Introduction

The seashore
One of the most striking features of the shore is the rich diversity of plant and animal life which is to be found there. A wide range of invertebrates, some highly mobile, others fixed or sedentary, and shore fishes, are a characteristic feature. Brightly coloured lichens often form distinct bands on the high shore; seaweeds may be present in abundance, and on mud flats flowering plants may dominate. Physical factors change rapidly and it is here that the student has the opportunity to observe and study some of the most fascinating adaptations shown by plants and animals.

The dominating force on the shore is the rise and fall of the tide. Tides result from the gravitational forces between the Moon and Sun, and the seas and oceans on the Earth’s surface. The tides with which we are most familiar in north-west Europe are semi-diurnal: that is, we usually experience two high tides and two low tides each day. This can be appreciated if we picture the Earth revolving on its axis during the course of a day and passing through a water envelope which has been distorted by the gravitational forces of the Moon and Sun as in Fig. 1. In reality, however, the length of time between successive high tides is about 12 hours 25 minutes; subsequently the tides are approximately 50 minutes later each day, and there will not necessarily be two high tides and two low tides every day. Superimposed on the regular daily pattern of the tides are changes brought about by the relative positions of the Earth, Sun and Moon based on a

Figure 1  The Earth sectioned through the equator is rotating on its own axis every 24 hours. At 0 hours high water is experienced; 6 hours later low water; 12 hours later high water, and 18 hours later another low water. For detail see text.
monthly and a yearly cycle. The Moon revolves around the Earth in approximately 28
days. At the times of full and new moon, the Earth, Moon and Sun are in line and the
combined pull of the Moon and Sun on the seas produce tides with a large range. Such
tides are referred to as spring tides (Fig. 2). At times of half moon when the Sun and
Moon are at right angles to one another, the gravitational pull on the surface of the Earth
is less, giving rise to tides with a smaller range. These tides are known as neap tides
(Fig. 2).

The revolution of the Earth around the Sun in an elliptical orbit during the course of
a year also affects the range of the tides. When the Sun is closest to the Earth its gravita-
tional pull is greatest, and in March and September the combined pull of Sun and Moon
results in very large spring tides, the spring and autumn equinoctial tides. Atmospheric
pressure variation and wind speed can markedly alter the predicted height of the tide
and the configuration of the coastline can also have a substantial effect. In the Bristol
Channel, for example, where the tide is funnelled between narrowing headlands, a spring
tide range of over 12 m is recorded.

The daily rise and fall of the tide results in different levels of the shore being covered
(submersed) and uncovered (emersed) for varying periods of time. Specific tidal levels
can be calculated: these prove to be useful reference points and five tidal levels are com-
monly referred to by shore ecologists. These are average levels and are: the mean high
water level of spring tides (MHWS), mean low water level of spring tides (MLWS), mean
high water level of neap tides (MHWN) and mean low water level of neap tides (MLWN)
(Fig. 3). Mean tide level (MTL) is the average of these four tidal heights. In some texts,
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Figure 3 Shore profile showing tidal levels. MHWS — mean high water level of spring tides; MHWN — mean high water level of neap tides; MLWN — mean low water level of neap tides; MLWS — mean low water level of spring tides.

reference is made to ‘extreme’ levels (Fig. 4). Animals living at MHWS are covered for only a short period of time at high water of spring tides and are not covered during neap tides. Animals at MLWS are uncovered for only a brief period at low water of spring tides and are permanently submerged at neap tides. These varying periods of submergence and emersion lead to the development of a gradient of physical conditions such as temperature and desiccation, from high to low shore. The response of animals and plants to this gradient, together with the effect of biological interactions between groups of organisms, such as competition for space and food, lead to zonation. Zonation can be seen on rocky shores all around the world and is the occurrence of different species of plants and animals at different levels on the shore.

