  [Endemic species](http://sainthelenaisland.info/endemics.htm)  [Galapagos Conservation Trust](http://galapagosconservation.org.uk/programme_areas/conserving-endemic-species/)  [Top 10 endemic animals of Galapagos Islands](https://themysteriousworld.com/top-10-endemic-animals-of-galapagos-islands/)  Mangroves:  [National Ocean Service](http://oceanservice.noaa.gov/facts/mangroves.html)  [Ocean portal: mangroves](http://ocean.si.edu/mangroves)  Antarctica:  [British Antarctic survey](http://www.antarctica.ac.uk/)  [Cool Antarctica](http://www.coolantarctica.com/Antarctica%20fact%20file/science/human_impact_on_antarctica.htm) |
| Methods of conserving biodiversity: ecological monitoring in conservation planning. | Students should understand the importance of ecological research in collecting the data needed for conservation monitoring.  This can be the focus for developing an understanding of Research methods, Practical skill methodologies and Sampling techniques. | Students should consider the importance of a knowledge of population dynamics in planning conservation strategies:   * population size * population distribution * survival rate * age structure.   If these are not known, the level of threat and success of conservation efforts cannot be assessed.  Practical activities should be developed that are appropriate to the opportunities available to each school/college. These can be based on fieldwork, or a mix of fieldwork and lab-based activities.  Practical activities should not be carried out in isolation of the knowledge and understanding gained elsewhere in the course.  Where practical activities are not carried out, it is still possible to consider the methodologies used in planning.  The development of new and specialist techniques can also be considered, especially how this can help increase knowledge through more data, new types of data and increased accuracy. | [Satellite tracking](http://www.spacetoday.org/Satellites/Tracking/SatTracking.html)  [Ocearch](http://www.ocearch.org/)  Use of drones:  [Conservation drones](https://conservationdrones.org/)  [Drones for environmental protection and conservation](https://www.sensefly.com/applications/environmental-protection.html)  [A guide to using drones to study wildlife](https://theconversation.com/a-guide-to-using-drones-to-study-wildlife-first-do-no-harm-57069) |

Life processes in the biosphere and conservation planning

This topic can be covered earlier before ‘Habitat conservation’ so students can apply the terminology and principles involved when studying this section of the specification.

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| How adaptation to the environment affects species' habitat requirements and influences conservation decision-making. | Students should understand that species must be adapted to their habitat with conditions within their range of tolerance. Adaptation should be considered in terms of how habitat management can create conditions that increase the survival of desired species. | This topic can be dealt with in isolation, but may be covered more cohesively if it is incorporated into habitat management, habitat creation or the planning of a nature reserve project.  Students could consider a range of factors and how the control of each could benefit particular species.  Abiotic factors:   * light * water * nutrients * pH * abiotic habitat provision.   Biotic factors:   * food * control of predation * pollination * seed dispersal * biotic habitat provision * other inter-species relationships.   Completion of an examples table.  Abiotic or biotic factor/adaptation/species. |  |
| Terminology to describe the roles of living organisms in their habitats and their interactions with the physical environment. | Students should be able to accurately apply ecological terminology to environmental situations. | Completion of gapped paragraphs using appropriate terminology.  Mindmap construction. |  |
| The control of ecological succession in conserving habitats. | Students should understand that natural ecological succession changes conditions and produces climax communities that are controlled by the climate.  Human intervention creates plagioclimax communities that may support important wildlife communities. | Students could investigate plagioclimax habitats in the UK to find the human activities that produce them and the management methods that can be used to conserve them, eg:   * lowland heathland * upland moorland * chalk grassland * hay meadows * water meadows * coppiced woodland. |  |
| How population control and the management of desired and undesired species affects the conservation of biodiversity. | Students should understand that a knowledge of population dynamics and carrying capacity can help in conservation programmes.  The importance of r- and k-selection strategies should be understood in predicting species' vulnerability to exploitation/population losses. | Students could analyse population data to identify conservation threats. |  |

