Marine Environmental Update

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FALL 2000

EPA Releases Final Total Maximum Daily Load Rule

On July 11, 2000, the Environmental Protection Agency issued its final Total Maximum Daily Load (TMDL) rule (see also *Marine Environmental Update*, Vol. FY00, No. 3). The EPA agreed to a number of changes in the program in response to the comments received after its initial proposal, including those from members of Congress. In general, the changes provide the States with significant new flexibility in implementing the program. These changes included: dropping provisions that could have required new permits for forestry, livestock, and aquaculture operations; significantly enhancing state flexibility; giving States four years instead of two years to update inventories of polluted waters; and allowing States to establish their own schedules for when polluted waters will achieve health standards, not to exceed 15 years.

The final rule was issued with an effective date of October 1, 2001, in order to comply with the language of a rider attached to House Resolution 4425, The Military Construction Appropriations Act, 2001 (subsequently signed by the President on July 13, 2000, becoming Public Law 106-246), which prevents the use of FY2000 or FY2001 funds to implement the TMDL rule. The EPA emphasized in its announcement of the final rule its commitment to clean water in America, and called on Congress to amend and/or eliminate the rider. Some of the key improvements in the final rule are:

- The rule has been upgraded to "major rule" status under the Congressional Review Act, allowing Congress ample time to review it if they chose.
- The proposed public petition process for review of lists or TMDL implementation has been dropped.
- States are not required to list "threatened water."

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- The proposal to require "offsets" before new pollution can be discharged to impaired waters prior to TMDL establishment has been dropped.
- The final rule does not include specific permit requirements for forestry, and the EPA withdrew its proposed revisions for expanded authority for permitting aquaculture and animal feeding operations.

The table below outlines the major changes introduced by the new Final Rule.

Final Rule:	**Existing Rules:**
Requires that a TMDL include an implementation plan that defines specific steps to be taken to restore polluted waters on a specific schedule.	Do not require implementation plans.
Requires that implementation plans provide a demonstration, or "reasonable assurance," that measures to reduce pollution from nonpoint sources will be implemented.	Do not require specific commitments to reduce nonpoint pollution or a demonstration of "reasonable assurance" of implementation.
States that implementation plans must identify a date by which the State expects that water quality standards will be attained and this date must reflect a goal of meeting water quality standards as expeditiously as practicable; if such date is not within 10 years of establishment of the TMDL, the State must demonstrate with credible and scientific information that this is not reasonable.	Do not address schedules for attainment of water quality standards.
States must develop TMDLs as expeditiously as practicable, at an even pace, but not later than 10 years after the first listing of a polluted waterbody (starting with 1998 lists), unless EPA grants an up to 5-year extension of schedules where establishment of TMDLs within 10 years is not practicable in a specific State.	Require that States set priorities and identify those TMDLs that they expect to develop over the next two years only (*i.e.* do not require a comprehensive schedule).
Requires that where both point and nonpoint sources are controlled, a schedule provides that nonpoint controls be installed within the term of the point source permit implementing the wasteload allocations; require that where only nonpoint sources are controlled, a schedule provide for implementing controls within 5 years when practicable.	Do not address schedules for implementing nonpoint source controls.

Final Rule:	**Existing Rules:**
The EPA must develop TMDLs where a TMDL submitted to the EPA is disapproved; the EPA must develop a TMDL where a State fails to make substantial progress under an approved schedule (*i.e.* misses the schedule by more than one year); the EPA must complete TMDLs within 2 years.	The EPA must develop TMDLs only where a TMDL submitted to the EPA is disapproved.
Requires a comprehensive listing of a State's polluted waters, including waters needing TMDLs, waters impaired by pollution, polluted waters with completed TMDLs that do not yet meet water quality standards, and polluted waters where existing controls will meet water quality standards before the next list is submitted (*i.e.* within 4 years).	List include only waters impaired by pollutants and still needing a TMDL.
Establishes a "rebuttable presumption" that States will give high priority for development of TMDLs to waterbodies where the problem pollutant is causing a drinking water system to violate a drinking water standard or where the waterbody supports threatened or endangered species.	Do not address drinking water problems or threatened or endangered species.
The EPA is required to establish lists of polluted waters and schedules for TMDL development where the EPA disapproves the list/schedule and where a State does not submit a list/schedule by April 1, 2002, and every 4 years thereafter.	The EPA is only required to establish a list of polluted waters where a State list (which does not include a schedule) is submitted to the EPA and the EPA disapproves it.
Requires that States provide the public with notice, and an opportunity for review and comment, on lists of polluted waters (including methodologies) and modifications to these lists; also requires notice and opportunity for comment on TMDLs.	Only require States to provide notice on the establishment of TMDLs in accordance with State procedures; require the EPA to provide notice when the EPA establishes lists and TMDLs.
Requires States to develop a methodology for assessing the health of waters and listing polluted waters with involvement of the public and the EPA.	Do not require a methodology for listing polluted waters.
Gives the EPA a new mechanism to object to and reissue expired State NPDES permits for waters not meeting water quality standards and to require permits for certain animal feeding/aquatic animal production operations in States authorized to issue Clean Water Act permits pursuant to a TMDL established by the EPA.	Provide no procedural mechanism to assure that expired NPDES permits are reissued, and do not provide that the EPA can designate animal feeding/aquatic animal production operations as needing a permit to implement a TMDL.

