

ACTIVITY BRIEF

Estimating environmental damage in freshwater

The science at work

The evidence for a pollution incident in freshwater, for example a stream or lake, is often only too obvious. Environmental scientists working for water quality monitoring agencies are often alerted by members of the public who have spotted dead fish (or worse) floating on the surface of the water. The causes of such pollution are many and various: for example, fuel oil from a storage depot or sewage from a farm may run into water courses when containers rupture or storms cause flooding.

In the UK, the *River (Prevention of Pollution) Acts 1951-1961* and *Control of Pollution Act 1984* established control over river pollution. These and subsequent legislation to meet the EU Water Framework Directive make it a criminal offence to pollute a lake, river, groundwater or the sea or to discharge any liquid into water bodies without legal permission. Scientists from the Environment Agency play an essential role in helping the UK government uphold legal requirements, so that we are spared the kind of extreme pollution that occurs in the New River in Mexico. As it flows into California the colours range from dark green to brown with thick patches of white foam. There is a pungent stench of raw sewage, especially when the temperature rises.

In the UK, scientists take action to limit the effects of pollution damage immediately when it occurs. They can move in and:

- take samples of the organisms and water for analysis
- establish the extent of the pollution
- determine the causes of the incident
- recommend or take action to minimise and remediate the damage
- if necessary, collect evidence for prosecution of a polluter.

However, their work will not end there. They will want to know how effective the action to remedy the effects of the pollution and to prevent further harm has been. They will return to the site at regular intervals to take fresh samples to assess the reduction, if any, of the environmental damage that has been done and to check that no further pollution has occurred.

As well as using a battery of chemical tests to assess the concentrations or effects of pollutants or their derivatives, the scientists use living organisms to measure the quality of the water. For example, many algae are intolerant of the anaerobic conditions and ammonia found in a sewage pollution incident. Water quality can be measured using *bioassays* e.g. conducted by growing algae in water samples, or by using invertebrates to obtain a *biotic index*.

The Trent Biotic Index is based on the fact that certain species tend to disappear and the species diversity decreases as the organic pollution in a water course increases. Unpolluted

water contains stonefly and mayfly nymphs, freshwater shrimps (*Gammarus pulex*) and caddis fly larvae, which therefore act as **indicator species** for clean water. The scale of the index runs from 0 for grossly polluted water, to 15 for the purest water. Scores obtained upstream and downstream of a pollution incident can be used to assess the extent of the damage. If effective action is taken, the scores downstream should return to match those found upstream in the cleaner water.

Your brief

Your task is to compare the water quality at different points in a stream or river. You will use freshwater invertebrates to obtain and compare biotic index scores for different sampling stations.

Use *Study sheet: The Trent biotic index*.

STUDY SHEET

The Trent biotic index

Introduction

This study sheet gives you the standard procedure for finding the Trent Biotic Index score for samples of freshwater invertebrates. It was developed by the Trent River authority to detect water pollution. It allows you to make comparisons of water quality without carrying out large numbers of chemical tests. Scores range from 0 for highly polluted water to 15 for clean water. You will need to decide how best to make use (if any) of this measurement in the design of your own investigations. Biological monitoring of this kind can detect:

- intermittent pollution which affects organisms but makes chemical detection difficult as it is washed away
- the effect of chemicals found in extremely low concentrations, but which accumulate in organisms
- pollution without having to test for all 1500+ known pollutants.

You will need to determine the position of sampling stations in a stream or shallow river (depending on the investigation) and decide on a standardised sampling procedure to use at each station. This procedure includes one possible method.

Identifying freshwater invertebrates is quite hard at first, but it soon becomes easier with a bit of practice.

Health and safety

Full risk assessment is essential before any work is undertaken. If possible, this should include an initial reconnaissance to identify hazards, check for stability of banks and locate suitable safety points. There are particular risks associated with fieldwork which should be taken into account. You should not work in the field alone or wander off from the group. You should have careful regard to the hazards associated with rivers and streams. You will need to be appropriately dressed. Discuss this with your teacher.

