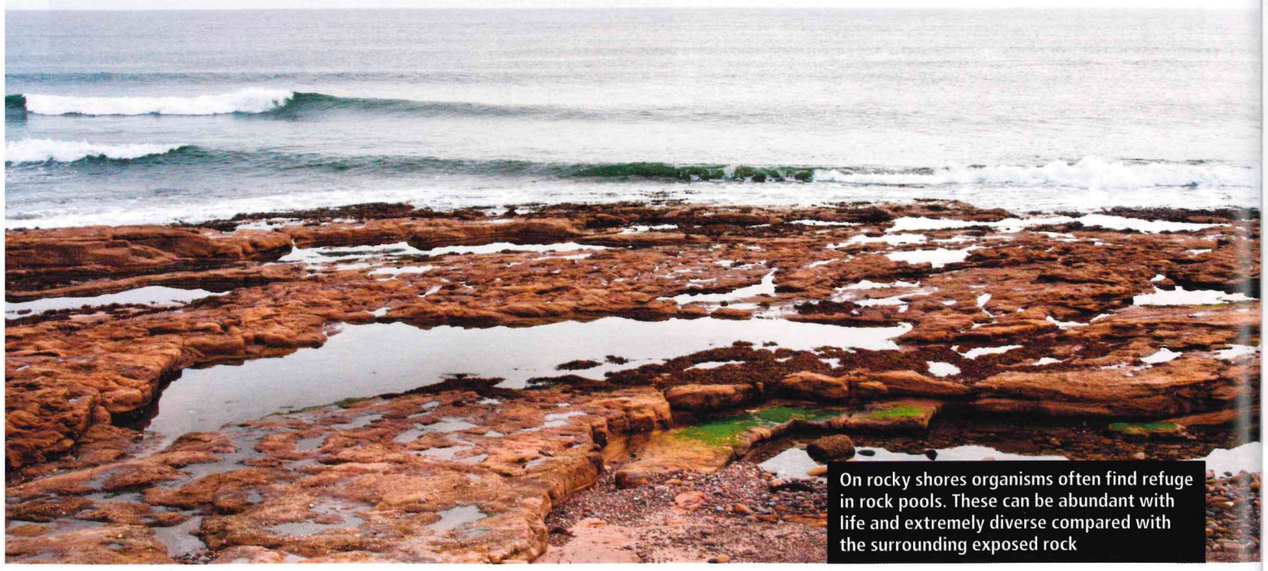
It's a hard life on the rocky shore

How organisms cope with a constantly changing environment



On rocky shores organisms often find refuge in rock pools. These can be abundant with life and extremely diverse compared with the surrounding exposed rock

Jack Thomson

Rocky shores provide us with a rare opportunity to view and study an entire natural community. Marine biologist Jack Thomson describes the behavioural and physiological mechanisms that shore-living animals use to deal with the world around them, in particular their individual behavioural coping styles when faced with challenge

Key words

Behaviour
Ecology
Habitat
Species
Community

Rock pools are an interesting distraction on seaside holidays. Shrimp mill about searching for food, periwinkles, limpets and whelks crawl on the rocks, while crabs and fish make the most of shelter, hiding away until night when they can forage more safely. Seaweeds (algae — plants) provide animals with both protection and food. But life on rocky shores can be very hard — and I'm not referring to the rock itself. Acted out under the cover of seaweed are fascinating interactions between organisms and with their environment.

Rocky shores are one of a range of different **intertidal** habitats that constitute a distinct environment somewhere between entirely marine and entirely terrestrial. The principal feature of a rocky shore is that the substratum is hard and impenetrable to all but a few animal species.

BiologicalSciencesReview*Extras*

Go online for more discussion about what algae are: **www.hoddereducation.co.uk/bioreviewextras** (Vol. 30, No. 1)

This means that animals are on the surface and, therefore, easily observed by researchers. But, compared with shores with soft sediment — sands and muds where animals can bury themselves — there are few opportunities for animals to escape from harsh environments, predators or competitors. The composition of the **communities** that are found on a rocky shore reflects how these organisms cope with both biotic (other organisms) and abiotic (physical and chemical) challenges.

The tides

The shore is dominated by environmental rhythms. The day–night cycle has an important influence on the ratio of respiration to photosynthesis in plants, and also affects animal physiology. The production of the hormone melatonin in fish and some invertebrates varies depending on the availability of light and on the time of day, and this hormone can influence behaviour. Many animals forage at night and thus avoid being seen by predators.

Another distinct rhythm on the shore is the tide — the rise and fall of the height of the sea relative to land, leaving the shore exposed or submerged. The tide rises and falls twice each day (with some unusual exceptions), with a cycle period of 12 hours and 25 minutes. The amplitude of the tide — how high and low the water goes — is largely a result of the gravitational pull of the Sun and Moon. Over the course of a month, as the relative positions of the Moon, Sun and Earth change, the pull of the Moon and Sun on the sea increases to a maximum when the Sun and Moon are aligned (spring tide) and decreases to a minimum when they are not (neap tide) (see Figure 1).