For further information contact Jim Pendergast, U.S. EPA, Office of Wetlands, Oceans and Watersheds (4503F), 1200 Pennsylvania Ave., N.W., Washington, D.C. 20460, (202) 401-4078 for information pertaining to Part 130; or Kim Kramer, U.S. EPA, Office of Wastewater Management (4203), 1200 Pennsylvania Ave., N.W., Washington, D.C. 20460, (202) 401-4078, for information regarding Parts 122, 123, and 124. The complete text of the final TMDL rule is available from MESO (543 KB Adobe™ Acrobat™ file). More information can also be found at http://www.epa.gov/owow/tmdl/finalrule/.

EPA Press Release, Tuesday, July 11, 2000.

Federal Register, Volume 65, Number 135, Thursday, July 13, 2000, pp. 43585-43670.

Federal Register, Volume 65, Number 136, Friday, July 14, 2000, p. 43840.

EPA Releases Draft Aquatic Life Criteria Update for Cadmium

On August 17, 2000, the Environmental Protection Agency released an update of its aquatic life criteria for cadmium for public review. The updated cadmium criteria reflect the latest scientific data and results in criteria that better protect aquatic organisms. Section 304(a) criteria provide guidance to States and Tribes in adopting water quality standards and provide a scientific basis for them to develop controls of discharges or releases of pollutants. The criteria also provide a scientific basis for the EPA to develop federal regulations under Section 303(c).

The EPA is recommending that for saltwater, aquatic organisms and their uses should not be affected unacceptably if the four-day average dissolved concentration of cadmium does not exceed 8.8 µg/L more than once every three years on the average and if the one-hour average dissolved concentration does not exceed 40 µg/L more than once every three years on the average. However, the limited data suggest that the acute toxicity of cadmium is salinity-dependent; therefore the one-hour average concentration might be underprotective at low salinities and overprotective at high salinities. The EPA believes that the use of dissolved cadmium will provide a more scientifically correct basis upon which to establish water-column criteria for metals.

The EPA is soliciting views from the public on issues of science pertaining to the information used in deriving the draft criteria. The complete text of the notice (121 KB Adobe™ Acrobat™ file) and the draft water quality criteria document (802 KB Adobe™ Acrobat™ file) are available from MESO. For further information contact Cindy Roberts, Health and Ecological Criteria Division (4304), US EPA, Ariel Rios Building, 1200 Pennsylvania Avenue N.W., Washington, D.C. 20460; (202) 260-2787; e-mail: roberts.cindy@epa.gov.

Federal Register, Volume 65, Number 160, Thursday, August 17, 2000, pp. 50201-50202.

Court Rules EPA Using Informal Guidance Documents To Bypass Formal Rulemaking Process

On April 14, 2000, the U.S. Court of Appeals for the District of Columbia Circuit made a substantial ruling concerning the EPA's tendency to govern through guidance documents rather than regulations. The court case, *Appalachian Power Company* vs. *U.S. Environmental Protection Agency (EPA) (No. 98-1512)*, dealt with the meaning of "periodic monitoring" in Title V state permit programs for air pollution sources under the Clean Air Act issued in 1992. In 1998, the EPA composed a document entitled *Periodic Monitoring Guidance for Title V Operating Permit Programs* in which it elaborates on what "periodic monitoring" means and clarified six specific circumstances for evaluating whether periodic monitoring requirements need be augmented. A group of electric utility companies filed a petition for review of the Periodic Monitoring Guidance document, saying that it was in effect a rule and that it should be ignored because the EPA did not follow the proper rule-making procedures. Judge Randolph concluded that the EPA did in fact amend the regulation and cannot do so without complying with the rule-making procedures (public notice, comment, publication in the *Federal Register*, *etc.*).

