DYNAMIC COASTS
BEACHES AT RISK: Key Stage 3 Resource Pack

NOTES FOR TEACHERS

For background information on the BAR project see "Introduction and habitats" at the beginning of this pack.

Recent comments on Key Stage 3 Geography have suggested that it should be more locally based, more up to date and relevant to current issues. This has been taken into account when preparing the accompanying worksheets.

Pupils could be introduced to the project by being told that they will be studying the important local problems of coastal erosion, flooding and habitat conservation, which are likely to become ever more pressing due to global warming. Their studies will be informed by the findings of the BAR project, which has been carried out by researchers in both Britain and France, and has been financed by the EC.

Long term assessment of the work could be based on titles such as:

- The likely effects of global warming on local coastlines.
- Coastal habitat conservation in a changing world.

WORKSHEET 1: INTRODUCTION TO BEACHES

1. WHAT ARE BEACHES?

a) Beaches are loose (unconsolidated) deposits of sand or stones along the coast. They can take many forms: smooth sandy beaches, shingle banks or barriers, fringing beaches below cliffs, spits etc.

Pictures on page 1.1 from top left clockwise:
1) Birling Gap, East Sussex, UK – shingle
2) Equihen, France – sand with dunes behind
3) Wissant, France – sand with dunes behind
4) Hastings, East Sussex, UK – shingle

2. WHO NEEDS BEACHES?

Try to introduce idea of categories in the list.

- Tourism, recreation and educational visits. Uses vary from the energetic (swimming, surfing etc.) to the sedentary (sunbathing, reading etc.).
- Employment generator in the area (hotels, restaurants etc.).
- Biodiversity resource. Beaches support many different habitats and therefore strengthen biodiversity. They are habitats for rare and specialised species.
- Erosion prevention. They help protect the land from erosion by the sea.
- Source of construction materials. Sand and gravel used to be taken for the construction industry. Now beaches are generally regarded as too valuable to exploit in this way. However, some beaches are raided for sand and shingle to put on beaches suffering erosion.
- Launch pad and laying up place for boats. Provide a gentle slope to launch and store boats. e.g. at Brighton and Hastings.

3. WHERE ARE THE BEACHES STUDIED IN THIS STUDY?

This exercise helps to locate the BAR study area and some of the case studies used in this project. It requires some atlas work, and understanding of scale and direction.

b) Dover and Calais 45 km
c) Newhaven and Dieppe 120 km
d) London to Paris via Dieppe 330 km
e) Yes it is the shortest in terms of distance as it is virtually a straight line.

This project is part-financed by the European Regional Development Fund (ERDF).

4. WHAT ARE THE BEACHES MADE OF, AND WHAT IS THEIR GEOLOGICAL ORIGIN? HOW WAS THE FLINT SHINGLE FORMED?
The passage below and the photo exercise help explain current thinking on the origin of flint.

a) Shingle beaches are made from **flint** pebbles and cobbles. These look greyish or brownish on the outside and shiny black or dark grey inside, if broken. Flint is a form of **silica** which developed in the **Chalk** when it was deposited some 70 to 100 million years ago, during the **Cretaceous** period (the latter part of the Dinosaur era). The Chalk was formed from calcareous mud deposited on the bed of a huge tropical **sea**, which covered much of North West **Europe**. Scattered within the mud were the remains of minute organisms, rich in silica, which had lived in the sea, glass sponges, **diatoms** and **radiolaria**. This silica dissolved in the circulating waters within the mud and then was redeposited as silica in the form of **nodules** and layers while the mud was accumulating and hardening into chalk. The silica, now known as **flint**, developed especially in the bedding **planes** or discontinuities in the laying down of the beds of Chalk. Thus the nodules occur in bands in the bedding planes, as do sheets of flint, which can be seen exposed on the **shore** platform.

Notes
- Glass sponges are sponges (multicellular organisms) that are strengthened by silica in their cells.
- Diatoms are microscopic unicellular algae, with silicified cell walls.
- Radiolaria are protozoa (microscopic unicellular animals) with silica skeletons.
- All these were sources of the silica that dissolved and then reformed as flint.

b) In the photo exercise pupils should be told that the flint is more resistant than the chalk and therefore it tends to project from the cliff face or platform surface.

WORKSHEET 2: MAKING SHINGLE

This worksheet revises the concept of weathering and erosion, which has probably been taught already in connection with rivers. The specific processes of coastal erosion are covered in detail.

2. WHERE DO WAVES GET THEIR ENERGY
a) The length of fetch from the Gulf of Mexico to the Channel is 10000 to 12000 km, depending on where measured. If the wind was blowing across the Channel, the fetch would be short.
b & c) Other factors affecting wave height are (1) strength of wind and (2) duration of wind.
d) Storms are most likely in the autumn or the winter.
e)

	Calm sea	Stormy sea
Length of fetch	**Short**	**Long**
Strength of wind	**Weak**	**Strong**
Duration of wind	**Short**	**Long**
Height of waves	**Low**	**High**
Force of waves	**Weak**	**Strong**
Amount of erosion	**Low**	**High**

WORKSHEET 3: CHATTERED, BATTERED AND SHATTERED

This is a worksheet about attrition.

1. HOW DOES FLINT FROM THE CLIFFS BECOME SHINGLE?
Pebble A: Chattered.

a & b) This is smooth and rounded. It has therefore been in the sea a long time, being battered by the process of attrition.

Pebble B: Battered.
c) This is partially rounded and chattered, but still has some angular faces, showing that attrition has not fully rounded it off. It has not been in the sea as long as **A**.

Pebble C: Shattered.
d) This is angular in shape as it has only recently fallen from the cliffs.

e) The chalk is softer and less resistant than the hard flint. The chalk fragments wear away very quickly, whereas the more resistant flint remains for much longer.

f) Pebbles A, B and C will gradually reduce in size as they undergo attrition. Pebbles B and C will also become more rounded. This does not necessarily mean they will become more spherical – an oval or elliptical shape is more probable.

2. BAR RESEARCH ON ATTRITION
a) Shingle must be taken from well out to sea. Severe erosion would affect beaches where the adjacent sea floor had been lowered by removal of shingle. Marine gravel beds are now known to be rich wildlife habitats, so the ecological impacts on marine habitats should also be considered.

b) In winter large storm waves may drag the shingle out to sea, or along the shore. The shingle beach would then have to be recharged again.

WORKSHEET 4: SWASH AND BACKWASH

a) The beach ball does not move forwards because the water is not moving forwards. The molecules are just making circular movements, transferring energy, not water.

b) The word swash means a washing noise, and is an example of onomatopoeia (where a word is formed from the sound that it describes).

c) No, it goes up the beach transverse to the waves, so that if the waves are coming in obliquely, then the swash will take an oblique course up the beach.

d) One & Two. The water will run back into the sea possibly dragging some shingle with it.
Some of the water may percolate into the beach material and soak away.

