

Making Sense From Measurements: Statistical Advances That Yield More, But Demand More



Loveday L. Conquest
Steve Rentmeester

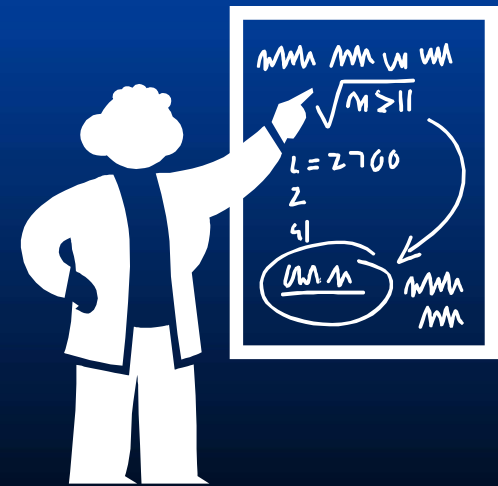
UW School of Aquatic & Fishery Sciences

Overview

- Review Traditional Sample Designs
- Discuss Recent Advances
 - Ranked Set Sampling
 - Multiple-Panel Sampling
- “Visual Sample Plan” Software
- Conclusions

Sampling--Why Do We Care?

- Good estimates
- Reasonable standard error
- Generalization of results
- Reasonable cost



United States
Environmental Protection
Agency

Office of Environmental
Information
Washington, DC 20460

EPA/240/R-02/006
December 2002



Guidance on Choosing a Sampling Design for Environmental Data Collection

**for Use in Developing a Quality
Assurance Project Plan**

EPA QA/G-5S

Quality

<http://www.epa.gov/quality/qs-docs/g5s-final.pdf>

TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
1.1 WHY IS SELECTING AN APPROPRIATE SAMPLING DESIGN IMPORTANT?	1
1.2 WHAT TYPES OF QUESTIONS WILL THIS GUIDANCE ADDRESS?	2
1.3 WHO CAN BENEFIT FROM THIS DOCUMENT?	3
1.4 HOW DOES THIS DOCUMENT FIT INTO THE EPA QUALITY SYSTEM?	4
1.5 WHAT SOFTWARE SUPPLEMENTS THIS GUIDANCE?	5
1.6 WHAT ARE THE LIMITATIONS OR CAVEATS TO THIS DOCUMENT?	5
1.7 HOW IS THIS DOCUMENT ORGANIZED?	
2. OVERVIEW OF SAMPLING DESIGNS	
2.1 OVERVIEW	
2.2 SAMPLING DESIGN CONCEPTS AND TERMS	
2.3 PROBABILISTIC AND JUDGMENTAL SAMPLING	
2.4 TYPES OF SAMPLING DESIGNS	
2.4.1 Judgmental Sampling	
2.4.2 Simple Random Sampling	
2.4.3 Stratified Sampling	
2.4.4 Systematic and Grid Sampling	
2.4.5 Ranked Set Sampling	
2.4.6 Adaptive Cluster Sampling	
2.4.7 Composite Sampling	
3. THE SAMPLING DESIGN PROCESS	
3.1 OVERVIEW	
3.2 INPUTS TO THE SAMPLING DESIGN PROCESS	
3.3 STEPS IN THE SAMPLING DESIGN PROCESS	
3.4 SELECTING A SAMPLING DESIGN	
4. JUDGMENTAL SAMPLING	
4.1 OVERVIEW	27
4.2 APPLICATION	27
4.3 BENEFITS	28
4.4 LIMITATIONS	28
4.5 IMPLEMENTATION	28
4.6 RELATIONSHIP TO OTHER SAMPLING DESIGNS	29

