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Excerpt
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Introduction

The seashore

One of the most striking features of the shore is the rich diversity of plant and animal life 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 often dominate. Physical factors change rapidly and it is here that the student has the opportunity to observe and study the fascinating adaptations to this environment shown by both plants and animals.

Tides

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, there are usually two high tides and two low tides each day. This can be appreciated if the Earth is pictured 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. 1.1. Because of the constantly changing positions of the Earth, Sun and Moon, the length of time between successive high tides is not exactly 12 hours but 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 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 gravitational attraction of the Moon and Sun on the seas produces tides with a large range. Such tides are referred to as spring tides (Fig. 1.2). At times of half moon when the Sun and Moon are at right angles to one another and their forces are in opposition, 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. 1.2). The height of the tide is measured in metres above a datum level known as chart datum (Fig. 1.3).

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

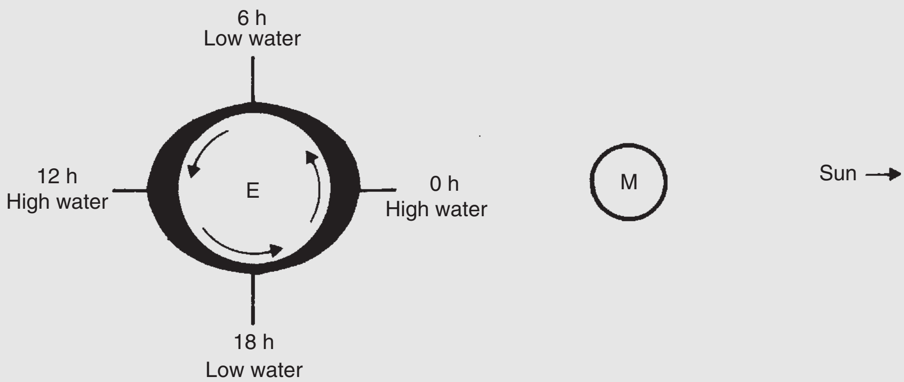

Figure 1.1 The Earth sectioned through the equator is rotating on its own axis every 24 hours. At 0 h high water is experienced; 6 h later low water; 12 h later high water; and 18 h later another low water. For detail see text.

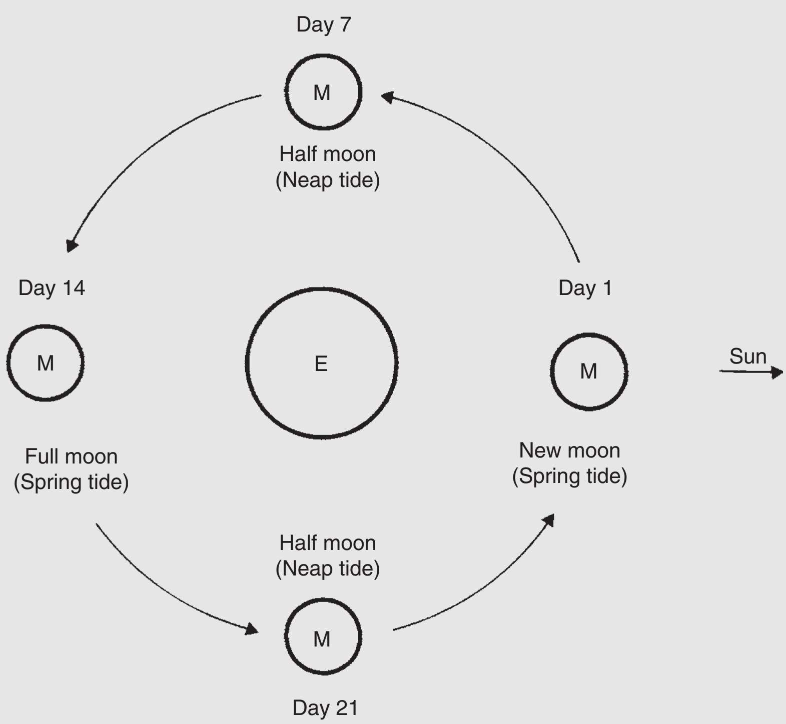

Figure 1.2 Orbit of the Moon around the Earth showing the times of spring and neap tides.