For a certain period each day, intertidal organisms are submerged or exposed, and this varies over the course of the lunar month. Those at the bottom of the shore spend the majority of their day under the water while those at the top may only be submerged for a few minutes. Unless they've

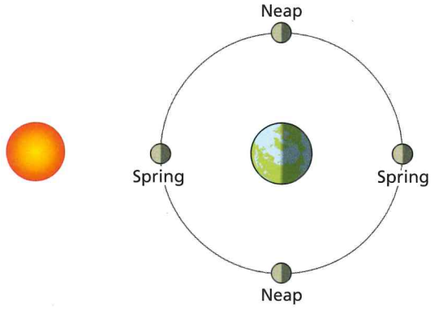


Figure 1 Relative positions of the Sun, Moon and Earth during the lunar cycle, and how these influence the tides. Spring tides have the widest range between high and low tide, neap tides the smallest

Gastropods, such as whelks and these periwinkles have a hard outer shell that protects them from predators and a harsh environment. Many marine snails also have a hard plate, or operculum, which covers the shell's opening, and reduces desiccation

found a rock pool or clump of seaweed in which to shelter, exposed animals face rapid and large changes in temperature and risk drying out (desiccation). Even those in rock pools face difficulties as the community in the pool steadily uses up oxygen and the temperature increases on hot, sunny days. The salinity of water in the pool also changes, either increasing as water evaporates or decreasing as freshwater rain falls or runs off the land into the pool. Until the tide returns, these animals are therefore under increasing physiological stress. Some are capable of protecting themselves. For example, periwinkles withdraw into their shell and seal themselves in using a hard **operculum**, a feature mostly absent in terrestrial snails. Animals must also be able to resist the impact of waves crashing against the rocks. This factor differs between shores, varying with the aspect and gradient of the shore, and with the weather. Some shores have high wave exposure, others are more sheltered.

Zonation

Abiotic factors such as the tides limit the extent to which aquatic animals and algae can extend up the shore. Being marine, most of these organisms

Terms explained

Community An assemblage of species living in the same geographical area.
Habitat An ecological area occupied by a particular species.
Intertidal Land between low water and high water tides.
Operculum A tough plate of calcium carbonate used to seal the shell of a gastropod, which prevents water loss and predation.
Pheromone A chemical produced by one animal that alters the behaviour of another.
Range The area over which a particular species is found.
Sessile Fixed in one place.
Zonation The structuring of a community by biotic and abiotic factors into discrete zones consisting of particular species or groups of species.

thrive better closer to low tide, where submersion time is greatest. When submerged they can respire and feed most effectively. Only those animals with physiological adaptations to resist the extremes of the high shore can extend their **range** into this environment. However, since all of these organisms are competing for limited space, the lower extent of the range of most organisms is defined by biotic factors including competition and predation.

The interplay between physiological tolerance to the environment and behavioural responses to competitors and predators results in zones of discrete groups of species. Each zone hosts those organisms that are best suited to, and best able to compete for, conditions at a particular shore height. Rocky shores provide one of the best-known examples of **zonation**, and this can often be clearly observed from just a short distance away as regions of different colour running horizontally along the shore. These colour bands are formed by bands of macroalgae — the large seaweeds. The seaweeds most tolerant to desiccation are found at the top, and the least tolerant are at the bottom on the low shore. Brown seaweeds show a conspicuous change in species at different tidal heights. On very exposed shores, where waves can rip them from the rock, seaweeds are replaced by mussels and barnacles, which also form distinct zones.

Biotic interactions

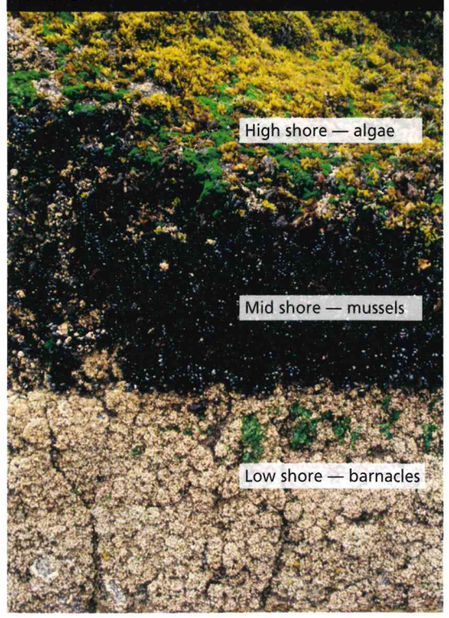
The biological interactions between and within species in a community involve a complex interplay between predation, grazing, competition and its inverse, facilitation (see Box 1). On rocky shores, potential competitors may be kept in check by predators, but competition is a major force driving community structure, especially when predators are absent.

