2 | Field Teaching Methods in Shore Ecology

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INTRODUCTION

The classic field course – the "Easter Course" at Bangor, Plymouth, Port Erin or Millport which formed an essential part of the training of so many British biology students – is still remembered by many of them as a high point in their undergraduate careers. For many zoologists it was, in fact, their only experience of fieldwork. Things have changed greatly in the last decade, however, with the expansion of universities; a far greater diversity of field courses has appeared, usually organized by the student's own university. The emphasis has moved from the traditional systematic approach – away from seeing organisms in their natural setting and later identifying and examining them in the laboratory – towards, in some cases, a more ecological approach involving quantitative work. In other courses, a laboratory-orientated series of physiological exercises is conducted, the "fieldwork" being merely the means by which the experimental material is obtained. The latter activity hardly merits the name of field course, however, and can be disregarded in the context of this paper.

Another trend is a move towards increased littoral fieldwork on the part of some secondary schools. A few of the more enlightened

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ones have always encouraged it; the present development is partly the result of the inclusion of a Marine Biology option in A-level biology syllabi. Like most A-level syllabi, these seem grossly overloaded so that a week's field course may be the only way in which the pupils may be introduced to the real pleasures of the subject, besides experiencing something of its diversity. Anything which encourages fieldwork in sixth forms is to be welcomed, but the enquiries which I receive through the post sometimes indicate a degree of inexperience in the organization of these courses; this suggests that a few words here may be of some value. It is proposed, therefore, to survey a range of methods which have been used and modified in long series of field courses at Menai Bridge and elsewhere for students at many levels of experience.

BASIC NEEDS

The methods used in a particular course must be selected to suit the previous experience and training of the students concerned, but there are a number of fundamental points which need consideration in the organization of all littoral fieldwork and which deserve a brief mention.

1. Time and Tide

The organizers of the course should make themselves familiar with "The Admiralty (Annual) Handbook of Tides", check that the dates selected for the course coincide with spring tides, and check when low water occurs on the shores they propose to visit. Their students should also be introduced to these tables. Check the times of low water against those of sunset – in spring and autumn this can cause problems in some places around Anglesey and the Isle of Wight.

2. Local Knowledge

If the organizer already knows the locality, well and good (they probably will – students who become teachers seem to return to the shores on which they were trained), otherwise local advice should be sought. It can save embarrassment and delay to know beforehand which shores can be worked in bad weather and which shores are good "typical" examples of sheltered rock or muddy sand. If you are to use a coastal laboratory, Field Centre or school it will be obvious whom to ask, otherwise try the local Naturalists Trust. If you are organizing a course for the first time there is a great deal to be said for doing so at a Field Centre or Marine Biology Station, where there will be a tremendous repository of local knowledge and experience.

3. Safety

Safety seems to be the fastest growing preoccupation in both industry and education at the present time. Little need be said here – perhaps fieldwork will be overlooked by the legislators of timidity and may proceed in the traditional (and remarkably safe) way – but it should be pointed out that there are a few rules. The inexperienced should avoid exposed surf-swept shores and, on any but calm days, should heed the warnings of locals. All should avoid short-cuts up or down cliffs. Carry a first aid outfit and learn how to use it – you are unlikely to need it but it is a valuable morale builder and insurance policy.

4. Clothing and Equipment

Most students on field courses seem to wear too little in winter and too much in summer. Windproof and waterproof outer garments are essential, except in hot weather, and rubber boots are also vital; you cannot avoid getting into the water and prolonged wading is uncomfortably chilly in British seas, except in late summer. Personal equipment should include polythene bags and some sort of container (basket or bucket), a strong knife or cold chisel and a hand-lens of not less than × 10 magnification (× 20 is very useful); note books and pencils are vital. I am doubtful of the wisdom of taking identification literature on the shore – books are expensive and are not designed for immersion in sea water.

5. Aims of the Courses

Careful thought beforehand can greatly increase the usefulness of the course. Is it to be mainly systematic – if so, what groups should be looked for on which shores? Should fruiting material be collected for study later? Are particular ecological phenomena to be investigated or demonstrated and if so will the identification of a limited number of organisms be sufficient? Is it hoped to teach particular sampling techniques and, if so, is the shore the best place or are there other principles on which it might be more profitable to place the emphasis?

6. Conservation

Biologists are not exempt from the rules of good husbandry; a scientific interest and the needs of research do not justify the collection of large numbers of organisms. Nothing should be done which will permanently damage a shore. Stones which have been turned over should be carefully replaced; digging on sheltered beaches should be limited to what is essential. Care should be taken to avoid accidental damage to rocky shores by sliding feet in wet weather. This is important; some shores on Anglesey and Pembrokeshire for instance have deteriorated in recent years as a result of too much enthusiastic but poorly-controlled activity.

7. Preparation

Students should read beforehand appropriate introductory texts. Yonge (1949) is an obvious choice, as is Southward (1965). Lewis (1964) is more specialized and will be found invaluable at later stages.

