Price/VanBlaricom Geoduck Aquaculture Harvesting Study Lacks Statistical Rigor

Gary A. Ritchie, Ph.D.

Washington State Shorelines Hearings Board Testimony

August 12, 2013

Impact of geoduck harvesting on benthic communities

- Proponents claim that there are no significant effects of geoduck harvesting on benthic communities in Puget Sound.
- Claim is based largely on a Master of Science thesis written by Jennifer Price at the University of Washington.

Jennifer Price MS Thesis

- "Quantifying the Ecological Impacts of Geoduck (Panopea generosa) Aquaculture Harvest Practices on Benthic Infauna," Jennifer Price; August 18, 2011.
- Study Objectives… (page 8) "to quantify the [geoduck] harvest impact (if any) on benthic organism abundance, diversity, and community structure…"
- Conclusion (page 33): "…the effects of geoduck harvest on the benthic community in Puget Sound are at most minimal."

Result is widely reported in meetings, hearings and the media

- Examples:
  - Longbranch SHB hearing. March 1, 2012. Dr. Glenn VanBlaricom presented results and conclusions of Price thesis.
  - Sea Grant Symposium, Alderbrook WA, March 6, 2012. Dr. VanBlaricom again presented results and conclusions of Price thesis.
  - Kitsap Sun, March 10, 2012. "Glenn VanBlaricom, a researcher with the UW School of Aquatic and Fishery Sciences, said benthic organisms, which live on or in the sediments, don't appear to be affected much by geoduck harvesting."
  - Henderson Inlet Hearing November 26, 2012. ENVIRON (a consulting firm) presented a review of environmental effects of geoduck aquaculture. Cited the Jennifer Price thesis as indicating that geoduck harvesting has no significant effect on benthic organisms.

I will argue that…

- the conclusion "…*the effects of geoduck harvest on the benthic community in Puget Sound are at most minimal.*" is not supportable…
- …because the statistics (experimental design and analysis) were not done correctly.

What are statistics?

- Descriptive statistics
  - Baseball scores
  - Populations of cities
  - Average income of a specific group
- Inferential statistics
  - Highly developed field of applied math that helps people "get their heads around" large volumes of data.
  - Essential in design of experiments and analysis/interpretation of experimental results.
  - Enables you to draw inferences regarding the results of an experiment.

Example

- Test of dog food supplement:

Treatment	Weight gain (lbs.)
Control (no supplement)	10.2
Level 1 (1x supplement)	10.8
Level 2 (2x supplement)	10.7

- Are differences "real" or result of random chance?
- Compute a statistic called an "F-ratio."
- F-ratio estimates probability of a "real" result.

Price study overview

Three sites

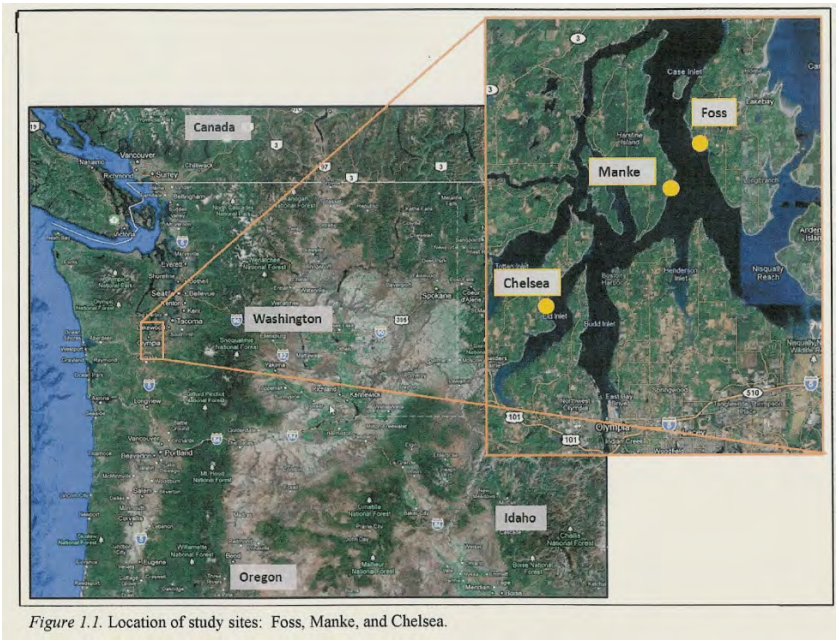

Figure 1.1. Location of study sites: Foss, Manke, and Chelsea.