You should also pay due regard to the fragility of the habitats that you are working in and keep collection of specimens and damage to environmental substrates to a minimum. Animals that have been collected should be handled as little as possible and identified and returned to the wild as soon as possible. For this reason, identification and counting is better undertaken in the field, with the minimum removal to the laboratory.

Procedure

For each site to be sampled:

1 Kick sampling

Obtain samples by agitating the stream bed with a boot (or use a stick or tool) upstream from a flat edged net held against the stream bottom. Use a fixed area sampler or mark an area with a quadrat and 'kick' for two minutes, covering the whole area evenly.

Place the catch in a shallow white tray with 2 cm depth of fresh water from the stream or river.

2 Identification

Use suitable keys to identify the invertebrates present, to species level if possible.

Compile a species list and a 'groups' list (see step 3). The use of groups makes it unnecessary to identify the more difficult species. Use the table in 3 and, where necessary, compare unknown specimens in the same taxonomic group and note how many different species are present. Even if you are unsure of the species identification, you can usually tell how many different ones are present.

Note that 'group' is used in different ways. For example, each species of alder fly larvae counts as a group, but it doesn't matter how many different black fly larvae species (Family Simuliidae) there are, they count as one group.

3 Number of groups present

Enter your results and count up the total number of groups. You will need a spare copy of the next page for each sample.

Group	Present? (✓)
Annelida ('ring worms) except genus <i>Nais</i>	
Genus <i>Nais</i>	
<i>Betis rhodanii</i> (a species of may fly)	
Family <i>Chironimidae</i> (blood worms - midge larvae) except <i>Chironomus thummi</i>	
<i>Chironomus thummi</i>	
Family Simuliidae (black fly larvae)	

Type	Tally each species present (each species of each type is a group)	Total groups
Platyhelminthes (flatworms)		
Hirudinea (leeches)		
Mollusca (snails)		
Crustacea (hog louse, shrimps)		
Plecoptera (stone flies)		
Neuroptera larvae (alder flies)		
Coleoptera (beetles and beetle larvae)		
Hydracarina (water mites)		

Type	Tally each genus present (each genus is a group)	Total groups
Ephemeroptera (may flies) except <i>Betis rhodanii</i> (see above)		

Type	Tally each family present (each family is a group)	Total groups
Trichoptera (caddis flies)		

Type	Tally each species present (each species is a group)	Total groups
Fly species not above		

Column total = GRAND TOTAL OF GROUPS	
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4 Trent biotic index

Work down the indicator species column to find the highest point that fits your sample. Then follow the appropriate row across the table to the column for the number of groups present. The number in the table where the row and column cross is the Trent Biotic Index for the sample.

A score of 10 or above is considered to be clean water.

		Total number of groups present									
		0-1	2-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
Indicator species		Trent Biotic Index									
Plecoptera nymph present	More than one species	-	7	8	9	10	11	12	13	14	15
	One species only	-	6	7	8	9	10	11	12	13	14
Ephemeroptera nymphs present	More than one species	-	6	7	8	9	10	11	12	13	14
	One species only	-	5	6	7	8	9	10	11	12	13
Trichoptera larvae present	More than one species	-	5	6	7	8	9	10	11	12	13
	One species only	4	4	5	6	7	8	9	10	11	12
<i>Gammarus</i> present	All above species absent	3	4	5	6	7	8	9	10	11	12
<i>Asellus</i> present	All above species absent	2	3	4	5	6	7	8	9	10	11
Tubificid and/or red chironomid larvae present	All above species absent	1	2	3	4	5	6	7	8	9	10
All the above types absent	Some species that do not require oxygen may be present	0	1	2	-	-	-	-	-	-	-

Teacher notes

This activity links to

OCR Unit 14 Ecology and managing the environment, and

AQA Unit 16 Ecology, conservation and recycling.

For both units, students must carry out an ecological study.

It is intended to supplement and extend work undertaken in the investigation of a freshwater habitat.