The full text of the ruling is available from MESO (191 KB Adobe™ Acrobat™ file).

Appalachian Power Company et al., v. Environmental Protection Agency, U.S. District Court of Columbia Circuit No. 98-1512; April 14, 2000.

Environment Reporter, Volume 31, Number 24, June 16, 2000, pp. 1284-1288.

R/V *ECOS* Surveys The Anacostia River

From July 6 through July 21, 2000, the Space and Naval Warfare System Center, San Diego (SSC SD) Environmental Sciences Division's R/V *ECOS* with the Marine Environmental Survey Capability (MESC) on board was deployed with a 5-man scientific crew to the Anacostia River, where it assessed the hydrodynamic conditions of the river, supported the development of a contaminant transport model, and measured a variety of water quality parameters in real-time to develop a synoptic map of the river and to provide a screening of sediment contaminants to better understand contaminant dispersion and distribution. The thrust of the two-week data collection effort was to support Navy compliance

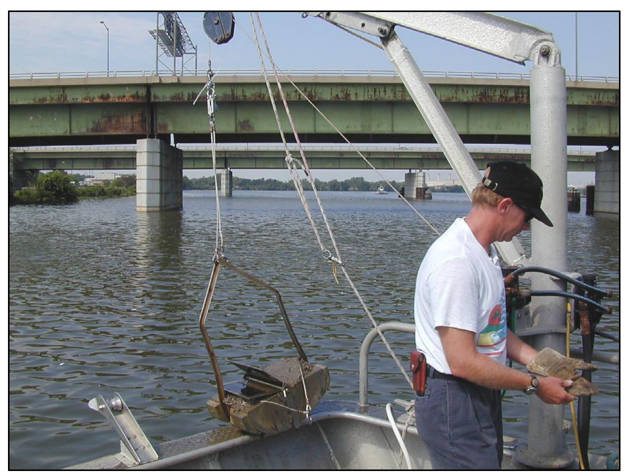
The R/V ECOS*, with Office of Naval Research personnel embarked, performs water quality measurements on the Anacostia River.* U.S. Navy photograph.

programs by supporting the Anacostia Watershed Toxics Alliance (AWTA) at the request of COMNAVDISTRICTWASH to develop a synoptic regional view of the river. Members of AWTA include the Navy, the Air Force, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the Fish and Wildlife Service, the Chesapeake Bay Program, universities and other stakeholders.

To celebrate the beginning of a new phase of research work for the restoration of the Anacostia Watershed, the AWTA sponsored a kickoff event on July 19, 2000, "Launching New Environmental Research on the Anacostia River," where the *ECOS* was made available for inspection. Speakers and attendees at the event included Deputy Undersecretary of Defense for Environmental Security Sherri Goodman; Commandant, Naval District of Washington RADM Christopher Weaver; EPA Region III Administrator Brad Campbell; and District of Columbia Department of Health Senior Deputy Director for Public Health Assurance Ted Gordon.

During her deployment, the *ECOS* and her team accomplished the following:

1. Assessed the hydrodynamic conditions of the Anacostia River to support ongoing and future development of contaminant fate and transport models. Measurements included:
   - Real-time currents using an acoustic doppler current profiler (ADCP)
   - Multiple fixed-point currents using ADCP and electromagnetic current meters
   - Multiple fixed-point tide heights using tide gauges
   - High resolution bathymetry
2. Measured a variety of water quality parameters in real-time to develop a synoptic map of the river. Measurements included:
   - Temperature, conductivity, salinity, density, sample depth, bathymetry
   - Dissolved oxygen and pH
   - Suspended sediment concentration and particle size
   - Chlorophyll α
   - Flow-through measurements of total PAH and metals analysis (Pb and Cd)
   - Discrete water samples for a variety of contaminants (PAHs, metals, and nutrients)
3. Provided a rapid screening of sediment contaminants to better understand contaminant dispersion and distribution and to guide further comprehensive sediment collection and analysis. Measurements included:



A sediment sample from the Anacostia River is brought aboard the R/V ECOS. U.S. Navy photograph.