IDENTIFICATION

The need for accurate identification of the organisms encountered is paramount. It will not be necessary at first to name everything (see below), but all that are named should be identified with all possible certainty. This will mean work with lens, microscope (this can seldom be avoided) and keys. The deservedly popular introductory volume by Barrett and Yonge (1958) is a most useful first step, particularly for the animals. Campbell (1976) has some excellent illustrations but lacks keys and is therefore of less value in teaching. For the most up-to-date listing of the key works available, Kerrick *et al.* (1978) should be consulted.

A very full account of the algal literature was recently given by Price (1978) and needs no amplification here. A good key to the marine and maritime lichens is available (Fletcher, 1975a,b). The situation is less satisfactory, however, in the animals. Eales (1967) is still a very useful book, treating the littoral animals and displaying more anatomical detail than Barrett and Yonge. Invertebrates are well illustrated in colour in George and George (1979). At the lower end, the Protozoa are poorly covered: Jahn and Jahn (1949) is useful at the generic level and Newell and Newell (1973) include a few Protozoa, although their work is essentially concerned with planktonic forms. Sponges lack a modern treatment and the Ray Society monograph (Bowerbank, 1864–1882) is now difficult to obtain. However, the photographic guide to the sponges by Earll (1978) will be found very useful and the forthcoming enlarged edition should be even more valuable. The coelenterates have Hincks (1867) on hydroids and Stephenson (1928) on anemones; both are good but not easy to obtain and a good modern key is badly needed. Earll's (in press) forthcoming photographic guide to the Anthozoa will be very useful here.

Few field courses concern themselves seriously with the nematodes or flat worms and there is no readily accessible key to either group; this is a sad state of affairs!

On the annelids, MacIntosh's (1873–1923) monumental work is far too cumbersome (and valuable) to use on fieldwork but Clark (1960) describes the Clyde area polychaetes in a compact volume and Fauvel (1923; 1927) offers a very complete account. Oligochaetes necessitate another large-scale work – by Brinkhurst and Jamieson (1971).

Gibbs (1977) has covered the Sipunculids in a volume of the Linnean Society Synopses of the British Fauna. In the same series some Arthropod groups have been included: Isopoda (Naylor, 1972), Pycnogonida (King, 1974) and Cumacea (Jones, 1976). Besides these, the Clyde Sea area series includes the Euphausiacea and Decapoda by Allen (1967).

The amphipods had no recent British coverage, though Lincoln's very recent book closes this gap; useful reference may also be made to Chevereux and Farge (1927), or to Sars (1895–1921). For barnacles the recent key of Southward (1976) is invaluable.

The key to the Malacostraca by Gledhill *et al.* (1976) is mainly concerned with freshwater organisms but is nevertheless valuable to marine field workers in its inclusion of all the British species of *Gammarus*.

The Mollusca are reasonably well covered by recent works: Prosobranchia by Graham (1971) and Opisthobranchia by Thompson and Brown (1976), which work is also the basis of Earll's (1980) excellent photographic illustrations. Chitons are treated by Matthews (1953) and Lamellibranchiata by Tebble (1966). Recent revisions of the littorinids have left some species in a state where field determination is difficult and there is a good deal to be said for beginners (at least) retaining the traditional view of *L. obtusata* (L.) and *L. saxatilis* (Olivi) – though in the latter the division into *L. neglecta* Bean, *L. nigrolineata* Gray and *L. rudis* Maton (Heller 1975) can usually be managed with practice and expert help.

Bryozoa have a recent key by Ryland and Hayward (1977) and the Echinodermata have good coverage in Mortensen (1927), from which Southward (1972) has developed her simplified key for use by correspondents of the Marine Biological Association's echinoderm survey.

Tunicates also have a volume in the Linnean Society's series (Millar, 1970). Fish are covered in a number of volumes, of which Wheeler (1969) is particularly complete, supplemented by the excellent illustrations of Lythgoe and Lythgoe (1971).

Most of the works mentioned above require some specialized knowledge and this has to be acquired gradually. Apart from the general books mentioned at the start, beginners should find out about the Field Studies Council's Aidgap project which is intended to help the novice.

It must be emphasized to students that a temporary identification supported by a specimen is perfectly satisfactory in an ecological survey, provided it is properly keyed out later.

DESCRIBING THE SHORE

Whether or not the account of the flora and fauna is to be purely qualitative, taking as its simplest form a check-list of everything seen, its relation to the habitat in which it was found will entail a description of the shore. Some of the habitat details will not be difficult to establish, e.g. the nature of the substratum (sand, sandy-mud, shell gravel, rock etc.) with an increasing amount of detail (rock type etc.); the position in relation to the surface (buried at a particular depth, on the surface, in cracks or crevices etc.); whether in pools or not; whether in sun or shade and so on. Other parameters of importance will be the intensity of wave-action and vertical position on the shore relative to low water mark (LWM). The former can be decided by reference to one of the biological exposure scales (Ballantine, 1961; Lewis, 1964); more direct methods of wave-force measurement are beyond the scope of normal field teaching.

