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# THE USE FOR TEACHING PURPOSES OF A ROCKY SHORE RECEIVING INDUSTRIAL EFFLUENT

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ABSTRACT

The paper describes the way in which a piece of scientific research into pollution of a rocky sea shore by the refinery effluent at Littlewick Bay, Dyfed, has been modified for teaching purposes. The methods employed in the original work have become the core material for an exercise which illustrates much broader "ecological" principles.

## INTRODUCTION

OVER the past few years, students and visiting staff on ecology courses at Orielton Field Centre have been requesting field exercises involving pollution studies. It is somewhat disappointing for them to discover that it is extremely difficult to demonstrate any appreciable environmental impact of the oil industry on the intertidal area, despite Milford Haven being one of the largest European oil ports and, according to "official criteria", one of the "dirtiest". (This latter point is, in itself, educationally useful. An "official criterion" of an oil port's "dirtiness" is the number of reported oil spills (ACOPS, 1979*a*). On this basis the policy in Milford Haven of reporting every spill, no matter how small, automatically means that the Haven must be classified as "dirtier" than a port which only reports spills which reach the magnitude of an "Amoco Cadiz disaster".) In practical terms, Milford Haven is one of the "cleanest" oil ports in the world (ACOPS, 1979*b*; ACOPS, 1980; Abbiss *et al.,* 1982; Little, *unpublished data*) and the refinery effluent discharging in the Littlewick Bay area (Petpiroon and Dicks, 1982) is the only local example of pollution effects on rocky shore organisms which can be used for teaching purposes.

No attempt is made in the teaching exercise to replicate the transect work used in the research studies. Such an exercise would be tedious, extremely time-consuming and would result in an unmanageable amount of data to interpret at the end of the day. Furthermore, it would be essential to follow exactly the original transect lines, resulting in damage to long-term research sites. In a teaching exercise it is more appropriate to study an effect visible "on the day", and use the research data to assist the interpretation of student observations. Consequently the fieldwork concentrates on the performance of limpets (*Patella* species). These, arguably the most conspicous and the most easily recognised animals in Littlewick Bay, are known to be particularly sensitive to oil and other water-borne pollutants (Dicks, 1973).

*Practical details*

Students attending ecology courses at Orielton Field Centre frequently spend 2–3 days studying the patterns of zonation on unpolluted rocky shores. The variation, in *Patella* density and size, between exposed and sheltered shores will have been demonstrated at the same time. The Littlewick Bay exercise extends and builds upon the experience of the earlier work.

In a preliminary talk, students are provided with information on:

1. The history and biological history of the area (Petpiroon and Dicks, 1982).
2. The physical and chemical nature of the effluent (Petpiroon and Dicks, 1982).
3. The reason for discharging effluents into a tidal water body, viz. rapid dilution and dispersion.
4. The theoretical reasoning behind the survey; the dilution of the effluent, coupled with the movement of the effluent plume parallel to the shore during the ebb/flood tidal regime, will produce a concentration gradient extending on either side of the discharge point. Detection of such a two-way gradient system of variation in the biota of the area will be indicative of a pollution effect. The variation in the biota caused by changes in exposure to wave action through the area would produce a one-way gradient across the entire area.
5. The practical nature of the survey.

The actual organisation of the field exercise depends upon the number of students and the time available. Ideally the students arrive on the shore at half-tide as the water is ebbing. A good class can complete the basic exercise in approximately 90 minutes.

The class is divided into groups (no more than four students to a group). One group establishes a sampling station on the discharge pipe and the others are despatched to set up stations on either side. Experience has shown that optimal results are obtained from between four and six stations on either side. The outermost should be at least 100 m from the pipe (or the limits of pollution effect will not be established) and not more than 250 m (since this is beyond the limits of any major effect, students would be collecting unnecessary data, and direct supervision of such students would be difficult). The criterion for station suitability is that the only variable between stations is their distances from the discharge point. Thus all stations are established at Mean Tide Level on steep bedrock areas which have a south-facing aspect.