The physical environment

The atmosphere

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Introduction. | This could be a relatively high level introduction that would prepare students for more detailed coverage later. | Discussion: why is the atmosphere important for:   * life on Earth   natural physical processes   * human activities.   From their previous knowledge students could draw a scale diagram of the Earth and its atmosphere, with labeled layers plus other details if they wish.  The plenary discussion could focus on how thin the atmosphere is: with 99.9% of the atmospheric gases being in a layer less than 1% the diameter of the Earth. |  |
| How atmospheric energy processes involving ultra violet (UV), infrared (IR) and visible light in the stratosphere and troposphere affect life-support systems. | Students should understand the involvement of UV and IR radiation in the atmosphere in preparation for coverage of global climate change and ozone depletion. | Students could construct a diagram/graph to show details of:   * the structure of the atmosphere * the movements of UV and IR energy * processes: transmission, reflection, absorption * the new energy forms produced * the layers of the atmosphere involved.   Students could study a graph of the spectra of solar energy reaching Earth and energy emitted by the Earth. | [Atmosphere: composition, structure](http://www.srh.noaa.gov/jetstream/atmos/atmos_intro.html)  [Atmosphere: structure and processes](https://www.ucar.edu/learn/1.htm)  [NASA atmospheric energy processes](https://earthobservatory.nasa.gov/Features/EnergyBalance/page6.php)  [Clouds](https://earthobservatory.nasa.gov/Features/Clouds/)  [Solar and terrestrial spectra](https://acontent.atutorspaces.com/content/16/acf866/Items/x_s250_3_1_2_1.html) |
| Global climate change: how interconnected natural systems cause environmental change. | Students should understand the processes involved in the natural greenhouse effect and how greenhouse gas emissions caused by human actions enhance the greenhouse effect.  Covering the carbon cycle here may be useful, with additional details added as part of biogeochemical cycles.  Students should understand how global climate change impacts:   * sea level * wind patterns and ocean currents * cryosphere * climate processes.   Students should understand the difficulties in monitoring and predicting climate change.  Distinctions may be made between different types of difficulties, for example:   * lack of understanding of natural processes * inaccuracies or uncertainties in measurements * uncertainty of timescales * a lack of understanding of interaction of processes.   Students should understand how environmental change can produce negative and positive feedback mechanisms and that positive feedback may lead to tipping points and further self-perpetuating change.  Students should consider differences in carbon footprints in different countries and how more sustainable lifestyles may be developed. | Students could analyse data from authoritative organisations, for example NASA and the IPCC to consider the reliability of the evidence for climate change. The IPCC report explains their levels of confidence. This is a good opportunity to emphasise the methodologies of Research methods and the skills detailed in Appendix A.  Students could construct a table to show:   * named greenhouse gases * relative effects * human activities that cause their production * (space for) how emissions/levels can be reduced (to be completed later).   Students could create a mind map/spider diagram of the impacts of climate change on ocean currents, cryosphere and climatic processes.  Students could create case studies of named species that are/may be affected by specific ecological changes. The emphasis should be on specific terminology and details, not vague terms such as ‘can’t stand’ or ‘don’t like’.  Students should understand that detailed, comprehensive, scientific knowledge of the planet has developed relatively recently. Increasing knowledge of continental drift, ocean currents, ocean chemistry and atmospheric movements have been especially important.  Students could explain why it is difficult to make precise predictions of changes caused by climate change.  For example:  Bat populations may:   * increase because a warmer climate may:   + produce more nights that are warm enough to feed and fewer when they are inactive and must fast.   + increase insect survival and therefore food supplies for bats. * reduce because a warmer climate may:   + increase evaporation and rainy periods when bats cannot fly.   + increase stormy periods, when bats cannot fly.   Predicting the extent, locations and timing of these changes is difficult.  Students could construct flow diagrams for negative and positive feedback mechanisms.  Students could produce fact sheets to explain how tipping points increase the urgency of tackling climate change.  Students could create information sheets on low carbon lifestyles with details of:   * what I can do * what my community can do * what business can do * what our Government can do * what the global community can do.   A focus in these could be how the different method work, for example:   * emission reduction eg catalytic converters * changed activities eg using renewable energy instead of fossil fuels * post-release strategies eg carbon sequestration * alternative approaches eg geoengineering. | [NASA climate change](https://climate.nasa.gov/)  [NOAA carbon dioxide data](https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html)  [Climate and climate change data](http://www.exploratorium.edu/climate/index.html)  [IPCC climate change report](http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf)  [100 years of temperature anomolies](https://www.weforum.org/agenda/2017/08/global-warming-chart-100-years-in-35-seconds)  [Climate change data](https://climate.nasa.gov/vital-signs/global-temperature/)  [CO2 data](https://www.co2.earth/)  [Proxy data for palaeoclimates: What are “proxy” data?](https://www.ncdc.noaa.gov/news/what-are-proxy-data)  [Proxy data for palaeoclimates: Paleo proxy data: what is it?](http://iedro.org/articles/paleo-proxy-data/)  [Sea surface temperatures](https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature)  [Ocean sediments, climate history, how science works](https://www.youtube.com/watch?v=JH0_xC7q9tU&feature=youtu.be)  [Satellite data on climate](https://earth.nullschool.net/)  [Carbon sequestration: what is it?](https://www.undeerc.org/pcor/sequestration/whatissequestration.aspx)  [CCS: CO2 stored](http://www.co2stored.co.uk/home/about)  [CCS: what is it?](http://www.ccsassociation.org/what-is-ccs/)  [CSS: Around the world in 22 carbon capture projects](https://www.carbonbrief.org/around-the-world-in-22-carbon-capture-projects)  [Geoengineering](http://www.geoengineering.ox.ac.uk/what-is-geoengineering/what-is-geoengineering/) |
| Ozone depletion. | Students should understand the difficulties in verifying theories that may explain newly observed environmental phenomena.  Students should understand that the development of improved research techniques was essential in finding important information on:   * stratospheric chemistry * the atmosphere of Antarctica * the chemistry of CFCs and other ODSs.   Students should gain knowledge of the strategies to restore the ozone layer and an understanding of how effective they have been. | Students could consider the research leading to the Rowland-Molina hypothesis.   * What variables and conditions should be included to create a representative artificial atmosphere? * Can the Rowland-Molina hypothesis be applied to changes in the global atmosphere? * What extra information was needed, particularly to explain temporal and geographical differences in ozone depletion? * What new equipment/techniques were needed?   Students could apply the methodologies in Research methods to the issue of monitoring ozone depletion:   * sampling site location * timing * sample size * number of samples * standardisation of techniques * statistical significance.   Students could construct a table of the uses of CFCs to include:   * why they were used * how alternative materials/methods and disposal techniques have allowed CFC use to be phased out.   Students could create a two-column table to compare the effectiveness of attempts to control greenhouse gas emissions and CFCs. | [Impacts of ozone depletion](https://www.epa.gov/ozone-layer-protection/health-and-environmental-effects-ozone-layer-depletion)  [The story of ozone depletion](http://www.theozonehole.com/ozoneholehistory.htm)  [Ozone depletion: putting the pieces together](http://undsci.berkeley.edu/article/0_0_0/ozone_depletion_03) |

The hydrosphere

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| The impact of unsustainable exploitation. | Students should understand that water is an abundant, renewable resource but there are often problems of:   * local shortages or surpluses * temporal variations * contamination * unsustainable use rates. | Students could produce an annotated diagram of the hydrological cycle to show how human activities have changed water movements and altered dynamic equilibria.  Students could develop a series of brief case studies to illustrate each of the difficulties that cause unsustainable exploitation. | [Aquifer depletion: USGS](https://water.usgs.gov/edu/gwdepletion.html)  [Aquifer depletion: World Resources Institute](http://www.wri.org/blog/2015/06/nasa-satellite-data-help-show-where-groundwater-%E2%80%93-and-where-it-isn%E2%80%99t) |
| Analysis and evaluation of strategies for sustainable management. | Students should gain knowledge of the strategies and methods that have been used to maintain or increase water supplies. |  | [Water and sustainable development](http://www.un.org/waterforlifedecade/water_and_sustainable_development.shtml) |
| Ocean currents: the importance of thermohaline circulation in distributing heat and regulating climate. | Students should understand that, in addition to human uses of water, water is important in distributing heat around the planet by ocean currents. | While this topic can be covered here, it can also be incorporated into the coverage of changes in ocean currents in global climate change, especially changes to the North Atlantic Conveyor. |  |
| Increasing sustainability by treating contaminated water. | Students should gain knowledge of the natural and anthropogenic contaminants that make water unusable.  Students should understand the methods that can be used to treat water for public use. | Students could create an annotated flow diagram to show the order of processes to treat water.  A table could also be constructed to show:   * contaminants * sources * the names, purposes and principles of the treatment processes. | [WHO summary of treatment processes in LEDCs](http://www.who.int/water_sanitation_health/hygiene/om/linkingchap6.pdf)  [DEFRA summary](http://dwi.defra.gov.uk/private-water-supply/installations/Treatment-processes.pdf) |
| Increasing sustainability by economical use and the exploitation of new sources. | Students should gain knowledge of the strategies and methods that can be used to make better use of existing resources.  Students should know the features that are essential for the exploitation of each category of water resource. | Students could create a table of methods that can be used by industrial and domestic users to make more efficient use or re-use of water and to avoid contamination.  Students could create a table of the essential features of each type of water resource and why they are important. | [Conservation of water](http://www.greenhotelier.org/know-how-guides/water-management-and-responsibility-in-hotels/)  [Rivers – unsustainable use](https://www.internationalrivers.org/rivers-in-crisis)  [River transfer schemes](https://www.ice.org.uk/knowledge-and-resources/briefing-sheet/what-are-water-transfers-and-interconnections) |