Fixing the position of specimens or collecting sites on the shore seldom requires mapping techniques. The Ordnance Survey produces excellent maps which, although rather more conventional in their representation of intertidal features as compared with the inland detail, are usually quite adequate for position fixing. It should be noted, however, that the LWM of these maps is well above the line to which good spring tides recede and this should be borne in mind when the extent of a muddy beach, for instance, is being reported. In all ecological work in Great Britain, the National Grid will be found a valuable reference system, particularly since a number of recording schemes take it as the basis for their mapping.

1. Mapping

Where mapping is required, it will usually be of small areas, to produce an outline, for instance, of a pool on which the distribution of organisms can be shown. The most convenient technique is the line and offset method, a standard surveying method which can be found described in all surveying texts. Briefly the method involves establishing a straight line either along or parallel to the long axis of the feature; a metric tape measure is ideal. At measured distances along this tape, perpendicular lines are measured from the tape to salient features on the pool edge. These can be recorded by the standard surveyor's method but for the limited size of the pools usually measured, a rough sketch on which the dimensions are inserted will be found adequate. The lines from the tape to the topographical features should be exactly at right angles to the tape; this can be ensured by the use of a surveyor's right-angled sighting prism or a large home-made T-square. It is worth emphasizing to students that they should keep in mind the fact that their observations are intended to produce a map at the end and that any extra notes which will prevent ambiguity should be included. Mapping of larger areas, usually by plane-table, will seldom be needed in shore ecology, although it can sometimes be useful on such places as salt marshes.

2. Levelling

On any shore there will be a major gradient of changing conditions at right angles to the water line from fully marine below LWM to fully terrestrial some way above HWM. Many changes in shore fauna and flora are related to this and so any attempt to display or explain these changes will have to take into account the vertical level of the organism above LWM. Other factors such as the slope of the shore will be important and the best way to summarize this information is by means of a shore profile. This involves the laying down of a metric graduated line along the ground in the direction required and the measurement of the vertical distance from salient points on this line to a fixed datum level. The transect line can be a measuring tape or, if available, a metric land chain. The latter has the advantage of not requiring weighting on windy days but is heavier to carry. The traditional Gunter's chain is graduated in inconvenient units and should be avoided. At its most primitive, the line can utilize a cord knotted at 1 m or other suitable intervals. The fixing of the datum level is described later. Once this is decided, various methods of levelling to it are available. In order of apparent simplicity, these include:

(a) Rules and spirit levels. If a metre rule has a spirit level lashed to it, it can be used with a second vertical rule as shown in Fig. 1. This is direct and simple and can be used effectively for detailed work over short distances on steep slopes; it is less useful on gentle gradients and very inaccurate if used over long distances since errors will accumulate. It is most useful if detail (say of pools or crevices) is to be added to a larger area survey.

(b) Stretched string and rule. This is an extension of method (a) in which a long cord, held straight and adjusted to a spirit level, provides

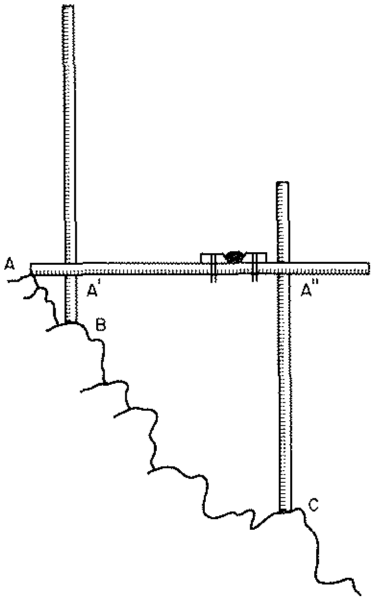

Fig. 1. A simple method of levelling using metre rules, one with a spirit level attached as shown. When this rule is held horizontal with one end on the known level, A, then a vertical rule placed successively on the points B and C allows their vertical heights below A (i.e. A′B and A″C) to be read off directly.

the datum line. It is very simple but requires several pairs of hands and is less convenient on steep slopes. Useful for such exercises as obtaining the profile of a pool, it may be convenient to extend the vertical measurement by fixing two or three metre rules together end to end on a lath. (Great accuracy cannot be expected from methods like this.)