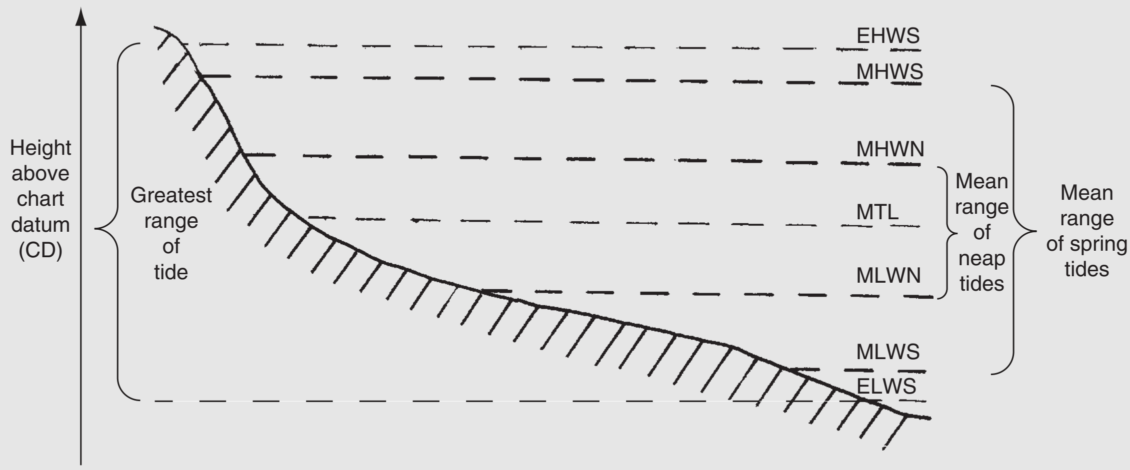

Figure 1.3 Shore profile showing tidal levels. EHWS, extreme high water level of spring tides; MHWS, mean high water level of spring tides; MHWN, mean high water level of neap tides; MTL, mean tide level; MLWN, mean low water level of neap tides; MLWS, mean low water level of spring tides; ELWS, extreme low water level of spring tides.

its gravitational 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 have a marked impact on the height of the tide and in extreme cases meteorological conditions can lead to storm surges during which the predicted height of the tide is greatly exceeded. This can lead to natural disasters such as that in the North Sea in January 1953 which resulted in extensive flooding of the coastlines of England and the Netherlands and serious loss of life. The configuration of the coastline also has a substantial effect on tidal range. In the Bristol Channel, for example, where the tide is funnelled between narrowing headlands, a spring tide range of over 12 m is recorded, compared with less than 1 m in some areas.

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 are often referred to and these prove to be useful reference points for shore ecologists. These are average levels and five such reference points are extensively used; these are: 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. 1.3). Mean tide level (MTL) is the average of these four tidal heights. Reference is also made to extreme spring tide levels (Fig. 1.3), these being the highest and lowest tides of the year. Animals living at MHWS are covered by the sea 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 submersed at neap tides. These varying periods of submersion and emersion lead to the development of a gradient of physical conditions such as temperature and desiccation from high to low shore and the response of animals and plants to this gradient, together with the impact of biological interactions between groups of organisms such as competition for space and food, lead to zonation (Plate 6).

Zonation is the occurrence of different species of seaweeds and animals at different levels on the shore and can be seen on rocky shores all around the world.

Rocky shores

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 seaweeds and animals. The nomenclature proposed by him is shown in Fig. 1.4 and it is important to note that the zones are not defined by reference to the tidal levels described above but by reference to biological factors, that is, the distribution of specific organisms or groups of organisms. The highest zone on the shore is the littoral fringe, the upper limit of which is marked by the upper limit of the periwinkles (p. 214) and black lichens (p. 70). The middle zone is the eulittoral zone, the upper limit of which is marked by the upper limit of the acorn barnacles (p. 305). The lowest zone is the sublittoral zone which extends below low water but its upper limit, marked by the presence of the large laminarian seaweeds (p. 57), can be explored at low water of spring tides (Plate 5b). The littoral fringe and the eulittoral zone together make up the littoral zone.

The upper limits of the zones on rocky shores are extended on coasts that are exposed to heavy wind and wave action (Fig. 1.4) 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 seaweeds and animals found on the shore as some species are more