WORKSHEET 5: BUILDING UP OR TAKING DOWN

1. CONSTRUCTIVE AND DESTRUCTIVE WAVES
a)The completed table is shown below:

	Constructive waves	Destructive waves
Usual season	**summer**	**winter**
Height	**low**	**high**
Shape	**flattened**	**tall**
Swash	**strong**	**weak**
Backwash	**weak**	**strong**
Number per minute	**less than 11**	**more than 13**
Effect on beach	**build it up**	**drag it down**

2. BEACH PROFILES
a) The winter profile is much flatter than the summer, because destructive waves with a strong backwash have dragged material down beach and out to sea. The beach is **depleted** of shingle.

The summer profile is much higher because constructive waves with a strong swash pushed material up the beach. The backwash is weaker because water percolated into the beach, rather than dragging shingle down towards the sea.

b) The ridges on the profile represent the shingle deposited by different high tides, the top being perhaps a winter storm tide, the next the highest spring tide and the lowest the high tide that has just occurred.

3. BEACH GRADIENTS

The larger the particle the greater the angle of slope, because the large particles interlock more easily. The larger particles have a greater angle of rest than the smaller.

In the suggested experiment it is envisaged that the materials will be poured into piles while dry. Were water to be used, the finer materials would be more easily washed down, making the slopes flatter (NB: it is difficult to demonstrate this with sugar or salt, which dissolve quickly! But it works with different grades of sand.) On real beaches the backwash would **percolate** into the shingle very rapidly, and could not drag the pebbles down the beach as easily as it could sand. So this is another reason why shingle beaches are much steeper than sand beaches.

Incidentally, storm berms tend to be fronted by steep slopes made of relatively coarse shingle and topped on their landward sides by finer shingle.

WORKSHEET 6: SHINGLE ON THE MOVE

This is a worksheet about longshore drift.

a) The **predominant** winds come from the south-west. They are south westerlies.

b) The most powerful waves come from the south-west. On the coast of South East England northerly winds have little effect since they largely blow off land, but on the French coast northerly winds can produce quite large waves and significant erosion because they blow onto land, from the open sea.

c) The main direction of longshore drift on the eastern Channel coast is from west to east.

d) The four stretches of coast in South East England and one in France where the drift appears to go in two directions are between Margate and Ramsgate, at Dungeness, at Beachy Head, and at Cap Gris Nez. These places are all at large **promontories, headlands** or bends on the coast that deflect the drift to the opposite direction.

e) The beach will be **depleted** of material and its level will drop.

f) This would mean that the waves would break nearer to sea walls and cliffs and would therefore attack them more strongly. Sea walls might be undermined and more likely to collapse. Cliffs would be eroded more rapidly by the waves.

g) The harbour arms or breakwaters would tend to prevent shingle moving along the coast, so increasing amounts would accumulate, causing beach levels to rise. Such extra beach material could be removed by diggers and trucks to replenish beaches where material is being lost, but this is clearly a very expensive process.

h) The longshore drift in this picture moves from left to right, because shingle is accumulating against the side of each groyne facing the front. Conversely, the area behind each groyne is depleted of shingle because it is sheltered from the longshore drift. So the sea comes in much further behind the groyne than in front of it, because the beach is much lower there.

i) The advantage of groynes is that they trap beach material between them and prevent or delay it moving along by longshore drift. They are also useful to shelter from the wind on the beach.

Disadvantages of groynes are that they tend to get undermined at their seaward ends. They also erode away eventually and are expensive.

WORKSHEET 7: MEASURING LONGSHORE DRIFT

This exercise could be used as a fieldwork exercise on a shingle beach that is fairly unfrequented, at least overnight. (Coloured stones tend to be picked up and moved by walkers, or even carried off as souvenirs!) It could be combined with the fieldwork in Worksheet 8, but note that at least two low tide periods are needed for this exercise so two days are probably needed.

Or it could be used as a class exercise.

i) Determine whether the stones are moving along at the moment

- Put out both sorts of pebbles at low tide during a period of **moderate** winds. (If the winds are too strong the waves may be too dangerous for pupils to work on the beach. The pebbles are likely to disappear anyhow, becoming buried below the surface or washed out to sea. If the winds are too weak there will be little recordable movement.)

- Find a place where you could mark the upper end of the transect line of pebbles at the back of the beach or on a sea wall, if present. The lower end could possibly be marked by burying a length of chain or old rope vertically in the beach.

- Using the compass and the two metre poles, set out a straight line with the tape and possibly the ball of string, down the beach. Place the stones equally spaced, noting the position of each numbered stone on your results sheet.

- At the next low tide, roughly twelve hours later, or at the second low tide, 23 hours later, return to the beach. Set out the line down the beach from the same starting point, using the poles and tape.

RECORD:

- For each painted or resin pebble that you can see, record its position.

- Record the number of the pebble on your results sheet.

- Run a tape transverse to the transect line down the beach towards the pebble.

- Record the length of the offset from the transect line to the stone, and which direction it is.

- Run the metal detector over the beach area to discover whether any of the resin pebbles with copper cores have been buried in the shingle.

ii) Which direction are they moving in?

Most of the pebbles will have moved in one direction. Is it the usual west to east longshore drift direction? If not, why not? (Occasionally the odd pebble for some reason will move the opposite way to all the rest.)

iii) What is the likely cause of the movement?

At the beginning and end of the experiment observe the direction of the wind and waves.
What is the direction of the wind? Hold up the flag or streamer and note the wind direction.

What is the direction of the wave fronts? Note the direction they are moving in.
Throw the floats into the waves and note the direction of their movement. Are they exhibiting the typical zigzag pattern of longshore drift?

2. ANALYSIS OF THE RESULTS OF THE ACTUAL STUDY
The data were gathered by a student as part of his A Level project.

a) Total lateral movement of all 15 pebbles = 139.3 metres
Mean or average lateral movement = 9.3 metres.

b) Apart from one pebble that moved very slightly westwards all moved in the expected eastwards direction.

c) Total up and down movement of all pebbles = 30.6 metres down beach.
The mean or average = 2 m.

d) The down beach movement shows the waves were destructive.

e) There is no relationship between the weight of the pebbles and the distance travelled.
The correlation was only 0.17 between weight and lateral movement. A relationship might have been expected as smaller pebbles can be moved more easily by low energy waves.

f) It would be unwise to multiply up to answer this question for 3 reasons:

1) A sample of just a single tidal cycle is not enough to make generalisations.
2) The wind does not always blow from the south-west.
3) A major storm can cause huge movements accounting for many years 'normal' transport in longshore drift.

g) The weaknesses (and ambiguities) of the experiment (as reported) were that:

1) Only one tidal cycle was sampled (in reality, the student studied many cycles).
2) The experiment was conducted with one transect line only. Was it representative?
3) There should have been a number of lines further along the beach.
4) Stones that were buried were not found.
5) The pebbles that moved may have spent part of the cycle buried.
6) There was no knowing how far out to sea some pebbles might have travelled.