Competition comes in many forms but is invariably over resources, such as space, food or mates. In rocky shore rock pools, cracks and crevices are in high demand, especially higher up the shore where submersion time is short. When space has already been taken, newly arriving organisms, such as water-borne larvae, may either fail to find room or may settle on top of other organisms, killing or displacing them.

Shore crabs are among the most motile of common residents on sea shores and generally aren't restricted to a particular shore height. They synchronise their movements up and down the shore with light and tidal movement. Competition among these animals is often focused around access to food and mates. When crabs come into contact with each other while foraging, they fight over available food and even engage in **kleptoparasitism** where one crab steals food from the claw of another. Males also compete over access to females, which they sense largely through the presence of sex **pheromones** in the water. Male crabs then hold on to a female until she is ready to copulate. So large is

Shore crabs can be extremely aggressive and take a fighting stance when faced with a threat

A contest between anemones. The anemone on the right has its fighting tentacles inflated and strikes down on its opponent



Three distinct zones on an exposed rocky shore, consisting of algae higher up but giving way to mussels in the mid shore and barnacles in the low shore

the inclination to obtain a potential mate that male crabs will grab and hold on to any inanimate object coated with these pheromones.

Some animals cannot move around so freely, so successfully competing for high quality territory becomes paramount. Beadlet anemones belong to a group of animals called Cnidaria (*Cnide* from the Greek work for nettle), which includes corals and jellyfish. Anemones may appear **sessile** but they can move around, usually very slowly. They position themselves in prime spots where, when submerged, they extend their feeding tentacles, embedded with stinging cells, and capture plankton (see Biological Sciences Review, Vol. 30, No. 2, pp. 12–15) or larger animals such as shrimp or fish. Suitable spots with ready access to food brought in by water currents are limited. They may not be submerged frequently enough, or already be colonised by algae or barnacles. So when an anemone is positioned in a good spot, it fights hard to keep it.

Anemones have a hidden arsenal. Lying beneath the feeding tentacles is a separate type of stinging tentacle, used specifically for fighting other anemones. When challenged, they inflate these tentacles with water and strike them down on their opponent, sometimes causing quite severe damage (see top photo and extra resources). Opponents repeatedly strike and sting each other until one cannot take any more and slowly retreats.

The extent to which these anemones fight depends on where on the shore they are found. Those higher up the shore are more likely to be aggressive than those found lower down. This seems counter-intuitive, since positions lower on the shore, where submersion time is longer, are usually held by the most competitive individuals. It may be that, since good, sheltered spots are in even shorter supply higher on the shore than lower down, anemones have to work harder to keep them.

Understanding how communities grow and develop, and how they respond to challenge, is an important component of ecology, and rocky shores provide an excellent example for the amateur and professional. Few other habitats boast such a range of environmental conditions in such a small space, nor have such diversity so clear to see.

Box 1 Facilitation

Individuals of the same or different species often compete for resources such as food and mates. In contrast, ecological facilitation describes positive, beneficial interactions within and between species, which encourage the development of diverse biological communities. For example, the presence of dense aggregations of barnacles on the high shore has been shown to act as a buffer to high temperatures, reducing rock temperature by several degrees Celsius. This in turn enhances the survival chances of other, temperature-sensitive species. An influx of blue mussels into the previously polluted South Docks in Liverpool not only provided a secondary habitat for other organisms but also improved water quality owing to the mussels' efficiency as filter feeders. This resulted in a dramatic increase in biodiversity over a period of just a few years.

Further reading

More information on rocky shores and the challenges organisms face there: **www.marbef.org/wiki/Rocky_shore_habitat**

Information on sandy shores — also a tidal habitat but with very different ecology: **www.marbef.org/wiki/Sandy_shores**

Lots of information about the wonderful range of organisms found on rocky shores: **https://tinyurl.com/y77zq6tz**

Find out more about tides: **www.ntslf.org/about-tides/tides-faq**

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Go online for 'Sea anemones stinging, fighting, swimming, reproducing and contributing to human health'
www.hoddereducation.co.uk/bioreviewextras

Dr Jack Thomson is a lecturer in marine and behavioural ecology at the University of Liverpool. He studies how aquatic animals respond to environmental challenges, including the influence of 'personality' on behaviour.

Key points

- The rocky shore is a dynamic environment with regular submersion by seawater and exposure to the air.
- Shore organisms face a range of challenges from other organisms and from their changing environment.
- How they cope with these challenges defines their position on the shore.
- Motile and sessile organisms use different strategies to cope with the stresses of life on the shore.