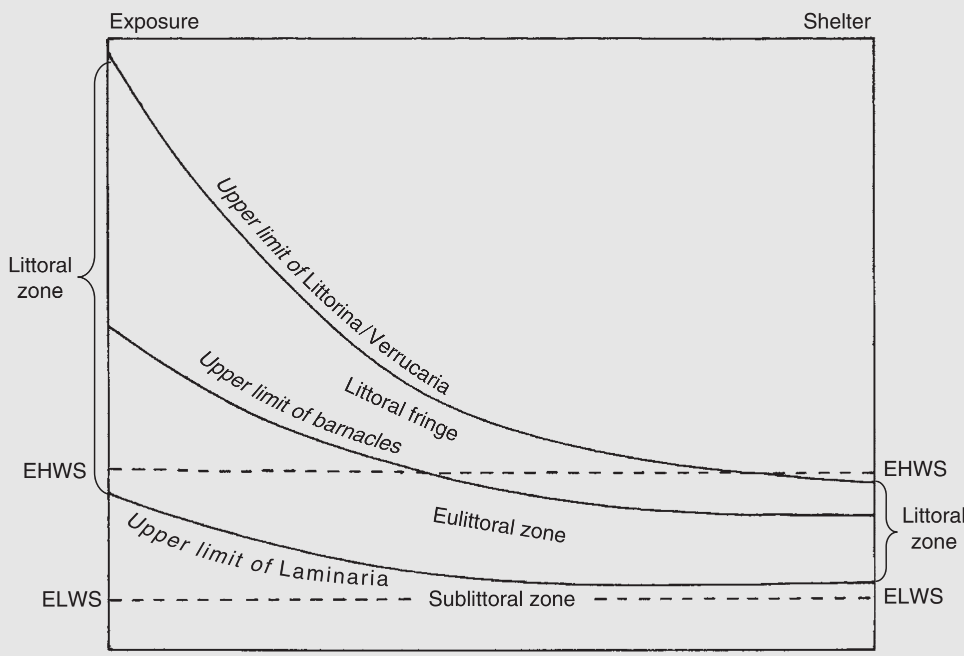

Figure 1.4 Rocky shore zonation. ELWS, extreme low water level of spring tides; EHWS, extreme high water level of spring tides (after Lewis, 1964).

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 is lower there compared with the middle and lower reaches where conditions are less stressful. Some organisms may be restricted to one zone on the shore but the distribution of the majority of species extends across more than one zone.

The distribution of littoral organisms rarely coincides with the boundaries of the zones defined above. As a result, the terms lower shore, middle shore and upper shore are often used by ecologists to note relative positions on the shore. These terms have been used extensively in this text: the lower shore extends from the upper sublittoral to include the lower part of the eulittoral zone, the middle shore refers to the middle region of the eulittoral, and the upper shore includes the upper eulittoral and littoral fringe.

Sandy and muddy shores

Rocky shores offer a stable, solid surface on which organisms can attach, and anyone walking or browsing on such shores will immediately be aware of a rich diversity of seaweeds and animals. This is in contrast to sandy beaches where there is a lack of stable surfaces on which organisms can attach and here the fauna generally lives buried in the sediment for protection. The size of individual particles making up the sediment is of great importance as it determines the stability of the shore and factors such as the amount of water that can be held by the sediment when the tide is out. Coarse pebble and shingle deposits are unstable habitats and when waves break on such beaches, the pebbles roll against one another and are likely to crush the fauna. When the tide retreats, the sea water drains quickly and little is retained in the spaces between individual particles. These are harsh physical environments and very few animals are adapted to living in these conditions. Sand deposits are largely made up of quartz particles, often with substantial amounts of calcareous material, and the characteristic yellow-brown colour results from iron deposits on the grains. Sand deposits have a much smaller particle size than pebble and shingle deposits and retain greater quantities of water during emersion. As a result, they offer more stable habitats for burrowing animals and sheltered sandy beaches support large numbers of animals but the number of different species, the species diversity, is generally less than that found on rocky shores.

The finest particles, known as silt and clay, are deposited in sheltered areas giving rise to mud-flats. Here, the increased stability of the sediment allows seaweeds and salt-tolerant flowering plants to gain anchorage and their presence further stabilizes 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 mud banks. These are rich in organic matter but there is little circulation of water through such fine deposits and this can lead to stagnant and anaerobic conditions. Just under the surface of mud deposits, oxygen may be completely lacking and in such situations anaerobic bacteria flourish, producing the characteristic smell of hydrogen sulphide so often detected when the mud is disturbed. Anaerobic conditions are also found in sandy deposits but these are generally encountered a few centimetres beneath the surface and are marked by a conspicuous black layer (Plate 24b) in which the sediment is discoloured by sulphide deposits produced through the metabolism of anaerobic bacteria. The presence of this black layer is a useful ecological indicator. The fauna of mud-flats survives anaerobic sediments by a variety of morphological and physiological adaptations and can therefore take advantage of the rich supplies of food available in the form of organic debris.