WORKSHEET 8: FIELDTRIP TO A SHINGLE BEACH

You must follow your School's Health and Safety Guidance. An example risk assessment is provided in this pack for reference.

Best results are likely to be achieved with pupils working in groups of four or five. It could form the basis of a full day's trip, combined with Worksheet 7, and the biodiversity work in Worksheets 16, 17 and 18, as well as the tourism in Worksheet 26 and 27. Please see notes for Worksheet 7 for how to lay a transect.

WAVE ACTION
If the waves are at all strong it is probably better not to attempt this part of the exercise.

EQUIPMENT

- Floats, e.g. dog biscuits
- Compass
- Small flag or streamer
- Clinometer (see note below)
- 50m long surveyors' tape
- Ruler

SURVEY OF THE BEACH
If the school has no clinometers, it is possible to make them quite easily and cheaply (see diagram overleaf). Note that it is easiest to label the protractor with the complement of the angle (i.e. 90– actual angle).

BIODIVERSITY
There is more information in Worksheets 16, 17, and 18 about the shingle flora and fauna and how to identify them.

GLOSSARY OF TERMS

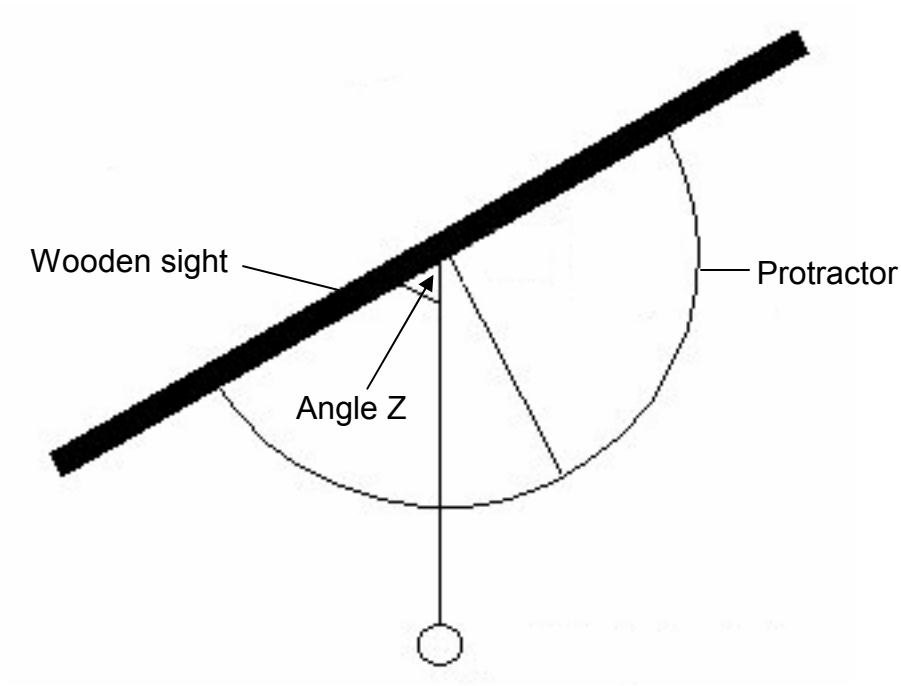
Berm: a narrow shelf or ledge, typically at the top or bottom of a slope; a mound or wall of sand or shingle.

Storm Beach: a beach affected by particularly fierce waves, usually with a long fetch. The effect is most often a very steep beach (up to 45^{o}).

The use of a clinometer to measure tree height.

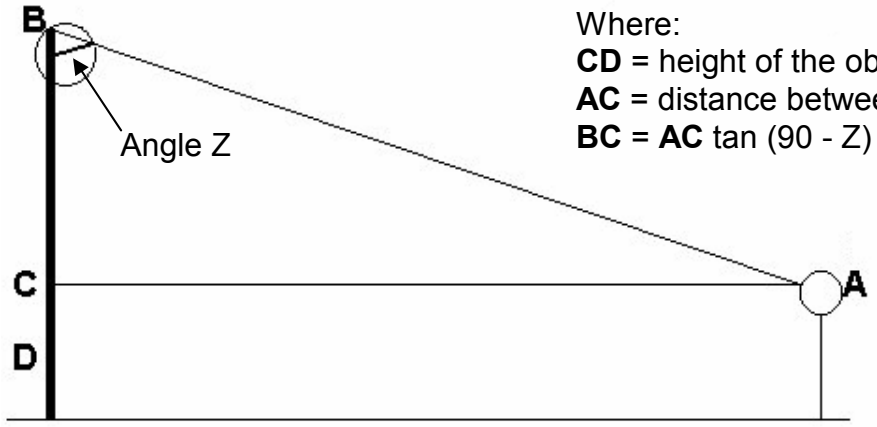
A clinometer is a fairly simple instrument which is used to measure the angle of a slope. By using the principles of trigonometry, the height of tall objects can be calculated from the angles measured.

A clinometer can easily be made from a large protractor. A narrow piece of wood should be glued to the base of the protractor to act as a sighting line. A weighted plumb line is then fastened to the mid point of the base line of the protractor.



To use the clinometer, hold the base (formed by the wooden sight) uppermost, so that the plumb line hangs down vertically (as shown above). Hold the clinometer out at arms length and sight along it, until your eye and your arm make a straight line to the top of the tree. Someone else should then read off the angle made by the plumb line on the protractor (Z).

Height of Tree = **BC**+**CD**



Where:
CD = height of the observer
AC = distance between the observer and the tree
BC = **AC** tan (90 - Z)

Source: Offwell Woodland & Wildlife Trust
http://www.countrysideinfo.co.uk/index.htm

WORKSHEET 9: CASE STUDY OF KINGSDOWN, KENT

a) There was a very wide expanse of shingle above the high water line.

b) There were many houses on the beach, a military camp, and fishing boats beached on the shingle.

c) The top half of the cliffs was completely vertical, as it still is. The slope beneath consists of debris that has fallen from the cliffs.

d) The beach looks narrower. A large house has been built in the foreground and a rectangular building in the middle of the beach. There do not seem to be any boats drawn up on the beach.

e) The breakwater will be impeding longshore drift as the beach material will be accumulating behind it, and not reaching Kingsdown. Other possible reasons could be rising sea-level causing more erosion of the beach, or a changing pattern of offshore sandbanks (the famous Goodwin Sands).

f) A curving sea wall with large boulders or riprap below it was built parallel to the road. The beach below the sea wall looks much steeper than it was, indicating that it is being seriously eroded.

g) The vertical face of the cliff is being eroded away and becoming gentler in slope, while the debris slope at the bottom becomes larger. The cliff has also become more heavily vegetated indicating greater stability.