- Metals analysis using x-ray fluorescence
- Total PAHs using immunoassay
- Total PCBs using immunoassay

The research being sponsored by AWTA will include multiple scientific studies designed to supplement past and current studies of the river. The research will help experts to better understand chemical contaminant toxicity, concentrations, loading, transport mechanisms, and their impacts on human health and the environment. Based on the results, the AWTA will evaluate and implement cost-effective management strategies to address existing contamination and to minimize current and future toxic chemical releases.

EPA Releases Two New WET Method Documents

The Environmental Protection Agency recently issued *Understanding and Accounting for Method Variability in Whole Effluent Toxicity (WET) Applications Under the NPDES Program* in response to questions on WET test method variability. WET applications are implemented under the National Pollutant Discharge Elimination System (NPDES) Program. The EPA released this document to clarify several issues regarding WET variability and reaffirm the EPA's earlier guidance and recommendations published in the Technical Support Document for Water Quality-Based Toxics Control (TSD, USEPA 1991). This document is intended to provide NPDES regulatory authorities and all stakeholders, including permittees, with guidance and recommendations on how to understand and account for measurement variability in WET testing.

Copies of the document may be requested from the Office of Water's Resource Center at (202-260-1827) or by contacting the National Center for Environmental Publications and Information (NCEPI) at (513-489-8190).The complete text of the document can be viewed or downloaded on the Internet at http://www.epa.gov/owm/npdes.htm and is also available from MESO (1.80 MB Adobe™ Acrobat™ file). For technical questions on this document, contact Debra Denton, (415-744-1919) or Laura Phillips (202-260-9522), Water Permits Division, (4203), USEPA, Office of Wastewater Management, 1200 Pennsylvania Avenue, N.W., Washington, D.C. 20460.

The EPA also announced the availability of *Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing (40 CFR Part 136)*. This guidance document updates recommendations and suggestions (with additional technical clarification) regarding WET test methods published by the EPA and incorporated by reference into regulations. The document includes specific technical guidance on nominal error rate adjustments, confidence intervals, concentration-response relationships, dilutions series selection, and dilution water.

The complete text of the subject guidance document may be viewed or downloaded on the Internet at http://www.epa.gov/OST/WET/ and is also available from MESO (293 KB Adobe™ Acrobat™ file). For further information contact Marion Kelly at the U.S. Environmental Protection Agency, Office of Water, Engineering and Analysis Division (4303), 1200 Pennsylvania Avenue, NW, Ariel Rios Building, Washington, DC 20460, call (202) 260-7117, or e-mail: kelly.marion@epamail.gov; or John Fox at the U.S. Environmental Protection Agency, Office of Water, Engineering and Analysis Division (4303), 1200 Pennsylvania Avenue, NW, Ariel Rios Building, Washington, DC 20460, call (202) 260-9889, or e-mail: fox.john@epamail.gov.

Federal Register, Volume 65, Number 138, Tuesday, July 18, 2000, pp. 44528-44529.

Federal Register, Volume 65, Number 146, Friday, July 28, 2000, pp. 46457-46458.

Washington State Releases Draft Strategy To Reduce PBTs

The State of Washington's Department of Ecology has determined that a decision to adopt the draft Persistent, Bioaccumulative, Toxic Chemical (PBT) Strategy could be an action under the State Environmental Policy Act (SEPA). While the draft PBT Strategy is designed to promote and enhance environmental quality, indirect or secondary adverse impact may result in the process of achieving an improved and enhanced environment. The starter list of chemicals they will focus on includes Aldrin/Dieldrin, Benzo(a)pyrene, Chlordane, DDT (& DDD/DDE), Dioxins & Furans, Hexachlorobenzene, Mercury, PCBs, and Toxaphene.

This draft strategy envisions continually reducing risks to human health and Washington's environment from exposures to PBTs, using the following goals:

- Reduce and phase-out existing sources of PBT chemicals.
- Clean up PBT chemicals from historical sources.
- Prevent new sources of PBT chemicals.
- Build partnerships to promote efforts to reduce and eliminate PBT chemicals.
- Ensure regulatory and non-regulatory approaches address cross-media (air, land, and water) impacts.
- Identify and prioritize additional PBT chemicals.
- Improve public awareness and understanding of PBT problems and solutions.
- Promote the development of information needed to make informed decisions on measures to reduce PBT chemicals.

This draft strategy calls for reducing and, where possible, eliminating PBTs by the year 2020 through phasing out the use and production of these chemicals. Key actions include:

- Reduce and phase out existing sources of PBT chemicals.
- Clean up PBT chemicals from historical sources.
- Prevent new sources of PBT chemicals.