Organisms living in estuaries experience water of constantly changing salt concentration or salinity. Sea water of the open oceans away from the influence of freshwater drainage from the land generally has a salinity of 3.5 grams of salt per 100 grams, and this has traditionally been expressed in parts per thousand as 35‰, i.e. 35 grams of salt per litre of solution. In 1978 salinity was redefined using a Practical Salinity Scale and salinities are now expressed in Practical Salinity Units (PSU) simply as numerical values. The constantly changing salinities in estuaries mean that organisms can experience values ranging from almost 0 to above 30. These are harsh physical conditions and as a result, diversity of species is low compared with adjacent marine and freshwater habitats but abundance of individual species can be very high. Productivity of estuaries is high and the high density and biomass of invertebrates make intertidal mud-flats important feeding grounds for a wide variety of birds, often seen feeding as the tide recedes, and a range of fishes some of which migrate into the estuary on the flood tide to feed, retreating as the tide ebbs. The drainage channels so conspicuous on mud-flats (Plate 27c) are home to a number of resident invertebrates and fishes and in some estuaries they may be important nursery grounds for the young of commercial species.

Collection of specimens

One of the primary objectives of all who use the shore should be to cause little disturbance to the organisms living there. Wherever possible, specimens should be identified in the field, where necessary with the aid of a good-quality hand lens. If specimens are removed from the shore, few should be taken and it should be borne in mind 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. Remember that tidal conditions, including the time and height of high and low waters, vary from one location to another. Tidal data are available on the internet and from *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 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 and quicksands can be encountered. Always seek local knowledge before working on sand- and mud-flats, and inform appropriate contacts of your whereabouts and programme of activities.

The type of shore being studied will determine the method of sampling, and survey methods are described in a number of texts listed in the introductory section of the Bibliography (p. 475). 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 species, while the surface of the weed is often colonized by hydroids, bryozoans and tubiculous 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 a wide range of fauna. Although the need for conservation on the shore cannot be emphasized too strongly, it can be very rewarding to take back to the laboratory small amounts of scrapings of, for example, acorn barnacles and the holdfasts of laminarians for examination in sea water under a microscope.

On sandy shores, where the fauna lives buried in the sediment (infauna), 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, and animals above this size, known as the macrofauna, are retained for examination. Smaller animals, members of the meiofauna, pass through the sieve. These 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.

Many macrofaunal species live in the surface 50 mm or so of sediment where the interstitial water circulates freely between the grains and is oxygenated. Others live deeper in the sediment. For example, the lugworm (p. 147) lives at depths of 200 mm or more and betrays its presence by worm casts on the surface (Plate 24c). A wide range of bivalve molluscs also lives in anaerobic conditions deep in the sediment and like the lugworm shows a range of adaptations to survival in these conditions. 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 scientific name follows the name of the organism. This person is known as the author. If, since the naming of the animal it 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 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, however, taxonomic research results in changes to scientific names and this can lead to confusion. In this text the former, sometimes more familiar, scientific name(s) has also been included. Common names in wide usage are also given. Rules governing nomenclature are given by the International Commission on Zoological Nomenclature (1999) and by McNeill *et al.*, International Code of Botanical Nomenclature (2006).

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.

The nomenclature and classification of organisms is constantly being researched and revised and for this reason information given in different texts may vary. The nomenclature used here mainly follows Costello, Emblow & White (2001) and The Marine Biodiversity and Ecosystem Functioning EU Network of Excellence (Mar BEF). Details of other sources used are given in the relevant chapters. The system of classification is based largely on Brusca & Brusca (2003).

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, lecturers 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 guide on p. 11. 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 introduction giving the main characters of the phylum or group together with a full classification in which those classes, subclasses, orders, etc. included in this text are highlighted 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. This information is included in the text where appropriate.

The entry for each species is presented as follows:

Genus species Authority (*former name(s)*) Common name(s) **Fig.**

Generic and specific names are shown in bold italic script followed by the name of the person(s) who described the species, the authority, which may or may not be in brackets (see p. 7). This is followed by any former names by which the species has been known and referred to in earlier/other texts. Finally, common names in wide usage are included, followed by reference to the figure number in bold type. In some cases there is also reference to a plate number.

For each species there is a statement of diagnostic features, in italic script, a drawing and notes on its biology. 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 and the glossary at the end of the book. Important diagnostic features for a particular group or individual species are labelled on the appropriate drawings. A scale has not been included on the drawings but for guidance the size of each species is given in the diagnostic features. For ease of reference, drawings are interspersed in the text.

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 biology of the species in question.

At the end of each chapter there is a short list of specialist references, useful in further identification, covering the phylum/group in question. Some of these have been referred to in the text where they are in bold type. Other references, cited in the text but not in bold type, are to be found in an extensive bibliography of research papers and books (p. 475) from which information on the biology of the species has been gathered. This will allow readers with specific interests to develop further lines of enquiry. For ease of reference the bibliography is broken down into phyla or in some cases classes.

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 and where appropriate reference to specialist texts and further reading is given. 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.