(c) Can and tube. In this method (said to be derived from methods used by Egyptian surveyors in setting out pyramid foundations) a length (say 30–50 m) of 10 mm diameter transparent plastic tubing is used. One end is fixed into a large (2–5 litre) plastic can or bottle which is filled with water. Suction is applied to the free end by mouth and the water made to siphon over; the tube is allowed to fill and the free end raised until the meniscus is below the opening;

Fig. 2. The use of can and tube for levelling. Providing that the siphon in the tube is unbroken, the water surface in the can and the meniscus at the distant end of the tube must be at the same level. This allows the height of another point to be measured directly as shown.

bubbles must be avoided. When the system has steadied, the water surface in the can and the meniscus must be at the same level. If the bottle is placed with the water surface at a known level, the difference between that level and any point below it on the transect can readily be measured by moving the free end of the tube to the appropriate position and measuring down to the tape (Fig. 2). A 2 m measuring rod (i.e. two metre rules) will give a useful range down the transect before the can has to be moved. At a pinch, this method can be employed single-handed, but two persons make it more convenient. Potentially this method is very accurate, despite the simple nature of the apparatus, and I find its operation very easily grasped by classes who find the use of staff and level puzzling. This is the only surveying method which does not require that the two points being compared should be intervisible, which can be useful on some very broken rocky shores. Long intervals, limited only by the length of tube available can be worked easily and accurately which makes the system useful on sand beaches. It also provides a rapid method of transferring a known level along a shore or between the two sides of a bay. To do this the can is held with the water surface at the known level, the tube is taken along the shore to its full extent and the meniscus level marked by chalk or chisel on a convenient rock surface. Can and tube are then advanced together until the can is at the chalk mark and the meniscus the tube length away, where it is used to mark a third point. The procedure is then repeated, so that the datum mark can be advanced along the shore almost as fast as people can walk over it.

(d) Cross staff. This is a method developed by workers around Milford Haven and has recently been described quite fully (Nelson-Smith 1979) so that a brief account will suffice here. The instrument is a wooden cross with a spirit level on the horizontal bar. The leg is placed on the ground at a known level and the operator sights along the cross bar. An inclined mirror over the level allows the observation of the bubble at the same time so that the sight is taken along a truly horizontal line.

Starting from a downshore position, the surveyor sights on another point higher up shore. This means that the target point is higher than the datum by the length of the leg. If the target point is marked, it can then become the next station for the leg so that the levelling can continue by a series of vertical jumps, each equal to the length of the leg.

This is a very quick and potentially single-handed method. In experienced hands it can give an accurate result, although if detail is needed of the region between the levelling stations, that must be obtained by another method such as (a).

(e) Staff and level. This is the classical and, in experienced hands, the most efficient method. The primary instrument required is a surveyor's level; the simpler "builders" or "Quickset" level will almost always prove entirely adequate. The marginally more accurate but vastly more expensive "engineers" level has a more powerful telescope which will allow sights over longer distances but the smaller models will serve over distances of 100 m, ample for most applications on the shore. A measuring staff will also be required;

the 4 m folding wooden type with standard metric graduation will be found more suitable than the more rigid but heavier telescopic models. Metal staffs of the telescopic pattern, in particular, suffer when used in sand and sea water by students. The method to be used need not be described here – a number of good basic surveying text books (e.g. Whyte, 1969; Wilson, 1971; Pugh, 1975, designed for non-professional surveyors) are available, any one of which will explain the methods with worked examples. The only disadvantages of this method are the expense and vulnerability of the instruments. The possibility of sighting over long distances is particularly valuable on gently sloping shores. In such places the capacity of the instrument to measure horizontal distances is also useful. Thus, if required, a transect line may be defined merely by locking the telescope in the required direction and measuring the level and, by means of the stadia lines, the distance to beach sampling positions in turn. It takes rather longer for students to become proficient in this method than in the others so that it is useful to arrange some time for familiarization before the first expedition onto the shore.

3. Recording the Results

Whatever method of levelling is chosen (but particularly if the surveyor's level is used) it is vitally important to insist that a systematic method of "booking" the results is adopted. The only method which can be unreservedly recommended is the standard system used by professional surveyors; this is set out clearly in the text books and utilizes a page ruled in a standard fashion. It is not necessary to supply students with a proper ruled surveyor's note book (though that is certainly the ideal solution) but at least a duplicated, ruled sheet should be provided. Scribbling on the backs of envelopes is a sure recipe for errors; if there is discord when the class is back in the laboratory, recriminations (and perhaps a second visit to the shore) will follow; the standard method has the advantage of built-in checks which should reveal errors at the time they are made. To those beginning fieldwork this booking system may seem unwieldy but this illusion will evaporate with practice – and in any case there is no alternative; anything less thorough will lead to errors and wasted time.

