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Planning biological surveys

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Why do biological surveys?

Biological surveys of estuaries and coasts may be carried out for a variety of reasons including the following.

Scientific research

The survey may be exploration of a new area, part of a wider study leading to (for example) energy flow modelling for a whole estuary, or a prelude to experimental work aimed (for example) at understanding the distribution of a single species.

Education

Estuaries and coasts are favourite biological training grounds. There is a rich variety of organisms and communities, and gradients (e.g., of salinity, wave exposure, and tidal emersion time) are easily available for studies relating the distribution of organisms to physical and chemical variables.

Conservation

Choice of priority sites for conservation arises from a ranking process which in turn requires site descriptions. A variety of criteria may be used for ranking purposes, e.g., diversity, uniqueness, or representativeness. Conservation concerns may also be at the root of environmental impact assessments, biological surveillance, and contingency plans.

Exploitation of natural resources

Survey information (e.g., concerning fish, shellfish, or algae) allows evaluation of the potential of an area. Surveillance or monitoring are prerequisites of effective action against over-exploitation.

Management of amenity
The recreational use of the shore and nearshore waters (e.g., for boating, fishing, including bait digging, and diving) is a particular type of exploitation of natural resources, with similar survey requirements.

Environmental impact assessments (EIAs)
Environmental impact assessments are now required by law for industrial and other developments in many countries. Examples of such developments are barrages, land reclamation, oil production in nearshore waters, and desalination plants.

Biological surveillance or monitoring
Surveillance and monitoring imply the use of a repeated protocol for the detection of temporal change. Choice of components for monitoring is best based upon an initial survey which reveals which organisms and communities are present in the area of interest. A baseline survey is a different concept – its purpose is to provide information against which subsequent monitoring data may be compared.

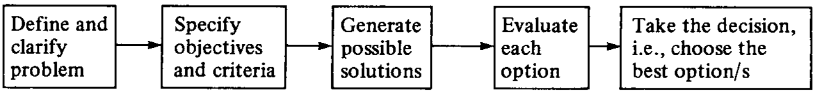
The terms surveillance and monitoring are sometimes used interchangeably; however, Holdgate (1976) restricted 'monitoring' to those cases where change is measured with a defined goal or standard in mind (whether or not it is mandatory).

Contingency plans
Murphy's Law states that (1) if it is possible for something to go wrong, sooner or later it will and (2) it is impossible to make any system foolproof because fools are so ingenious (Holdgate, 1976). Contingency plans are a response to Murphy's Law and have probably been best developed with regard to oil spill response. An essential feature of contingency plans is identification and mapping of vulnerable areas, and consideration 'before the event' of priorities for protection.

Damage assessment
After accidents such as spills of toxic chemicals it may be necessary to describe which organisms or communities have been affected, and over what area. Settlement of compensation claims may rest upon this information. It is also possible to do 'one-off' surveys around chronic discharges, e.g., sewage works outfalls, to find the spatial distribution of sedentary organisms and so estimate the area affected by the discharge.

Thinking around the problem

A survey is a way of tackling a problem. A common mistake is to spend insufficient time thinking about the problem (i.e., how to fulfil the aims of the survey) and consequently to plunge too soon into inappropriate survey routines. Deliberate use of a rational decision-making process helps (after Open University, 1983):



Setting objectives and criteria

It is essential that thinking about the problem leads to clear objectives and criteria as these influence all subsequent aspects of the planning and execution of the work. Several objectives may emerge from each problem. See Table 1.1 for some examples of specific objectives.

Criteria may be both scientific and operational, as illustrated by the following examples.

Must yield quantitative data, with a pre-defined level of precision.
Must be carried out during August:
So that results are comparable with those of a previous survey.
To take into account the seasonal behaviour of species X.
Must cost less than £10000.

Table 1.1. *Examples of survey objectives*

Problem (how to fulfil the aims of the survey)	Specific objectives
How to find the best site for a tidal barrage taking into account the conservation value of salt marshes	Carry out an aerial reconnaissance plus colour and false colour infrared aerial photography Select sites from the photographs and visit them to collect 'ground truth' information on vegetation Prepare maps showing distribution of salt marshes and main vegetation types
How to map the national distribution of conspicuous species of the shallow subtidal zone	Develop identification guides and recording cards suitable for use by amateur divers Publicise scheme among diving clubs and enlist support Develop computer-based data-handling system

Options

The central box of the decision-making process illustrated above is concerned with the generation of solutions or options. This stage in particular benefits from discussion with colleagues. Brain storming or lateral thinking techniques (Open University, 1983) may be useful here, though they do not seem to have been much used for survey planning purposes.

