River Esk Investigation

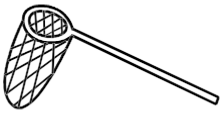
Secondary Data to Support River Studies

This resource pack is designed to help teachers extend learning around a river study activity delivered by the National Park Education Service. It will support both primary and secondary level investigations so teachers should select the parts which are suitable for the age and ability of their pupils.

This data will support investigations designed to test hypotheses of how various characteristics of a river change with distance downstream.



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Introduction to the River Esk

The source of the River Esk is approximately 400m above sea level on Westerdale Moor. Here a series of small streams called the Esklets merge. The river then flows for 28 miles (45 km) through sparsely populated areas of open moorland and farmland to flow into the sea at Whitby.

Like many moorland streams, the Esk can be affected by rain passing through peat soils. This, along with the presence of ironstone in the ground, can cause the water to turn brown. These factors can limit the numbers and diversity of invertebrate life in the headwaters of the river although, generally, the water quality of the Esk may be described as being very good.

The Esk supports a wide range of wildlife including kingfishers and otters and is particularly important as Yorkshire's only sea trout and salmon river. It is also home to the county's last surviving population of one of the longest lived invertebrates known, the freshwater pearl mussel which can live for over 100 years. The National Park Authority is involved in a project involving river habitat restoration work and a captive breeding programme to reverse the decline in numbers of this species.

Rivers are vital for people as well as for wildlife as they provide water for us, our farm animals and our crops. Water is taken from the river at Ruswarp and treated to provide a drinking water supply for local communities.

Rivers are also an important part of the character of our landscape and provide scenic and inspiring places for us to enjoy. Outdoor activities including rowing and canoeing take place on the Esk at Ruswarp. Angling for salmon, sea trout and brown trout occurs along almost the entire length of the river.

Since 2008 the local community has been working with the North York Moors National Park Authority and other organisations to develop schemes to generate green electricity. This includes a 50kW hydroelectric turbine incorporating a 'fish friendly' Archimedes screw at Ruswarp. Find out more at http://whitbyeskenergy.org.uk/

Links to Further Information

Further information about the River Esk: http://www.northyorkmoors.org.uk/discover/rivers

Catchment map: http://www.northyorkmoors.org.uk/discover/rivers/River-catchment-map.pdf

River wildlife: http://www.northyorkmoors.org.uk/discover/rivers/wildlife-on-the-river

Pearl mussel and salmon recovery project:
http://www.northyorkmoors.org.uk/looking-after/our-projects/pearl-mussels

Reports, policy documents and action plans about river catchments in the North York Moors:
http://www.northyorkmoors.org.uk/discover/rivers/reports-and-resources

Data Collection Sites

See photos provided separately

Site 1 Grid reference 665013
This site is located in Westerdale, a remote area of moorland near to the source of the River Esk at 'Esklets'.

Site 2 Grid reference 658054
This site is located on the upper river, close to a road bridge and wooded area, near to the village of Westerdale.

Site 3 Grid reference 686084
This site is located on the middle river close to farmland (improved grazing) and the village of Castleton.

Site 4 Grid reference 719078
This site is located near Danby on the middle river close to farmland (improved grazing), a road bridge and a packhorse bridge.

Site 5 Grid reference 762076
This site is located on the middle river close to the stepping stones in the village of Lealholm.

Site 6 Grid reference 824055
This site is located on the lower river close to a ford and the confluence of the Murk Esk and Esk at Grosmont.

Practical Field Work

The data collection sites described above were selected at intervals along the length of the river to provide data to support investigations looking at how various characteristics change from source to mouth. Please note that these sites are not necessarily suitable for use by school groups, either because there is no coach access or because the river is not suitable for pupils to enter.
It is quite difficult to find sites along the main channel which are accessible and safe for schools to use.

The National Park Education Service can provide a river study activity where pupils can gain experience of data collection techniques at one or two sites along a small tributary stream. Pupils' own results can then be combined with this secondary data to allow source to mouth type investigations.