4. Datum Levels

It is usually desirable to relate levelling to the local LWM of spring tides. To establish this exactly may be difficult but a reasonable approximation is fairly easy to fix in calm weather at the time of spring tides by waiting until low water and marking the tidal position. (In passing, it is worth pointing out that, given sufficient time and tolerable weather, it is possible to follow the tide down shore, marking successive levels over a half cycle to low water.) However, things are not always so straightforward and, if necessary, the level can be obtained by using as a datum the level of the tide at a recorded time on a particular day and, by reference to the Admiralty Tide Tables, calculating the vertical distance from this arbitrary datum to LWM of spring tides. This requires only logical thought and simple arithmetic and reference to the worked examples of problems in the first section of the handbook will assist; it must be admitted, however, that these calculations seem to give students inordinate difficulty! Allowances may still have to be made for such effects as low or high barometric pressure and strong winds. Ordnance Datum is only of limited use in littoral ecology. It approximates to mean sea level at Newlyn and is denoted by Ordnance Survey land marks. These are seldom to be found conveniently close to the shore which is being studied and even if one is available, the relation between the local tidal regime and OD is difficult to establish accurately. An approximation can be made via the Admiralty Tide Tables in which the difference between OD and local chart datum (which approximates to ELWST) is quoted for each Standard Port.

5. Drawing the Profile

Students should never be allowed to lose sight of the fact that these observations are intended to be used to produce a scale profile. Errors and omissions in collecting the data (the limits and depths of pools, the size of overhangs, the nature of the substratum etc.) are then less likely to occur. In the graphical reproduction of the profile either a true scale diagram or one with some distortion such as an exaggeration of the vertical scale can be drawn. If the parameters measured have been (i) distance along a tape laid on the ground, and (ii) heights above a datum, a true reproduction can be obtained only by plotting the tape distances to scale along the line of the profile, using dividers. This is necessary if such factors as the slope of the shore are important in the exercise concerned. If, however, vertical distances and zone limits are the major consideration, the drawing of the profile can be speeded up by making tape distance the x-axis of a graph and height the y-axis; in this case slopes will be poorly represented – without a vertical exaggeration, a perpendicular cliff will appear as a 45° slope. However, if the latter system is adopted, the quantitative distribution of organisms along the tape (see below) can readily be represented by histograms in which the columns are (as they should be) of equal width; on a true scale diagram the projection of equal tape distances will result in unequal horizontal intervals. Recording the distances along the line of sight or by horizontal rules can, of course, avoid this problem; it is, in any case, of little significance on gently sloping shores.

RECORDING THE BIOTA

An assessment of the fauna and flora of a rocky shore presents some problems that are different to those encountered on a mobile beach. On the former animals and plants are principally on the surface, even if obscured by other organisms; in the latter many are buried and can be found only by disturbing the beach. Thus it is only on a rocky shore that an idea of the distribution can be obtained by visual inspection. One matter is, however, common to both. Some familiarity with the animals and plants is essential; at least the commoner forms must be recognized and a qualitative picture of what is present is a necessary basis for all quantitative work. Careful observation with lens, microscope and key is vital – there is no short cut. Apart from this, the fieldwork in the two habitats can be considered separately.

1. Rocky Shores

The listing of all animals and plants on the shore would be a major undertaking and, for most ecological purposes, is unnecessary. The main principles can be explained by reference to perhaps 20 common species of algae and about the same number of animals. To expect the novice to remember much more than this from a week's field-work is rather optimistic. Rarities have their undoubted value as indicators but their study can be left to the more advanced students.

The basic recording will therefore consist of a list of animals and plants from a particular shore. The next stage is to list those from different habitats (pools, shady places, open sunny rock etc.) and those which occur in particular positions on the shore (supra-littoral, upper or lower littoral etc.); as soon as the latter is attempted the need for more exact recording of position will become apparent and the listing of species will need to be combined with a description of the shore topography of the kind outlined in the preceding section. A general description of the shore in terms of the plant and animal communities present may be attempted by simple observation and much valuable classical descriptive ecology has been done in this way. However, success by this method is the outcome of long experience and for the less expert some form of systematic sampling will be required with appropriate treatment of the collected information. Time on the shore is limited by the tides so that completely randomized sampling by large numbers of quadrats on the Braun-Blanquet model is usually impractical, as is sampling on a large grid. It is usually more convenient to begin one stage forward and to accept (at least as a working hypothesis) that the apparent distribution of organisms in bands parallel to the sea is real and can be described by recording along a line or band running downshore perpendicular to the shore line. This serves as a rapid method by which a small group of two or three workers (nearly always better than single individuals working alone) can cover the whole shore from the supra-littoral to sub-littoral fringe. Ideally this should be tried out on a steep, even slope – a quay wall is ideal! Recording in small groups means that a number of lines can be worked simultaneously and subsequently compared. The simplest line transect technique involves laying a tape along the shore and recording everything that it touches either as a single point at a particular distance (e.g. limpets or littorinids) or as a length of the tape in contact with a large plant or clump of organisms. Both the uppermost organisms and those below the canopy must be included. This method is quick and suffers only from the disadvantage that small scattered organisms tend to be missed. One way of avoiding this bias is to combine the result of several adjacent line transects.