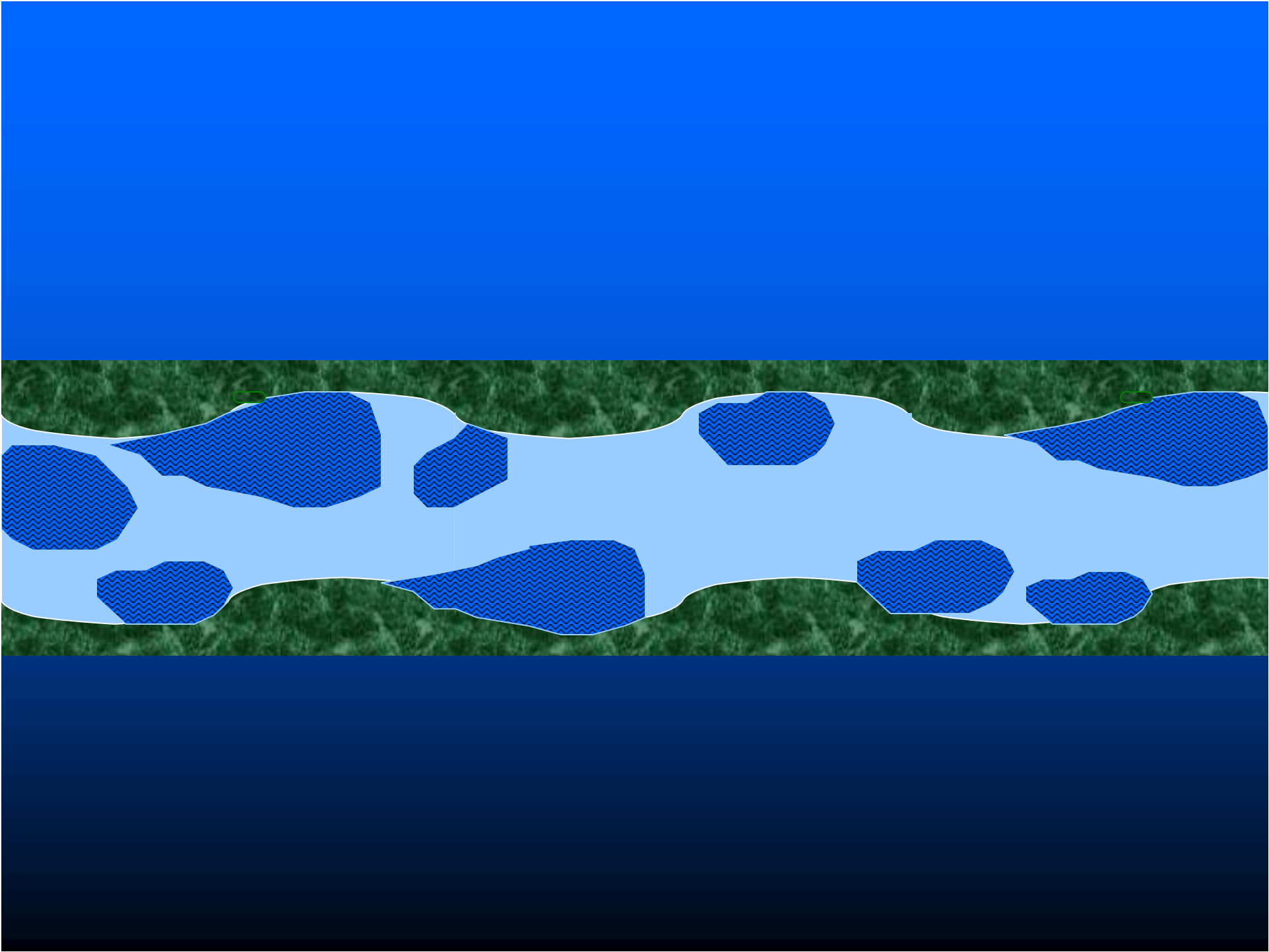
2.4.1 Judgmental Sampling.....

