National Water Quality Monitoring Council
Working together for clean water

Water Quality Monitoring:

A Guide for Informed Decision Making

Statistical Survey (Probabilistic) Design

About the Series

This is one in a series of fact sheets describing different water quality monitoring designs and the specific questions that can best be addressed by each. They are intended to point out the strengths and limitations of each design and to illustrate the role of each in a comprehensive monitoring program.

About the Design

A statistical survey design (sometimes referred to as a probabilistic design) allows one to make statements about a large population based on a smaller unbiased sample of the population. A variety of fields use statistical surveys, including public health, economics, and market research, to provide representative, scientific information when it is not cost-effective or possible to measure the characteristics of each member of the population. The Center for Disease Control uses a statistical survey design when conducting the National Health Interview Survey (NHIS) to track health status, health care access, and progress toward achieving national health objectives.

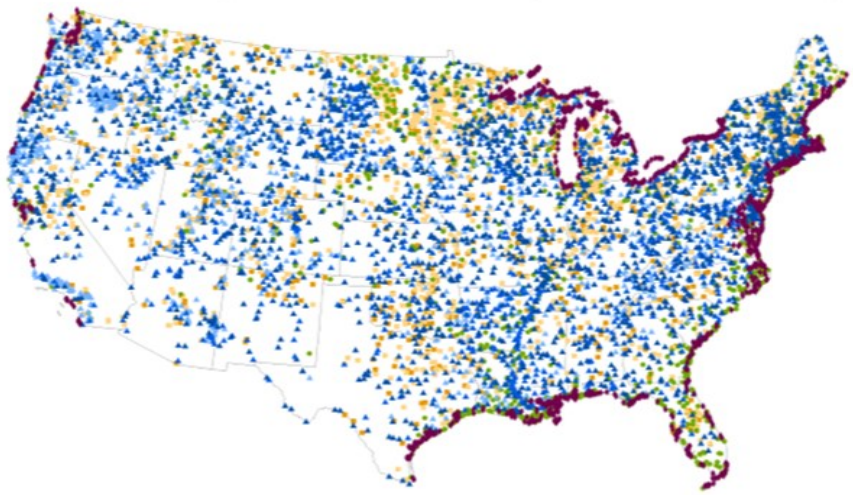

Figure 1: Probability monitoring sites sampled through the National Aquatic Resource Surveys.

The strength of the results from statistical surveys is their ability to characterize and describe the overall population, with documented confidence.

What you need to know

Statistical surveys are an important element of a comprehensive monitoring program and do not replace other designs (see other fact sheets in this series). EPA, States and others use statistical surveys as a cost effective tool for assessing our Nation's water resources. Using an unbiased sample, statistical surveys can be designed to estimate conditions for the national, state, watershed, or other geographic scales.

A statistical survey estimates the extent of impacted water across a state and supports analysis of whether the impacted water have common attributes that could inform management priorities. While the statistical surveys describe the extent of impacted waters, it doesn't identify the specific location of each impacted. Other types of data analyses, modeling, and targeted monitoring contribute information on specific locations of impacted waters.

Statistical Survey Design Summary

Questions Addressed	Limitations
Estimates the extent and proportion of the population in condition classes (i.e. meeting or not meeting standards) with known levels of precision and documented margin of error	Not designed for localized or site specific characterizations, though data at sites sampled supports detailed characterizations
Repeated surveys track changes and trends in condition across the population to evaluate effectiveness of overall protection and restoration investments	Generally not applied to characterize local , site specific effectiveness assessments (e.g. TMDL's, BMP's)
Identifies patterns as well as associations between indicators to broad analysis of stressor/response signals	As with all designs, changes detected by repeat surveys must consider hydrologic and other factors
Flexibility: can be based on a single or multiple visits, rotating basins, or ecoregions, etc	

Table 1: The above table outlines the strengths, limitation, and products produced by statistical surveys.

How are surveys conducted?

In order to pick an unbiased, random sample it is necessary to first know the location of the members of the population of interest. Typically a map of waters is used as the "sample frame" for a population. Next, a set of sites are randomly selected from that population, where every element in the population has a known probability of being selected for sampling. This key feature ensures that the results of the survey reflects the full range, in both character and variation, of the whole population. For a geographically widespread population of interest, the site selection process can also be controlled for spatial distribution to make sure sample sites are evenly distributed across the entire population of interest.

The selected sites are then sampled with a predetermined frequency for a set of indicators of interest. This can be a single visit for biological community assessment, or seasonal, bi-monthly, monthly, or weekly sampling events, depending on the parameter of interest and the frequency necessary to meet the appropriate water quality standard and/or assessment methodology.