Alternatively, a rule of some suitable length (say 10–30 cm) can be slid along the tape at right angles to it and all organisms which it touches can be included. For very long transects this may be too tedious (e.g. lines across a salt marsh!) and in that case recording the organisms touching the tape at predetermined intervals (10 cm, 50 cm, 1 m etc.) can be tried. The flatter the shore, the larger the gaps can be made.

Recording at intervals in this way may easily miss small scattered organisms and a system which is less likely to do this is to record the presence of the species in a series of quadrats 50 cm × 50 cm or 1 m square placed edge to edge along the tape. This belt transect will give a better presence/absence picture than the pure line transect and can be completed fairly quickly. The use of constant-sized sampling units lends itself to easier graphical representation of the results or to other data processing.

A modification of the line transect, useful for a very rapid recording of a zonation pattern, is to run a 1 m rule down a tape at right angles to it, recording the level of the uppermost and lowest specimen of each species encountered.

2. Quantitative Methods on Rocky Shores

One of the primary considerations in quantitative sampling is that the methods adopted should be non-destructive. This means that one should not undertake (particularly on a sheltered shore) a biomass survey which involves scraping rocks clean of plant and animal material in a series of quadrats and finding, for example, the dry weight, unless there is a real scientific need for the information. Such exercises should be avoided for teaching classes – the information and experience might be useful but the example offered would be bad.

If biomass figures are required, the areas sampled should be restricted to the minimum possible and confined to spot checks to calibrate non-destructive methods. Of the latter, the belt transect readily lends itself to rapid quantitative work. The quadrat frames (a 50 cm square is convenient) are set out along the tape as indicated and quantitative values for each species recorded in each square.

(a) Plants. For most algae, recording the percentage of each square covered by the species in question provides valuable data. The plants

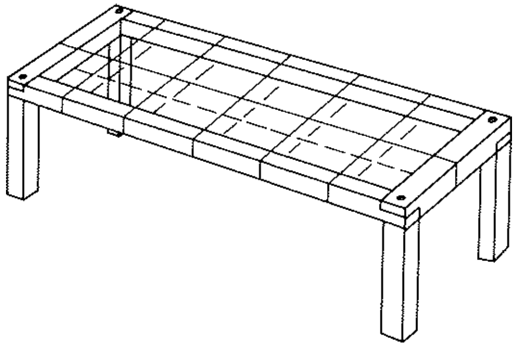

Fig. 3. A simple wooden frame measuring 10 cm × 50 cm provided with short legs and five sets of upper and lower cross wires which may be aligned to give optically sighted points on the ground. The frame is placed at five successive positions down a 50 cm quadrat to provide 25 sampling points.

are first recorded as they lie, then carefully pushed aside and those below recorded in the same way. In its simplest form this process involves only the estimate of percentage cover by subjective inspection. This is not too inaccurate when carried out by an experienced observer but the individual estimates produced by novices can vary alarmingly and, even when carried out by the same observer, the results can vary according to, for instance, the severity of the weather. This implies that subjective sampling should be avoided wherever possible (though it is still better than non-quantitative recording) and an objective method adopted instead; one which has proved successful is the use of a modified point frame. It is necessary that the frame should be high enough above the substratum to avoid any need to move it when the uppermost plants are pushed aside. Pins are not really satisfactory under these circumstances and optical cross-wires have been used instead. There are 25 cross-wire "points" available in each transect square. While a full scale 50 cm quadrat frame can be constructed on this principle, it is rather cumbersome and a more convenient form is a 50 cm × 10 cm frame with a simple set of five cross-wires (Fig. 3). This can be set at five successive positions in each square, to give the total. In use each "hit" on a plant counts as 4% cover of that species. A 25-point quadrat is a compromise – fewer points allow greater speed but much reduced accuracy; a 100-point frame is much more accurate but its use is very time-consuming. In completing a belt transect it is best that a class should work in pairs or groups of three, each group taking responsibility for one section of the transect; this should allow ample time to complete a 30 m transect before the tide returns to cover it. Lichen thalli are rather small to be satisfactorily treated by these methods although mention is made elsewhere in this volume (Jones, *et al.*, 1980) of the use of a 25-point 50 cm square frame for lichen recording. Later methods used a 10 cm perspex square ruled into 100 subsquares, in each of which the presence of a species counted as 1%; this is a very useful sampling method for encrusting supra-littoral lichen thalli and can form the basic unit of a belt transect.

(b) Animals. Some species, such as barnacles in high-density populations, can be sampled by a point frame as used for plants. For most species, however, counting is much better. This is easy in the case of fairly large animals such as *Patella* spp., the larger littorinids, *Nucella* and similar organisms, but is much less convenient for barnacles. Where barnacle densities are high, counting in a smaller square can be effective. A 10 cm or even a 5 cm square can be used. If four 10 cm squares are used (placed as shown in Fig. 4), in each square the total count from the four multiplied by 25 gives the density in animals/m^2. If the first 25 barnacles are identified in each square, the total for each species gives the percentage for the population at that level.