WORKSHEET 10: WHY WORRY IF SOME BEACHES ERODE AWAY? COASTAL FLOODING

The class could be divided into 6 groups for this. The research work on the different areas could be done as homework if there is enough internet access. Some pupils might make Power Point presentations if there is equipment available.

WORKSHEET 11: MANAGING AND CONSERVING BEACHES

This worksheet deals mainly with the technical aspects of beach management.

1A.
a) The waves are reflected back from the cliffs and may interfere with the next waves, reducing their force.
b) However, they may also scour the base of the sea wall, hastening the day when it finally collapses.
c) The sea wall with the lip is designed to reflect the waves back from the wall and reduce the amount of water overtopping the wall.

1B
a & b) The advantage of rock armour or gabions is that they are much cheaper than walls and tend to dissipate the force of the water, which filters through between the rocks. They are, however, very rough and people climbing on them may slip and injure themselves. Above the high tide level they may harbour rats that feed on beach litter.

1C
a) Groynes help protect the coast by slowing down (in some cases stopping) longshore drift, thus building up beach levels. This reduces the force of the waves on cliffs or sea walls and helps prevent undermining. However, it can have impacts on stretches of coast downdrift.

b) Wooden groynes are rather cheaper to build than rock groynes on an individual basis, but over twice the number are needed for each stretch of beach. Wooden groynes have to be made from timber that can withstand the salt water. Imported hardwoods, mainly Greenheart from Guyana, are preferred. Timber groynes have to be deeply embedded in the beach by noisy pile drivers.

Rock groynes can be dumped directly onto the beach. They are usually made from quarry waste, either larvikite brought by boat from Norway, or limestone from the Mendip hills. Rock groynes are very rough and people can have accidents while climbing on them.

2A
a) Shingle is brought from far offshore to avoid lowering the sea-bed nearer inshore, which might cause erosion. Bringing it from inland pits by truck is expensive and more polluting as well as wasting of the land.

WORKSHEET 12: WHY DO CLIFFS COLLAPSE?

The sea **erodes** the base of the cliffs, by the processes of wave **pounding**, hydraulic action and **abrasion**. This occurs mainly below the level to which the **highest tides or storm waves** reach, and leaves a **wave cut notch** at the base of the cliffs. The upper part of the cliff is then left **undercut** by the erosion so that the cliff is top-heavy and not well supported.

The cliffs are also attacked by **weathering**. For example rain and salt laden sea spray may soak into the **cracks and joints** widening them, weakening the rocks and **chemically** attacking the minerals. In winter, this moisture trapped in the rocks may **freeze into ice**, expanding and widening the joints, and shattering the rock.

The erosion of the **base of the cliff** and the weathering of the cliff-face result in **cliff falls**, which can be massive, sudden and dangerous. As the falls occur, the cliffs are gradually worn backwards and **retreat** leaving a platform at their base, called the **shore platform or wave cut platform.**

WORKSHEET 13: ROCKS AND THE COAST

a) The main types of rock are the Chalk, sandstone and clay.

b) High cliffs are formed on the Chalk and on sandstone, but lower cliffs are also formed on clay.

c) Cliffs are formed on high ground.

d) Clays, gravels and sands form low-lying coasts.

3. DIFFERENT ROCKS – DIFFERENT CLIFF PROFILES
For chalk cliffs: 2, 5, 8.
For sandstone cliffs: 1, 3, 6, 10.
For clay cliffs: 4, 7, 9.

4. SANDY BEACHES
a) The sea has eroded the cliffs by wave pounding, abrasion and hydraulic action, causing boulders to break off and fall from the cliff. The boulders are further eroded by these processes as well as by attrition. Sand grains are the end result.

b) Because the drift from west to east moves the sand in the opposite direction.

c) As the cliffs are eroded, and collapse, material from the cliff top falls into the sea.

Weathering may also cause the cliff top sands to loosen and slide over the cliff top in the process of **mass movement**.

Some other explanations for the origin of the sand might be:

- From ground down flint? Experimental work suggests that flint grinds down into silt rather than sand (silt is finer than sand but coarser than clay), so the answer is probably, no.

- From river deposits? Sampling of estuary water reveals very little sand, only silt.

- From deep down on the floor of the Channel? There were widespread deposits, many dating from the last Ice Age, when summer flowing rivers brought down meltwater and sediments off the Downs. These sands could have been cast up onto the beaches as sea-level rose after the Ice Age.

- From sandy deposits along coasts further away from the South East? This answer is possible. See Worksheet 7 on longshore drift.

WORKSHEET 14: CASE STUDY: CLIFF RETREAT AT PEACEHAVEN

This worksheet introduces ideas of cost/benefit analysis, includes a role play about a public inquiry, and looks at the costs and technicalities of building coastal protection.

1. a) The width of the promenade has narrowed considerably by 2006.

3. SEA DEFENCES AT PEACEHAVEN

a) The advantages of this design of sea wall are:

- The wall has a curved lip that reflects the waves back.
- A walkway is provided for recreation.
- A splash-wall protects the base of the cliff from erosion.

b) The disadvantages are:

- The sea could scour under the sea wall and cause it to collapse.
- The cliff, even though trimmed, could still collapse onto the walkway.
- Little or no flint is released from the cliffs to provide beach material, so beaches are likely to become depleted.

4. WHAT ARE THE EFFECTS ON THE ENVIRONMENT?

a) The shape of Friars Bay is deeply indented and rugged compared to the cliffs at Peacehaven which are relatively smooth.

b) The reason why it is so different from the cliffs at Peacehaven is because it has not been protected from erosion by a sea wall. Also there is less beach material drifting eastwards as in the past because of the sea wall protecting the cliff at Peacehaven. The defences at Peacehaven mean less flint is being released from the cliffs.

c) The likely future for Friars Bay is that it will continue to erode back into the land. There are few houses behind it, so it is unlikely that it will be protected in the future.

WORKSHEET 15: COASTAL PROCESSES CROSSWORD

a)

A				L	O	N	G	S	H	O	R	E		D	R	I	F	T
B				S	E	A		W	A	L	L	S						
C								A	T	T	R	I	T	I	O	N		
D		G	R	O	Y	N	E	S										
E								H	I	G	H		T	I	D	E		
F						T	R	A	N	S	P	O	R	T				
G	S	O	L	U	T	I	O	N										
H					S	A	N	D										
I							A	B	R	A	S	I	O	N				
J						B	E	A	C	H								
K					F	E	T	C	H									
L								K	E	N	T							
M								W	A	V	E							
N				H	Y	D	R	A	U	L	I	C						
O								S	H	I	N	G	L	E				
P							C	H	A	L	K							

WORKSHEET 16: LIVING ON THE EDGE - VEGETATED SHINGLE:

A UNIQUE COASTAL HABITAT UNDER THREAT

See also Worksheet 8 (fieldwork).

