7 Monitoring/Sampling

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Chapter 7. Monitoring/Sampling

Collecting and analyzing data

Introduction

There are numerous ways that sampling and monitoring enter into oil spill response activities. Frequently, some sampling will be done immediately after the spill to help determine the immediate response. Taking samples of the oil to determine a "fingerprint" (identify the source of the oil) is one example. Some response activities will be approved contingent on a monitoring program being conducted, such as using dispersants, or bioremediation. In these cases, oil spill response personnel will find themselves involved in decisions regarding monitoring programs that are conducted in conjunction with these response techniques.

Response personnel may also, on occasion, wish to initiate monitoring projects themselves. These could be simple projects designed to answer questions about the effectiveness of a particular response, or to provide follow up monitoring after a spill. Knowing what environmental impacts were associated with the spill as well as the response activities can be very useful information that may be applicable when responding to future spill events.

Though not all spill response personnel will be directly involved in the collection of samples and the design of experiments, they will be in positions where they need to interpret data and make decisions based on these interpretations. Some possible examples include determining the validity of studies of new response techniques, evaluating bioassays to determine if adverse environmental effects can be expected, or evaluating studies on the effectiveness of particular treatments.

Even a basic knowledge of statistics and a minimum comfort level with analyzing data will help to defuse the "mystique" often inspired by the use of data and numbers. Being able to form one's own opinions about studies and results will provide a real advantage over having to rely on someone else's interpretations, especially in a field that is as politically charged as oil spill response.

Establishing objectives and endpoints

Objectives

Stating a clear objective often seems so obvious that it is not explicitly mentioned by people considering sampling projects. However, it is frequently the case that objectives are not well thought out, and consequently, data is collected that does not answer the question originally intended. When objectives are clearly defined and explicitly stated, then hypotheses and sample designs follow easily from them. Figures 7-1 and 7-2 present several examples of objectives that might be used in studies associated with oil spill response.

Hypotheses

Though not all sampling plans and experiments will involve the use of formal hypotheses, many questions lend themselves to a simple hypothesis test, which can then be subjected to a statistical test. An hypothesis is merely a restatement of the objective in statistical language that can later be subjected to a statistical test, where the hypothesis will be accepted or rejected, depending on the data results. Experiments that have several components may have several different hypotheses. Formulating an explicit hypothesis will also necessitate selecting the endpoint to be used for determining whether the hypothesis is accepted or rejected.

Endpoints

Endpoints are specific measures of the objectives of the experiment, and determine how parameters such as “effectiveness” or “toxicity” or “similarity” will be measured. Endpoints should ideally be a measurable quantity, such as “the concentration of PAH in tissue, measured as dry weight,” or “the relative abundance of selected species counted in intertidal quadrats.” Endpoints may include qualitative data, as in the fingerprinting example in Figures 7-1 and 7-2, but the type of data and the way it will be used should be specified as closely as possible. To establish endpoints, any

Bioremediaton

Effectiveness: Will proposed bioremediation with 'BIO-Wonder' work here?

Objective:
Will the bioremediation treatment degrade oil faster or in greater quantities than background rates?

Hypothesis:
The mean TPH from plot A (oiled, treated) will be the same as the mean from plot B (oiled, untreated)

Null hypothesis:
Ho: X_a (treated) = X_b (untreated)

Endpoint:
Chemical measurement of total petroleum hydrocarbon (TPH) in sediment samples collected from each plot.

Toxicity: Will 'Bio-Wonder' harm the environment?

Objective:
Will 'Bio-Wonder' cause toxic effects to marine organisms?

Hypothesis:
Bioassays using oyster larvae will show the same acute mortality rates with 'Bio-Wonder' as with plain seawater

Null hypothesis
Ho: M_p (product) = M_s (seawater)

Endpoint:
Mortality of bivalve larvae after 48 hours

Figure 7-1. Examples of objectives, hypotheses and endpoints for a bioremediation example

Oil Fingerprinting
Is all the oil found on the beach from the spill?

Objective
Is the oil sampled from the beach the same as that carried by the stricken tanker?