2.4.2 Simple Random Sampling.....

2.4.3 Stratified Sampling.....

2.4.4 Systematic and Grid Sampling...

2.4.5 Ranked Set Sampling.....



Judgmental Sampling

- Allows one to use biological/physical process knowledge to choose a 'representative' sample of units
- But, NO standard error/confidence interval estimates result

Simple Random Sampling

- “Sampling 101”--the first thing we learn!
- All samples of size “ n ” equally likely
- Standard errors obtainable
- Not so good in heterogeneous environments
- Not so good with small sample sizes

Stratified Sampling

- Useful in heterogeneous environments
- Randomly sample within each stratum, then combine estimates at the end
- Unequal sample sizes can account for stratum variability and cost
- Strata must be well defined

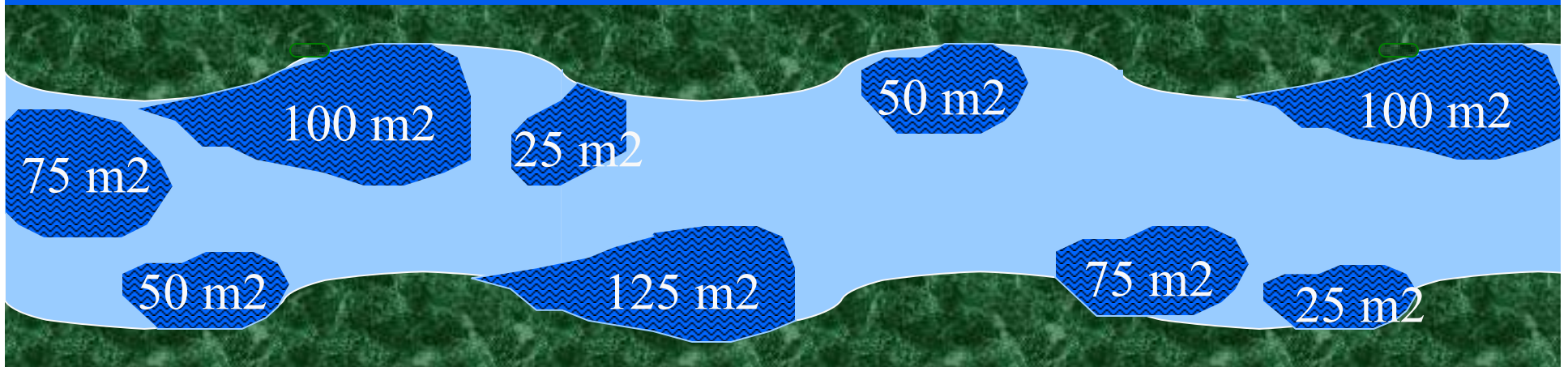
Sampling Issues

- Small sample sizes in a heterogeneous environment
- Sampling for both status and trend simultaneously
- Accounting for spatial and temporal correlation

Let's look at an approach that incorporates judgment:

- Want “some small, some medium, some large”--a representative sample!
- Stratify on the ranks of the data
- Useful when measurement is costly (so final sample size is small) but guesses are cheap