This section could be used on fieldwork on a field day on a shingle beach. Many more plants could be studied than the three detailed here, such as those discussed in Worksheet 17.

a) Plants require light, fresh water, nutrients and shelter.

b)

- Plants normally survive on beaches only above High Tide Level, out of the reach of the waves and the moving shingle. (On salt marshes, plants can grow at lower levels, with the water rising over the plants at high tides).
- Storm waves can be very powerful and hurl shingle on top of the vegetation.
- The plants may be deluged with salt water or salt spray.
- Winds can be very strong and there is little shelter for the plants.
- Temperatures can become very high due to the heat absorbed by the shingle on hot summer days.
- There is little fresh water amongst the top layers of shingle for plants to use.

- There is little soil and few nutrients in the shingle.
- Grazing by rabbits and attack by insects may also harm the plants.
- Human activity such as trampling, making paths across the shingle, dragging boats, and picking flowers may harm the plants.
- Shingle may be removed for construction purposes, or damaged in coastal protection work.

Sea-kale is a very tough plant that survives just above high tide level on the shingle, and shows clearly adaptations necessary for this hostile environment.

Lack of fresh water: Its roots are up to 2m long to reach the fresh water deep down in the shingle.
Lack of shelter in winter: Sea-kale shows **seasonal adaptations** to the extreme winter weather conditions, high winds and storms, by dying back to become a very low growing clump in winter, able to survive burial by fresh shingle flung up by storm waves.
High temperatures and evaporation rates in summer: In summer, Sea-kale grows to become a large, showy, cabbage-like plant with thick, wavy blue-green leaves. A waxy coating helps cut down water loss by evaporation through the leaves.
The need to attract insects for pollination: Strong branching heads of white flowers attract insects to pollinate them.
The need to disperse its seeds quite widely: Large numbers of buoyant, waterproof, spherical seeds develop in the autumn that can float for several days in the sea, or blow around on the shingle, before settling somewhere favourable and **germinating** into new plants the next year.

WORKSHEET 17: MORE PLANTS LIVING ON THE EDGE

The completed table should look something like this:

Adaptation	Very deep roots	Waxy leaves	Hairs or bristles on leaves	Succulent	Method of reproduction	Low growing in winter
Reason	Fresh water often far below surface/ helps plant remain attached to ground	Reduces water loss from the leaves	Reduces water loss	Reduces water loss	Many seeds or waterproof seeds are useful	Survive wind and storm
Sea-kale	✓	✓	no	thickened	Large, waterproof, buoyant seeds	Plant dies back and root overwinters
Yellow Horned-poppy	✓	✓	✓	no	Many small seeds flung out of pods	Overwinters as low growing rosette
Biting Stonecrop	Shallow	Slightly	no	✓	Many small seeds, and small pieces can root. (Vegetative reproduction)	Low growing all year round
Viper's-bugloss	✓	no	✓	no	Many seeds	✓
Sea Pea	✓	Slightly	no	no	Peas flung out as pods ripen. Buoyant and waterproof	Low growing all year round.
Orache	Uses spring rains	Slightly	no	Slightly succulent	Annual. Produces many seeds	Dies in winter
Sea-holly	✓	✓	Spines	no	Many seeds	✓

WORKSHEET 18: WHICH PLANTS GROW WHERE ON THE SHINGLE?

a)

Vegetation Zones	Amounts of humus and soil	Water supply	Shelter	List key species in this zone
Ephemeral zone nearest the sea, just inland from high tide level	**Very little; dried seaweed**	**Slight, just after rain**	**Nil**	**Orache**
Pioneer zone just inland from the ephemeral zone	**Very little**	**Layer of fresh water deep in the shingle**	**Slight**	**Sea-kale; Yellow Horned-poppy; Sea Pea**
Intermediate zone, still further from sea	**Slightly more. Dead leaves. Rabbit droppings**	**Slightly more held in humus**	**More**	**Sea Bindweed Biting Stonecrop**
Established zone on the landward edge of transect	**Greater amounts. Often covered in thin layer of soil**	**Better since soil holds it**	**Improved**	Grasses, clovers, thistles mosses and lichens

ANSWERS TO GUESS THE PLANT

1) Thistle, growing in the Established community.
2) Yellow Horned-poppy, growing in clumps in the Pioneer community.
3) Orache growing along the strand line in large numbers in the Ephemeral zone.
4) Sea-kale, large isolated plants in the Pioneer community.
5) Sea Bindweed in the Intermediate zone.
6) Biting Stonecrop in the intermediate zone. (NB: 5 and 6 are interchangeable)
7) Lichens on stones, showing that this area has been vegetated for quite a long time, and is in the Established zone.
8) Grass. Again this is in the Established zone and colonises when a quantity of humus and soil has built up.
9) Sea Pea. An isolated plant or one growing in very small groups in the Pioneer zone. Rare and often present in very small numbers, so few are shown on the map.
10) Scrub and bushes are starting to develop on the landward end of the transect, showing that a good soil cover has now formed.

This exercise could be further developed by asking for a belt transect, 1 cm wide, to be drawn across the map, in a place of the student's choice, from the sea to the track.
Using a paper strip transfer the position of each plant on the transect onto a piece of graph paper. Draw blocks or bars to represent each plant. Then shade to show the four zones.

WORKSHEET 19: SHINGLE BEACH ECOSYSTEMS, FOOD CHAINS, AND FOOD WEBS

1. THE SHINGLE BEACH FOOD CHAIN

a)
T4 Fox
T3 Bird
T2 Caterpillar
T1 Sea Spurge

2. FOOD WEBS

FURTHER FACTS ABOUT SHINGLE PLANTS AND ANIMALS

- Green plants such as Sea-kale and Sea Pea photosynthesise and use nutrients from the soil to grow: T1
- Weevils eat plants such as Sea Pea: T2
- Snails eat plants such as Sea-kale: T2
- Caterpillars eat plants: T2
- Rabbits eat plants: T2
- Linnets, Goldfinches and Greenfinches eat seeds, T2
- Spiders eat other insects: T3
- Thrushes eat snails and caterpillars. They sometimes fly to shingle beaches to feed, though they breed elsewhere, often in nearby bushes: T3
- Blackbirds and Starlings also fly in to eat caterpillars:T3
- Wheatears eat insects and spiders from the ground, and occasionally catch flies in the air: T3
- Ringed Plovers eat crustaceans like sand hoppers: T3
- Grass Snakes and lizards eat insects, slugs and snails: T3
- Little Terns, Common Terns, and Oystercatchers breed on shingle and eat invertebrates and fish: T3
- Badgers eat fruits, seeds and insects: T2/T3
- Foxes, Hen Harriers, Kestrels and Sparrowhawks eat birds and Rabbits: T4
- Fleas live on the blood of birds and mammals, such as Rabbits and Foxes: T4

d) The badger's feeding pattern is different because it feeds from two trophic levels, from plants or producers, and from beetles which are consumers.

e) The badger is an omnivore. Humans are also in this category.

f) Fleas are not conventionally given top place, but they do feed on the blood of top carnivores!