Mineral resources

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Minerals extracted from the lithosphere. | Students should understand the importance of a wide range of mineral resources gained from the lithosphere. | Students could construct a table of the uses of a range of mineral resources.  A more issue-based approach is to create a table of human activities with details of the mineral resources that are needed and what would be more difficult/impossible if they were not available, for example, building construction, a mobile phone, a modern car.  Emphasis should be placed on the increasing reliance on resources, such as rare earth metals, that are much less abundant than traditional materials such as iron and copper. | [Mineral resources and their uses](http://scienceviews.com/geology/minerals.html) |
| Geological processes that produced localised concentrations of recoverable mineral deposits. | Students should understand that the average crustal abundance of all metals is too low for economic exploitation. Exploitation is only possible where geological processes have produced local concentrations. | Students could create a summary table of the resources that are produced by geological processes:   * hydrothermal deposits * metamorphic processes * proterozoic marine sediments * physical sediments: alluvial deposits, evaporates, secondary deposits * biological sediments. | [Ore formation processes](https://www.youtube.com/watch?v=agJB5H4Ao3w)  [Video animation of continental drift](https://www.youtube.com/watch?v=uLahVJNnoZ4) |
| Reserves, resource and Lasky’s principle. | Students should understand that the amount of every metal that is present in the lithosphere far exceeds realistic human demands, but only a proportion of it will ever be exploitable and even less can be exploited economically now.  Students should understand the differences between resource and reserves. Lasky’s principle should be used to show how a small drop in the ore purity that can be exploited dramatically increases reserves. | Students could construct an annotated block graph to illustrate the effect of technological developments, economics and ore purity on the resource and reserves. | Diagram from exam question: Legacy specification ENVS2, May 2011, question 8. |
| How a range of exploratory techniques work. | Students should understand that exploration for recoverable mineral deposits is expensive, so large-scale, cost-effective methods are used first, followed by more expensive methods in the most promising areas. | Students could create a table to give details of different exploratory techniques, their principles of operation and minerals or geological structures for which they collect information.  Details of locations/carrier systems may also be included:   * ground-based truck/drill * drones/aircraft * satellite. | [Applications of remote sensing techniques in mineral exploration](http://www.geol-amu.org/notes/b8-4-2.htm)  [Introduction to remote sensing and mineral exploration](http://investingnews.com/daily/resource-investing/precious-metals-investing/gold-investing/introduction-to-remote-sensing-and-mineral-exploration/)  [Seismic surveys](https://www.appea.com.au/oil-gas-explained/operation/seismic-surveys/)  [Drones in exploration and mining](https://www.sensefly.com/applications/mining.html) |
| Factors affecting mine viability. | Students should understand that, even if valuable materials have been found, a range of other factors must be favourable if the mine is to be viable. | Students could produce a table or annotated mine cross-section to show the other factors affecting mine viability. |  |
| Control of the environmental impacts of mineral exploitation. | Students should gain knowledge of the environmental impacts of the various methods of mineral exploitation:   * deep mining * open-cast mining * placer/alluvial deposits * seabed deposits: shallow/deep * extraction from seawater. | Students could construct a table of mining methods, environmental problems and control measures. | [Environmental effects of mining](https://www.environment.co.za/mining-2/effects-of-mining.html) |
| Strategies to secure future mineral supplies. | Students should understand that there are three main approaches to increasing future supplies:   * better exploration * increased efficiency of traditional methods: mining * new extraction methods eg: extraction from the deep seabed   + phytomining   + bioleaching   + adsorption from seawater. * end-of life strategies:   + recycling   + cradle to cradle design. | Students could individually research methods and produce brief summaries which can be used to make a class booklet.  Each student could produce a summary table of the methods and details of their uses/advantages/disadvantages.  Students could bring in examples of materials that illustrate the advantages/difficulties of recycling. | [Seabed mining](https://www.oceanfdn.org/resources/seabed-mining)  [What is seabed mining?](http://kasm.org.nz/seabed-mining/what-is-seabed-mining/)  [Seabed mining project](http://www.pewtrusts.org/en/projects/seabed-mining-project)  [World-first seabed mining project news story](http://www.abc.net.au/news/2016-12-10/world-first-png-seabed-mining-project-forges-ahead/8107934)  [Minerals from seawater](http://pubs.rsc.org/en/content/articlehtml/2017/ew/c6ew00268d)  [Bioleaching presentation](http://www.talvivaara.com/files/talvivaara/Presentations/Talvivaara_Technical_Seminar_London_May_Presentation.pdf)  [Bioleaching slideshare](https://www.slideshare.net/anassaleem95/bio-leaching)  [Phytomining](https://www.archimedesnz.com/phytomining) |

Biogeochemical cycles

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| The importance of biogeochemical cycles for living organisms. | Students should understand the importance of biogeochemical cycles in recycling elements within the physical environment and between the physical environment and the biosphere. | A class discussion could be used to refresh prior knowledge of biogeochemical cycles. The focus could be placed on:   * how processes link together to create cycles * the role of living organisms.   A broader discussion could take place around: what is your body made of and where have the atoms been before? |  |
| The carbon, nitrogen and phosphorus cycles including human influences. | Students should understand the natural processes involved in the C, N and P cycles, with emphasis on the roles of living organisms and the environmental conditions that control the rates of these processes.  Although they are called cycles, there are alternative pathways that atoms may take, with varying transfer rates.  Students should gain knowledge of the human activities that affect them and how these affect dynamic equilibria and the reservoirs of these elements.  The wider environmental effects of these changes should be emphasised, for example, on climate, biological productivity, species survival and distribution.  Strategies to achieve sustainable management should be analysed. | Students could annotate diagrams of the natural cycles to show how environmental conditions affect the cycles, for example, aerobic/anaerobic conditions, temperature, populations of organisms involved, pH, geological processes, soil moisture.  Students could calculate mean residence times for different reservoirs and the total time from one location to another, travelling by different routes.  Students could construct flow diagrams of the three cycles with annotations to show human actions and their impacts.  Students could construct a table to show details of human actions, impacts, methods to counteract the human actions and how these work. |  |

Soils

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| How human activities affect soil conditions and fertility. | Students should understand how human activities alter soil conditions and fertility. | Practical activities related to soil can support the theoretical coverage of this topic:   * bulk density * water content * organic matter content * biota * texture measurements and use of the soil triangle * pH measurement. | Appropriate practical equipment. |
| Causes of soil degradation and erosion. | Students should understand that soil erosion is naturally part of the dynamic equilibrium between erosion and formation.  Human activities may increase erosion and/or reduce the rate of formation, leading to a net loss of soil.  Students should have knowledge of the different types of erosion, the natural processes that reduce erosion and the human activities that increase erosion rates. | Students could compare maps of possible inter-connected factors:   * wind erosion * water erosion * rainfall * vegetation cover * land use * land use change. | [Soil erosion](http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm) |
| The Universal Soil Loss Equation (USLE). | Students should be able to use the USLE to estimate the erosion rates under different management practices. | USLE calculations.  Students could carry out calculations to see how changes in farming practices can reduce soil erosion. | [USLE](http://www.omafra.gov.on.ca/english/engineer/facts/12-051.htm) |
| The environmental impacts of soil erosion. | Students should understand the impacts of soil erosion on natural environments and human activities. | Students could identify other topic areas where soil erosion is relevant, with guidance if necessary, for example:   * natural habitats, eg coral reefs, rivers, lakes * water supplies * water supply reservoirs * HEP reservoirs * irrigation systems * agricultural productivity. |  |
| Soil management strategies to increase sustainability. | Students should gain knowledge of the methods that can be used to reduce soil erosion. | Students could construct a table with details of soil management strategies and how they work. |  |