- To achieve these actions over the next 20 years, the following steps or "building blocks" will need to be accomplished:
- Build partnerships to promote efforts to reduce and eliminate PBT chemicals.
- Ensure regulatory and non-regulatory approaches address cross- media (air, land, and water) impacts.
- Identify and prioritize additional PBT chemicals.
- Improve public awareness and understanding of PBT problems and solutions.
- Improve information needed to make informed decisions on measures to reduce PBT chemicals.

The complete text of the draft strategy document is available from MESO (685 KB Adobe™ Acrobat™ file). More information can be found on the internet at http://www.ecy.wa.gov/biblio/0003002.html.

Special Feature: An Introduction To Environmental Sampling Planning

NOTE: This article is available in its entirety, complete with example calculations, as a separate document directly from MESO (323 KB Adobe™ Acrobat™ file).

Introduction

One of the most difficult challenges scientists/environmental managers must address when conducting a site assessment or survey is determining the number of samples to be taken. Too many samples will waste time and resources, both in collection and analysis of the data. On the other hand, too few samples can make the whole study scientifically indefensible, or even worse, lead to errors in interpretation (Eckblad, 1991). Consideration must be given to cost of the sampling itself and to the availability of the resources needed to complete the analysis. In some cases, time of year is also a factor and will influence the design of a sampling plan and also the statistics used to analyze the data. Statistics can be defined as a theory of information. Such information is obtained by experimentation or, equivalently, by sampling; it is employed to make an inference about a larger set of measurements, called a population (Ott, 1988).

The aim of this article is to offer some guidelines on how to take available data (or to use pilot study data) and design a sampling plan to suit the needs of a specific project in the most time-efficient and cost effective way.

Hypothesis Testing

The cornerstone of scientific analysis is hypothesis testing. The idea is that you formulate a hypothesis (H_1) into a statement, collect appropriate data and then use statistics to determine whether the hypothesis is true or not. However, the statistical tests do not provide a simple answer of true or not. For every hypothesis there will be an associated null hypothesis (H_0), which is the parameter that most statistical procedures test.

The null hypothesis is simply a statement of “no difference” between the actual value (derived from an experiment) and an expected value. A statistical test determines the probability that the null hypothesis is true (p-value). If the probability is low then the null hypothesis is rejected and the original hypothesis (H_1) accepted.

Wrong inferences, however, can be drawn for testing the null hypothesis. These are called Type I (α) and Type II (β) errors. In a Type I error, the null hypothesis is really true but the statistical test leads to the assumption that it is false. This type of error thought of as a “*false positive*”. In a Type II error, the null hypothesis is really false but the test has not conclusively established this difference. Small sample sizes can often lead to a Type II error. Although Type II errors are less serious than Type I errors, a Type II error should still be avoided, if possible. Usual convention is to use a critical p-value of 0.05, which states that the probability of a null hypothesis being true is 5%. (Dytham, 1999). Depending on the study objectives and subject matter, the wrong interpretation of Type I and Type II errors can provide misleading results.

Sampling Design

Several things must be considered before the sample design and analysis can occur. Study objectives (hypotheses) must be clearly stated, as well as conceptually defined in temporal and spatial terms (*i.e.* determination of time frame and physical distances necessary to define a population). Collection of background information and historic data applicable to a given site is crucial in picking the optimal sampling method. Potential trends and variability in historic data can be examined for usefulness in a current study, assuming there is confidence in the original study design. Part of the pre-planning process is to determine sample types required and other field parameters to collect. Above all else, a solid quality assurance program must be implemented. (Gilbert, 1987). If a proposed sampling site has large-scale environmental patterns of some kind, break the area up into homogenous subsections and take samples from those areas that are proportional to the size of the subsection. Additionally, pick a sample size that will give the precision desired, yet be representative of the population as a whole (Green, 1979). Determine what statistics to use for sample analysis, and assess the uncertainties associated with estimated quantities like arithmetic means, trends, average maximums, *etc.* (Gilbert, 1987).

This article focuses on the two concepts presented by Green (1979) because they are the key to effective sampling design and data gathering: 1) breaking up sampling sites with large-scale environmental patterns into homogenous subsections and taking subsamples from those areas that are proportional to the size of the subsection, and 2) picking a sample size that will give you the precision desired and yet be representative of the population as a whole.

Depending on site specific conditions and program objectives, multiple sampling techniques may be used to best characterize each different regions within an area. Also, certain analytical techniques require sampling be conducted in certain ways.