3. BIOMASS and PYRAMID OF NUMBERS

a) The number of trophic levels is small because much energy is lost between levels.

WORKSHEET 20: VEGETATED SHINGLE AT RISK

Several lessons or homework units are needed for this. The worksheet should generate excellent classroom display material.

WORKSHEET 21: SAND DUNES - LOCATION AND FORMATION

WHAT CONDITIONS ALLOW COASTAL DUNES TO DEVELOP?

A good supply of sand

The three qualities of a beach that ensure a good supply of sand:

a) Wide beach
b) Flat beach
c) Sand that dries out on the surface, so that it can be blown.

Strong winds blowing off the sea

d) The predominant winds from the south-west blow sand straight up the beach at Camber Sands. These also affect the dunes south of Boulogne on the French coast. On the French coast around Wissant, and north east of Calais, the dunes are more affected by north and north-easterly winds.

e) Because sand dunes are bound together by the roots of plants that manage to grow there.

TRANSECT ACROSS COASTAL DUNES (Plants/animals to be inserted in Worksheet 23)

Predominant wind →	A	B	C	D
	Mobile dunes Fresh sand accumulating sea	Mobile dunes Fresh sand accumulating	Fixed dunes Little sand accumulating.	Hollow in dunes
Type of dune	Embryo	Yellow or Fore dunes	Grey dunes	Dune slack
% bare sand	80	20	Below 10	Usually low
Humus content	Very little	A little accumulating	More humus, making it look grey	High
Water content	A little salt water	Slightly more fresh water.	Fresh water content slightly higher. Held by humus	High
Plants	Prickly Saltwort along strandline. Marram.	Marram, Sea Bindweed, Biting Stonecrop.	Sea-buckthorn, Ragwort, Biting Stonecrop, Sea Bindweed, Lady's Bedstraw.	Rushes, Dwarf Willow
Animals	Snails, wasps, moths.	Snails, insects including wasps and moths, rabbits, foxes and hawks.	Rabbit, insects including Brown-tail Moth, Cuckoo, Starling, Thrush, Blackbird, Fox, hawks.	Frogs, Grass-snakes Rabbits.

g) Hotter, drier summers, associated with global warming, are likely to make conditions even harsher. Water supplies will be even deeper down in the sand, while temperatures and evaporation rates will be higher.

h) Increased house building and greater demand for water supply from groundwater may lower the water table, causing great stress for dune plants. Water supplies will be much lower down in the sand and plants may not be able to reach it.

i) If embryo dunes are damaged, they can easily be blown away, leaving the dunes behind much more vulnerable. At Camber Sands attempts have been made to encourage the development of embryo dunes using fencing.

WORKSHEET 22: SAND DUNE ECOSYSTEMS

HOW DO SAND DUNE PLANTS SURVIVE THE HOSTILE CONDITIONS?

a) Five ways in which the sand dune environment is hostile to living things are:

- Blowing sand accumulates around (or on top of!) the plants
- No shelter from wind

- Extreme dryness
- Very salty
- Few nutrients
- Possible inundation by the sea.

b) The major world environment or **BIOME** that the Channel Coast sand dunes are most like is **HOT DESERT**.

c) The Channel Coast sand dunes differ from this biome because:
- The coastal dune zone has much more rainfall;
- Also much more vegetation;
- In coastal dunes there is a progression from embryo to grey dunes to established dunes. This does not exist in hot deserts where dunes generally remain mobile and unvegetated.

f) How does stonecrop survive on dunes?
It is a succulent and can store water in its leaves. It has numerous very fine roots that can absorb any water available after rain. It forms a low mat close to the ground that resists being blown by the wind, and helps bind the sand together. Small pieces that become detached can be blown along, take root and form new plants.

g) Although Sea-buckthorn is a dune plant, it is largely outside its natural range in much of the BAR area in South East England. It was introduced in an attempt to stabilise sand dunes. It is often regarded as a thug because it is such a strong plant, with spreading roots that can give rise to many suckers. Birds eating its berries disperse the seeds, which may then sprout and become seedlings. At Rye Harbour, buckthorn has crossed the River Rother from Camber Sands, presumably as a result of bird dispersal. Sea-buckthorn tends to cover large areas very quickly once established. It prevents other plants growing by shading them out.

h) It is very difficult to clear because it is so spiny and its root system is so extensive. The roots have to be dug out extremely thoroughly because any pieces that are left sprout into new plants.

WORKSHEET 23: CHANGING CONDITIONS ACROSS AN AREA OF DUNES

This Worksheet should be combined with Worksheet 21, particularly the transect of the dunes.

a) Prickly Saltwort (A), Marram Grass (A/B), Sea Bindweed (B/C), Sea Spurge (A/B), Rushes (D), Sea-buckthorn (C), Ragwort (C), Biting Stonecrop (B/C).

b) If all foxes were cleared, their prey in the trophic level below, such as rabbits, would increase in number. This would mean that the plants the rabbits eat would be overgrazed.

c) If all rabbits were cleared, then vegetation would grow much taller, allowing nutrition for more herbivores. Rabbit predators such as foxes would diminish in number. Some animals that need bare sand, e.g. some invertebrates and reptiles, may also decline in number.

d) If all the Sea-buckthorn were cleared, the dunes would be vulnerable to erosion. However, there would be much more chance for other plants of established dunes to flourish without the overwhelming competition. The birds and animals that the Sea-buckthorn sheltered would disappear.

See completed transect with plants and animals at end of notes on Worksheet 21.

BLOWOUTS:

e) The dune ecosystem might be affected by a major Blowout destroying all the vegetation and accumulated humus. The process of colonisation would have to start all over again. This is not necessarily a bad thing.

f) The coastal problems that might be caused by Blowouts are:

- The sea might be able to encroach on the destroyed dune area, and endanger low lying areas behind the dune belt.
- Sand might blow over inland areas, roads and houses, and cause problems.

WORKSHEET 24: SAND DUNES CONSERVATION AND MANAGEMENT CAMBER CASE STUDY

What might be done to prevent the dunes eroding again?

a) Two methods to try to prevent the sea encroaching on the dunes are:

- to try to trap more sand by using fencing or netting or brushwood (e.g. old Christmas trees).
- to plant more Marram and encourage it to grow more thickly on the dunes.

b) Both these ideas would raise the height of the dunes and strengthen them. If the sand was more stable and more vegetated there would be less sand to blow onto the village.

c) Aligning paths away from the prevailing winds, and making them zigzag would help to prevent Blowouts that might endanger the dunes. Board walkways over the sand would also reduce erosion. Fencing in the paths with netting prevents people straying sideways and widening the paths, causing more likelihood of Blowouts.

d) Display boards in car park and at entrance to beach explaining the issue. Leaflets in car parks, at local shops, in holiday camp, guest houses, hotels etc.

e) Very spiny. All the tough wide spreading roots must be removed.

f) Could be used, like the Christmas trees, to trap sand in the embryo and fore dune areas.