Hypothesis
Oil collected from site A (on beach) is the same as oil collected from the slick emanating from the tanker

Null hypothesis
(Not applicable)

Endpoint
Gas chromatographs, will be compared between the two samples with a focus on specific tracer compounds.

Figure 7-2. Examples of objectives, hypotheses and endpoints for an oil fingerprinting example.

laboratories that will be used for analysis should be consulted prior to sampling to ensure that samples are handled appropriately. Though most people understand the need for objectives and even hypotheses, in many cases, even elaborate and costly experiments do not select *in advance* the endpoint that will be used to answer to the original question. This is especially pertinent for environmental parameters that may be difficult to define, as well as measure (for example, “biodegradation” or “environmental recovery”).

Two major problems can result from the failure to select an endpoint for an experiment:

1). The data collected may not have been handled appropriately for the analyses that are needed;
2). The type of data or the way it was collected may not be appropriate to answer the original objective.

Specific selection of endpoints is also very important when several parties are involved in an experiment, as is frequently the case with oil spill monitoring. At the conclusion of the project, it may be found that the data collected do not answer the question posed. Or, when several different kinds of data are collected, disagreement may ensue between the different parties involved over what constitutes the "real" endpoint, and thus, the "real" result.

Sampling design

An appropriate sampling design helps ensure that the data collected provide answers to the initial questions posed. Sampling designs may be simple or very complex, but they should follow after the objectives and endpoints that have been selected. Sample design includes consideration of control sites, the number of samples, the locations where samples will be collected, the timing of sampling, and sample handling and analysis. For monitoring or sampling projects other than very simple ones, the best procedure will be to consult with a statistician while still in the planning stage.

Controls

A crucial part of most experiments is the reference or control site. Most objectives will involve detecting differences, or making comparisons, and thus require a baseline, or reference from which to measure change. In the absence of some sort of reference, interpreting the data will be difficult and possibly meaningless. In theory, controls should be replicates of the tested plot or experimental unit, the same in every way, except for the treatment applied. Some examples of possible controls are listed below:

- For a laboratory flask test: seawater containing no product (e.g. dispersant or bioremediation) at the same salinity and temperature as in the treated flask

- For a field study: a marsh plot containing the same plant species, with similar densities and oiling effects as the treated plots

In practice, control sites in field studies will never be completely identical to the test sites. Usually, one must settle for a "representative control" that is as similar or as representative as is feasible. Other options include the use of experimental units placed in the environment, such as sediment boxes. This technique was used by Berge (1990) to study colonization of biota to sediments impacted by oil, compared with control sediments.

One way to establish controls at spills of opportunity is by the use of "set-asides" (areas that are impacted by oil that are set aside, and left untreated for experimental purposes). NOAA arranged for such "set asides" immediately after the *Exxon Valdez* spill. Having these sites made it possible to conduct the long term study of treatment effects in Prince William Sound that is still ongoing.

Numbers of samples

The number of samples to be collected will depend on:

- the question being asked,

- the kind of data analysis to be done (including the statistical certainty desired)

- practical considerations (area available, time and access, personnel, cost)

A larger number of samples often allows greater power for statistical analysis, but will be more costly. If the parameter being measured is highly variable, such as the distribution of oil in sediments, a large number of samples will be needed to have the power necessary to conduct statistical testing. A small number of samples will provide an indication of the processes occurring, but may not be representative of the entire study area. One strategy is to collect a large number of samples in the field and then to analyze only a subset of the samples collected, based on the initial results.

In many field sampling situations, the number of samples that can be collected will be limited by logistics and practical considerations. These may include the area available, time and access constraints, personnel, cost, etc. In any event, it will almost always be more useful to take a few carefully thought-out samples than to take numerous samples without proper planning and subsequent follow-through.

Locations of samples

The locations chosen for sampling will depend on the number and types of habitats or shoreline types to be investigated, as well as on the sample analysis that will be conducted. A common approach is to select one or more plots to be sampled, with each plot representing a particular environment or treatment. Then, random sampling can be conducted within each plot. In a marsh monitoring, for example, transects could be placed in a control marsh, a trampled section of marsh, and in a washed section of marsh. Then replicate quadrats would be located randomly along each quadrat.