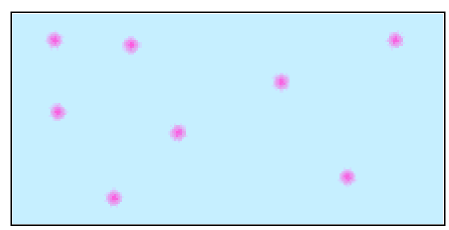
The four basic methods for sample collection are:

- haphazard sampling;
- judgement sampling;
- probability (statistical) sampling; and
- search sampling.

Haphazard sampling consists of sample collection from anywhere within the study area the investigator wishes, which can obviously lead to severely biased results. Judgement sampling involves the selection of specific sampling locations by professional judgement. If the person or group is knowledgeable, this method may actually result in accurate data collection, but the degree of accuracy can be difficult to quantify. Hot spots and area of pollution sources, for instance, may be found through the use of judgment sampling. Be advised, however, this technique requires a lot of background data to support station selection and can possibly require more high tech equipment to complete accurately. Probability sampling uses a specific method of random sampling and allows for determination of spatially distributed variables, as well as allowing sampling along time and space scales. There are six probability sampling methods: simple random sampling, stratified random sampling, two-stage sampling, cluster sampling, systematic sampling, and double sampling (Gilbert, 1987).

I. Simple Random Sampling

An unbiased estimate of a population is only possible if the sample units are representative of the total population. The easiest way of achieving this is for each sample unit to contain a random sample of the population under investigation (Dytham, 1999). A random sample may be defined as a sample drawn in such a way as to ensure that every member of the population has an equal chance of being included. Random sampling procedures increase the chances that a sample will be unbiased and one of their major purposes is to minimize possible bias on the part of the experimenter (Schefler, 1979).



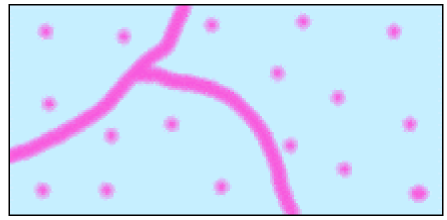
Simple Random Sampling

Simple random sampling is an efficient way for estimating means and totals if the population does not contain major trends, cycles, or patterns of contamination (Gilbert, 1987). There are several techniques which can be used for random sampling. Random sampling gives an unbiased estimate of population parameters, allows for the calculation of confidence intervals and allows hypothesis testing to be carried out. It is very time consuming, however, to implement. Basic assumptions of random sampling include:

- individuals are selected in one stage;
- the chance of being selected is equal for each sample unit in the population; and
- selection of one sample does not effect the chances that another sample would be selected. (Portier & Arvanitis, 1998).

II. Stratified Random Sampling

Stratified Random Sampling involves the division of the target population into subdivision or strata in order to get a better estimate of the mean or total of the entire population. Sampling locations within each strata are then selected using the simple random sampling technique. This is useful to break down a heterogeneous population into groups that are themselves homogeneous (Gilbert, 1987). Strata must be constructed so that strata averages are as different as possible and that strata variances are as small as possible.



Stratified Random Sampling

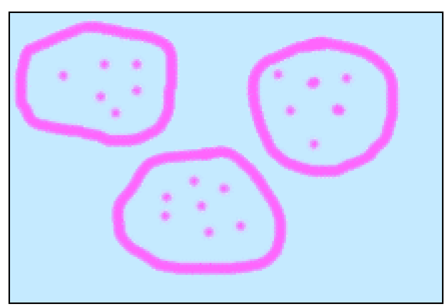
Stratified random sampling requires prior knowledge of the population being sampled and is very time consuming. It is, however, likely to give a more representative sample of the population. The main assumption of this sampling method is that all variables of interest are variable within the population (Portier & Arvanitis, 1998).

III. Two-Stage Sampling

Two-Stage Sampling involves taking samples (primary units) using the simple random sampling technique and then taking an aliquot of those samples (Gilbert, 1987). Two-stage sampling allows for a lower error than cluster sampling and costs less than simple random sampling for larger populations. It does, however, have a higher error than simple random sampling.

IV. Cluster Sampling

Cluster Sampling is very selective in how it can be employed. It is useful in situations where population units cluster together naturally (like schools of fish, rooted vascular plants) and each unit in each cluster can be measured independently of one another (Gilbert, 1987). Cluster sampling, in general, is easier to carry out and in most cases less expensive, but it may not be representative of the whole population because samples would not be random, which increases sample error and causes statistical calculations to be complex.