In his book on the ecology of rocky shores, Lewis (1964) divided the shore into three major zones marked by the presence of conspicuous and widespread plants and animals. The nomenclature proposed by him is shown in Fig. 4. It is important to note that the zones are not defined by reference to the tidal levels described above. The highest zone on the shore is the littoral fringe, the upper limit of which is marked by the upper limit of the periwinkles and black lichens. The middle zone is the eulittoral zone, the upper limit of which is marked by the upper limit of the acorn barnacles. The lowest zone is the sublittoral zone which extends below low water but its upper limit, marked by the presence of large laminarian seaweeds, can be explored at low water of spring tides. The littoral fringe and the eulittoral zone together are known as the littoral zone.

The upper limits of the zones on rocky shores are extended vertically on coasts which are exposed to heavy wind and wave action (Fig. 4) as a result of spray being carried far up the beach. In very exposed situations, the upper limit of the littoral fringe is raised by many metres forming a broad zone extending well above the level of the highest tide. On sheltered shores the littoral fringe is narrow. Exposure to wave action also affects the range of plants and animals found on the shore, as some species are more tolerant of exposure than others, and the density, diversity and form of the seaweeds on rocky shores are useful indicators of exposure to wave action (see Ballantine, 1961). The upper
reaches of the shore are harsh physical environments and it is not surprising to find that the number of different species of plants and animals is lower there compared with the middle and lower reaches where conditions are more favourable.

The distribution of littoral organisms rarely coincides with the boundaries of the defined zones explained above. As a result, the terms lower shore, middle shore and upper shore are often used by ecologists and have been used extensively in this text. The lower shore extends from the upper sublittoral to include the lower part of the eu-littoral zone; the middle shore refers to the middle region of the eu-littoral, and the upper shore to the upper eu-littoral and littoral fringe.

Anyone walking or browsing on a rocky shore will immediately be aware of the plants and animals living there, but on sandy and muddy beaches the animals generally live buried in the sediment. The size of individual particles making up the sediment is of great importance as it determines the stability of the shore and the nature and abundance of the fauna. Coarse pebble and shingle deposits are unstable habitats supporting few species. When waves break on such beaches, the pebbles roll against one another and are likely to crush the fauna. When the tide retreats, the water drains quickly and little is retained in the spaces between individual particles. Very few animals are adapted to living in such harsh conditions, whereas sandy shores offer more stable habitats for burrowing animals and retain greater quantities of water during emersion. Generally, fine sands contain more species and individuals than coarse sediments. Sand is largely made up of quartz particles, the characteristic yellow-brown colour resulting from iron deposits on the grains. Some sands contain substantial quantities of calcareous material.
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Sheltered sandy beaches support large numbers of animals but the number of different species is less than that found on rocky shores.

The finest particles, known as silt and clay, are deposited in sheltered areas: in such places mud-flats occur. Here, the increased stability of the sediment allows seaweeds and salt-tolerant flowering plants to become established, while their presence helps to stabilize the mud surface. Muddy shores are found most frequently in estuaries, where there is a heavy load of particulate matter in suspension, mainly brought down by rivers as runoff from the land. When fresh and salt water meet, the fine particles tend to flocculate and settle to form the mud banks so characteristic of estuaries. There is little circulation of water through mud deposits and this leads to stagnant and anaerobic conditions. Just under the surface of mud, oxygen may be completely lacking and in such situations anaerobic bacteria flourish, producing the characteristic smell of hydrogen sulphide so often detected when muddy deposits are disturbed. Anaerobic conditions are also found in sandy deposits, generally a few centimetres beneath the surface, and are marked by a conspicuous black layer in which the sediment is discoloured by sulphide deposits produced through the metabolism of anaerobic bacteria. The fauna of mud-flats survives in anaerobic sediments by a variety of morphological and physiological adaptations and can take advantage of the rich supplies of food available in the form of organic debris.

Organisms living in estuaries are further subjected to constantly changing salinities and because of the harshness of the physical conditions estuaries are frequently referred to as stress environments. The diversity of species is low compared with marine and freshwater habitats but abundance of individual species is high. Productivity of estuaries is high and the high densities of invertebrates makes intertidal mud-flats important feeding grounds for fishes such as flounders which migrate into the estuary on the tide, and for a wide variety of birds which feed as the tide recedes.

