FACTFILE:
GCE BIOLOGY

BIODIVERSITY

Rewarding Learning

Biodiversity

Learning outcomes

Students should be able to demonstrate knowledge and understanding that agricultural practices can have an impact on biodiversity, including:

- agricultural practices that can promote biodiversity by developing a variety of habitats and/or providing different foods sources, for example:
  - – polyculture versus monoculture;
  - – crop rotation;
  - – hedgerow conservation and maintenance;
  - – using predator strips at field margins; and
  - – integrated pest management and biological control versus pesticide use;
- demonstrate knowledge and understanding of the additional advantages and disadvantages of the agricultural practices listed above; and
- recognise that using intensive agricultural practices results in increased food production, as well as economic benefits, but has biodiversity costs.

Students should be able to demonstrate knowledge and understanding of the significant consequences on biodiversity that can be caused by pollution of waterways by, for example:

- organic pollution by slurry and silage effluent; and
- mineral enrichment (eutrophication) as a result of fertiliser run-off.

Students should be able to demonstrate knowledge and understanding of the effects these organic pollutants and mineral enrichment have on biological oxygen demand (BOD) and on flora and fauna in waterways, and strategies to reduce the incidence of these types of aquatic pollution.

Students should be able to demonstrate knowledge and understanding of global warming and climate change, including:

- consequences for flora and fauna, for example local extinctions or shifts in ecological ranges;
- potential consequences for species and ecosystem biodiversity.

Agriculture and the Environment

1. Polyculture vs monoculture

Polyculture involves growing more than one crop in the same area of land; one method involves planting two crops in a field during one growing season, one being planted after the other is harvested. Another involves planting two or more crops in a field at the same time, for example in alternate rows. Crop rotation (see later) can also be considered a form of polyculture.

Polyculture provides a variety of habitats for insects and other soil organisms, as well as a variety of food sources, leading to more complex (and therefore more stable) food webs. There are also other benefits; the crops involved are carefully chosen to make sure the soil is not stripped of particular nutrients, reducing the need for fertiliser application. It can also be a more efficient way of using resources such as water for example, when shallow-rooted and deep-rooted plants are grown together. Depending on the method of polyculture employed, there may also be a reduction in pest populations. However, while polyculture has biodiversity advantages, it is generally less profitable than monoculture. This is mostly due to the 'economies of scale' which are possible with large monocultures.

Monoculture involves growing just one crop (and often one variety of that crop) in an area. Modern intensive farming methods have taken this practice to extremes, where huge fields of a single crop are grown and harvested, year after year. This practice does not improve biodiversity, since only one food source is available which will only support a narrow range of consumers. It may also rely heavily on the application of fertiliser and/or pesticides, which have further negative consequences for biodiversity. In addition, monocultures are more susceptible to pests and disease than polycultures. However, monocultures can be very profitable for farmers due to their simplicity. The needs of just one crop can be focused on and the farmer can become a specialist in one type of production, ensuring maximum yields. Harvesting is straightforward since it can be largely automated.

2. Crop rotation

The practice of changing crops grown in a field from one year to the next is called crop rotation. This practice avoids the depletion of particular minerals from the soil, given that each crop has its own profile of minerals which it takes up from the soil. Crop rotation also makes it less likely that pest populations will become established and reduces the overall need for fertiliser, particularly if leguminous plants (such as clover, beans, peas) are included. Since it involves different crops, crop rotation provides a variety of habitats and food sources for other organisms, improving biodiversity. It also reduces the need for pesticides, since pest populations become less of a problem.

While crop rotation is beneficial to biodiversity, it requires more expertise and technical knowledge than monoculture; for example farmers must be able to grow a variety of crop plants, instead of just one and the changes in soil minerals are more complex.

3. Hedgerow Conservation & Maintenance

Hedgerows are important habitats for many species, so their maintainance is vital for biodiversity. They also provide shelter and act as wildlife corridors. Regulations and guidelines are in place to ensure they remain a diverse and viable habitat:

- cutting of hedges should be confined to autumn and winter on a two-yearly cycle, in order to avoid disturbing nests and destroying food sources such as berries
- hedges should be cut in an A-shape, in order to provide different widths and hence different microhabitats
- a variety of plant species should be used in hedges, to increase the variety of microhabitats
- some hedgerow trees should be left to act as important habitats, as well as song posts for birds.

While hedgerows make a significant contribution to biodiversity, they can hinder the movement of machinery between fields and this has been a reason for their removal to make fewer, larger fields.

4. Predator strips at field margins

This is an uncropped/ungrazed margin of approximately 1m around the edge of a field, with the aim of establishing an area of relatively diverse plant life, including grasses. There are three major benefits of this practice:

1. The strip provides a habitat for many species, both vertebrate and invertebrate species.
2. Some of the insects inhabiting the strip over winter will act as predators of crop pests in the spring, reducing crop losses and the need for pesticides. Others will act as food for higher trophic levels.
3. Some of the vertebrates, such as wood mice, are a food source for larger vertebrates like barn owls.