Raw Data for the Physical Characteristics of the River Esk

Site 1
Grid reference 665013
Width = 0.70m

Distance from water's edge starting on the left bank when facing upstream (m)	Depth (m)	Pebble Length (cm)	Pebble roundness (see recording sheet)
0.0	0.00	16.0	2
0.1	0.02	19.0	1
0.2	0.00	30.0	1
0.3	0.05	9.9	2
0.4	0.04	8.7	1
0.5	0.02	8.7	3
0.6	0.04	6.4	3
0.7	0.05	16.0	1

Site 1: Float times (over 5 metres)				
Time 1 (secs)	Time 2 (secs)	Time 3 (secs)	Time 4 (secs)	Time 5 (secs)
14.70	17.10	16.40	18.75	15.00

Site 2
Grid reference 658054
Width = 7.20m

Distance from water's edge starting on the left bank when facing upstream (m)	Depth (m)	Pebble Length (cm)	Pebble roundness (see recording sheet)
0.0	0.04	1.9	3
1.0	0.09	8.0	4
2.0	0.11	8.8	3
3.0	0.10	15.8	4
4.0	0.11	12.5	3
5.0	0.14	19.0	3
6.0	0.14	9.5	4
7.0	0.07	10.0	3

Site 2: Float times (over 5 metres)				
Time 1 (secs)	Time 2 (secs)	Time 3 (secs)	Time 4 (secs)	Time 5 (secs)
7.50	7.59	10.78	6.85	6.90

Site 3
Grid reference 686084
Width = 8.60m

Distance from water's edge starting on left bank when facing upstream (m)	Depth (m)	Pebble length (cm)	Pebble roundness (see recording sheet)
0.0	0.13	8.7	4
1.0	0.33	6.0	4
2.0	0.26	13.8	4
3.0	0.17	6.4	3
4.0	0.15	12.5	3
5.0	0.19	9.4	3
6.0	0.26	6.5	4
7.0	0.25	5.3	3
8.0	0.27	10.0	4

Site 3: Float times (over 5 metres)				
Time 1 (secs)	Time 2 (secs)	Time 3 (secs)	Time 4 (secs)	Time 5 (secs)
5.63	6.10	5.81	5.57	5.59

Site 4
Grid reference 719078
Width = 9.20m

Distance from water's edge starting on left bank when facing upstream (m)	Depth (m)	Pebble Length (cm)	Pebble roundness (see recording sheet)
0.0	0.19	9.0	4
1.0	0.22	2.7	5
2.0	0.22	12.8	4
3.0	0.22	11.5	4
4.0	0.25	10.1	4
5.0	0.18	10.1	4
6.0	0.17	11.6	4
7.0	0.18	10.2	4
8.0	0.13	7.1	4
9.0	0.16	5.0	4

Site 4: Float times (over 5 metres)				
Time 1 (secs)	Time 2 (secs)	Time 3 (secs)	Time 4 (secs)	Time 5 (secs)
4.00	3.59	3.88	4.21	4.60

Site 5
Grid reference 762076
Width = 18.20m

Distance from water's edge starting on left bank when facing upstream (m)	Depth (m)	Pebble Length (cm)	Pebble roundness (see recording sheet)
0.0	0.08	10.6	4
2.0	0.15	8.7	3
4.0	0.17	6.0	4
6.0	0.18	18.0	3
8.0	0.14	11.5	4
10.0	0.07	11.2	4
12.0	0.14	6.8	5
14.0	0.17	12.7	4
16.0	0.21	9.5	5
18.0	0.09	11.0	6

Site 5: Float times (over 5 metres)				
Time 1 (secs)	Time 2 (secs)	Time 3 (secs)	Time 4 (secs)	Time 5 (secs)
4.06	4.09	4.15	4.13	4.32

Site 6
Grid reference 824055
Width = 18.50m

Distance from water's edge starting on left bank when facing upstream (m)	Depth (m)	Pebble Length (cm)	Pebble roundness (see recording sheet)
0.0	0.01	1.5	6
2.0	0.16	5.0	5
4.0	0.18	8.7	5
6.0	0.16	10.0	5
8.0	0.12	8.6	5
10.0	0.13	7.8	5
12.0	0.10	6.3	6
14.0	0.20	3.0	4
16.0	0.10	6.3	4
18.0	0.10	5.6	5

Site 6: Float times (over 5 metres)				
Time 1 (secs)	Time 2 (secs)	Time 3 (secs)	Time 4 (secs)	Time 5 (secs)
3.75	3.69	3.81	3.44	3.75

Suggestions for Analysis

Use the raw data to calculate one or more of the following for each site and then complete a data summary table.