Example:

Objective: To delimit the area of effect of an effluent discharge flowing over a rocky shore.

Options include:

- Ignore biology altogether, use tracer dyes combined with aerial photography, or salinity measurements, at different stages of the tide.
- Colour and false colour infrared photography of shore at low tide from nearby cliff top.
- Walk around the shore and make notes and a sketchmap.
- Grid the shore (parallel transects); at grid stations record abundance of:
  - All taxa to species level if possible, or
  - Selected taxonomic groups, or
  - Functional groups, e.g., producers/herbivores/carnivores.
- As above but just record presence/absence at grid stations.

Planning considerations

Levels of planning

Planning is commonly required on different levels, those of (1) the estuary or coast, (2) the habitat, community, or population, and (3) the sample. A different dimension is (4) the amount of time required. For any survey a time budget should be developed, including data processing and reporting. Thus one may have hierarchies of objectives, criteria, and options.

Estuary/coast

Examples of planning considerations:

- What area is to be included?
- What is known already about this area?
- Can local people help with information?
- What components (e.g., subtidal macrobenthos, salt-marsh invertebrates, bacteria, birds) are to be included?
- Will remote sensing further the aims of the survey?

How is it possible to travel within the area?
What restrictions on working time are imposed by tidal conditions?

Is it necessary to obtain permission in advance to visit any parts of the area?

What hazards may be expected and what safety precautions should be taken?

Habitat/community/population

Examples of planning considerations:

What access points are available (e.g., to rocky shores)?

How will time of year affect the population distribution/species present/size of organisms? Should a series of surveys be carried out at different times of year?

How should sampling sites be located?

Samples

Examples of planning considerations:

How will the sample be taken (e.g., quadrat, corer, grab, suction sampler)?

What is the optimum size for the sample?

How many replicates should be taken? Could the sample comprise pooled sub-samples?

What degree of taxonomic discrimination or classification scheme is appropriate?

How will the taxa be recorded (presence/absence, abundance scale grade, density, biomass, etc.)?

What size taxa will be recorded (e.g., anything over 0.5 mm, less than and greater than 5 mm shell length, comprehensive size-frequency classes)?

Should the sample (e.g., a quadrat of vegetation) be recorded photographically as a supplement to or substitute for detailed field recording?

Which physical and chemical variables should be recorded in the sampling area?

Should the sampling area be permanently marked (e.g., with a wooden post or pat of concrete) to facilitate future surveys/surveillance?

How will the data be processed?

Location of sites and stations

The different chapters of this book contain information relevant to specific habitats or groups of organisms. The purpose of this section is to highlight important considerations of general relevance.

A strategy provides a rationale for the location of sites and stations, and it should be based on as much pre-existing information (e.g., maps, aerial photographs) as possible. The term 'site' refers to the locations within the estuary or along the coast at which the work is being carried out, and the term 'station' refers to the division of the site into survey or sampling units. Strategies for major components of the estuarine or coastal system are usually considered separately, and this is reflected in the structure of this book.

Options

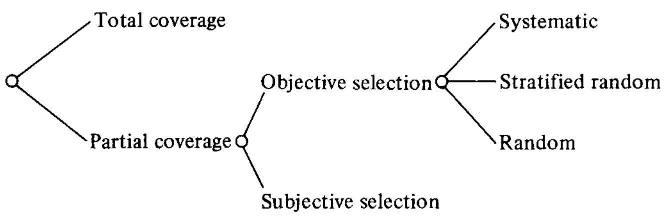
The options for site and/or station selection can be represented in the form of a decision tree (Fig. 1.1).

Total/partial. The need for choosing sites is eliminated with those survey approaches that give total coverage, e.g., aerial photography; walking along an entire shoreline and recording main habitat types on a map. Conversely, if taxonomic and/or quantitative detail are required, attention must be focused on small parts (sites) of the general area of interest.

Objective/subjective. A site may be chosen on subjective grounds (e.g., because it looks representative or because someone is worried about its conservation status) or objectively (e.g., because it is at an intersection on a national cartographic grid).

Different objective approaches. Systematic location of sites or stations, usually along transects or using a grid system, is appropriate for distribution/mapping studies, or in cases where environmental (including pollutant) gradients are suspected. Random location (using random numbers) is necessary if the requirement is for quantitative data with the maximum potential for parametric statistical analysis. In practice many surveys employ a stratified random strategy – sites are located systematically or

Fig. 1.1. Decision tree for site/station location.



with respect to predetermined divisions of the area into different environmental categories, but replicate stations at each site are randomized.