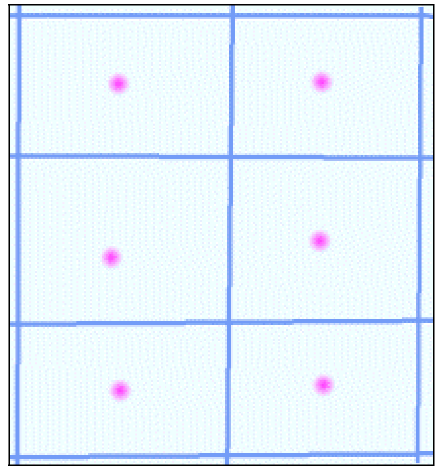
Cluster Sampling

V. Systematic Sampling

Systematic Sampling is good when the intention is to estimate trends or patterns over space. Samples are taken at even intervals after a random start is chosen. It can be a dangerous method to use if the sampling pattern corresponds to an unsuspected pattern over space or time (Gilbert, 1987). Cochran (1977) suggests using this sampling method when:

- the ordering of the population is essentially random or it contains at most a mild stratification;
- stratification with numerous strata is employed and an independent systematic sample is drawn from each stratum;
- subsampling cluster units; and
- sampling populations with variation of a continuous type, provided that an estimate of the sampling error is not regularly required.

Systematic sampling may contain unsuspected bias, but is easy to do and quick to carry out. It can be expensive to carry out when dealing with large populations, however. It can be unbiased if the population is arranged randomly in respect to the parameter(s) being investigated. It assumes that the sample frame is randomly ordered with respect to values of the random variables of interest (Portier & Arvanitis, 1998).



Systematic Sampling

VI. Double Sampling

Double Sampling involves having samples collected in two different ways. (For example, using a portable monitoring device in the field along with traditional analysis from a certified environmental laboratory. It is useful when data using one measurement technique are nearly linear to data obtained from a less resource-intensive technique.

Double sampling determines the most cost effective way of both sampling and measuring samples. It enables a minimum sample to be taken for clear-cut cases of accept/reject hypotheses. This design assumes that there is a high degree of correlation between the supplemental and target measurement random variables, and that this degree of correlation can be expressed as a linear relationship between measurements (Portier & Arvanitis, 1998).

VII. Search Sampling (Hot Spot Sampling)

Search Sampling is good for determining whether or not local areas of contamination, a.k.a. “hot spots,” are present in a region. In order to use this method, the following assumptions are required:

1. the definition of a hot spot is precisely stated;
2. the hot spot is of the circular nature;
3. samples are taken on a triangular, square or rectangular grid;
4. the distance between samples is larger than the total area sampled, meaning that only a small area is being investigated; and
5. there is no confusion in deciding when a hot spot was hit.

There are specific equations used with this kind of sampling design to calculate:

- grid spacing;
- the maximum size of a hot spot that can be located at a given risk and cost;
- the probability of that a hot spot exists even though it may not be found; and
- the probability of not finding a hot spot at all.

This type of sampling is most beneficially used for examining, in much greater detail, areas already known to be of concern, ones where prior samples have already been taken, and can pinpoint study areas more accurately. It is not good for estimating average concentrations over large areas, nor for evaluating large areas that have no prior background data available (Gilbert, 1987).

How Many Samples Are Enough?

The optimum number of sample to collect is nearly always limited by the amount of resources available. However, it is possible to calculate the number of samples required to estimate population size with a particular degree of accuracy. The best sample number is the largest sample number, keeping in mind that no sample number will compensate for poor sampling design. In other words, quantity should not be increased at the expense of quality. Poor quality data will have more inherent error and, therefore, make the statistics less powerful. (Dytham, 1999). Precision of estimated mean values will increase with increasing sample number, but there is a law of diminishing returns. Standard error is defined as an estimate of the standard deviation, or spread, of the sampling distribution of means, based on the data from one or more random samples. (Dytham, 1999). The standard error of the mean decreases in proportion to the square root of the sample number. An increase in sample number from 4 to 9 reduces the standard error by a third. To achieve another reduction by 1/3 a sample number of 21 would be required, and to achieve another, 46. (Green, 1979).