At their station each group of students select 20 random positions in which to place a 25 × 25 cm quadrat, using a 0–99 random number table and a tape (Fig. 1). Students count the total number of limpets within each quadrat. They standardise the edge-effect by including all those individuals wholly or partially enclosed. All the limpets in a quadrat are measured (in mm), using calipers (or dividers and a rule), along the longest basal axis. The recording of lengths is continued until eventually measurements are completed in the quadrat which contains the 100th limpet. To avoid possible counting errors or re-measurement of the same limpets, the students mark each one that they count and/or measure with chalk.

At the time of low water the students make a series of general observations to complement the limpet data. They are asked to visually divide the shore into the three main regions of the littoral zone and, within a 10 m-wide strip of each region, assess the abundance of brown seaweeds, periwinkles, topshells, live barnacles and dogwhelks, using a seven-point abundance scale (Petpiroon and Dicks, 1982, Table 3). The individual species need not be distinguished if time is limited.

Student groups that finish well before the others are sent beyond the outermost stations to estimate the distance beyond those points at which they first find dogwhelks (***Nucella lapillus***). This information is used in the discussion because *N. lapillus* is not found within the survey area proper. They also measure the distances

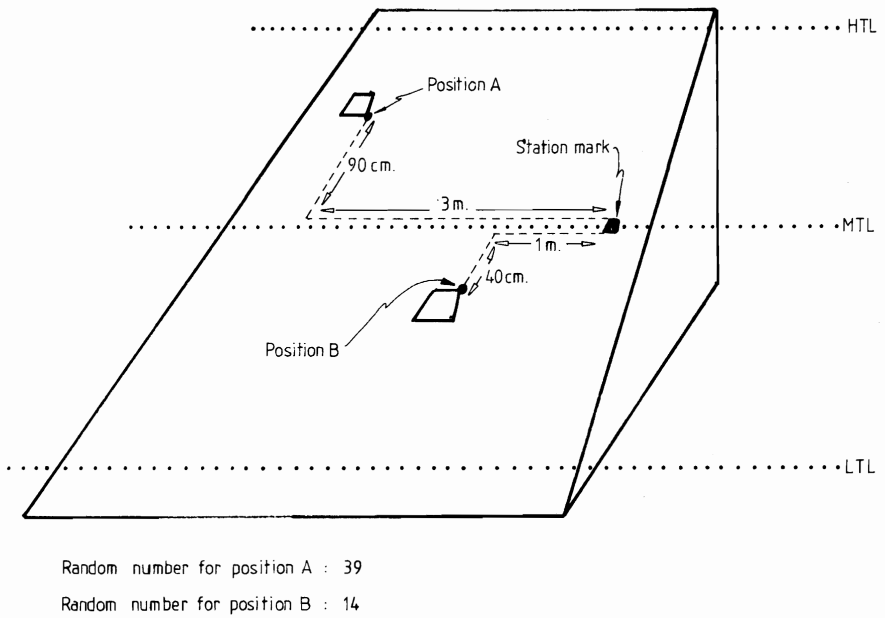



FIG. 1.

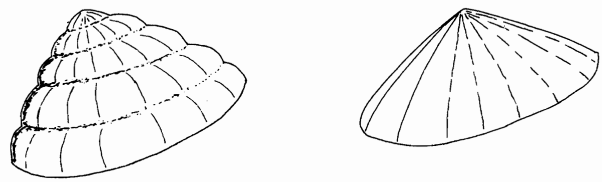
Diagram to illustrate method of finding random positions for quadrats. To find Position A, using the random number 39, take the first digit of the number (i.e. 3) and move this distance in metres horizontally along the shore from the station mark, moving away from the effluent discharge pipe. Then take the second digit of the number (i.e. 9), multiply by 10 to find the distance in centimetres to move up the shore. Moving up the shore (if the second digit is an odd number) and down the shore (if the second digit is an even number) reduces the incidence of overlapping samples.

of the stations from the discharge point. If even more time is available, density counts of live adult barnacles and barnacle spat in each of 20 randomly-positioned 5 × 5 cm quadrats may, at the correct time of year, be usefully obtained as an alternative to assessment of their abundance.