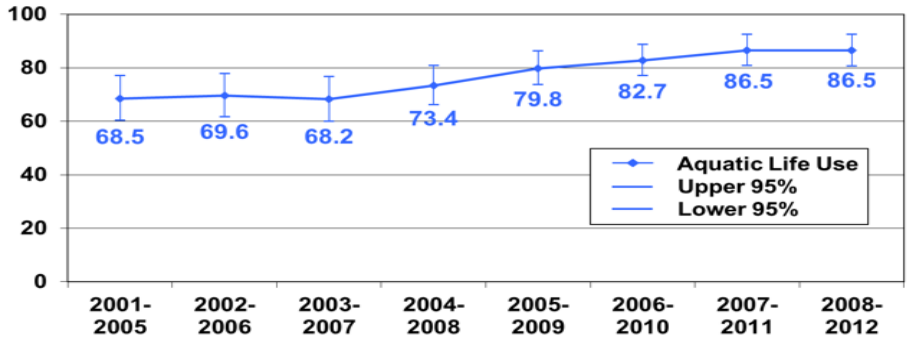

Figure 3: Percent of South Carolina streams fully supporting aquatic life use over eight sampling cycles between 2001-2012, including 95% confidence limits.

What can the surveys tell us?

Condition of the nation's waters

The National Aquatic Resource Surveys (NARS), conducted by USEPA and the states, are examples of national scale statistical surveys. Figure 2 reports the extent of stream miles in a condition category and the margin of error (i.e., confidence intervals surrounding the point estimate such as 42% ±3%).

Assessing trends over time

When statistical surveys are repeated iteratively, as shown for South Carolina in Figure 3, they are capable of discerning changes and trends in the condition of the resource over time. Statistical surveys are particularly well suited to answer the question, "Has the quality of streams in my state improved or gotten worse over time"?"

In this case, a statistically significant change appears to be occurring over time as aquatic life use improves. By using a statistical Survey design, such inferences can be made about the population of streams assessed allowing decisions makers to consider whether the collective water quality management actions across the state, region or watershed are making a difference.

Statistical survey water quality data can also be used to make inferences, with a known margin of error (confidence), about the relative impact of various stressors. The products of a statistical survey monitoring design are intended to be statistically valid statements about water quality for large populations of interest.

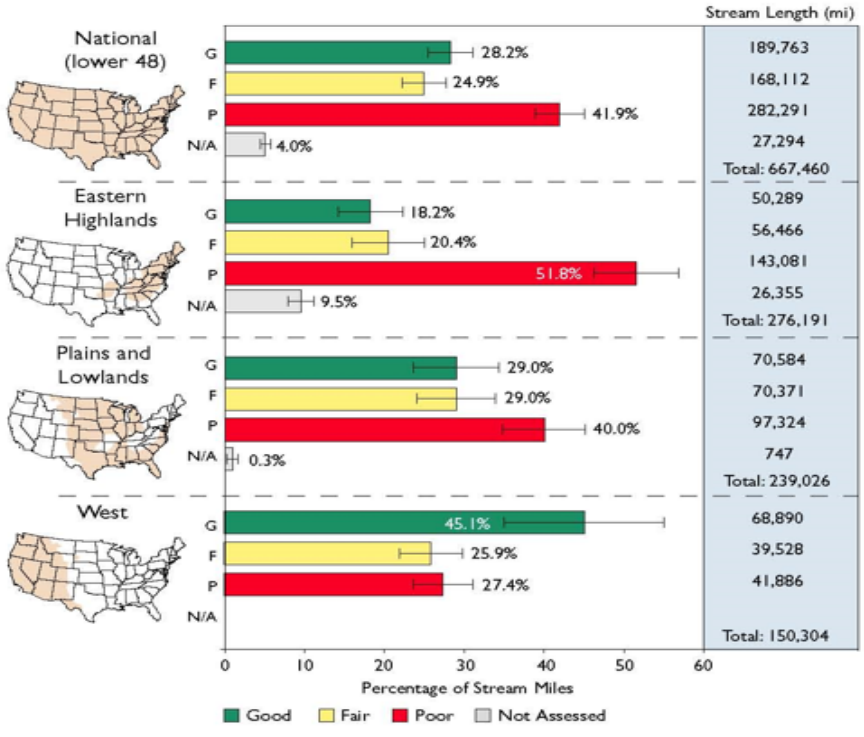

Figure 2: The Wadeable Streams Assessment (WSA), a statistical survey conducted in 2004, assessed more than 670,000 miles of streams in the conterminous U.S. and showed that 28% were in good condition, based on a macroinvertebrate MMI, while 25% were in fair condition and 42% were in poor condition. The WSA also found that conditions differ across the country, with the largest percent of stream miles in poor condition located in the east and the smallest percent in the west.

For more information on statistical survey designs:

National Environmental Methods Index (https://www.nemi.gov/home/)

General Overview of Probabilistic Surveys (http://www.epa.gov/nheerl/arm/designpages/monitdesign/survey_overview.htm)

Aquatic Resource Monitoring (http://www.epa.gov/nheerl/arm/)

Spatially balanced survey designs for natural resources, 2012. Olsen, T., Kincaid, T., Payton, Q., in *Design of Analysis of Long-term Ecological Monitoring Studies*, ed. R.A. Gitzen, J.J. Millspaugh, A.B. Cooper and D.S. Licht. Published by Cambridge University Press.