When possible, it is best to avoid taking samples in areas with outside influences that may confound the results, such as areas near outfalls or freshwater streams. Samples taken in the middle of a plot will usually be more representative than samples taken along the edge. One method for locating samples within a plot is to lay a grid pattern over a map of the test area and choose samples randomly in each designated area. (See Figure 7-3 for examples of different sample designs using plots).

Timing of sample collection

Timing refers to both the duration of the experiment, and the frequency with which samples will be collected. This could vary from a one-time sample collection, up to a multi-year monitoring program where sampling is conducted seasonally. As for other aspects of sample design, the appropriate time frame for collecting samples will depend on the questions being addressed. For this, one must refer back to the original objectives.

Some preliminary information will be helpful when determining both duration and frequency. For instance,

- Does the parameter of interest vary seasonally?
- Is there a minimum length of time necessary for acquiring useful information from the sampling program?

Dispersant monitoring, for example, will be conducted on a very short time frame, on the order of a several hours to days. Bioremediation, in contrast, must be sampled over a period of at least a week, and preferably over several weeks to be able to detect biodegradation. Ecological processes are ideally monitored seasonally over a long time frame, of several years duration, if possible.

Qualitative and quantitative data

Data can be categorized into two rough types, qualitative and quantitative.

Qualitative data is best described as descriptive; information that helps describe something, and gives the experimenter general background information. Qualitative data does not enable one to attribute a degree of certainty to the conclusions, since it does not include measures of variance. Because of this, qualitative data cannot be extrapolated to a larger environment or population.