- Average depth (m)
- Cross sectional area (sq.m) = width (m) x average depth (m)
- Calculate the average float time and use this to calculate velocity

  Velocity of water (m/sec) = distance travelled by floats (m) ÷ average float time (seconds)

  Eg. For site 1:

  Velocity of water (m/sec) = $\frac{5.00}{16.39}$ = 0.30 m / sec

- Use velocity and cross sectional area to calculate the discharge at each site. Discharge is the volume of water passing a certain point per second.

  Discharge (m^3 /second) = velocity (m/sec) x cross sectional area (sq.m)

- Calculate the average pebble length
- Calculate an average pebble roundness index
- Distance from the source for each site
  Provide students with the grid references for each site and a 1:25,000 OS map and ask them to work out the distance from the source to each site. The grid reference for the source is 668013. Measure distance in centimetres using the edge of a piece of paper or a piece of string, then convert to km using the map scale.
  If you don't have access to OS maps, you could use the map provided to work out approximate distances from the source.

Data Summary Table for the River Esk **(Data collected 6 June 2012)**

Site	Approx. distance from source (km)	Width (m)	Ave depth (m)	Velocity m/sec	Cross sectional area (sq.m)	Discharge (m^3/sec)	Ave pebble length (cm)	Ave pebble roundness index	Gradient (degrees)
1	0.4	0.70	0.03	0.30	0.02	0.01	14.3	2	6.00
2	5.4	7.20	0.10	0.63	0.72	0.45	10.7	3	1.50
3	10.5	8.60	0.22	0.87	1.89	1.64	8.7	4	1.00
4	15.0	9.20	0.19	1.23	1.75	2.15	9.0	4	1.25
5	20.9	18.20	0.14	1.20	2.55	3.06	10.6	4	0.50
6	31.2	18.50	0.13	1.36	2.40	3.26	6.3	5	0.25

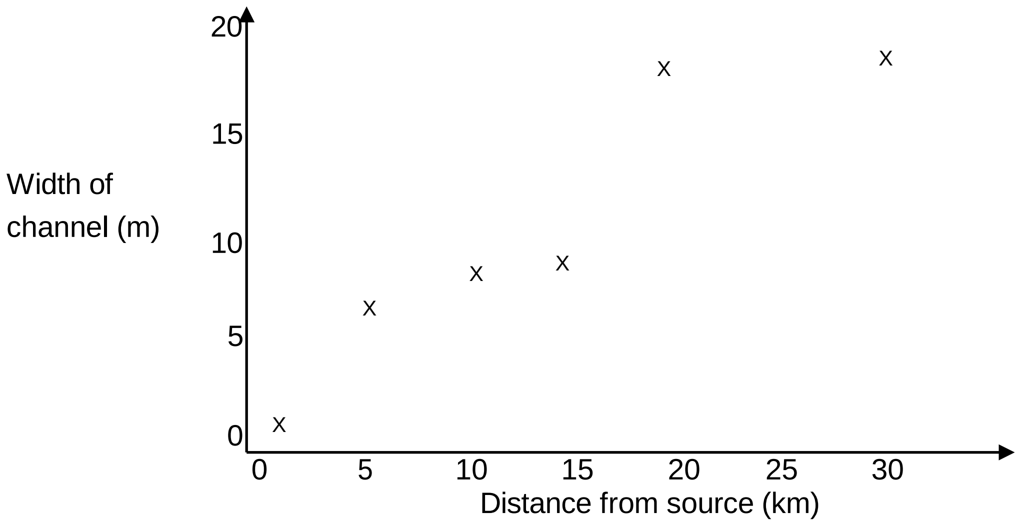
Developing Hypotheses

Ask pupils to consider what happens to one or more of these variables as you move downstream from source to mouth.