One Cultured/Reference plot on each site

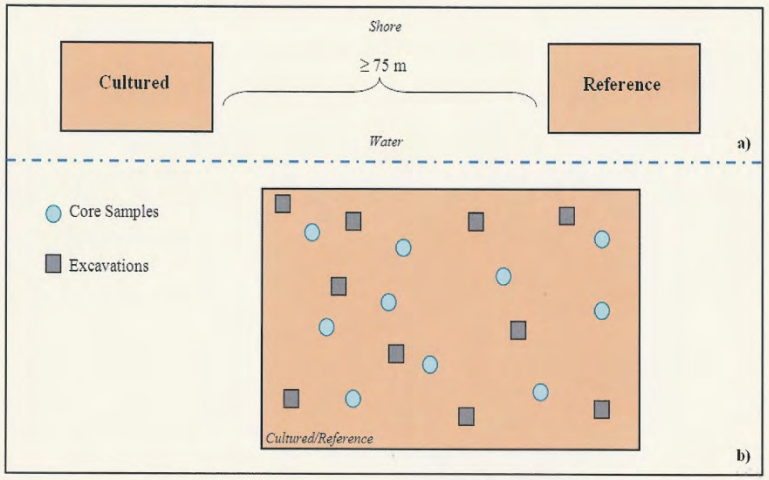

Figure 1.2. a) Relative layout of cultured and reference plots in the intertidal zone, b) sampling strategy within cultured and reference plots.

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So, what's the problem?

- The researchers unwittingly fell into a statistical trap called

"Pseudoreplication"

- **Replication** is the independent application of a treatment.

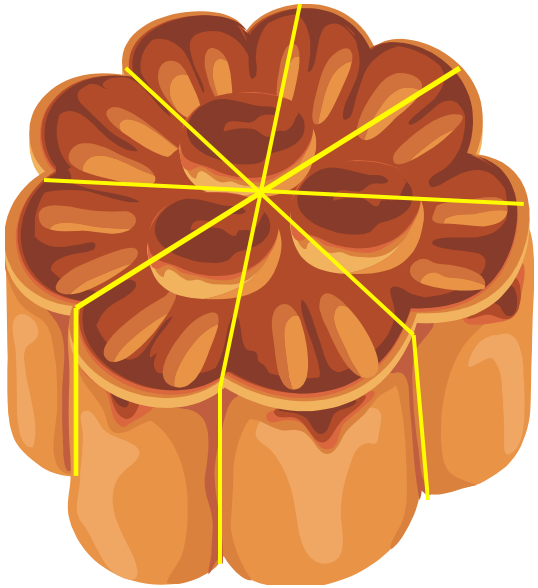
- **Pseudoreplication** is treating something as a replicate that really isn't a replicate (sub-samples, repeated measures, etc.).