Energy resources

The importance of energy supplies in the development of society

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| The relationship between energy supplies and the level of development of society. | Students should understand how the amount and types of available energy resources affects the rate and direction of development of society. | Group or class discussions could focus on the following:  How does energy availability vary between different countries?  How did the availability of energy resources affect the development of industrial society?  How does energy make human actions possible/easier/quicker/more efficient?  How would energy shortages affect our lives?  If energy availability declined a lot what would you give up first/last?  How would a change in the type of energy resource available affect the development of society? This leads into later discussions on post-fossil fuel societies.  These questions can be considered with reference to different industries:   * Agriculture * Fishing * Industry – extraction, processing, services * Water supplies * Transport * Domestic life.   Emphasis could be placed on how the reliance on energy increases, for example:   * increased mechanisation in agriculture * the transition from locally grown to imported food * commuting longer distances to work * fishing in more distant fishing grounds   Students could collect details of the origins of the foods they have at home/are on sale in a supermarket. | US Aid  [The role of energy in development](http://www.energytoolbox.org/library/infra2007/references/energy/The_Role_of_Energy_in_Development.pdf)  [The role of energy in economic growth](http://www.resilience.org/stories/2011-10-20/role-energy-economic-growth/)  [Energy and society](https://cleanet.org/clean/literacy/energy7.html)  [World economic forum](http://reports.weforum.org/energy-for-economic-growth-energy-vision-update-2012/)  Oil price  [How energy availability affects economies and societies](http://oilprice.com/Energy/Energy-General/How-Energy-Availability-Affects-Economies-and-Societies.html) |

The impact of the features of energy resources on their use

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Properties of energy resources, effect on its use and impact on societies development. | Students should understand how the properties of energy resources affect their uses and the development of the societies that rely on them. | Students could construct a table of energy resources and the properties that affect their use.  A distinction can be made between properties that are advantageous, such as high energy density and renewability, compared with disadvantageous ones such as intermittency  Key properties include:   * abundance * energy density * locational constraints * intermittency * need for energy conversions * renewability * environmental impacts * need for further technological developments.   These issues can be discussed with reference to the usefulness of renewable energy and nuclear power as replacements for fossil fuels.  These issues are developed throughout the topic of energy and in other topics, such as pollution and sustainability.  Quantitative data can be used to compare energy resources and develop independent thinking skills.  Students should gain an understanding of how different units are used to quantify energy resources, use and power. | These sources of information can be used throughout the energy topic.  [BP statistical review of world energy](http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html)  [International Energy Agency](https://www.iea.org/statistics/)  [World Energy Council](https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Scenarios-2016_Full-Report.pdf) |

The sustainability of current energy resource exploitation

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Introduction. | This can be an introductory topic to provide context to the coverage of the individual energy resources.  Students should develop an understanding of the different ways in which current energy use is not sustainable:   * environmental impacts * depletion of reserves.   Students should gain an understanding of the scales of problems caused by different resources and the difference between very obvious but minor problems and less obvious but serious problems.  Emphasis should be placed on the difference between direct impacts, such as pollution caused by fuel combustion, and indirect impacts, such as those caused by embodied energy and carbon footprints. | Students could work in groups to research the sustainability of different energy resources, possibly giving brief presentations.  Some issues are developed further in other topics such as pollution and sustainability. | [Renewability and sustainability](http://energyeducation.ca/encyclopedia/Renewable_and_sustainable_energy)  [Union of Concerned Scientists](http://www.ucsusa.org/clean-energy/renewable-energy/public-benefits-of-renewable-power#.WbprzbKGPIU)  [World Nuclear Association](http://www.world-nuclear.org/information-library/energy-and-the-environment/sustainable-energy.aspx) |

Strategies to secure future energy supplies

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Evaluation of improved extraction/harnessing/processing technologies related to a range of energy technologies. | Students should re-visit their prior knowledge of energy resources as the basis of understanding the contribution they can make to future supplies.  Emphasis should be placed on how improvements to the technologies can reduce the problems caused by use of a resource, such as pollution, or reduce a limitation such as intermittency.  The focus should be placed on the current contributions that each resource makes and how this may change in and future. | Students could construct a series of tables or information leaflets to highlight the issues related to each energy resource.  Key issues to consider include:   * the properties of the resources * improved extraction/harnessing technologies * technologies to reduce environmental impacts * new energy storage technologies. | [Science daily](https://www.sciencedaily.com/news/matter_energy/fossil_fuels/)  [Clean coal](http://www.world-nuclear.org/information-library/energy-and-the-environment/clean-coal-technologies.aspx)  [World Coal Association](https://www.worldcoal.org/reducing-co2-emissions/high-efficiency-low-emission-coal)  [The Carbon Capture and Storage Association](http://www.ccsassociation.org/)  [CCS in the North Sea](https://www.statoil.com/en/news/co2-ncs.html)  [World Oil](http://www.worldoil.com/)  [Natural Gas](http://naturalgas.org/)  [Alternative energy news](http://www.alternative-energy-news.info/)  [Renewable Energy World](http://www.renewableenergyworld.com/index.html)  [Scottish Renewables](http://www.scottishrenewables.com/sectors/renewables-in-numbers/)  [Renewable UK](http://www.renewableuk.com/)  [Wave power](http://wavenet.cefas.co.uk/Map)  [Plutonium/fast neutron reactors](http://www.world-nuclear.org/information-library/current-and-future-generation/fast-neutron-reactors.aspx)  [Thorium reactors](http://www.world-nuclear.org/information-library/current-and-future-generation/thorium.aspx)  [Nuclear fusion](https://www.sciencealert.com/the-uk-has-just-switch-on-its-tokamak-nuclear-fusion-reactor)  [Tokamak energy](https://www.sciencealert.com/the-uk-has-just-switch-on-its-tokamak-nuclear-fusion-reactor)  [ITER](https://www.iter.org/)  [HiPER](http://www.hiper-laser.org/)  [Energy storage technologies](http://www.ucsusa.org/clean-energy/how-energy-storage-works#.WbqCM7KGPIU)  [BM reports](https://bmreports.com/bmrs/?q=eds/main) (scroll down to Generation by fuel type)  [National Grid data](http://www.gridwatch.templar.co.uk/)  [National Grid live status](http://nationalgrid.stephenmorley.org/)  [German grid data](https://www.energy-charts.de/power.htm) |

New energy conservation technologies

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Energy conservation development. | Students should gain an understanding of how improved and new technologies can reduce energy use.  The development of improved and new technologies should be emphasised. | Students could review their existing knowledge of energy conservation methods, focusing of the scientific principles by which they work. They could then consider how improvements have increased their efficiencies.  Students could review new developments in conservation methods and the contribution they can make to reducing energy demand.  Students could identify the energy conserved by strategies with other primary aims, for example, extending the lifespan of appliances, increasing recyclability and reducing the mass of items.  A quantitative approach could be used to compare the energy usage of different appliances. | [Earth sheltered buildings](https://www.niftyhomestead.com/blog/earth-sheltered-homes/)  [V2G](http://www.v2g.co.uk/) (vehicle to grid)  [P2G](http://www.itm-power.com/sectors/power-to-gas-energy-storage) (power to gas)  [Power to gas: the other storage solution](https://unearthed.greenpeace.org/2016/09/02/power-gas-storage-solution/) |