Finally, all students are given a short walk and talk in the immediate vicinity of the effluent discharge pipe to establish the following points:

1. The sand/gravel substrate immediately adjacent to the pipe does not support *Patella*. (This observation rules out the possibility that the old, large limpets have migrated onto the pipe from other areas.)
2. The unusual mixture of fucoid seaweeds on the pipe. (*Fucus serratus* mixed with *F. spiralis,* indicative of the substantial changes in community structure produced by removing *Patella*.)
3. The extremely large size of the limpets on the pipe (70 mm+). Dr. J. R. Lewis (*personal communication*) has commented that they are some of the biggest specimens that he has seen on any shore in the British Isles. (Used to stress that food availability is an important factor in size determination.)
4. The presence of a few relatively small (c. 10 mm) limpets on the pipe (rapidly-growing juveniles).
5. The presence of limpets (c. 30–50 mm basal length) in which the basal part of the shell may have a band (up to 10 mm wide) which is free of encrusting growth (suggestive of new and rapid growth of shell).

6. The presence of limpets with unusual shell morphology (Fig. 2). Dr. W. J. Ballantine (*personal communication*) has suggested that this ring effect is due to differential shell growth patterns and that each ring may represent one year's growth. (Since limpets with four to eight rings can be seen on the pipe, this may be indicative of recruitment to the pipe area on several occasions in recent years.)



A. B.

FIG. 2.
A. Diagram of a limpet from the pipe, showing the "stack of rings" morphology of the shell.
B. Diagram of a "normal" limpet, showing a typical smooth-sided conical shell.

*Data processing and analysis*

Once back at the Field Centre, the abundance data are easily presented in a tabulated form (Table 1). Processing of the numerical data will, to a certain extent, depend upon the experience, capabilities and resources of the students and the time available. A computer programme is available to handle all the numerical data, but a queue will develop whilst each station's data are processed. To speed things up, students are usually asked to process the density data themselves. Since the sample size (20) is low, it is a useful statistical exercise for them and any errors are easily spotted and rectified. The large volume of limpet size data can then be processed by the computer.

Table 1. *A typical set of student data*

| | | Density of *Patella* (per quadrat) | | Size of *Patella* (mm) | | *Abundance Rating* | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Brown seaweeds | | | Periwinkles | | | Topshells | | | Live barnacles | | | *Nucella* | | |
| Station | Distance from discharge pipe (m) | Mean value | 95% confidence limits | Mean value | 95% confidence limits | Lower shore | Middle shore | Upper shore | Lower shore | Middle shore | Upper shore | Lower shore | Middle shore | Upper shore | Lower shore | Middle shore | Upper shore | Lower shore | Middle shore | Upper shore |
| 5W | 210 | 11.3 | 2.3 | 16.6 | 0.2 | 5 | 3 | 0 | 2 | 7 | 0 | 2 | 4 | 0 | 7 | 7 | 2 | 1 | 0 | 0 |
| 4W | 180 | 12.5 | 2.8 | 17.2 | 0.3 | 4 | 2 | 1 | 0 | 1 | 3 | 2 | 2 | 0 | 6 | 6 | 3 | 0 | 0 | 0 |
| 3W | 120 | 7.3 | 2.9 | 21.5 | 0.3 | 5 | 4 | 5 | 4 | 1 | 6 | 4 | 1 | 6 | 5 | 6 | 2 | 0 | 0 | 0 |
| 2W | 60 | 11.2 | 3.5 | 19.7 | 0.4 | 0 | 6 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 2 | 0 | 0 | 0 |
| 1W | 30 | 2.1 | 2.0 | 34.4 | 0.4 | 7 | 6 | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 |
| 0 | 0 | 1.0 | 0.2 | 39.7 | 0.4 | – | 5 | – | – | 1 | – | – | 0 | – | – | 2 | – | – | 0 | – |
| 1E | 45 | 2.6 | 1.7 | 41.4 | 1.1 | 5 | 7 | 6 | 0 | 3 | 0 | 0 | 1 | 0 | 4 | 4 | 2 | 0 | 0 | 0 |
| 2E | 75 | 15.8 | 3.1 | 21.2 | 0.5 | 3 | 5 | 7 | 1 | 2 | 4 | 0 | 0 | 0 | 6 | 5 | 3 | 0 | 0 | 0 |
| 3E | 120 | 13.2 | 4.4 | 21.3 | 0.4 | 5 | 0 | 6 | 4 | 5 | 4 | 0 | 0 | 1 | 4 | 6 | 3 | 0 | 0 | 0 |
| 4E | 150 | 11.5 | 2.6 | 24.4 | 0.5 | 4 | 4 | 2 | 0 | 3 | 4 | 0 | 2 | 4 | 7 | 6 | 4 | 0 | 0 | 0 |
| 5E | 180 | 18.6 | 3.6 | 21.2 | 0.4 | 5 | 1 | 3 | 2 | 3 | 2 | 0 | 2 | 3 | 5 | 5 | 3 | 0 | 0 | 0 |