There is a cost to the farmer as less productive land is available to farm. However, if field margins larger than 1m are created, subsidies are available to the farmer to offset the loss of productivity.

Futher information

PDF – RSPB farming for wildlife in Northern Ireland on rough grass margins

5. Pest control

A pest can be defined as 'an organism that causes economic damage or harm to human health'. Pest control is important for farmers, to maximise their crop production. This control can be chemical or biological, or a combination of both (integrated pest management).

Pesticides constitute chemical control, the most common being herbicides and insecticides. While they may be effective in controlling weeds and insects, they have environmental costs.

- 'Broad-spectrum' insecticides kill a range of insect species. Removing several species from food webs can have implications for other organisms so an ideal insecticide is one which is narrow-spectrum.

- Often, a broad-spectrum pesticide will kill a pest's natural predators, as well as the pest itself. Over time this can lead to 'pest resurgence', where the pest population begins to grow again after the application of pesticide. Since the pest's natural predators are missing, the population can grow unchecked and often reaches a level higher than ever.

- The pest may become resistant to a chemical pesticide, rendering the pesticide useless. If one or two individual pests have genetic mutations which mean they are unharmed by the pesticide, these individuals will be able to begin establishing a new resistant pest population with little or no intraspecific competition.

- Pesticides which do not break down naturally in the environment (i.e. they persist) can result in bioaccumulation. The pesticide remains in or on the body of an invertebrate and as materials pass through a food chain, the pesticide becomes more concentrated in the tissues of organisms at each trophic level. As it builds up, it can reach toxic levels in top carnivores and increase mortality.

Due to these potential adverse effects, significant research should be carried out on a chemical pesticide before its release into the environment.

Biological control is an alternative to chemical pesticides and involves targeting the pest in different ways. The following are examples of methods of pest control which fall under the heading of biological control:

a) Introduction of a natural enemy of the pest, such as a predator, a parasite or a pathogen. A small number of control agents can be introduced and its population will grow as it exploits the pest. The advantages of this approach includes specificity and persistence in the environment (so repeated applications of the control agent are not necessary). However, the control agent must be very carefully researched prior to its introduction, in an attempt to avoid disruption of the ecosystem. Successful examples of biological control include *Encarsia* for whitefly and *Phytoseiulus* for red spider mite.

b) Release of sterile males which 'mate' with females but no offspring are produced. This technique successfully eradicated the screw-worm fly, a parasite of livestock, in the USA in 1982.

While biological control avoids many adverse effects of chemical pesticides, it requires a lot of expensive research prior to the release of the control agent. It also does not eradicate the pest and in the short-term it may be seen as less effective than chemical control.

Integrated Pest Management (IPM) involves bringing together more than one element of pest control in order to balance pest reduction with care of the environment. Chemical pesticides are used sparingly in IPM, with biological control managing the bulk of the pest population.

Further information

PDF - Department of Agriculture, Fisheries & Food Actions to promote Biodiversity

Pollution of Waterways: The Problem

Slurry, silage effluent, fertiliser run-off

All three forms of pollution above can result in an increase in decomposing bacteria in the waterway. The aerobic respiration of the bacteria uses up large amounts of dissolved oxygen, resulting in increased BOD (Biological/Biochemical Oxygen Demand).

BOD is defined as the amount of oxygen required by bacteria to metabolise the organic material in a sample of water. It is usually expressed as milligrams of oxygen per litre of water

Slurry

Slurry (a mixture of manure, water and other farm wastes) contains large amounts of organic and inorganic nutrients so it provides a readily utilisable form of nutrition for a population of decomposing bacteria and can quickly lead to a population explosion of these bacteria. This creates a simultaneous, rapid increase in BOD.

The decomposer population will decline in time, once the resources are used up, as would be the case in a one-off pollution incident with slurry.

Silage effluent

Silage effluent is one of the most concentrated pollutants produced on a farm. It is a liquid produced in the process of making silage, where crops harvested for cattle fodder are left to ferment anaerobically, in order to make the material more easily digestible by livestock. Depending on the storage method and the type of silage being produced, up to 30 litres of liquid per tonne of silage per day can be produced and farmers must have procedures in place to manage this waste.

The problems associated with silage effluent reaching waterways include:

- immediate increase in BOD, since the effluent itself has a very high BOD,
- eutrophication, due to the high organic and inorganic nutrient content of the effluent (this may be followed by algal blooms),
- reduction of pH of waterways, since the effluent is acidic (pH 3.5-5).

Fertiliser run-off

Artificial fertiliser contains highly soluble inorganic nutrients, including phosphates and nitrates. This makes it fast-acting and easily utilisable by the crop plants it is sprayed on. However, it also means it can be washed into waterways, where it can cause mineral enrichment (eutrophication). This mineral enrichment provides a favourable habitat for the growth of microscopic algae, resulting in an algal bloom.