Pollution

The properties of pollutants

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Pollutant properties. | Students should develop a knowledge and understanding of how the properties of a pollutant make it cause harm.  Students should understand that the development of our understanding of natural systems and improvements in monitoring technologies have made it much easier to predict and prevent pollution. | Group/class discussions could focus on prior knowledge of pollutants and why they caused problems. The explanations can be clarified by defining the key properties of pollutants.  Students could be given information about past pollution events, but without the knowledge that was eventually gained of the causes, for example:   * aquatic insect larvae started to disappear * the fish died * top predators became rarer * bird breeding became less successful * orca breeding declined.   Students ask questions to try and find the causes of these events.  Although the teacher provides answers, the students must consider how the information would have been gained. Vague or simplistic questions would not be allowed, such as:   * Is it acid rain? * What chemicals were found? | [US Government EPA index](https://www.epa.gov/environmental-topics/z-index) |

How environmental features affect the severity of pollution

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Factors that affect dispersal.  Environmental factors that affect rates of degradation. | Students should understand that environmental conditions affect the severity of pollution:   * dispersal by winds and water * temperature * light * aerobic/anaerobic conditions * pH * the presence of other chemicals * temperature inversions * presence of adsorbent materials.   These factors can affect dispersal, degradation and chemical transformations to secondary pollutants. | Case studies of specific pollutants could be analysed to consider why pollution in particular locations was more severe than in other areas.  This may be done as a separate topic before covering the individual pollutants in detail or may be incorporated into the individual pollutant coverage.  This activity could be combined with the activity in the previous section. |  |

Strategies to control pollutants based on their properties and features of the environment

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Strategies to control pollutants. | Students should understand that controlling pollutants involves strategies to predict their behaviour:   * critical pathway analysis * critical group monitoring * decision-making over the timing and location of discharges. | Students could work in groups to consider individual case studies of pollutants to illustrate these principles. |  |
| An approach to creating strategies to control different types of pollution. | A general approach can be taken to each pollutant:   * sources * effects * controls.   Specific approaches can be taken for pollutants which:   * are well understood, where a retrospective approach can be taken * are not well understood, where more research is needed * require the development of new control technologies.   The general approach should use past knowledge of pollutants, properties and environmental features to predict the behaviour of new potential pollutants. | Students could construct a table/mind map for each pollutant to summarise the main features of each pollutant.  Students could work in groups, each having a different scenario of a potential pollutant. Their task is to identify the extra knowledge that is needed to identify any harm that may be caused.  They should apply the skills identified in Appendix A: Working Scientifically. | [Atmospheric pollution in cities](http://aqicn.org/city/)  [Oxides of nitrogen](http://www.apis.ac.uk/overview/pollutants/overview_NOx.htm)  [Thermal pollution](http://www.pollutionissues.com/Te-Un/Thermal-Pollution.html)  [Oil pollution](http://worldoceanreview.com/en/wor-1/pollution/oil/)  [How oil harms animals and plants](https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/how-oil-harms-animals-and-plants.html)  [Pesticides](http://www.fao.org/docrep/w2598e/w2598e07.htm)  [Use of pesticides in agriculture](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2984095/)  [Inorganic nutrient pollution](https://www.epa.gov/nutrientpollution/problem)  [Nutrient pollution](https://oceanservice.noaa.gov/facts/nutpollution.html)  [Acid mine drainage](http://www.miningfacts.org/Environment/What-is-acid-rock-drainage/)  [Heavy metals](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4144270/)  [Noise](http://www.boeing.com/commercial/noise/list.page)  [Noise map](http://www.extrium.co.uk/noiseviewer.html)  [Radioactive waste](https://www.cefas.co.uk/publications/posters/31110web.pdf)  [Radioactivity in food and environment](https://www.food.gov.uk/sites/default/files/rife-2015.pdf)  [Transfer of radioactivity](http://www.rsc.org/images/choon-yee-tan_tcm18-223099.pdf)  [Waste](https://dounreay.com/about/decommissioning-projects/waste/)  [OSPAR Commission](https://www.ospar.org/site/assets/files/1173/factsheet_historic_dumping_final.pdf) |
|  |  | A more detailed approach involves scenarios based on real pollutants, but the real-life events are not revealed until the students have finished their task to assess whether they predicted the real-life events, for example:   * a pesticide (organochlorines/organophosphates/ neonicotinoids) * a fuel additive (tetra ethyl lead) * an industrial solvent (PCBs) * nuclear waste discharges (Sellafield/Dounreay) * inert construction material (asbestos) * any situation involving the production of secondary pollutants. | Resources of real data to give context to the theoretical scenario:   * map * wind patterns * water currents * human population * geology * land uses. |
| The use of scientific knowledge to develop new pollution control technologies. | Students should understand that pollution control is a rapidly developing area with new technologies for the monitoring and control of pollution. | Students could construct a table of control technologies and details, with a range of methods to illustrate technologies that:   * reduce emissions * remediate contaminated sites * monitor pollutants * reduce pollution in other ways eg ship tracking and navigation. | [NASA](https://www.nasa.gov/feature/langley/the-future-of-monitoring-air-quality-from-space)  [Atmospheric monitoring with satellites](https://earth.nullschool.net/)  [Ship tracking](https://www.marinetraffic.com/en/ais/home/centerx:3.1/centery:48.0/zoom:5) |