Essentially the following information is required for each station:
1. Mean value and 95% confidence limits for *Patella* density.
2. Mean value and 95% confidence limits for *Patella* size.
3. Size-frequency table for *Patella*.
[4. Mean value and 95% confidence limits for adult barnacle density.
5. Mean value and 95% confidence limits for barnacle spat density.]

All these data are presented to the class in a tabular form (Table 1) and the students draw up the limpet density and size values in a graphical form (Fig. 3.). The *Patella* size-frequency information is usually plotted as a bar chart by the student group responsible for a particular station and then all the charts can be shown to the class. All groups must use the same scales for the axes. If time is available, a master size-frequency table for all stations is prepared, photocopied and distributed to each student for future reference. The students are now in a position to analyse and explain their results. This is done either by a question-and-answer session or by asking the student groups to spend approximately 20 minutes thinking about the problem themselves and providing a written summary. Whichever approach is used, emphasis is placed upon offering as many hypotheses as possible to account for the results that they have obtained. There then follows a class discussion, using all the information and experience that is available to them from their work on rocky shores throughout the course, to establish the most probable explanation(s).
The important features stressed in the analysis are:

1. The reciprocal relationship between *Patella* density and size governed by proximity to the discharge point.
2. The increase in seaweed abundance close to the discharge point compared to the reduction in the abundance of animals.

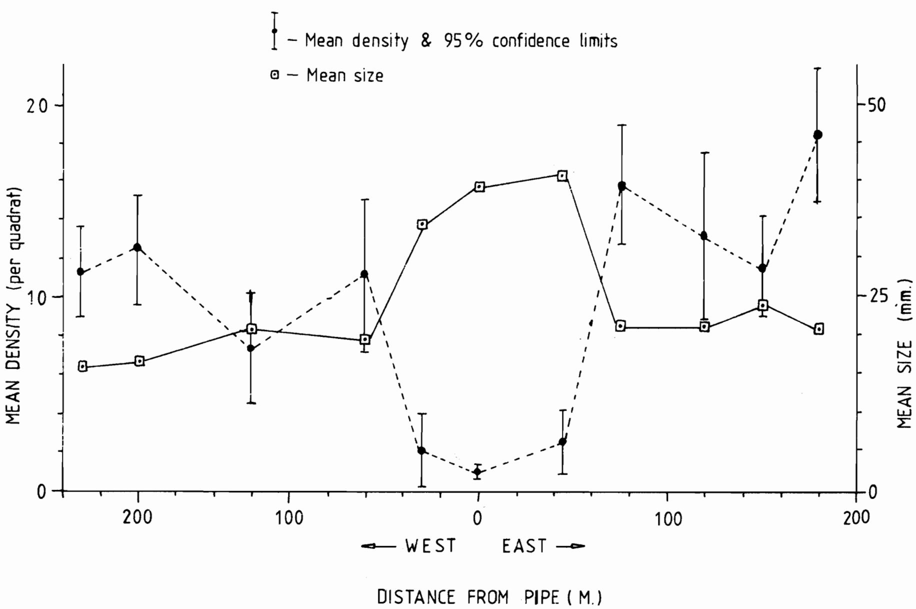



FIG. 3.
The relationship between limpet density and limpet size at varying distances from the effluent discharge pipe. (Data taken from Table 1.)