Variable	**What happens to this variable as you move from source to mouth?**	**Hypothesis**
Width	Gets wider	The river gets wider as you move downstream because …..
Depth		
Gradient		
Velocity		
Discharge		
Bedload size		
Bedload shape		

Ask pupils to select the data they need, illustrate it and then analyse it to test their hypothesis.

Example
To test the hypothesis that width increases with distance from source, draw a scatter graph showing distance from source along the x axis and width along the y axis. You could ask pupils to draw a line of best fit through these points.



What conclusion can be drawn from this graph?
The width of the river channel increases with distance from the source.

Can you explain this relationship?
As the river flows downstream, more and more tributaries join the main channel so that the volume of water increases. Where the banks of the river are made of soft sand and soil they are easily worn away (eroded) in times of heavy rain so that the channel becomes wider.

Suggestions for explaining hypotheses

Variable	**What happens to this variable as you move from source to mouth?**	**Hypothesis**
Width	Gets wider	The river gets wider as you move downstream because of the increased volume of water entering it from the catchment which then erodes the channel in times of flood
Depth	Generally gets deeper	The river generally gets deeper as you move downstream because of the increased amount of water entering the system, but it varies with width at specific sites and recent amounts of rainfall
Gradient	Generally decreases	The river starts life in upland hilly areas and flows downwards into the more gently sloping river valley and flatter flood plain.
Velocity	Increases	As the channel widens and deepens downstream, friction is reduced between the water and the river bed, speeding up the rate of flow
Discharge	Increases	This is because more water enters the river from more and more tributaries as the river flows towards its mouth.
Bedload size	Decreases	As rocks and pebbles are bounced and rolled downstream in the current, pieces are constantly knocked and scraped off so they gradually become smaller.
Bedload shape	More rounded	As rocks and pebbles bounce and roll downstream, sharp corners are knocked off and they gradually become rounded and smooth.

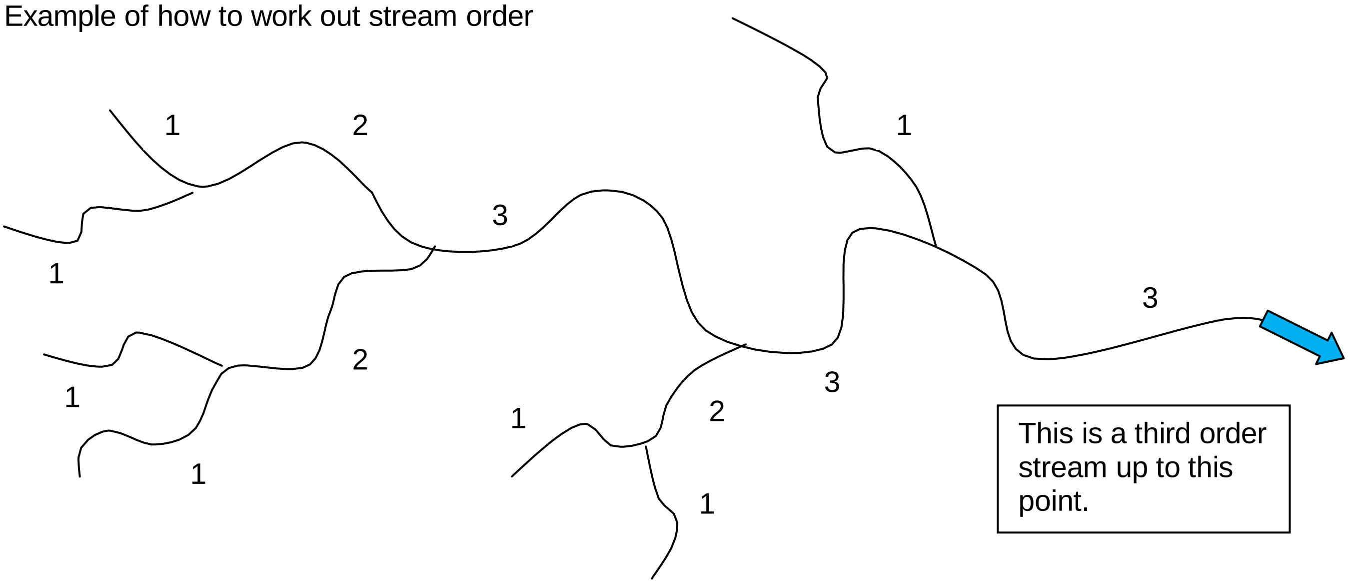
NB. The data provided here was collected on a day when the discharge was ‘normal’ in our opinion. If you have collected your own data at a site in the Esk catchment, your results may or may not be comparable to those presented here. Can pupils think why?