Biological resources

Agriculture

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Agroecosystems. | Students should develop a knowledge and understanding of the different aspects of agroecosystems and how human developments have increased food production.  A continuing focus should be consideration of the sustainability of food production and how this may be increased. | Students could use their knowledge of ecology to discuss how farming allows human populations to increase by controlling food as a density dependent factor. |  |
| The selection of species. | Students should understand that species selection depends upon suitable environmental conditions that are within the species’ range of tolerance. However, control of the environment and the genetic composition of the species can allow them to survive in areas where this would not naturally be possible and produce higher yields or better products. | Students could discuss the requirements of selected crops and livestock species and consider their global/regional distribution, for example:   * rice * wheat * maize * potatoes * bananas * apples * cattle * sheep. | Maps of the distribution of food species.  [Crop distribution](https://www.brookings.edu/blog/future-development/2016/03/21/where-does-the-worlds-food-grow/)  [Crop selection](http://www.sswm.info/category/implementation-tools/water-sources/hardware/conservation-soil-moisture/crop-selection)  [Plant classification](http://www.cropsreview.com/plant-classification.html) |
| The biotic factors that affect productivity. | Students need to understand how the control of predators and competitors of food species increases the amount of food in the human food chain, as well as the support of species that aid food production, such as pollinators and soil biota. | Students could discuss the advantages and disadvantages of different pest control methods.  More general limitations could be considered, such as the range of pests to which the methods apply, for example, the limited applications of sterile male techniques or pheromone traps. | [Biological pest control](http://www.biocomes.eu/biological-control/biological-control-examples/)  [Integrated pest management](https://www.epa.gov/safepestcontrol/integrated-pest-management-ipm-principles) |
| Using agrochemicals to control pests and pathogens. | Students should understand the advantages and disadvantages of using agrochemicals to control pests and pathogens. | Students could discuss the benefits of reducing or stopping the use of antibiotics as growth promoters and pesticides, compared with the difficulties in doing so.  Students could construct a table to compare the properties, advantages and disadvantages of different insecticide groups:   * organochlorines * organophosphates * pyrethroids * neonicotinoids. | [Antibiotic – NHS report](https://www.nhs.uk/news/medication/antibiotic-use-in-farm-animals-threatens-human-health/#what-does-the-report-say)  Information sheets for each group. |
| The abiotic factors that affect productivity. | Students should understand that the control of abiotic limiting factors increases food production. | The class could be divided up with individuals/groups each being allocated different abiotic factors. They should produce a brief information sheet on:   * its importance * specific crops/livestock affected * how the factor can be controlled. | [Fertiliser use by crops](ftp://ftp.fao.org/agl/agll/docs/fpnb17.pdf) |
| Manipulation of food species to increase productivity: the advantages and disadvantages of the methods that are available to improve crop and livestock gene pools. | Students should understand that agricultural production can be controlled by changing the gene pool.  They should gain an understanding of the advantages and disadvantages of the different methods of changing the gene pool. | Students could consider case studies to illustrate extremes of these principles, for example:   * features of different crop varieties * features of different livestock breeds.   The Green revolution could be used as an example of increased food output achieved by a breeding programme. The social, economic and environmental issues related to this could be considered.  Students could discuss the concerns of some over GM and the scientific evidence to support/dismiss these concerns. |  |
| Agricultural energetics and population density/uniformity. | Students should understand that the energy inputs, intensity of production and population density affect productivity. | Students could use case studies to consider the impact on productivity of the following:   * intensive/extensive systems * monoculture/polyculture. |  |
| Environmental impacts of agriculture. | Students should understand how agricultural practices affect the environment and sustainability. These issues can be re-visited and developed when considering agricultural sustainability. | Students could review previous studies of other topics where agriculture has been considered, for example:   * conservation of biodiversity * the hydrosphere * biogeochemical cycles * energy resources * pollution.   Students could identify the scales over which the impacts occur:   * on the farm * local * regional * global. |  |
| Social/economic/ political factors which influence agricultural production. | Students should understand that agriculture is affected by social/economic and political factors that affect which foods are produced, where they are produced and the methods used. | Students could consider a range of case studies to consider the impacts of social/economic and political factors, for example:   * production subsidies * reduced transport costs * different labour costs * ability to afford machinery * demand for organic/Fairtrade/local food * cultural preferences * religious factors. |  |
| Strategies to increase the sustainability of agriculture. | Students should gain knowledge of the methods that may be used to reduce environmental impacts, use renewable resources and therefore increase sustainability. | A class/group discussion could focus on the associated changes that would be needed to make the desired improvements in sustainability, for example, changes in:   * consumer preferences * energy inputs * nutrient management * control of soil erosion * pest control * irrigation and water management. | [FAO: Systems at risk](http://www.fao.org/docrep/017/i1688e/i1688e.pdf)  [Union of Concerned Scientists](http://www.ucsusa.org/food-agriculture/advance-sustainable-agriculture/what-is-sustainable-agriculture#.Wbut_7KGPIU)  [OECD – video on water and agriculture](https://www.youtube.com/watch?v=TbCwZyJEb8Y) |

Aquatic food production systems

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Marine productivity. | Students should understand that marine productivity is very variable and is controlled by light levels and nutrient supplies.  Students should note that the temperature is not a major controlling factor.  The low productivity of open oceans should be considered to help explain why it is difficult to find new unexploited fisheries. | Students could look at a world map of seasonal changes in marine productivity to identify the environmental features that control light and nutrient supplies.  Graphs of seasonal changes in productivity and related abiotic factors can extend the study.  Students could re-visit their understanding of coral nutrition and symbiosis to explain why such a biodiverse ecosystem can exist where nutrient levels are usually low. | Maps and graphs on productivity and related factors.  [Upwellings](https://oceanservice.noaa.gov/facts/upwelling.html) |
| Fishing. | Students should gain an understanding of the methods used to catch marine species in preparation for understanding the environmental impacts of fishing and how sustainable exploitation may be achieved.  Students should gain knowledge of the environmental impacts of fishing. This should include coverage of how habitat and food chain impacts can affect future catches. | Students could produce a table or information sheets on the key features of the main fishing methods, for example:  Features   * catch effectiveness * catch selectivity * energy inputs * environmental impacts * overfishing * by-catch * ghost fishing * habitat damage – seabed * food web impacts.   Methods   * pelagic and demersal trawling * purse seining * drift netting * long lining * shellfish traps. | [Methods](http://goodfishbadfish.com.au/?page_id=31)  [Impacts of fishing methods](http://www.mcsuk.org/downloads/fisheries/Most%20sustainable%20fishing%20methods.pdf)  [Marine Stewardship Council](https://www.msc.org/)  [EU fisheries controls](https://ec.europa.eu/fisheries/cfp/aquaculture/aquaculture_methods_en) |
| Population estimates. | The methods of estimating fish populations and maximum yield. | Students should review their knowledge of population dynamics and population regulation to suggest the information needed to monitor fish population size, biomass and changes in these.  They could also suggest why it is more difficult to monitor fish populations than many terrestrial species. |  |
| Reducing environmental impact of fishing. | Students should develop an understanding of how the environmental impacts of fishing can be reduced. |  |  |
| Aquaculture. | Students should gain an understanding of extensive and intensive fishing methods and how biotic and abiotic conditions are controlled to improve production. | Students could compare the relationships between:  Hunting and agriculture  and  Fishing and aquaculture. | [Methods](http://goodfishbadfish.com.au/?page_id=33)  [FAO review](http://www.fao.org/docrep/t8598e/t8598e05.htm)  [EU summary](https://ec.europa.eu/fisheries/cfp/aquaculture/aquaculture_methods_en)  [Marine Harvest (aquaculture company)](http://marineharvest.com/)  [Aquaculture Stewardship Council](https://www.asc-aqua.org/) |
| Potential of aquaculture. | Students should gain an understanding of the extent to which aquaculture can replace fishing. | Students could be given information about aquaculture to assess the similarities/differences with agriculture, for example:   * trophic level of the food product * most farmed fish are carnivores * fish are ‘cold blooded’ * the extent of suitable sites * differences in food conversion rates * use of agrochemicals. | Data on the quantity of food produced by fishing/aquaculture in recent decades. |
| Reducing environmental impact of aquaculture. | Students should know how new and improved methods can be used to reduce the environmental impact of aquaculture. | Students could research aquaculture case studies to find specific examples of impact reduction. | NOAA  [Environmental impacts](http://www.eolss.net/sample-chapters/c10/E5-05-04-09.pdf)  [Talkingfish.org](https://www.talkingfish.org/2012/did-you-know/all-about-aquaculture-environmental-risks-and-benefits)  [Marine Harvest annual reports](http://marineharvest.com/investor/annual-reports/) |