Collection of specimens

One of the prime concerns of all who use the shore should be to cause as little disturbance as possible to the animals and plants living there. As far as possible specimens should be identified in the field, where necessary with the aid of a good-quality hand lens. Specimens should only be collected when it is essential to do so and even then as few as possible should be taken. It is as well to remember that many species will survive if returned to the beach from which they were collected after careful handling and observation in a laboratory. Before going to the shore it is essential to have information on any peculiarities of the rate of ebb and flow of the tide and the times of high and low water for that area. Such data can be calculated for the British Isles and north-west Europe from Volume 1 of the *Admiralty Tide Tables* published by the Hydrographer of the Navy, but most coastal authorities now produce inexpensive tide tables covering the coastline within their district. Sampling should begin just before the time of low water, starting on the lower shore and moving up well in advance of the incoming tide. Special care is required when working in estuaries, where tidal currents can be very fast. Always seek local knowledge before working on sand- and mud-flats.
The type of shore being studied will determine the method of sampling, and survey methods are described in Baker & Wolff (1987). Many animals are immediately visible on rocky shores, but careful searching of crevices and rocky overhangs will reveal many more specimens. The moist conditions under a dense cover of seaweed offer refuge for a diversity of plant and animal species, while the surface of the weed is often colonized by hydroids, bryozoans and tubicolous polychaete worms. The holdfasts of the large laminarian seaweeds provide shelter for a surprising variety of small invertebrates, and boulders and large rocks can be lifted (but always returned to their original position), to reveal brittle-stars, crustaceans, polychaete worms, chitons and sea-anemones. Although one cannot emphasize too strongly the need for conservation on the shore, it can be very rewarding to take back to the laboratory small amounts of scrapings of, for example, acorn barnacles, encrusting sponges and the holdfasts of laminarians for examination in seawater under a microscope. The empty shells of barnacles provide a niche for small gastropods, bivalves and crustaceans, while sea-spiders and crustaceans are often found associated with sponges.

On sandy shores, where the fauna lives buried in the sediment, sampling has to be carried out by digging. The surface few centimetres of sediment are removed and wet sieved through a brass sieve, generally of mesh diameter of 0.5 mm. In this way the larger animals, known as the macrofauna, are retained for examination. Smaller animals, members of the meiofauna, pass through the sieve and are not included in this book. They are adapted to living in the tiny spaces between the sand grains and different sampling techniques are required for their capture.

Most macrofaunal species live in the surface 50 mm or so of sediment but there are exceptions. For example, the lugworm lives deep in the sediment, betraying its presence by worm casts on the surface. Animals living in mud often construct permanent burrows and the practised eye can detect the openings of these on the surface. Such specimens can be dug for selectively, but it must be borne in mind that much damage can be done to sand- and mud-flats by indiscriminate and reckless digging.

Nomenclature and classification
All organisms described in this text have been given their scientific name. The system of scientific nomenclature in use today stems from the work of the Swedish naturalist Linnaeus, and the publication of the 10th edition of his Systema Naturae in 1758. This marked the beginning of the binomial system of nomenclature by which plants and animals are given two names. The first (the generic name) is the name of the genus to which the organism belongs and begins with a capital letter. The second is the species or specific name, which begins with a small letter. The name of the person (or persons) who assigned the specific name follows the name of the organism. This person is known as the author. If, since the original use of the specific name, that species has been transferred to a different genus, the name of the author is in parentheses. Two names are often written after the scientific name of a plant. This means that subsequent to its original description by the first author (whose name is in parentheses), the plant has been transferred to a new genus by the second named author. It should be noted that
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in most texts the names of the authors of plants are given in abbreviated form. The internationally accepted system of nomenclature using the scientific name followed by the author ensures that there is no ambiguity regarding the species under consideration. In some cases, the scientific names have undergone revision and here the former, sometimes more familiar, scientific name has also been included in the text. Where appropriate, the common name or names are given.