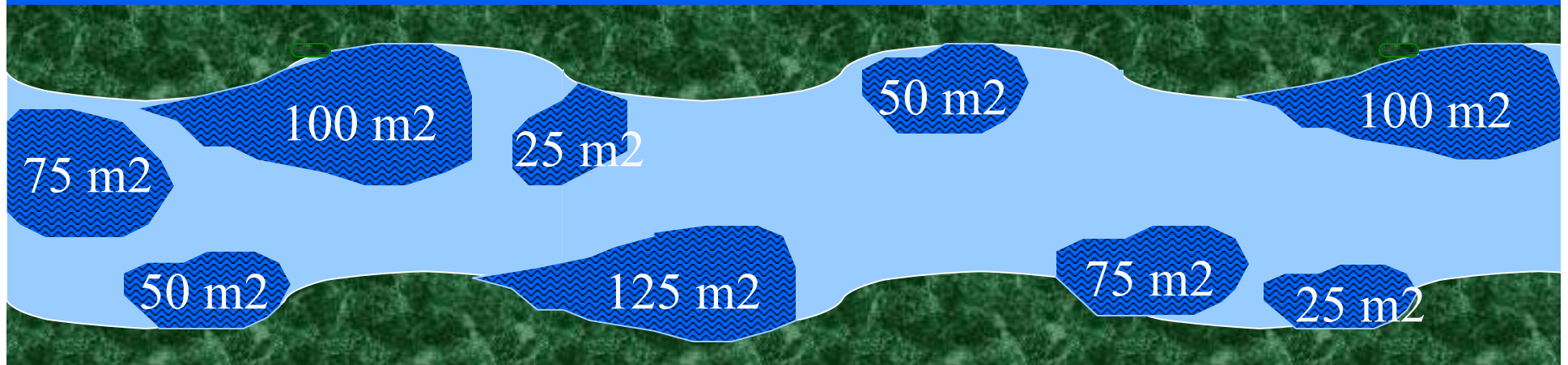
Ranked Set Sampling



Randomly Select Sets

Set 1	25	50	100
Set 2	100	75	75
Set 3	50	125	25

Ranked Set Sampling



Randomly Select Sets

Set 1	25	50	100
Set 2	100	75	75
Set 3	50	125	25

Rank Sets and Select Pools

Set 1	25	50	100
Set 2	75	75	100
Set 3	25	50	125

Ranked Set Sample

- “Set size” = 3; final sample size = 3
- To increase sample size:
 - Increase set size
 - Repeat entire process (cycles)
- Generate estimate and variance (standard error)

Ranked Set Sampling: Examples

- Mean pool size in Oregon salmon streams (Mode et al. 1999)
- Height and diameter of spruce trees (Patil et al. 1994)
- Shrub phytomass in an oak forest (Martin et al. 1980)

Ranked Set Sampling: Summary

- Stratifying on the ranks of the data
- RSS costs less than SRS for given level of precision
- Software, cost models available (Mode et al., 1999, 2002; Buchanan et al., 2004, *Environmetrics*)

How to take care of both
status and trend in the same
sampling design.

Multi-panel Sampling Design

THE OREGON PLAN *for* *Salmon and* *Watersheds*



Sampling Design and Statistical Analysis
Methods for the Integrated Biological and
Physical Monitoring of Oregon Streams

Report Number: OPSW-ODFW-2002-07



Multi-panel Sampling Design: Context

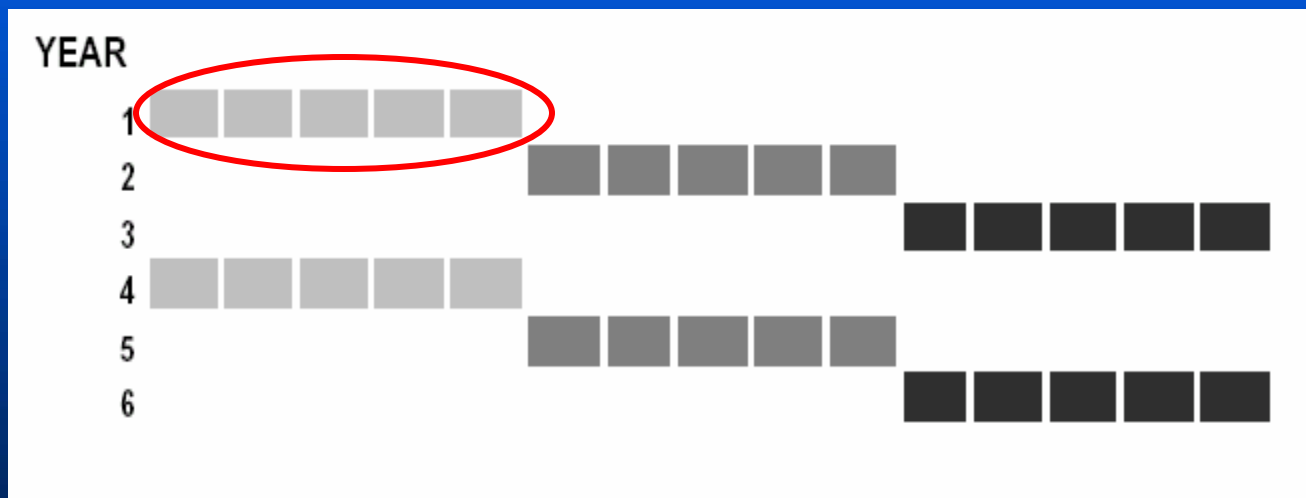
- Monitoring for both status and trend
 - Status: spatial coverage (sites)
 - Trend: temporal coverage (times)
- Can accomplish both with this design!