Additional Analysis

Stream Order

Stream order can be used to classify rivers on a world wide scale. Several systems have been developed but the one by Strahler is most commonly used. In this system, small streams with no others joining them are called first order streams. When two first order streams join, they form a second order stream. A second order stream stays a second order stream until it is joined by another second order stream and they then form a third order stream and so on. The stream order of each measuring site can be worked out from the map.

Example of how to work out stream order



To qualify as a stream, a hydrological feature must have water in the channel for at least part of the year. The order number of a stream can range from 1, a river with no tributaries, to 12, the order of the Amazon at its mouth. The Mississippi is order 10 at its mouth. Estimates are that 80% of the rivers on the planet are first to third order rivers.

In low order rivers, there can be a higher chance of flooding, as the water will be concentrated in fewer channels rather than spread out, as in a higher order river. Stream orders can be used by scientists to indicate which parts of a drainage basin are more likely to flood.

Data for Freshwater Invertebrate Sampling

Numbers of invertebrates found at each site on the River Esk						
Invertebrate	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**
Stonefly nymph	12	3	2	1	0	2
Mayfly nymph	1	0	4	10	7	15
Cased caddis fly larvae	0	0	0	0	2	2
Caseless caddis fly larvae	0	1	0	0	1	8
Midge larvae	2	4	1	6	0	4
Water beetle	1	0	0	1	0	0
Beetle larvae	0	0	0	0	2	1
Freshwater snail	0	0	0	0	4	1
Freshwater limpet	0	4	1	5	6	0
Water mite	0	0	0	1	0	0
Leech	0	0	0	5	10	1
Worm	0	4	2	3	0	3

Suggestions for analysis

- Draw a bar chart or a pie chart to illustrate the numbers and types of invertebrates found at each site. Can you see any patterns or trends?

- Calculate the total number of each type of invertebrate found.
  Which invertebrate was most common?
  Which invertebrate was least common?

- Which type of invertebrate has the largest range of values?

Invertebrates as Water Quality Indicators

Pollution is something that causes harm when added to the environment. Different types of invertebrates are able to tolerate different amounts of pollution in the water. Some, such as stonefly nymphs, can only tolerate very clean, well oxygenated water whereas others, such as midge larvae, can tolerate polluted water with lower levels of oxygen. See the water pollution indicator chart provided.

Can pupils suggest what sort of pollution, if any, could be in the River Esk?
The River Esk flows mostly through farmland which is used for grazing cattle and sheep. Any pollution getting into the river is likely to drain into the river from fields, roads and villages, such as:

- slurry and manure from grazing animals
- fertilizers, herbicides and pesticides
- fine sediment and silt from farmland
- oil and salt from roads
- effluent from septic tanks from houses
- effluent from sewage treatments works (one in most villages along the Esk Valley)
- effluent from the water treatment works at Ruswarp

Ask pupils to formulate a hypothesis about water quality – do they think water quality will change along the course of the river. If so, how and why?

Primary Schools
If pupils haven't done so already, draw bar charts or pie charts to illustrate the types of invertebrates found at each site. Colour in the bars or pie segments according to whether the invertebrates can live in poor, moderate or good quality water.

Secondary Schools
Pollution can be measured using the animals themselves by calculating the **biotic index**.
For each site:
Find out the pollution score (listed on the pollution indicator chart) for each type of animal found. Add up the scores to make a total score. Calculate the average score for the site by dividing the total score by the number of types of animal found at that site. This is the biotic index.