Organisms are grouped according to their similarities and affinities and are thus arranged in a system of classification. Closely related species are grouped into genera, and genera into families. Families are grouped into orders; orders into classes and related classes are grouped into phyla. Morphological and anatomical features are used by taxonomists when considering classification and in some cases the creation of subphyla, subclasses and suborders has proved useful.

references

The seashore

Collection of specimens

Nomenclature and classification
Design and layout of the book

This book has been designed both as a guide to the identification of the common and widespread organisms of the shore and as a biological text giving information on their biology and ecology. It is intended for use by students and teachers, and also by naturalists and others who might have little or no formal scientific training.

In the following pages, the different groups of organisms are arranged in phylogenetic sequence. Readers who are unable initially to assign an organism to its phylum or group are referred to the illustrated key on p. 10. When the phylum or group to which an organism belongs is known, reference can be made directly to the appropriate chapter where the reader will find an outline classification of the group or phylum in which the classes, subclasses, orders, etc. included in the text are shown in bold type. A brief statement on the morphology and biology of the group is also included. For most groups a simple dichotomous key is provided. In some cases this is to the level of families and leads to a full statement of family characteristics, followed where appropriate by a key to species. In other cases the phylum or group has been keyed directly to species. Morphological features are the basis on which identification is made but in many cases the type of substratum on which the organism is found, position on the shore and distribution are important characteristics.

For each species there is a statement of diagnostic features, a drawing and notes on its biology. The names in brackets following the species name and authority are the synonyms by which the species might be known in older texts. Common names are included as appropriate. Scientific terminology used in the description of species has been kept to a minimum and is explained in the introductory sections at the beginning of each chapter. For ease of reference a glossary is given at the end of the book. A scale has not been included on the drawings but the size of each species is given in the diagnostic features.

The inclusion of family and species keys followed by a full statement of diagnostic features for each species has led to some repetition, but this enables those readers more familiar with the identification of shore organisms, and using the book as a reference text, to turn directly to an appropriate page reference where their provisional identification of an organism can be confirmed and where they will find detail on the general biology of the species in question.

*The keys cover only those organisms included in this text and readers will undoubtedly come*
across species not included here. For this reason, every effort has been made to prevent false identification. Attention is drawn to cases where confusion might arise. Where identification to species is beyond the scope of this book, identification has been made to genus. When an organism has been identified to a family, it should be checked against the family characteristics before proceeding further. When identification to species has been made, this should be checked carefully against the diagnostic features, the drawing and the habitat characteristics given for that species. If a specimen cannot be identified from the information given in this book, reference should be made to the specialist keys listed at the end of the section.
Illustrated guide to the plants and animals of the shore

The following guide has been designed to help those readers who are unable initially to assign an organism to its correct phylum or class. The guide is divided into nine groups, each recognized by the general characters given, for example, encrusting, worm-like, etc. Each of these groups is broken down into subdivisions which are described and illustrated, and for each subdivision a page reference is given where further information can be found. In a few cases the guide will indicate that an organism belongs to one of two or more subdivisions, and for each a page reference is given. To design a guide covering a broad range of plants and animals for use by readers with widely differing background knowledge is difficult as its success will to some extent be affected by subjective assessment of the characters listed. Representative sketches of each group of organisms have been included as a further aid to identification.

Plants and plant-like animals

Encrusting, without a hard shell, shell plates or a hard tube

Attached at base, lacking tentacles; gelatinous. Not plant-like

Worm-like animals, varying in shape from long and rounded to flat and leaf-like

Animals with jointed appendages, mobile

Animals with a spiny skin, hard outer skin; hard shell, shell plates or hard tube; without jointed appendages (or jointed appendages not obvious)

Soft and slug-like or leathery and cucumber-shaped; creeping

Soft and gelatinous, swimming or floating

Fishes

Group 1 (p. 11)

Group 2 (p. 15)

Group 3 (p. 16)

Group 4 (p. 17)

Group 5 (p. 21)

Group 6 (p. 23)

Group 7 (p. 27)

Group 8 (p. 27)

Group 9 (p. 28)