Multi-panel Sampling Design-- What is a panel?

- Panel = set of sites with a revisit period
- Panels chosen to reflect spatial patterns

Multi-panel Sampling Design

Simplified Rotating Panel Design:



Reproduced from: Firman, J.C. and Jacobs, S.E. 2003. A Survey Design for Integrated Monitoring of Salmonids. Oregon Department of Fish and Wildlife

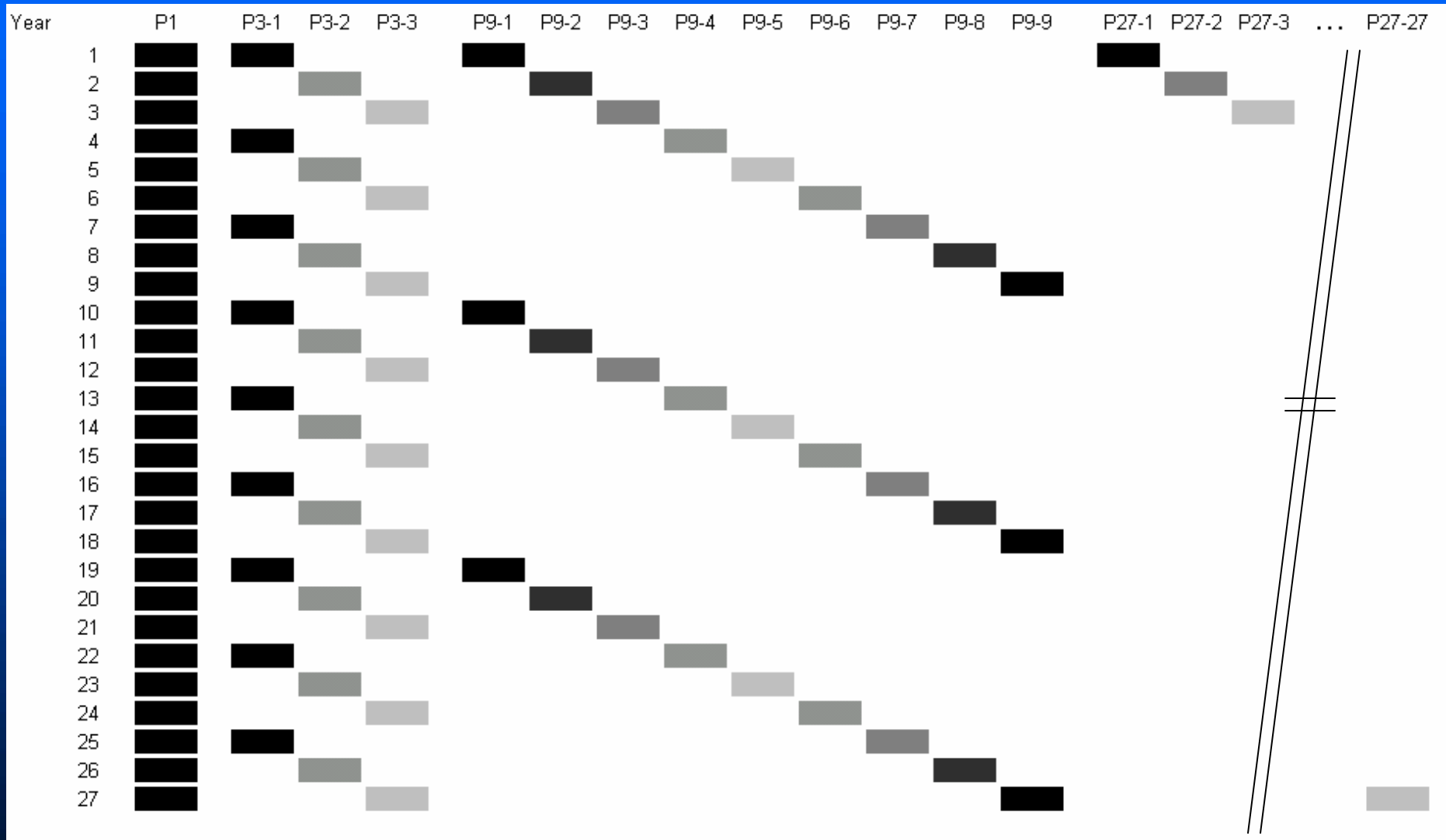
Multi-panel Sampling Design

Slightly More Complicated Panel Design:



Reproduced from: Firman, J.C. and Jacobs, S.E. 2003. A Survey Design for Integrated Monitoring of Salmonids. Oregon Department of Fish and Wildlife

ODFW Integrated Monitoring Design:



Modified from: Firman, J.C. and Jacobs, S.E. 2003. A Survey Design for Integrated Monitoring of Salmonids. Oregon Department of Fish and Wildlife

Multi-panel Sampling Design

Panel designs are usually based on a 3-5 year rotation.

ODFW's design adopted a three-year rotation to coincide with the three-year life cycle for coho salmon.

Multi-panel Sampling Design

In ODFW study a panel consisted of:

- ~ 79 Habitat Sites
- ~ 41 Spawning Sites
- ~ 13 Juvenile Sites

Multi-panel Sampling Design: Summary

- Useful when both spatial and temporal coverage required
- Accounts for temporal correlation at a site and spatial correlation among sites
- Requires all sites be known to define the panels

“Visual Sample Plan” Software

- Uses site maps and interactive questions to determine # samples, cost, sampling locations
- User imports a site map
- Spatial sampling, but not set up for stream networks
- <http://dgo.pnl.gov/vsp>

Visual Sample Plan (VSP)



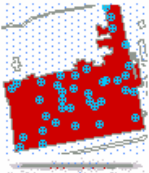
The screenshot shows the Visual Sample Plan (VSP) website. On the left is a vertical navigation menu with a black background and yellow text. The main content area has a white background. At the top right is the 'DQO Data Quality Objectives' logo. Below it is a link for 'Security and Privacy'. The 'Visual Sample Plan (VSP)' section includes a descriptive paragraph and a small map of a red area with blue sampling points. Below this is a list of two bullet points. At the bottom are links to download the latest VSP version and the VSP Beta version, along with a link to the VSP Description.

DQO Data Quality Objectives

[Security and Privacy](#)

Visual Sample Plan (VSP)

VSP provides statistical solutions to sampling design, world-class mathematical and statistical algorithms, and a user-friendly visual interface, while answering two important questions in sample planning.



VSP

- How many samples are needed?
The algorithms involved in determining the number of samples needed can be quite involved and intimidating to the non-expert. VSP can quickly calculate the number of samples needed for various scenarios at different costs.
- Where should the samples be taken?
Sample placement based on personal judgment is prone to bias. VSP instantly provides random or gridded sampling locations overlaid on a user-input site map.

Download the latest **Visual Sample Plan** version [here](#).

Download the latest **Visual Sample Plan Beta** [here](#). (Version 2.2 Now Available)

[VSP Description](#)

Navigation Menu:

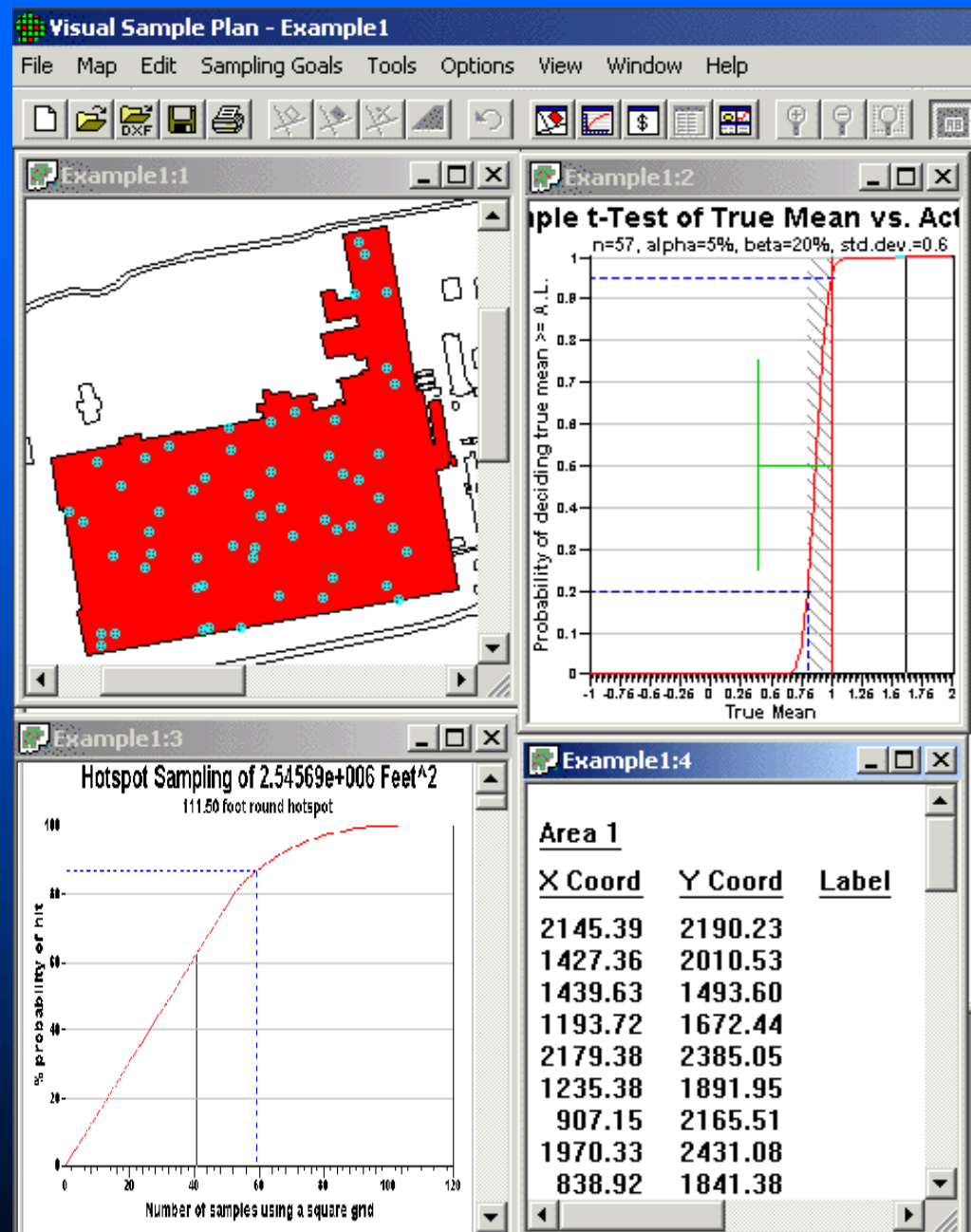
- ▶ [Homepage](#)
- ▶ [Why DQOs?](#)
- ▶ [Case Studies](#)
- ▶ [VSP Software](#)
- ▶ [Other Software](#)
- ▶ [Training](#)
- ▶ [Publications](#)
- ▶ [Hanford DQO](#)
- ▶ [Related Links](#)
- ▶ [Search](#)

<http://dgo.pnl.gov/vsp>

Visual Sample Plan (VSP)

Modified from:

<http://dgo.pnl.gov/vsp>



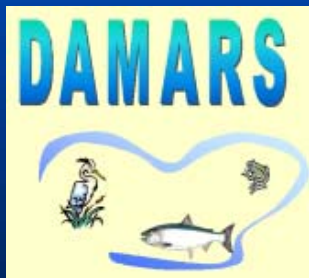
Conclusions

- Sampling approaches take into account complex and connective nature of stream networks
- Computationally complex estimates, but better attention to spatial and temporal correlation
- Requires more up front collaboration between biologists and quantitative folks

Acknowledgements



EPA Cooperative Agreement
CR82-9096-01 (STAR)



Program on Designs and Models
for Aquatic Resource Surveys,
Don Stevens, Director
Oregon State University

Web Sites

- www.epa.gov/quality/qa_docs.html
- dgo.pnl.gov/vsp
- oregonstate.edu/dept/statistics/epa_program/docs/

FINITO