Four examples of

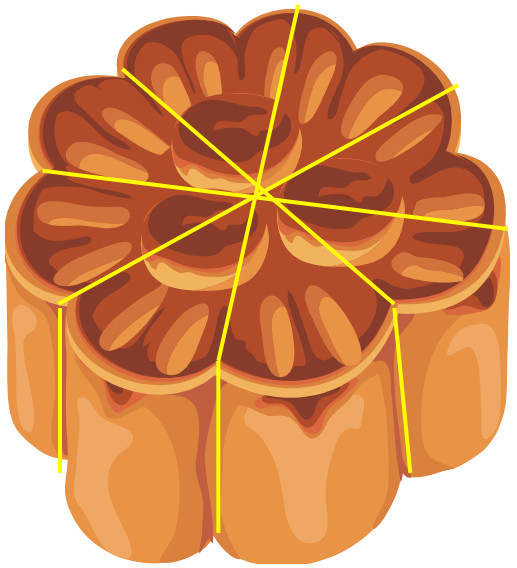
pseudoreplication

1. Cake experiment

Betty Crocker



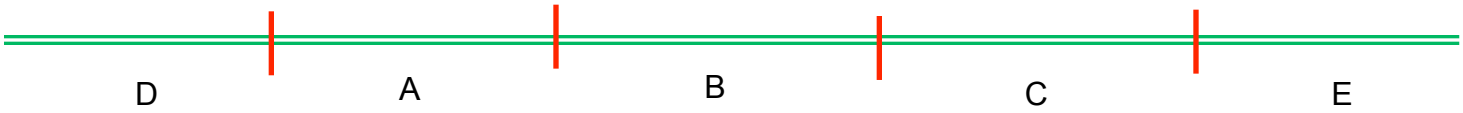
Brand X



2. Row plot experiment

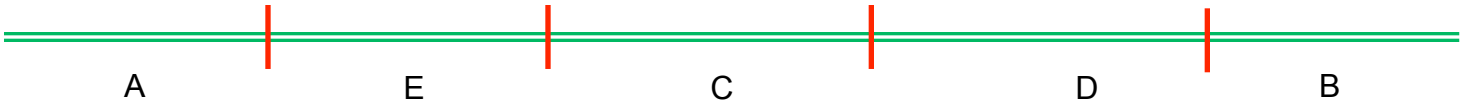
- Control

- Var. 1

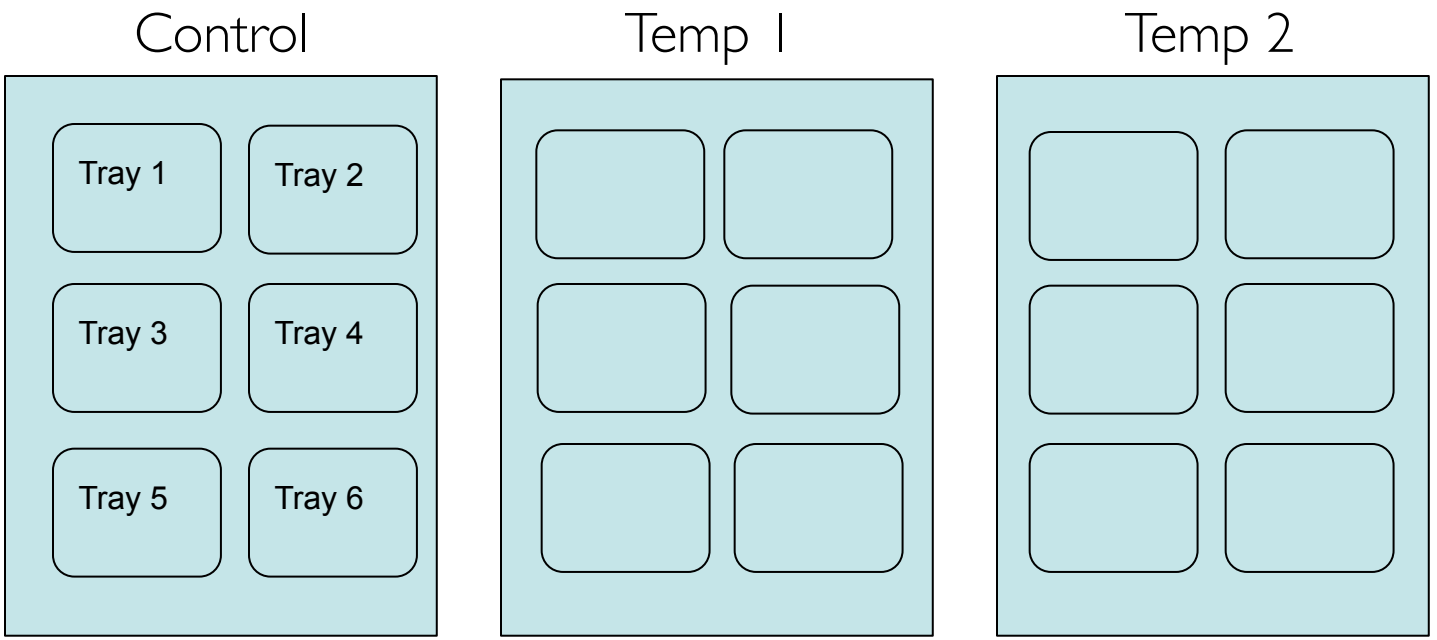


- Var. 2

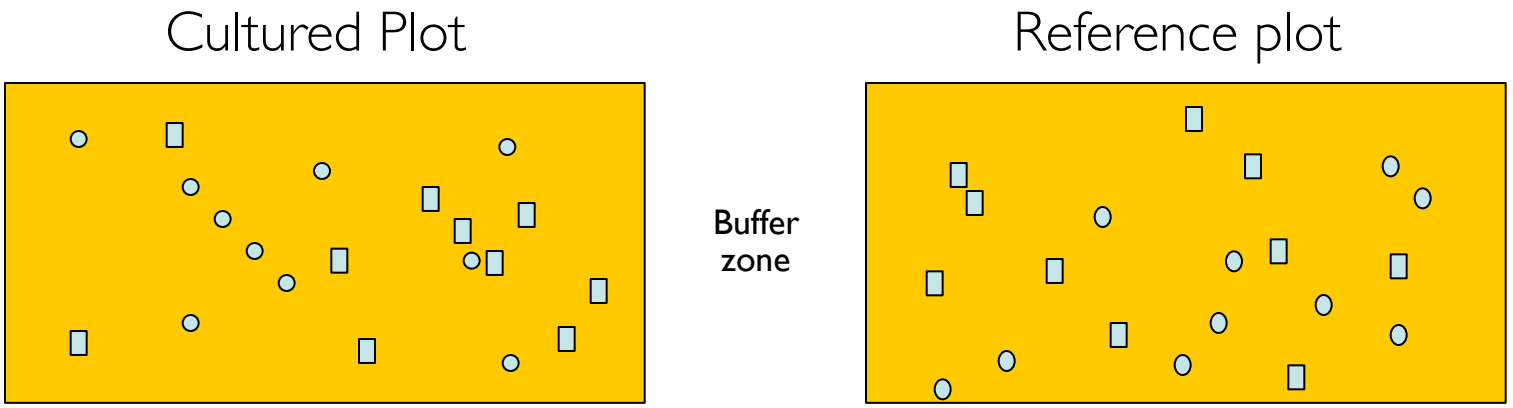
- Var. 3



3. Controlled environment chamber experiment



Geoduck harvesting study



What's wrong with pseudoreplication?

- Without true replication you *cannot test for significance between treatments* because you cannot compute "error variance" necessary to conduct the F-test of statistical significance (Milliken and Johnson 1997*).

- R.A. Fisher: "No one would…dream of testing the response to a treatment by comparing two plots, one treated and the other untreated."

- George Milliken, Pers. Comm.: "Pseudoreplication is like going back to the same doctor for a second opinion."

*Milliken, G.A. and D.E. Johnson. 1997. Analysis of Messy Data: Vol. 1, Designed Experiments, Chapman and Hall, London, New York, 473 p.

Pseudoreplication is a common statistical trap

- I fell into the pseudoreplication trap early in my career with the Growth Chamber experiment I described earlier.
  - I served for 25 years as a referee for nine scientific journals.
    - *Canadian Journal of Forest Research*
    - *Forest Science*
    - *New Forests*
    - *Journal of Tropical Forest Science*
    - *Scandinavian Journal of Forest Research*
    - *Annales des Sciences Forestieres*
    - *Western Journal of Applied Forestry*
    - *Tree Physiology*
    - *Annals of Botany*
- Pseudoreplication was the most common statistical problem I encountered.
- The ecological literature contains many examples of pseudoreplication.

Back to the Price study

- They had no replication on any of the three sites, hence they cannot make valid statistical comparisons between treatments at any site.