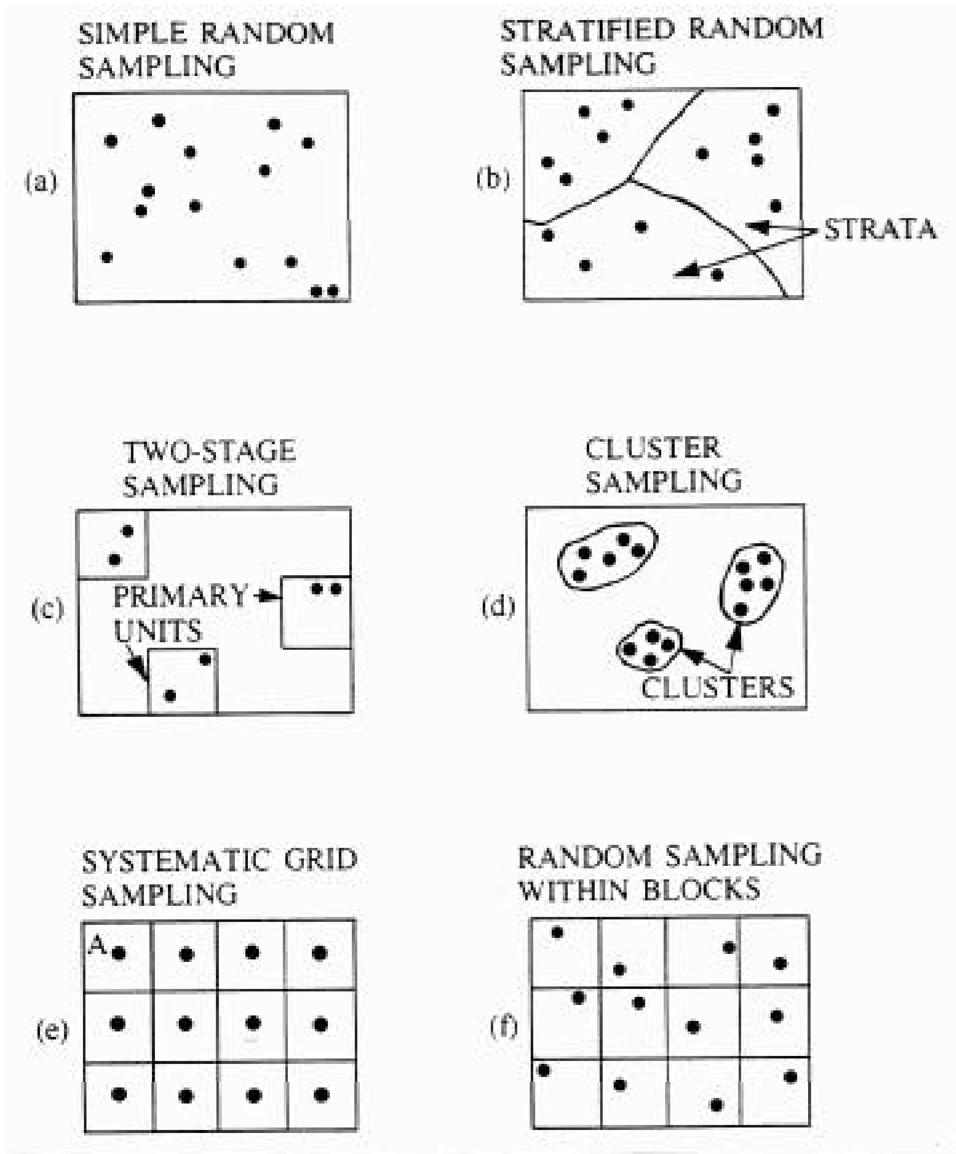

Figure 7-3. Some two-dimensional probability sampling designs for sampling over space (NAS 1985).

Qualitative data is useful for data exploration purposes, for identifying possible trends, and for "getting a feel for what is going on." Certain kinds of investigations are, by nature, descriptive, such as those that would address the following questions:

> What kind of oil is this?
> What type of habitat is this?

What species of plants or animals live here?

Initial, or pilot investigations will often be qualitative, and serve as a first source of information to use in developing future sampling plans. Field observations, made in the form of simple field notes, are very important types of qualitative data. Observations from people on the scene, that record things such as weather patterns, unusual occurrences, where oil was observed, etc. may be very helpful in clarifying what actually happened at a later date.

Qualitative data is limited, in that it cannot be used in the following ways:

- Extrapolating to broader universes
  (the sample collected may not be representative of other areas)

- Statistical testing
  (all statistical tests assume certain things about the data, for instance, that the samples were collected in a randomized manner)

Quantitative data means data that has been collected from random sampling, with some measure of variability (replication), and is representative of a larger population or universe. Quantitative data will usually result from a carefully planned experimental design. The advantages of this type of data area that there are many options for analysis, including performing statistical tests, and attributing statistical significance to the results.

As discussed earlier, it is by no means always necessary to obtain quantitative data. If the objective can be met by a simple collection of qualitative data, then there may be no reason to conduct more elaborate sampling.

Some considerations for analyzing data

When looking at your own or data collected from other sources, it is important to be on the lookout for measures of uncertainty that might make the results questionable. Two sources of uncertainty in sampling are bias and systematic sampling errors. Bias could result if something in the sampling plan or the sample collection makes the samples not representative of the population being studied. Systematic errors stem from errors that occur while sampling such as malfunctioning equipment.

When laboratory analyses are performed, look for the existence of a quality assurance, quality control program that cross-checks laboratory work. Also examine the detection limits of the work, to know the degree of accuracy of the data.

Some simple ways to gather data

Useful information can be gathered by people who will be on scene at incidents in several ways that do not involve excessive cost or effort. Some examples of these are as follows:

- Establish intertidal transects on shorelines
  - survey species found along the transects
  - survey the species found inside quadrats
  - photograph the transect and/or the quadrats to determine percent cover of vegetation or invertebrates

- Establish test plots corresponding to different treatment techniques

- Observe impacted areas over time
  - re-visit the site at definite intervals (seasonal, monthly)
  - take photographs from marked areas or known vantage points

Summary

- Objectives, hypotheses and endpoints should be clearly specified before a sampling project is designed

- Sample design will include the following:
  - Proper controls,
  - An appropriate number of samples (this will depend on the analysis to be conducted),
  - Locations representing the habitats being studied,
  - Duration and frequency of sampling appropriate to the objectives.

- Qualitative data is descriptive in nature and cannot be extrapolated to broader populations

- Quantitative data can be used for statistical testing, but must be from random samples

- Uncertainty in data can result from
  - biases in sampling, or systematic errors
  - errors in analysis (check for quality control and detection limits)

- Some simple ways to monitor
  - establish transects
  - use photography
  - establish plots by treatment
  - re-visit impacted sites

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