When the algae die (through self-shading and mineral depletion, but also because they are short-lived organisms), they are decomposed by bacteria in the waterway. Since there is a large volume of dead matter to decompose, a large population of decomposing bacteria is supported. (Water plants below the surface may add to the dead matter, as a result of being shaded by the algal bloom and dying through lack of photosynthesis.) Consequently, BOD increases. This increase is less rapid than with pollution by slurry or silage effluent. It is also longer-lasting, since the source of pollution is often diffuse and on-going.

As a result of the increased BOD in waterways caused by slurry, silage effluent or fertiliser run-off, many aquatic invertebrates and vertebrates including fish, struggle to gain sufficient oxygen to survive. Hence pollution of waterways by these pollutants contributes to the death of large numbers of organisms and a consequent reduction in biodiversity. Some invertebrates thrive in these habitats since they have adaptations which allow them to overcome the high BOD. For example rat-tailed maggots and sludgeworms can survive in highly polluted waters. They are often found in large numbers in polluted water, where their adaptations allow them to outcompete other species.

In order to avoid these forms of water pollution, there are guidelines which farmers should abide by in an attempt to keep these pollutants out of waterways; for example all stores of slurry and manure, as well as silage bales should be kept at least 10m away from water courses. There are also restrictions on fertiliser application, including closed spreading periods and a requirement to limit fertiliser application to those times when rain is not expected.

Balancing Food Production and Biodiversity

Intensive agriculture practices allow farmers to maximise production from their land; pesticides wipe out herbivores which could eat the crop plant, fertilisers improve growth of crops and monocultures are generally more profitable than polycultures. These practices help farmers meet the demands of a growing population, as well as helping to ensure that agriculture remains a viable industry and contributor to the economy.

However, as described above, there are biodiversity costs associated with many of these practices and government initiatives continue to encourage a shift towards more sustainable practices. In this way, it is hoped that the longer term health of the land, including agricultural land will be safeguarded.

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More details can be found from the following documents:

PDF – The Code of Good Agricultural Practice for the prevention of pollution of water, air and soil

Article – The Nitrates Action Programme 2015-2018 & Phosphorus Regulations

Global Warming & Climate Change

Candidates are expected to build upon the knowledge of this topic gained at GCSE level, where the causes and potential consequences of the 'greenhouse effect' are studied, as well as the nature of the collected evidence for global warming and climate change.

In addition at AS level there is a requirement to look at some of the smaller scale ecological changes which may result from global warming and climate change.

Most species have a relatively narrow range of environmental temperatures in which they can survive. In aquatic habitats, dissolved oxygen decreases with increasing temperature. So, if environmental temperatures in a habitat increase beyond the upper limit of a species, that species could potentially become extinct in the habitat. In addition, as temperatures increase, the habitat could potentially become suitable for other species which have not previously been able to survive there. Climate change, thought to be a consequence of global warming, may also contribute to local extinctions and/or changes in ecological ranges. Changes in rainfall, flooding/drought and increased soil erosion can all contribute to significant habitat changes which may alter the species makeup of a community (species biodiversity). In addition, ecosystem diversity may be affected as whole habitats change. For example low-lying areas may become flooded, so that habitats which were once marsh or estuarine become marine habitats. Elsewhere, increased desertification may occur.

Changes in ecological range

In the British Isles there is much evidence that so-called southern (warm) species are increasing their ecological range northwards, while the distribution of northern (cold) species is reducing (although there is less evidence for the latter).

Two examples of bird species which appear to have been affected by climate change are the Little Egret and Cetti's warbler. The Little Egret (*Egretta garzetta*) began breeding in Ireland in 1996, having previously been found most abundantly in Mediterranean and African wetlands. In Britain, Cetti's warbler (*Cettia cetti*) is increasing its range northwards, having first bred in southern England in 1972. Both of these bird populations are thought to be increasing due to warmer temperatures. Some marine invertebrate species, such as the warm water jellyfish *Pelagia noctiluca* are also thought to be increasing their ranges due to warmer sea temperatures in the North Atlantic.

Local extinctions

When a species becomes extinct in a habitat, it is difficult to tease out the reason(s) why. Global warming and climate change are thought to have been responsible for local extinctions, but not always directly. Dabberlocks *(Alaria esculenta)* is a brown alga which has experienced local extinctions in coastal areas around south-west Britain and since this species is sensitive to changes in temperature, rising sea temperature seems a likely explanation. However, in cases of local extinctions of other species rising temperatures could have an indirect effect; for example populations of predators, prey, pollinators, competitors or pathogens could be affected by changes in temperature and one of these may have a knock-on effect on a vulnerable species.

Additional information can be found here:

PDF – The effect of climate change on bird species in the UK

Article – How does climate change cause extinction?

More information on local biodiversity issues and protective measures can be found at:

The Department of the Environment website

Article – SACs

Biodiversity Action Plans in your area

Department of Agriculture, Environment, and Rural Affairs website

Article – Northern Ireland priority species (2010)