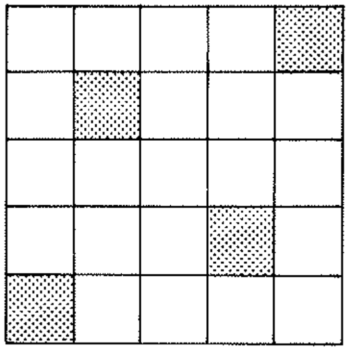

Fig. 4. Positions within a 50 cm square quadrat in which four 10 cm sampling squares may be placed to facilitate counting of barnacles etc. (see text).

Abundance scales such as those of Crisp and Southward (1958), based on numbers but used to increase the accuracy of subjective assessments, are valuable when used by experienced workers, particularly in rapid surveys of large areas of shore. In the hands of novices, however, these scales are less reliable and lead to difficulties in graphical presentation of results or in further numerical analysis. A purely quantitative method on a linear scale (numbers, percentage cover etc.) is generally preferable.

3. Mobile Shores

Shores of mud or sand or mixtures of these materials present a different sort of problem. In general, the coarser materials occur in the more wave-swept places and contain little interstitial life but beaches of finer particles, which accumulate in sheltered places, are often very rich and it is these which most frequently occupy the attention of field courses. They have very gentle slopes and so present extensive areas at low water. Little evidence appears on the surface of the beach to indicate what lies below, apart from worm casts and burrows; an investigation requires digging. Such sampling is destructive; the less the beach is likely to be disturbed by natural forces, the greater is the disrupting effect of digging. For this reason the number of holes made should be kept to a minimum and it is therefore better to avoid large-scale random sampling unless information is required which can only be obtained in this way. Under normal conditions, it is better to approach the sampling in the same way as that on other types of shore; that is, by a line along the main environmental gradient from low to high water.

Sampling the sediments can be accomplished by digging out a predetermined volume, but more accurate sampling can be achieved with less disturbance by coring tools. This can conveniently be a length of metal (preferably brass) pipe, ideally of internal diameter 11.3 cm to give a cross-sectional area of 100 cm^2 (or 16 cm diameter to give an area of 200 cm^2). This is pushed into the sediment to a required depth (100 cm depth gives a 1 litre sample) and carefully dug out with its contents. Similar samples can be pooled and samples can also be taken from deeper into the sediment, if desired, after the upper level of the beach has been removed. Patchiness in the distribution of organisms makes the pooling of a number of small samples (four from each station is adequate) more representative than the collection of one large one and the disruptive effect is less. Cores of this size will not give satisfactory samples of larger organisms (*Mytilus* and *Arenicola* for instance).

To examine the fauna in the sample, it must be passed through a fine sieve.* Metal sieves are expensive and vulnerable to the sampling treatment which involves washing the sediment through the sieve with water. The best available material is bolting nylon (similar to that used in plankton nets but manufactured for flour grading) held in a suitable frame. Mesh of 1 mm will serve on many beaches but sandy beaches containing small animals may require the use of 0.5 mm mesh. Following the sieving, the fine particles will have passed through leaving a mixture of shell fragments with organic material, as well as the animals. Some separation of these can be accomplished by panning the residue (Yukon fashion) using fresh-water which tends to relax the animals and causes many to relinquish their hold on mineral fragments. Sorting and counting the animals under a binocular microscope is inevitably a time-consuming job but it is the essence of the whole process and cannot be avoided. Larger animals require different methods. Superficial bivalves (*Mytilus* and *Cerastoderma*) can be sampled by counting or collecting in random quadrats; frames of 0.1 m^2 area (31.63 cm square) are convenient. Both the above animals occur in large numbers and can be collected freely without causing ecological damage, but class organizers should make sure there are no local fishing rights or byelaws which would be contravened by such action. Samples of *Cerastoderma*, in particular, allow the development of a number of useful exercises since the biomass can readily be determined and the age structure of the population can also be established by examination of the shells. For further information on sampling in sediment, see McGrorty (1973).

OTHER PARAMETERS

The estimation of wave force has already been mentioned; besides this, the aspect of the shore, obtained either by compass or from the map, should be noted, together with whatever other information seems likely to be required.

Climatic information is often better obtained from the Meteoro-

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*See also data in Coulson *et al.*, this volume, pp. 244–246.

logical Office or a local station than by collection of data at the time of the exercise. Although instantaneous air and water temperatures are valuable, it is the range over the year or growing season which is important rather than spot values on a particular day. The daily range of temperature in pools may be usefully measured, however, and comparisons made between temperatures on sheltered and exposed shores. Humidity measurements may be instructive, though a whirling hygrometer reading will normally have to be taken too far above the ground to be a really useful indication of the micro-climate in which the organism lives (under damp seaweed, for instance). Here a small hygrometer or the Loribond Comparator Humidity Tester will be more useful.