Forest resources

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| The resources and life-support services gained from forests. | Students should gain knowledge of the wide range of resources gained from forests and the life-support systems they maintain. | Group discussions on the benefits gained from forests and whether they work on local, regional or global scales. | [EU forest strategy](https://ec.europa.eu/agriculture/forest_en)  [FAO forest resources](http://www.fao.org/docrep/w7718e/w7718e06.htm) |
| The relationship between forest productivity and biodiversity. | Students should understand that the methods used to increase productivity often reduce biodiversity. | Students could review their knowledge of woodland management for wildlife conservation and compare them with the methods used for commercial forestry. | [Forest monocultures](https://news.mongabay.com/2008/09/monoculture-tree-plantations-are-green-deserts-not-forests-say-activists/) |
| Deforestation. | Students should understand the different causes of deforestation, distinguishing between over-exploitation and changing land uses. | Students could consider different examples of deforestation to compare benefits and problems for different stakeholder groups over varying timescales, for example:   * Short-term benefits of logging compared with long-term problems of soil degradation. * Immediate benefits of conversion to farmland compared with long-term benefits of medicinal discoveries. | Information sheets on deforestation case studies. |
| Sustainable forest management. | Students should understand the principles that can be used to increase the sustainability of forest management. |  | [Forest Stewardship Council](http://www.fsc-uk.org/en-uk/get-involved/teachers/education) |

Sustainability

Dynamic equilibria

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Dynamic equilibria | Students should understand that many natural processes are controlled and stabilised by dynamic equilibria. | Students could discuss the situations where dynamic equilibria create stability, for example:   * energy flow in the atmosphere * hydrological cycle * biogeochemical cycles * population regulation.   The importance of negative feedback in maintaining stability should be considered. Students could identify issues in which human actions create positive feedback and go past equilibrium tipping points.  Students could discuss the stability created in diverse systems and consider how this could be applied to human systems. |  |

Energy

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Energy resources which drive natural systems. | Students should gain knowledge of how natural systems are generally driven by low energy-density renewable energy resources at low temperatures. | Students could discuss how the non-renewable, high energy-density energy resources used by humans can be replaced and the new technologies that must be developed, for example:   * energy storage * energy transport * biotechnology for manufacture. |  |

Material cycles

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Movement of materials in natural systems. | Students should understand that materials in natural systems usually move through inter-connected processes which create cycles that re-use the materials. Human systems are often linear. | Students could discuss the human activities that could be modified to increase the use of cyclical systems. This could include:   * designs that increase recyclability * changes in materials used to make re-use easier. * reducing the toxicity of wastes. |  |

The circular economy

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Principles and importance of circular economy. | Students should understand the principles of the circular economy and its importance in developing more sustainable lifestyles. | Students could consider the principles of the Circular Economy through a consideration of case studies at different scales, for example:   * international organisations * Governments * commercial organisations * community groups * individuals. | [Ellen Macarthur Foundation](https://www.ellenmacarthurfoundation.org/circular-economy)  [Global Footprint Network](http://www.footprintnetwork.org/our-work/)  [Living planet report](http://wwf.panda.org/about_our_earth/all_publications/lpr_2016/)  [Airbus](http://company.airbus.com/responsibility/Environment-and-Sustainability.html)  [Boeing](http://www.boeing.com/principles/environment/index.page)  [Maersk](https://www.maersk.com/en/business/sustainability/risk/the-environment)  [Mazda](http://www.mazda.com/en/csr/environment/)  [Fiat](https://www.fcagroup.com/en-US/sustainability/environment/Pages/default.aspx)  [WWF Living Planet Centre](http://assets.wwf.org.uk/custom/stories/lpc/?_ga=2.78356948.1745989432.1505556136-1863894525.1505556136)  [High voltage DC grids](http://new.abb.com/about/hvdc-grid)  [Mediterranean solar plan](https://www.plansolairemediterraneen.org/)  <https://www.plansolairemediterraneen.org/> |

Research methods

Consideration of Research methods should not be restricted to the occasions when students have opportunities for first-hand practical activities. The principles should be applied throughout the course whenever data and validity are an issue, such as climate change, ozone depletion, aquifer depletion, mineral reserves and soil erosion.

Whenever quantitative data is involved, or conclusions based on it, students should be encouraged to consider questions such as:

* is this information reliable/representative/statistically significant?
* who collected it?
* where/when/how was it collected?
* how large was the data set?

Students should be encouraged to consider how changes in research methods have increased the validity of the conclusions that can be reached.

For example, the original conclusion that the currents in the North Atlantic had weakened by 30% was based on 5 measurements spread over 40 years. There are now (2017) nearly 3800 Argo floats continually collecting data throughout the world’s oceans. Similarly, a satellite in low polar orbit can survey the entire Earth’s surface in about 15 days.

The variations in species, locations and other environmental variables means that there is rarely a single method that can be used in all situations, even ones that seem very similar. For example, there is no single method for collecting insects, estimating mammal populations, identifying plants or recording humidity. Students should understand the conditions of the context of the study, be able to select appropriate techniques, modify them where necessary and understand their limitations.

The value of preliminary studies in testing a technique should be understood.

The opportunities for practical activities and the development of associated skills vary between schools and colleges, so each can develop its own activities with a combination of fieldwork and lab-based activities. Some activities may combine a range of methodologies and techniques, while others may focus on a single issue.

Scientific methodologies

Students must develop an understanding that the sampling techniques used in a study will only give valid results if the methodologies used in planning the study are appropriate. Coverage of the methodologies of random sampling, systematic sampling and number of samples should include the decision making in planning the activities as required in Me1, Me 2, Me 3 in Appendix A: Working Scientifically.

In addition to the data that students collect, their understanding can be reinforced using data from secondary sources, including data developed specifically to illustrate key principles.