3.The differences in the reduction in abundance of periwinkles, topshells, barnacles and *Nucella* close to the discharge point.

The students usually have little difficulty in reaching similar conclusions to Petpiroon and Dicks concerning the inverse relationship between density and size in *Patella.* Thus the argument runs that the majority of the limpets close to the discharge point are killed by the effluent (at some stage in their life history) but those that survive grow rapidly in the enhanced feeding conditions caused by the reduced competition for food. The exact point of mortality is difficult to determine but the evidence suggests that these effects stem from a low level of larval recruitment in the area close to the discharge point. Whether this is a regular recruitment of a few tolerant larvae or a spasmodic recruitment of all larvae during occasional "clean" periods cannot be answered. The presence of relatively small individuals and of individuals with the "annual growth rings" tends to counteract the suggestion of a true "relic" population left over from before the start of effluent discharge.

The increase in abundance of fucoid seaweeds close to the discharge point is a consequence of the reduced grazing pressure, by limpets in particular. (Although this change in the seaweeds has taken place since the industrialisation of the area, the possibility should not be discounted that the breakwater effect of the jetty may have produced marginally more sheltered conditions in the bay, thus also favouring the fucoid establishment.)

The tutor uses the opportunity to emphasise that the size of *Patella* is governed by age and by food availability, and that the removal of a single species may lead to more widespread changes in community structure. Reductions in the abundance of many animal species and the absence of some, e.g. topshells, at stations close to the discharge point is directly attributable to the effluent discharge. Some species are clearly more tolerant of the effluent than others, e.g. rough periwinkles.

The total lack of *Nucella* within the survey area is an important point in terms of interpretative skills. The results themselves cannot be used to say that there is a pollution effect, but when coupled with extra information (from outside the survey area or from experience on unpolluted shores) they become highly indicative of a pollution effect. The apparently greater sensitivity of *Nucella* to the effluent, as judged by the area of effect, may be attributable to reduced salinities rather than oil or other chemicals, showing students that there is still scope for further research in the area. If numbers of barnacle adults and spat/larvae have been counted, low adult densities can be attributed to poor larval settlement rather than mortality of adults. The parallel with limpet data is obvious.

The changes in the abundance of organisms tend to be most pronounced in the mid-shore region. This is not unexpected since the tidal cycles will mean that this area of the shore is subject to the greatest contact with the effluent. The student data can be used to establish the limits and some of the properties of the effluent effect. Since in this case the effect is very localised, the discussion now leads into the desirability of increased pollution control, bearing in mind the much more dramatic and widespread effects of natural factors, e.g. hot summers and cold winters (Moyse and Nelson-Smith, 1964). The educational value of the site is emphasised, as is the prohibitive cost of relocating the effluent discharge point.

Nevertheless, widespread, long-term effects of chronic pollution as well as localised and short-term effects have to be borne in mind (the story of DDT is a useful and well-known parallel). The setting of quality standards, the introduction of the necessary legislation, likely financial costing and the ultimate source of funding should be contemplated (Ward and Dubos, 1972). It is quite salutory for the students to realise at the end of the day that they have progressed, during the course of the exercise, from going out "to look at a few more snails" to the general conclusion that an unpolluted world is possible but only if they themselves are prepared to "pay the piper".

*Conclusion*

The monitoring programme of research work described by Petpiroon and Dicks was and is a vital ingredient in the teaching exercise. It provided the original idea and gives the course tutor the necessary background information to introduce the topic on a factual basis. Secondly, it allows students to interpret their field data against a wider background.

The teaching exercise stands in its own right, providing an introduction to the use of field surveys in the assessment of the environmental impact of pollution situations as well as extending to more general ecological and sociological considerations. Nevertheless, the teaching exercise can be an equally valuable adjunct to the research project. Visits to the site are much more frequent than would be possible for the monitoring programme, so that major changes will be noticed sooner. This may make interpretation of the changes easier, since more exact correlation with the timing of other contributory factors will be possible and seasonal changes can be recognised as such. Lastly, student data and student interpretations will inevitably throw up additional lines of investigation.

## References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