It can be carried out alongside other activities that are necessary to meet unit requirements. On its own it will not cover all aspects of the following sections of the specifications, but it relates to and can be integrated with work undertaken to address these parts of the specification:

OCR Unit 14: Ecology and managing the environment

Students must:

produce evidence of your investigation on ecology and managing ecosystems

This evidence needs to include:

AO3: *a planned investigation of an ecosystem.*

To gain the highest marks, student should:

- *demonstrate a thorough knowledge and understanding of the relationship between the organisms, their physical environment and each other in ecological succession*
- *use appropriate scientific terms and conventions accurately*
- *research the effect of agricultural practice, human habitation and greenhouse gas production on ecosystems and biodiversity, selecting a wide range of relevant information and presenting it clearly and logically*
- *evaluate the information available and justify the choice you included*
- *organise information to evaluate the scientific, moral and ethical reasons for preserving ecosystems and species diversity*
- *describe a range of methods used to manage ecosystems and preserve species diversity*
- *interpret, explain and evaluate a range of data relating to the success of a project managing one ecosystem*
- *carry out complex calculations on ecological data involving the statistical analysis of the data obtained (e.g. chi-squared or t test)*
- *obtain the correct solutions to an appropriate degree of accuracy and demonstrate an understanding of the significance of the outcomes.*

AQA Unit 16 Ecology, Conservation and Recycling

In this unit you will learn about:

- *conducting an ecological survey and how to estimate the distribution and/or number of organisms in a habitat*
- *how to describe a habitat*
- *the environmental damage caused by an activity and how this damage may be reduced*

25.2 How you will be assessed

You need to produce a portfolio of evidence which considers the ecology of an ecosystem and the impact mankind has had on the environment.

Your portfolio of evidence should comprise:

A. details of an ecological survey, including food chains, food webs and energy flow within a chosen habitat including:

- *the identification of a particular habitat*
- *an account of research undertaken in relation to the ecological survey. This will include and explanation of techniques which could be used*
- *the use of a suitable sampling technique, to estimate the distribution and/or numbers of organisms and use this information to estimate population size*
- *a summary of the physical and biological characteristics of the habitat based on the findings of your sampling*
- *details of feeding relationships including food webs and food chains based on the findings of your sampling*
- *energy flow within the habitat based on the findings of your sampling*

B. a report which describes how humans may have caused, or may cause, damage to a habitat. How this actual or potential damage can be/has been reduced, and the relevance of any conservation measures, including:

- *the identification of the reason for one cause of actual or potential damage to the environment*
- *the explanation of the effects of this actual or potential damage*
- *how this actual or potential damage can be/has been reduced*
- *the identification of any conservation measures that would be put in place to address this damage*

25.3 You need to know, understand and be able to demonstrate

In order to complete the requirements of this unit you will need to know, understand and be able to demonstrate relevant knowledge of the following:

- *the type and populations of organisms that live in a habitat*
- *the relationships of organisms with their physical and biological environment*
- *environmental change and damage*

Aims and teaching strategies

If students elect to undertake freshwater studies to tackle the requirements of this unit, they will need to collect and identify freshwater invertebrates. One of the most convenient ways to do this is to use kick sampling in a stream or shallow river. This technique can be modified to make it semi-quantitative for the purpose of comparing the invertebrate populations of different sites. This may be done by using random quadrats or equally spaced quadrats along a transect, to mark a measured sampling area and by 'kicking' for a given time period, say 2 minutes. Alternatively a frame with a fixed net and stirring the substrate with a stick can be employed (Surber sampler). Some indication of how close the abundance scores are to the actual values can be obtained by collecting a second or third sample by switching nets and continuing the kicking process. This will show if there is likely to be a significant difference between the sample estimates and the real values.

Study sheet: The Trent biotic index

This work should not be undertaken in isolation. Organised in a manner to collect suitable data, sampling of freshwater invertebrates will contribute to those parts of the specification which require population estimates or the use of relative abundance scales, the establishment of feeding relationships and energy flow, the biological characteristics of a habitat and contribute to a discussion of human impacts and damage to the environment.

Since students need to collect and identify the invertebrates obtained in freshwater sampling, it is a simple step to incorporate the use of a biotic index. The *Study sheet: The Trent biotic index* provides instructions.