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Sample location: random sampling. | Students should understand that using random sample location avoids the bias caused by deliberately selecting sites. | A random number generator or random number table of appropriate number range could be used to locate sampling site coordinates in a study area. | Random number table.  Tape measures. |
| Sample location: systematic sampling. | Students should understand that samples may be collected at fixed intervals along a line or across an area. | Students could construct line and belt transects along an environmental gradient to collect data on abiotic and biotic factors, such as light levels, temperature, humidity, percentage cover, species richness.  Students could collect data across an area to calculate mean values for soil pH, soil water content or biodiversity.  Selecting the interval between sampling sites involves the skills associated with the number of samples (see below). | Tape measures. |
| Sample timing | Students should understand that multiple samples collected over time may be needed when values change over time. | Students could collect data over a period of time to investigate the ideal interval between observations. Emphasis should be placed on the link between sampling interval and the rate of change of values and the duration of fluctuations. For example, the temperature of the atmosphere changes much faster than the temperature of the sea.  If students collect weather-related data, they could compare their observations with long-term data sets.  Students could use long-term data sets to analyse how different sampling intervals affect the reliability of the conclusions drawn. Suitable data sets include sea temperature at Eastbourne or carbon dioxide concentration at Mauna Loa. | Appropriate equipment for the selected techniques.  [UK climate - Historic station data](http://www.metoffice.gov.uk/public/weather/climate-historic/#?tab=climateHistoric)  [Historic weather data: UK and regional series](http://www.metoffice.gov.uk/climate/uk/summaries/datasets#rankOrdered)  [Historic weather data: wunderground](https://www.wunderground.com/history/index.html?error=AMBIGUOUS&query=london&day=1&month=1&year=2017&finalday=(null)&finalmonth=(null)&finalyear=(null))  [Recent weather data](http://www.metoffice.gov.uk/public/weather/observation)  [Sea temperature (Eastbourne has the longest data set)](https://www.cefas.co.uk/cefas-data-hub/sea-temperature-and-salinity-trends/station-positions-and-data-index/)  [Carbon dioxide at Mauna Loa](https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html) |
| Sample size. | Students should understand that the size of individual samples that are needed to produce a reliable result, such as a calculated mean, depends upon the variability of the values. | Students could collect multiple samples of different sizes from a single location to investigate the effect of sample size on the reliability of the result.  Suitable studies include:   * soil water content * quadrat size for species richness in a grassland. | Appropriate equipment for the selected techniques.  Data sets from secondary sources to illustrate the principles of sample variability. |
| Number of samples. | Students should understand that the number of samples needed to produce a reliable result, such as a calculated mean or to identify a trend, depends upon the variability of the values. | Students could collect multiple samples of a representative standardised size from multiple locations or times to investigate the effect of the number of samples on the reliability of the result.  Suitable studies include:   * multiple soil samples from a field to estimate the mean soil water content * light level readings to estimate the mean light level. | Appropriate equipment for the selected techniques.  Data sets from secondary sources to illustrate the principles of sample variability. |
| Standardisation of techniques. | Students must understand the importance of standardisation of techniques to ensure the reliability and comparability within a study and between studies. | Students could be asked to collect data on a single factor, followed by a discussion of the exact method they used, for example, light readings. How were/could/should the following have been standardised:   * orientation of the light meter – compass angle and angle relative to the horizontal * position in relation to obstacles, such as shading/reflection from the student. | Appropriate equipment for the selected techniques. |
| Collection of statistically significant data. | Students must understand the importance of statistical significance.  Since most environmental studies are assessing differences or changes in values, it is vital to know whether any differences or similarities are reliable: are they statistically significant? | Students must be familiar with the use of standard deviation (SD) and how it gives a measure of the dispersion of values around the mean. Students do not need to carry out any statistical tests.  Since most studies use means calculated from multiple values, SDs can be calculated from the individual values.  A range of primary and secondary data sets can be used to compare the SDs from similar situations, for example, using historical weather records to compare mean temperatures from different years. | Primary or secondary data sets. |

Sampling techniques

|  |  |  |  |
| --- | --- | --- | --- |
| **Learning objective** | Content | **Learning activity** | **Resources** |
| Standard environmental techniques. | Students should gain a knowledge and understanding of the use of the standard environmental techniques.  The techniques for which students must gain first-hand experience are listed in Appendix A.  For each technique, students should know:   * why the method is used * the procedures involved * the limitations of the method. | A range of fieldwork and lab-based activities should be used, as appropriate for the opportunities available to the particular school or college. | Appropriate equipment for the selected techniques. |
| Fieldwork and laboratory activities. | Students should know how to select and use methods from the standard environmental techniques to collect valid data on:   * population size/density * species frequency * species distribution * biodiversity * soil analysis. | The emphasis in developing activities should be placed on:   * application of appropriate methodologies * selection of appropriate techniques * understanding of how the data collected can inform conservation management planning. | Appropriate equipment for the selected techniques. |
| Fieldwork and laboratory activities. | Students should plan studies to investigate the range of specific scenarios included in the specification. As far as is possible, they should carry out these planned investigations. | The focus of these studies should be the use of standardised techniques to collect reliable data that can increase understanding of environmental issues.  The principles of scientific methodologies and sampling techniques included in 3.7. and Appendix A should be used wherever appropriate. |  |
| Specialist techniques. | Students must develop a knowledge and understanding of these techniques and how they can be used in environmental research.  First-hand experience is not required. | Students could review the applications of particular techniques using information gathered from the internet.  Emphasis should be placed on features of the technique that:   * allow data to be collected that was not previously possible * are more cost effective * allow more data to be collected. | Many environmental documentaries include details of specialist techniques.  The following websites include details of the use of specialist techniques and their environmental applications.  Some give details of companies that sell equipment. These have been included to illustrate the range of equipment available, not to endorse particular companies or suggest that equipment must be bought.  **Image databases**  [Wildbook for wildlife data management](http://www.wildbook.org/doku.php)  [Mara-Meru cheetah project](http://marameru.org/)  [NOAA Fisheries](http://www.nmfs.noaa.gov/pr/species/finbase.htm)  [Cardigan Bay Marine Wildlife Centre](http://www.cbmwc.org/downloads/CBMWC_2011_PhotoID_Catalogue_vc.pdf)  [Darwin: manual photo-identification](http://darwin.eckerd.edu/?page=photo_identification.html)  **Drones, ROVs, UAVs**  [Conservation drones](https://conservationdrones.org/)  [The use of drones in rhino conservation](https://www.savetherhino.org/rhino_info/thorny_issues/the_use_of_drones_in_rhino_conservation)  [Marine fish monitoring](http://wdfw.wa.gov/conservation/research/projects/marine_fish_monitoring/puget_sound_bottomfish/)  [Woods Hole Oceanographics: spray glider](http://www.whoi.edu/main/spray-glider)  [Argo](http://www.argo.ucsd.edu/)  **Tracking**  [Global shark tracker](http://www.ocearch.org/)  [bio track](http://www.biotrack.co.uk/)  [Sirtrack](http://www.sirtrack.co.nz/index.php/terrestrialmain/gps)  [National Geographic: Tracking wildlife for science could actually help poachers](http://news.nationalgeographic.com/2017/03/wildlife-watch-gps-data-hacking-poaching-wildlife/)  [RSPB](https://www.rspb.org.uk/birds-and-wildlife/multimedia-and-discussion/satellite-tracking/)  [Migrate Technology Ltd](http://www.migratetech.co.uk/index.html)  Examples of satellite platforms for environmental monitoring:  GOES 15  NOAA-19  Landsat8  Sentinel-2  Grace 1 + 2  Aura  Jason-3  **Bat detectors**  [Wildlife acoustics authorised resellers: UK](https://www.wildlifeacoustics.com/company/resellers#united-kingdom)  [Wildlife services: bat detectors](http://www.wildlifeservices.co.uk/batdetectors2.html)  [Bat Conservation Trust](http://www.bats.org.uk/pages/manufacturers_and_suppliers.html)  [nhbs](http://www.nhbs.com/)  **Acoustic recording/sonograms**  [Wildlife acoustics](https://www.wildlifeacoustics.com/)  [Long-range acoustic tracking of Antarctic blue whales](http://www.marinemammals.gov.au/__data/assets/pdf_file/0005/135608/Miller-2013-Antarctic-blue-whale-voyage-acoustics-for-IWC-SC65a-SH18.pdf)  **eDNA**  [Freshwater Habitats Trust](https://freshwaterhabitats.org.uk/projects/edna/edna/)  [Science Direct](http://www.sciencedirect.com/science/article/pii/S0006320714004443) |