Elliott (1977) suggests a simple way, although limited in its applications, to estimate suitable sample size when dealing with benthic invertebrate samples. Elliott suggests taking samples in 5 sample-increments (5, 10, 15, 20…) and calculating the means of every 5 samples until the point is reached where sample means do not vary much. The sample number used to reach that point can be considered a suitable sample size for the study. This method is not useful when in the field, but is a quick approach if a small pilot study is to be conducted.

Each of the six types of probability sampling methods mentioned in the previous section have their own ways of calculating sample number given predetermined levels of variance, correlation and degree of error. See Gilbert (1987) & Elliott (1977) for specific equations and assumptions. For further details, see references listed at the end of this article.

Summary

This article outlines the major facets of scientific analysis-from basic statistics and hypothesis testing to sampling design. It offers some guidelines on how to take available data (or to use pilot study data of your own) and design a sampling plan to suit the needs of any project in the most time-efficient and cost effective way. A list of highly suggested references to consult for further details and information on the application of the concepts mentioned here is listed in the Bibliography.

Bibliography

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New Marine Environmental Quality Documents Available

Sediment Quality Characterization Naval Station San Diego, Final Summary Report

This report summarizes a study that was carried out to characterize the current status of San Diego Bay sediment quality in the vicinity of Naval Station San Diego (NAVSTA). The objective of this study was to provide an assessment of the extent of potential ecological consequences of sediment contamination. The study focused on two issues: the characterization of contaminated sediments, and the evaluation of the processes that control the levels, transport, and biological exposure of this contamination. The scope of the study was limited to evaluation of sediment quality, and the processes acting on those sediments, for the region offshore from NAVSTA (the area of San Diego Bay extending approximately from Sweetwater River on the south, to the Coronado Bridge to the north, and from the NAVSTA shoreline on the east to the Silver Strand on the west). Sediments were characterized on the basis of a range of physical, chemical, and toxicological testing. Processes that were evaluated included contaminant sources, sediment transport, sediment-water exchange, and degradation. As part of the study, new technologies were demonstrated alongside traditional methods.

On the basis of comparison to Effects Range Median (ERM) levels and background contamination levels in relatively "clean" regions of the California coast, this study describes which particular contaminants appear to be elevated and in what spatial areas elevated levels were found. In general, concentrations of copper, mercury, and zinc were measured at elevated levels, and concentrations of arsenic, chromium, and nickel were mostly found to lie below the ERM thresholds at or near background levels. Biological effects from sediment exposure were evaluated on the basis of numerous tests (bioassays, benthic community structure, *in-situ* biomarker assay and bioaccumulation studies) on a broad range of test organisms and exposure mechanisms. Three mechanisms of transport of contaminants were investigated in this study including benthic fluxes, leaching from sediments resuspended by ships, and tidal transport of sediments resuspended by ships. Also, modeling of sediment inputs from storm water was conducted.

The document is available at http://www.spawar.navy.mil/sti/publications/pubs/tr/1777/tr1777.pdf (4.49 MB Adobe™ Acrobat™ file).

Quantifying In Situ Metal Contaminant Mobility in Marine Sediments

This report summarizes the work conducted to demonstrate and validate the use of Benthic Flux Sampling Device (BFSD) for quantifying in situ metal contaminant mobility in marine sediments. A complete description of the equipment, processes, and methods is given. Test and demonstration results along with analysis and interpretation are included in the report. Performance and cost analysis is also included. The specific objectives of the project were as follows:

- Evaluate the quality of water samples collected using the BFSD, specifically for use in determining if a statistically significant flux was occurring at the test location in comparison to the blank flux results for the BFSD.
- Evaluate the BFSD for repeatability.
- Evaluate the logistical and economic resources necessary to operate the BFSD.
- Evaluate the range of conditions in which the BFSD can be operated.

The California Environmental Protection Agency's Technology Certification Program was selected for independent evaluation of the performance objectives. A set of detailed performance claims that embodied the above project objectives were established. A replicate series of three full system blank equipment tests were conducted to statistically establish system baseline performance. Two formal demonstrations were then conducted with evaluator oversight. The demonstrations used contaminated sites in San Diego Bay, CA, and in Pearl Harbor, HI, where fundamental differences allowed the evaluators a broad set of results to compare with claimed performance. Standardized processes and methods were followed. Pre- and post-development preparations, logistics, material, and labor costs were also evaluated.

The document is available at http://www.spawar.navy.mil/sti/publications/pubs/tr/1826/tr1826.pdf (1.53 MB Adobe™ Acrobat™ file).

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