Students can be trained to use the index in part of a single classroom session, by applying the study sheet to invertebrate illustrations on cards. Different 'populations' can be provided for students to obtain random samples by shuffling and dealing out, say, 50 at a time.

If the cards are also used to introduce the use of keys for identification, longer will be needed. However, this is a useful exercise to get students used to using the keys.

Good illustrations of specific freshwater invertebrate species that can be used for identification at both the nymph/larvae and adult stages of the life cycles can be found at <http://schools.ceh.ac.uk/advanced/freshpoll/pf-freshpoll3.htm> This website is written by the Centre for Ecology and Hydrology (CEH), formerly the Institute of Freshwater Ecology and the leading UK body for research, survey and monitoring in terrestrial and freshwater environments. It contains much useful information.

The *Scientists at work* package includes a video on investigating river pollution. This provides excellent background, showing scientists from the Environment Agency in the field and laboratory, testing water samples and using a biotic index to assess water quality.

<http://www.4science.org.uk/products-science-enhancement.htm>

The work can be undertaken at a number of different levels. An investigation of the principles and uses of the technique might be applied to a single use of the index. However, sampling at selected stations along a stream could be used to determine whether pollution is taking place, or subsequent to a known pollution incident, determine the extent of recovery. Students are unlikely to have access to a site which has suffered a pollution incident, but investigations might be related, for example, to considerations of water quality in a stream running through a housing estate compared with upstream in open country. There are opportunities to liaise with local environmental scientists and agencies, including university departments.

The Trent biotic index (TBI) could also be measured alongside and compared with a measure of diversity, such as Simpson's index. One disadvantage of the TBI is that stonefly larvae prefer well oxygenated water and therefore tend to be more abundant in faster flowing upstream waters than in slower moving water downstream.

An invertebrate reference collection is very useful to aid identification of specimens. These can be stored in sealed containers preserved in 95% ethanol. In the field, avoid fragile glass containers as far as possible.

Other methods

The B.M.W.P (Biological Monitoring Working Party), a more complicated but improved biotic index which uses more taxonomic groups than the TBI, was developed by the National Water Council (NWC) and is in common use.

The RIVPACS (River Invertebrate Prediction and Classification Scheme) was devised as a biological classification of unpolluted running-water sites and to determine whether the fauna to be expected at an unstressed site could be predicted from physical and chemical features only.

Health and safety

Full risk assessment is essential before any work is undertaken. If possible, this should include an initial reconnaissance to identify hazards, check for stability of banks and locate suitable safety points. There are particular risks associated with fieldwork which should be taken into account. Students should not work in the field alone and should have careful regard to the hazards associated with rivers and streams. Students need to be appropriately dressed and so you will need to speak to them about this before the field trip. For example, hat, sunscreen, suitable footwear. Refer to *Safety in biological fieldwork*, which can be obtained from the Institute of Biology. It is also necessary to adhere to government education department and employer policies for field work.

Students should also pay due regard to the fragility of the habitats that they are working in and keep collection of specimens and damage to environmental substrates to a minimum. Animals that have been collected should be handled as little as possible and identified and returned to the wild as soon as possible. For this reason, identification and counting is better undertaken in the field, with the minimum removal to the laboratory.

Further reading

<http://field-studies-council.org/reports/biologyfieldwork/report2/report2.aspx> Creating the right balance: Delivering fieldwork for effective 16-19 ecology teaching

www.environment-agency.gov.uk/subjects/waterquality/ and www.environment-agency.gov.uk/maps/960669/ are useful Environment Agency websites

www.bristol.gov.uk/ccm/portal/ (type *living rivers introduction* in search)

<http://www.defra.gov.uk/environment/water/index.htm>

<http://www.pca.state.mn.us/water/milestone.html>

<http://europa.eu/scadplus/leg/en/s15005.htm>

http://w/briefiww.foe.co.uk/resourcengs/vol_initiative_water_poll.pdf

<http://www.environmentcareers.org.uk/>