Where, under estuarine conditions, in heavy rain, or after long drought on the shore, the salinity is to be tested it is unlikely that titration or conductivity methods will be available. In this case a hydrometer reading, with reference to Knudsen's tables (1948) will be the most convenient method and quite accurate enough, even without the corrections, for most ecological purposes.

Sea water is a buffered medium and is usually saturated for oxygen; it is therefore only in upshore pools in hot weather that oxygen content (by the Winkler method) or pH is worth recording.

Light is another parameter which it is difficult to measure meaningfully with apparatus which is generally available. However, comparative readings (say in the sun or the shade of an overhang can be made by a photographic exposure meter pointed at a white card or with an incident light attachment. The shade reading can be expressed as a percentage of full daylight measured at the same time.

As always the question should be asked, why is this information being collected? For what will it be used?

On mobile beaches a number of other parameters will be relevant. The grain-size distribution, the organic content, the dilatancy and the level of certain chemical compounds (for example, carbonates, sulphates, sulphides) may also be required. Unfortunately, there is no biologically-orientated work which covers this ground and recourse must be made to other disciplines; Akroyd (1964) will be found a valuable source of information on these techniques.

Grain-size analysis will require the sieving of the sample, after drying, through a series of sieves of decreasing mesh size. Metal sieves, hitherto the standard equipment for this task, are now both difficult to obtain and expensive. Nylon bolting netting will be found to be the most suitable material when mounted in cylindrical plastic sleeves.

USING THE COLLECTED DATA

It is unfortunately necessary, at least in the beginning, to impress upon students that the fieldwork does not end with the collection of the data and that, unless it is processed and presented in a coherent form, little useful information will result.

As a first step the data require tabulation – a convenient grid has quadrat numbers or tape distance on one axis and species on the other. It is convenient to list the latter, starting at the top, in the order in which they occur down the shore. In presence/absence records, each occurrence can be shown by a cross or other symbol, replacing this in quantitative records by a value (e.g. number counted; % cover). At this stage, inspection of the table may indicate some patterns of distribution; where this is not easily seen from the table, graphical representation may be useful. This can take the form of a "Kite diagram" or histogram. The simplest form of the former, representing only the presence of various species, is essentially the tabulated matrix expanded into a series of lines connecting the positive records in the table. For quantitative results, the line is broadened at each quadrat position to a width proportional to the quantity recorded. Examples of both types can be seen in Lewis (1964) and Nelson-Smith (1979), in relation to rocky shore records; similar representations are suitable for mobile beaches. The relative merits of vertical or horizontal format will depend on the shore concerned (horizontal format is more suited to gently sloping shores) and the particular feature which it is desired to emphasize.

The picture is completed by the inclusion on the diagram of the shore profile, which allows deductions to be made about changes in distribution related to local shelter, slope, and so on. The first indication of interaction between species may also appear and so suggest where more sophisticated analysis may be applied. At this stage it is possible to demonstrate many of the generally accepted features of littoral communities directly from the results obtained. That this can in fact be done with classes encountering marine biology for the first time on a week's course has been clearly shown by courses at Field Studies Centres (Barrett and Crump, *personal* *communications*) and it is obviously desirable educationally that students should arrive at their conclusions in this way rather than by lectures!

As has been hinted above, the next stage is the numerical analysis of the data to show how the species are associated into communities and how these may vary in different environments or over periods of time. This aspect of the study is being covered elsewhere in this volume (Jones *et al.*, pp. 171–192; Russell, pp. 137–170) for rocky shores; for suggestions on the processing of data from sedimentary shores, reference should be made to Elliott (1977). No more need be said here, *but this must not be taken to imply that this aspect of data* presentation is unimportant – it represents a powerful tool in our efforts to understand the complex life of shore communities.

POSTSCRIPT

Ecological exercises on the shore have two purposes: first, to encourage the student to know the plants and animals, to see how they relate to their environment and to each other; secondly, to illustrate general ecological truths by the use of appropriate examples and methods. Toward the first of these aims, all kinds of shores can legitimately be studied; for the second, it must be asked whether a particular shore is the best place to demonstrate the technique in question. For instance, a sheltered muddy beach could be used for an exercise in random sampling, but since this involves destructive digging, conservation requires that a different site should be chosen – a flat rock platform would be less vulnerable – but it might be better still to use a stretch of permanent pasture such as a playing field! Other conservation requirements were mentioned earlier. These are not unreasonable requirements; more and more parties are visiting shores on biological excursions and the observance of these principles will enhance their experience rather than otherwise.

Finally, many students have received the first real firing of their interest on marine field courses. A perfect opportunity is then offered to teachers to transmit their enthusiasm; this is one of the *major merits of shore fieldwork and forms the justification for the* careful preparation and long hours of teaching which such courses involve. Pursued in this spirit, there is nothing else in the whole range of human education which can at the same time give so much pleasure and painlessly impart so much understanding of the natural world.

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