- But they had 3 sites:
  - Page 11: "*Because of site differences, each site was analyzed independently and the sites were not considered replicates.*"
  - So there is no replication either at the site or plot level.
- With no replication anywhere in the study, statistical significance cannot be computed and no conclusions can be drawn.
- I conferred with two statisticians on this conclusion: ***both agreed***.

What should they have done?

- Achieve broader scope of inference by using more, carefully selected sites.
- Determine the size of the impact they were trying to detect using power analysis.
- Incorporate more replications on site based on results of power analysis.
- Perhaps user smaller plots, fewer subsamples, to achieve more replications.

Other concerns

Narrow scope of inference (moot)

- Three sites in lower Case Inlet would not seem to support the conclusion: "…the effects of geoduck harvest on the benthic community in Puget Sound are at most minimal."

Lack of statistical power (moot)

- How big an effect were they looking for?
- How was size of the experiment determined?
- Not discussed in Price thesis.

Data quality control

- What measures were put into place to ensure that no data errors occurred?
- Not discussed in Price thesis.

Summary and conclusions

- The Price thesis did not contain proper replication, so statistical tests conducted on the results are invalid and no conclusions can be drawn from them.
- Even if the study had been properly replicated, the narrow scope of inference would not support Puget Sound-wide conclusions.
- In his verbal presentations and on the Sea Grant web site, Dr. VanBlaricom has emphasized that the results of the Price thesis have neither been peer reviewed nor published, hence they **must not be cited.**
- Unfortunately his admonitions have fallen on deaf ears.