WISSANT CASE STUDY

g) Stabilising the dunes, using the ideas from Camber (a) above, and concentrating particularly on re-vegetating them, would help to prevent the dunes advancing again.

h)

- Similar ideas would help the embryo and fore dunes to become more stable.
- A sea wall or riprap is urgently needed in front of the village

WORKSHEET 25: CROSSWORD

a)

1	D	E	C	O	M	P	O	S	E	R							
2		F	O	O	D		W	E	B								
3							C	A	R	N	I	V	O	R	E		
4			B	R	O	W	N	-	T	A	I	L		M	O	T	H
5				S	E	A		B	I	N	D	W	E	E	D		
6				P	R	O	D	U	C	E	R						
7								C	O	N	S	U	M	E	R		
8				S	E	A	-	K	A	L	E						
9					R	O	O	T	S								
10								H	U	M	U	S					
11						E	C	O	S	Y	S	T	E	M			
12						H	E	R	B	I	V	O	R	E			
13					S	H	I	N	G	L	E						

b) Sea-buckthorn

WORKSHEET 26 COASTAL TOURISM CAN IT BENEFIT THE ECONOMY WITHOUT HARMING THE ENVIRONMENT?

Symbols:
* slightly harmful
** moderately harmful
*** very harmful

The class may have slightly different ideas about this table!

Activity	sandy beaches, dunes	shingle beach	shore platform	in the sea	What sort of environmental problems does the activity cause?
Picnics	**	**			Litter. Also encourages gulls to grab food!
Off road vehicles	***	***	***		Erosion. Damages and disturbs wildlife.
Rock pooling			**		Wildlife can be destroyed.
Horse riding	***	**			Crushing wildlife.
Dogs	**	**			Faeces problem. Destruction of birds nests.
Power boats	*	*	*	**	Disturbs wildlife. Very noisy.
Fires	***	***			Destroys vegetation. Hot stones burn feet of people and animals. Heat shatters flints into sharp fragments.
Camping	*	*			Crushes vegetation. Creates litter.
Removing beach material	***	***			Causes erosion and disturbance.

This worksheet could obviously form the basis for a proper field trip, possibly on the same day as that in Worksheet 8, and incorporate material selected from the shingle or sand dune exercises

If an actual field survey talk about politeness and follow your School's Health and Safety Guidance. In particular, for safety, remind students to:
Remain in groups of 3 (or more)
Never go off with anyone!
Beware of traffic.

Questions and statistical diagrams that might be suggested include:

- Total numbers: Has this figure changed over the years? So, are they managing to attract more tourists? A line graph would make a useful display.

- How much money has each visitor spent? What was it spent on? Would have to divide into classes such as less than £10, £10-20, over £75. Bar charts could be used to display the results.
- Seasonality: Which months have most and which fewest visitors? Bar chart.
- Distance/time travelled: Divide up into groups of distances and use divided bars.
- Home town: South East England is near the Channel Tunnel, so expect some visitors from Europe. Flow map.
- Were they staying nearby on holiday? These are classed as tourists who have travelled from some distance to stay a number of nights in the area, and are known as 'day from away' visitors.
- Were they travelling from home today? This is usually known as leisure and recreation, rather than tourism, and may be counted as 'day from home' visitors.
- What sort of transport did they use? Divided bars would make a good display.
- Would they have used public transport if it had been more frequent, cheaper, better advertised?
- Age groups? What age ranges would you use and why? How many and what ages of children were with them? Pie charts.
- Social class? How would you define these and divide them up? Does this have any effect on how the park is used. Pie chart.
- What did they do while visiting the Park? Present a list of possible activities with tick boxes. Bar chart, pie chart.
- Could ask a range of questions about conservation.
- What other facilities would they like to be installed? Discuss whether these would be a good idea.
- What did they not like?
- How long did they stay at the park? 1 hr, 2, 3, 4, 5, etc. Bar chart.
- Did they ever consider their effect on the environment in visiting the Park? If so, what did they consider might be the effects on the environment? Categorise these and draw a bar chart.
- Have all suitable methods of graphing and statistical diagrams been used?
- From these the most relevant 10 questions could be selected, by class discussion.

SAMPLING:

- Always try to use a large random sample. Different ages, gender, wealth etc.

- If the class works in groups of 2 or 3 students to ask the questions, then the responses can be collated at the end of the work.

- Be careful that the same visitors are not approached by more than one group.

DISCUSSION OF CONCLUSION TO SURVEY:

- How might the answers affect the future planning of the site?
- What would be the economic advantages?
- What would be the benefits and threats to the environment?
- Are there any opportunities to enhance the environment?

WORKSHEET 27 CASE STUDY: SEVEN SISTERS COUNTRY PARK

This work could also form the basis of a fieldwork visit to the Park, combined with other worksheets.

1. MAP WORK ANSWERS
b) TV 519995

c) Meanders.

d) Because it has been artificially straightened.

e) South.

f) 1.7 to 2.0 km.

g) The walk is along a flat-floored valley, the flood plain of the River Cuckmere, through which the river meanders. On the west side of the river there are winding creeks (remnant saltmarsh creeks) and straight ditches.

The valley sides are steep, rising 60 to 80 metres. (These are the slopes of the Chalk hills of the South Downs, but this could not be deduced from the map extract). There is a side valley on the east side, leading to Foxhole Farm (TV523983) above which are a number of dry valleys descending the Downs.

Near the sea there are two lagoons (one of which was actually dug out artificially to provide a habitat for breeding waders and other birds, but this couldn't be deduced from the map).

The river takes a fairly straight course into the sea at Cuckmere Haven, across its shingle delta. Early in the last century it flowed into the sea on the east side of the floodplain, under the first of the Seven Sisters, but it then migrated westwards to take up its present position, and is now held in place by structures called training walls.

2. TOURIST SURVEYS IN THE PARK
a) 5491/ 1894 = 2.9 approximately.

f) Problems of seasonality: (Suitable for class discussion)
In winter, numbers are not a problem, but if they could be increased Park revenues could be usefully raised, helping to pay for all the staff, which still have to be employed.

In the summer holidays, numbers certainly approach Carrying Capacity, with large numbers of visitors, noise and disturbance to wildlife. The environment that people have come to enjoy is probably being harmed by so many visitors.

The main way of controlling numbers is to limit car parking.