Examples

1. Stratified random strategy

Quantification (density estimates) of organisms on a tidal flat (Fig. 1.2). The three strata (based on a preliminary inspection) are mud, poorly sorted sediments, and the mussel bed. Each stratum is considered separately for the random location of sampling stations. The optimum number and size of samples (see next section) will probably be different for each stratum.

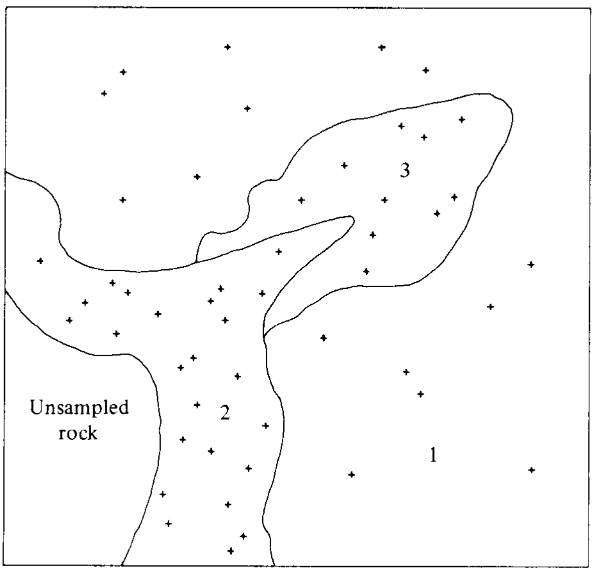
If the area to be considered is very large then two levels of stratification could be considered before randomization. Primary strata would be the mud, poorly sorted sediments, and mussel bed, as before; secondary strata could be systematic grids imposed separately on each primary stratum. Sampling stations would then be randomized within each square of each grid.

2. 'Complex' strategy

Rocky shore survey of a large bay (description of the distribution and abundance of macroflora and macrofauna) (Fig. 1.3).

The rocky shores are located using maps, photographs, and preliminary

Fig. 1.2. Tidal flat sampling in three strata: (1) mud; (2) poorly sorted sediments; (3) mussel bed.

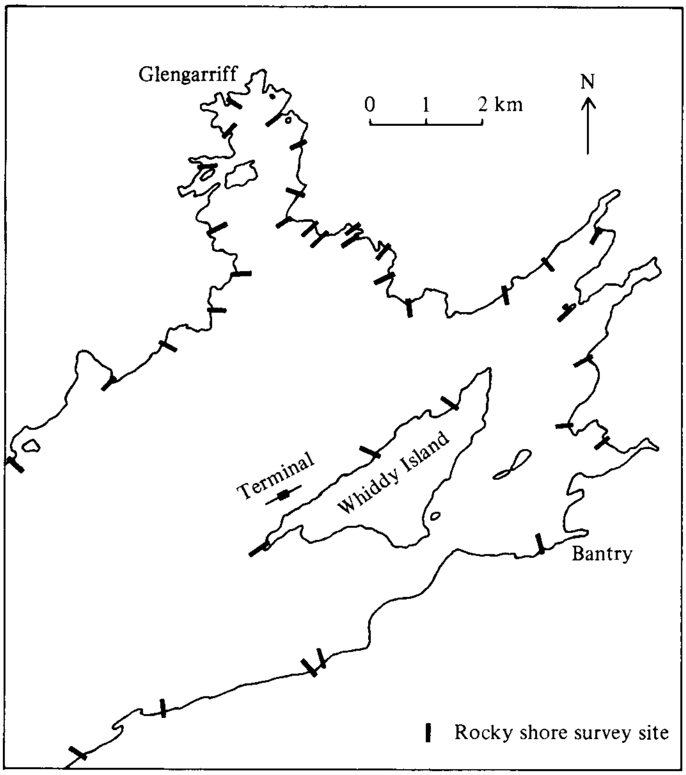


inspection. This amounts to 'stratification' of the bay into two components – rocky shores and the rest. Rocky shore sites for detailed survey are chosen using a 'modified' systematic approach, i.e., the sites are as evenly distributed round the bay as possible bearing in mind the two main constraints of rocky shore distribution and safe access. The final choice of site may be partly subjective in that it may be chosen, on the basis of a rapid inspection of a relatively large area, to be representative of the area.