Example:

Invertebrate	Number found at Site 1	Pollution score
Stonefly nymph	12	10
Mayfly nymph	1	10
Midge larvae	2	2
Water beetle	1	5
Total		27

$$\text{Biotic index} = \frac{\text{total pollution scores}}{\text{number of types of animal found}} = \frac{27}{4} = 6.7$$

The biotic index should be between 0 and 10, the higher the score the cleaner the water.
A biotic index of zero would indicate no life at all. A biotic index of 10 would indicate a very clean upland stream.

Do these results indicate any change in water quality along the course of the river?

Adaptations

Ask pupils to choose one or more invertebrate and carry out some research. List the ways in which they are adapted to living in a river habitat.
Examples of adaptations:

- Streamlined body shape facing into current
- Flat body shape to help cling to stones
- Hooks to help cling to stones
- Tiny size to help cling to stones
- Spins silken thread for safety line
- Build protective cases around their bodies
- Burrow in mud or sand
- Long tails help to steer in strong currents
- Body armour for protection
- Legs with strong claws for clinging

Is your invertebrate better adapted to fast flowing 'riffles' or slow moving pools?

Life Cycles

Ask pupils to carry out some research to find out more about their chosen invertebrate's life cycle.

Nymphs and incomplete metamorphosis (egg → nymph → adult)

Many freshwater invertebrates begin life under water as an egg. Once they have hatched they live underwater for some time, sometimes up to several years, as a young insect until they emerge from the water to continue the adult stage of their life cycle as flying insects eg. stoneflies, mayflies, dragonflies, damsel flies and caddis flies.
As the young insects grow under water, the protective outer case of their bodies often does not and they have to moult several times, each time growing a new, bigger outer casing. Some young insects look similar to their adult forms and change gradually with each moult until they become adults. Examples are **stoneflies, mayflies and dragon flies**.
The young stages of these insects' life cycles are called **nymphs** and the gradual process of moulting to become an adult is called incomplete metamorphosis.

Larvae and complete metamorphosis (egg → larva → pupa → adult)

Other insects have young stages which look nothing like the adults with no sign of wings, often living in completely different habitats. The young stage is called a larva. At each moult the larva becomes larger until the last moult when it splits to reveal a pupa or chrysalis (a non feeding and inactive stage). Inside the pupa the whole body is broken down and reorganised to form an adult. When it is completely transformed the adult finally emerges from the pupa. This is called complete metamorphosis. Examples that begin life in freshwater habitats are **caddisfly larvae, blackfly larvae, beetle larvae and midge larvae.**
Other examples include butterflies, moths, beetles, flies, ants, wasps and bees.

Links to Further Information and Resources about Rivers

The following links are to external websites. The National Park Authority is not responsible for the content or management of these sites but they may provide useful information and resources.

Update on the Archimedes screw at Ruswarp from the Whitby Esk Energy Group
http://whitbyeskenergy.org.uk/

Fold out identification key for freshwater invertebrates
www.field-studies-council.org/publications/pubs/freshwater-name-trail.aspx

Resources about rivers from the Field Studies Council
www.lifeinfreshwater.org.uk/Web%20pages/Rivers/StreamsandRivers.html

Resources about flooding and managing flood risk from the Geographical Association
http://www.geography.org.uk/resources/flooding/

Resources about the River Tees from source to mouth from Channel 4
www.channel4learning.com/support/programmenotes/netnotes/series/seriesid17.htm

Resources for schools from Yorkshire Water
www.yorkshirewater.com/education-and-learning/school-zone.aspx

Resources about rivers for primary schools
http://www.topicbox.org.uk/geography/rivers/

Resources about rivers from the BBC
www.bbc.co.uk/schools/riversandcoasts/

Adaptations to Aquatic Habitats – suitable for KS 3 and 4 from the British Ecological Society
www.britishecologicalsociety.org/documents/education/adaptations_ponds.pdf

Information and resources from the Canal and Rivers Trust
www.canalrivertrust.org.uk/about-us/education and www.wow4water.net/

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