4. ACTIVITIES
b) Most of the activities involve visitors taking exercise and enjoying wildlife in a quiet way.

c) These are not typical leisure activities for the majority of the population. (So what does this suggest about the type of visitor that goes to Seven Sisters?)

d) The questions about the types and lengths of walks are poorly drafted and overlap. The respondents were presumably allowed to give more than one answer because the percentages add up to well over 100, so it would be interesting to know how many short/long walkers watched birds or picnicked as well, etc.

5. NEW ACTIVITIES
a) They seem to be very satisfied!

b) Other possible facilities might include a bird-watching hide and, in the visitor centre, a marine aquarium based on the local marine habitats. Probably many more will be suggested.

6. MANAGEMENT PLAN
a)
For the Plan:
It provides for the needs of two sorts of visitor: the ones who remain in the vicinity of the centre and enjoy the honey pot facilities provided but don't really want to walk to the sea, or to study wildlife. The other slightly larger group have the opportunity of an interesting, increasingly quiet walk to the sea, where the peaceful environment should allow the enjoyment of the fine views and a diverse range of land and marine wildlife.

Against the Plan:
Wildlife enthusiasts might worry that birds like the kingfishers and egrets that are often near the honey pot car parks do not get enough protection. Wildlife enthusiasts who are unable to walk down to the sea might wish for some sort of transport to be provided down to the beach. Others might want more commercialised development in the honey pot area or even near the sea.

- What are the verdicts of members of the class?
- Do they agree with the negative aspects?
- What is not allowed in the Park? Do they agree with these?

Conflicts of interest
b) The farmer may wish to fence in his stock. This may not suit the interests of walkers and others enjoying their recreation in the Park.

Conservationists usually require pasture land to be grazed at very specific times of year to allow wildflowers to grow and bloom, and to encourage ground nesting birds. After the flowers have seeded and the birds flown, the pasture is usually grazed to reduce competition from coarser plants. This seasonal grazing regime may not suit the farmer's needs.

Conservationists, aiming to increase biodiversity, try to avoid the use of fertilisers that favour coarse grasses to the detriment of a more diverse flora. The farmer, however, may wish to use fertilisers to increase yields.

c) Rules to protect flora and fauna
- Remain on the paths to avoid trampling the vegetation.
- Avoid loud noises and disturbance.
- Leave plants and animals for others to enjoy.
- Take photos, not specimens.
- Keep your dog on a lead.
- Take your litter, including dog mess, home with you.
- Do not light fires.

In addition the **Sea Shore Code of Conduct** has a rule that asks people to:
Replace carefully any overturned rocks to their original position.

Reasons for this rule:
So that the side facing the light, and the shaded sheltered side, which are home for different types of organisms, are replaced as they were, not reversed. The very specialised organisms that live in shade could be killed by exposure to sun, and vice versa. Replace carefully and in exactly the same place so as not to crush any organisms.

WORKSHEET 28 EFFECTS OF BEACH LITTER ON PEOPLE AND WILDLIFE

a) Sources of litter that accumulate on beaches

- from visitors
- from boats
- from fishing
- from rivers
- from sewage outfalls
- blown in off the land
- from longshore drift, from beaches to the west

c)

- The proportion of litter that might be attributable to **beach visitors** at Seven Sisters seems much less than the Beachwatch average. This may be because the survey was taken in June, at the start of the season, rather than September, towards the end of the busy summer season.
- At Seven Sisters people have to walk a long way to reach the beach, so are less likely to deposit litter, than on beaches where there is a car park very nearby.
- The beach is never very crowded, unlike the beaches at resorts such as Brighton or Eastbourne.
- **Fishing debris** seems to be more important at Seven Sisters than in the Beachwatch Survey results.
- **Sewage related debris** is much less at Seven Sisters because there is no sewage outfall nearby.
- The River Cuckmere that flows out into the sea at Cuckmere Haven is quite small and runs through a rural area, so is unlikely to be bringing down a great deal of debris.

d) In general, the beach at Cuckmere Haven is quite a clean beach, because it has a fortunate location, and it is well looked after by Park staff.

IMPACT ON PEOPLE AND WILDLIFE

This is a difficult exercise, because it depends partly on opinion. It is included to make the pupils think hard about the problems and what discarded debris could do to man and wildlife.

b) The ranking shown overleaf is a possible answer but not necessarily the correct one.

Harm to humans	Type of Litter	Harm to Wildlife
3	Fishing Net and lines	1
3	Wooden Planks	6
2	Glass bottles	3
1	Sewage	5
3	Plastic Bottles	3
3	Plastic Bags	2

i)

TO HUMANS

Sewage is probably the worst hazard as it can spread hepatitis, ear infections and other diseases. Broken glass is another major hazard. Discarded syringes and containers of dangerous chemicals are further hazards to humans.

Marine litter is harmful to tourism, particularly (sewage related debris) which suggests that the sea and beach may be contaminated, and therefore the area should be avoided. This could deter many tourists and affect livelihoods. Sewage can contaminate shellfish, and harm this type of fishing.

Broken glass is a major hazard especially to children playing in the sand. This tends to be a problem after concerts and other events on popular beaches.

Litter looks extremely unsightly and is very off-putting to potential tourists.

Debris in the sea may damage both leisure and fishing boats, and nets may be snagged.

TO WILDLIFE
Wildlife is affected in two main ways:

- Either by **entanglement** in netting, fishing line, hence ranked first in the list, or by being trapped in bottles and cans.
- Or, by **ingestion or swallowing** where the animal mistakes plastics or other discarded objects for food.

Entanglement:
Discarded fishing net is perhaps the major culprit, floating round in the sea, 'ghost fishing', killing seals, fish and many birds. Their corpses can sometimes be seen on the strand line, wrapped or shrouded in netting. Anglers' discarded lines have also been implicated.

Bottles and canisters can often seem like sheltered homes for wildlife, but the problems these containers cause leads them to being ranked third in the list. They can easily entrap their occupants, so that they roast on a hot beach, freeze to death exposed to winter air, or starve to death. These new homes can also float off in sea currents, transporting this wildlife to other areas, where, as aliens, they may cause ecological problems.

Ingestion or Swallowing
Eating marine litter, especially plastics, can damage the animal or bird's intestines and sometimes completely block them, leading to starvation.

On the Isle of Mull, Scotland, a rare Cuvier's beaked whale was washed up. The entrance to its stomach was completely blocked with a long cylinder of shredded bin liners and fishing line.

Toxins are present in certain plastics, and when these are eaten by marine mammals, fish and birds, their immune systems may be harmed, making them more susceptible to infections. Very fine fragments of toxic plastics can be absorbed by tiny marine invertebrates that might then be eaten by the fish that we consume, concentrating the toxins up the food chain.

The overall effect of litter on marine ecosystems is not totally understood, but the problem is increasing all the time, all over the world, as litter floats or is blown into even the most remote areas.