At each site a belt transect is established and the abundance of organisms assessed systematically, e.g., at regular vertical height intervals along the transect. Each transect may be a stratified random sampling scheme in itself, with regular placement of transect stations combined with random quadrats, e.g., for limpet density, at each station.

Further examples of survey strategies are given elsewhere in this book, for example, see Chapter 5 for benthic sampling grids and Chapter 8 for a variety of rocky shore transect strategies.

Fig. 1.3. Distribution of rocky shore survey sites in Bantry Bay, Eire. After Baker & Hiscock, 1984.



Sizes and numbers of samples

A sample is the unit of investigation at a survey station. On a large scale, countries or regions can be sampled (on the ground or using aerial photographs or satellite-derived imagery) for habitat types or other major environmental features. More usually, a sample is the unit within which organisms are listed and their abundance assessed. Examples of such units are:

- A measured 50 m along a rocky shore, within which the presence or absence of one rare species of particular interest is recorded.
- A 1 m^2 quadrat on salt-marsh vegetation, within which percentage cover of the different species is estimated.
- A photograph of a quadrat, with percentage cover estimates worked out from the photograph in the laboratory.
- A 15 cm wide × 20 cm deep core on a mud flat, with subsequent sieving and counting of the different species.
- A timed trawl for large epibenthic organisms on subtidal sediments.
- A timed haul of a plankton net.
- A count of shore birds at a high-tide roost.

In practical terms, there is an obvious trade-off between sample size and the numbers of samples possible at any particular survey site. The first example above is of a large sampling area where replication would not be necessary – one would move on to another length of shore, i.e., another survey site. The second example could easily be replicated and this would be essential if the aim were to quantify salt-marsh organisms. Large or rare organisms will not be detected if the total sample area is too small, whilst several small randomized replicates are best for estimates of populations of common or widely distributed organisms.

If the main purpose of a study is to obtain an idea of the species richness of a site for comparison with other sites, the *minimum sampling area* needs to be considered. Minimum area curves and their interpretation are described in most texts on ecological methods, e.g., Mueller-Dombois & Ellenberg (1974) and Shimwell (1971). Hawkins & Hartnoll (1980) provide a critical review (with particular reference to rocky shores) and further methods based on probability theory for the extrapolation of minimum-area curves. The basic technique used to obtain a curve is to plot the cumulative number of species present against increasing sample area (e.g., from a number of quadrats). The point at which a 'satisfactory' proportion of the total number of species present in a community is collected is arbitrary. It has been usual to select a point along the curve at which an increase of 10% of the total sample area yields only 10% or 5% more species of the total number recorded. However, this method is greatly affected by the slope of the curve. Another approach which can be taken is to determine the mean increase in species number between quadrats, tabulate the percentage increase in species numbers per sample increment, and make an arbitrary determination of the point at which the majority are included. Drew (1971) suggests that a suitable point to select as a minimal area is that at which a 100% increase in area yields only 10% or perhaps 5% more species.

If it is required to obtain information on the quantity of a species for comparison either with other sites or for following temporal change in the abundance of that species, an *optimum number of samples* will need to be determined. Inevitably it will only be possible to calculate mean abundance within reasonable statistical limits for a small number of species in a community, unless enormous numbers of samples are to be taken. The acceptable statistical limits thus have to be set in an arbitrary fashion. Plotting a running mean for the quantity of a species present is a rapid way of assessing the adequacy of a sample number (see, e.g., Kershaw, 1973). A method based on probability statistics is given on p. 207.

For further reading on sampling, see the excellent handbook by Green (1979) on sampling design and statistical methods for environmental biologists. A useful statistical checklist on sampling (by Jeffers) is available from the Publications Officer, Institute of Terrestrial Ecology, Monks Wood Experimental Station, Abbots Ripton, Huntingdon, Cambridgeshire, U.K.

Comparability and reproducibility

If spatial and/or temporal differences between sites are to be identified, it is crucial to employ standardised and adequate methods, and to give good descriptions of the methods employed. This may seem blindingly obvious, but consider the conclusions of Nichols (1973) and D. H. Dalby (personal communication). Nichols reviewed about 20 studies of the benthos of San Francisco Bay carried out since 1912 (the majority since 1950). Despite the considerable expenditure of resources, it was concluded that there were few reliable quantitative data with which to compare future assessments of the benthos of the area, because of the range of methods used to collect and treat the benthic samples, coupled with subsequent incomplete or erroneous species identification. Dalby identified five different recording schemes used during a ten year period on a single intertidal monitoring study.

One means of cross-checking methods is to undertake laboratory intercalibration exercises. Recent literature on this subject indicates that