Title: Estimating Sufficient Sample Sizes to Detect Changes in Eelgrass Density.

Abstract: Eelgrass (*Zostera marina*) provides important ecological services in the nearshore, has been designated as critical habitat, and is protected by a no-net-loss policy in Washington State. When projects are proposed that may impact eelgrass, such as installing docks or underwater cables, the state of Washington may require surveys to monitor changes in eelgrass density. The guidelines for surveys required by the Washington Department of Fish and Wildlife are sufficiently general to allow rigorous monitoring. However, specific guidance describing sufficient sample sizes and analytical methods has not yet been developed. We used data from a previous study to estimate the number of samples required to reliably detect a range of declines in shoot density using a before-after-control-impact (BACI) survey design. Sufficient sample size to detect a change in eelgrass density is a function of the magnitude of the change in density (effect size), sampling design (including number of samples), variation of eelgrass density among samples, and selected probabilities of Type I and Type II errors. Our study demonstrates the need to consider these factors, with particular reference to Type II errors, when developing sampling designs. Our results have implications for most eelgrass monitoring projects.

Biography: Kirk Krueger is a research scientist with the Washington Department of Fish and Wildlife, Habitat Program, Science Division.

Key Words: Eelgrass, Statistical Power, Monitoring, Effect Size, Shoot Density.

Presentation: Poster presentation by primary author[1].

Topic:Poster Group 7: Seagrass and Other Aquatic Vegetation.

Introduction

Eelgrass (Zostra marina) and is an important ecosystems component that provides habitat for many species, including imperiled salmon (Simonstad 1994). Because of its importance as an ecosystem component, eelgrass is designated a habitat of special concern by the Washington Department of Fish and Wildlife (WDFW) and critical habitat by the Washington Department of Ecology. Eelgrass density and persistence are affected by human activities (Short and Wyllie-Echeverria 1996, Burdick and Short 1999) such as the installation of docks and the armoring of shorelines. In the Georgia Basin/Puget Sound the geographic distribution of eelgrass is declining and is becoming increasingly fragmented (Dowty et al. 2005).

Several studies have been initiated to assess the status and trends of eelgrass and to measure the effect of human activities on eelgrass. In Washington, monitoring is required to ensure no net loss of eelgrass on projects permitted under the WDFW's Hydraulic Project Authority. However, spatial and temporal variation in eelgrass density can render equivocal the results of otherwise well-designed studies (Fresh et al. 2006). We provide an example of some challenges faced by scientists and suggest some methods to improve eelgrass study efficiency. Our goal is to provide information that facilitates the development of more efficient study designs and increases the probability of obtaining reliable results. Specifically, our objectives were to 1) examine empirical data to identify opportunities for improved efficiency, 2) conduct power analyses using empirical data to estimate sample sizes sufficient to reliably detect differences (changes) in eelgrass density, and 3) identify some important decisions scientists can make before initiating a study.

Methods

Fresh et al. (2006) collected eelgrass shoot density data at 11 floats at 10 locations in Puget Sound to assess the efficacy of using light-permeable grating to reduce the impacts of dock floats on eelgrass density. Eelgrass densities were measured by SCUBA divers within 0.25-m^2 quadrats along transects under floats (impact areas) and in control areas (Fresh et al. 2006). From 16 to 90 samples were collected at each location. We used density data collected from one pre-impact survey and one post-impact survey at each float and control to calculate sample sizes sufficient to detect declines in density (effect size) of 10, 25, 50, 75, and 100 percent using a before-after-control-impact (BACI; Green 1979) design and one-tailed ANOVA at critical values (α) of 0.05 and 0.10, and statistical power ($1-\beta$) of 0.8 and 0.9. We calculated the mean and range of predicted sufficient sample sizes for each of the 11 locations to demonstrate variability in sampling sufficiency among studies.

Results

Mean eelgrass density varied within and among study locations (Figure 1, Fresh et al. 2006), affecting large estimates of sufficient sample size that differ substantially among locations (Figure 2). Selection of critical values had a relatively small effect on estimates of sufficient sample size (Figure 2). Changing α from 0.05 to 0.10 decreases the mean predicted sufficient sample size at statistical power = 0.90 and 0.80 by approximately 22% and 26%, respectively. Meeting specific levels of statistical power also had a relatively small effect on sufficient sample size. Changing statistical power from 0.90 to 0.80 at $\alpha = 0.05$ and 0.10 reduces estimates of sufficient sample size by 25% and 30%, respectively. The selection of detectable effect size had a relatively large effect on estimates of sufficient sample size. Changing the effect size from a 25% to 50% decline in mean eelgrass density reduced the estimates of sufficient sample size by 74%. The effect of the detectable effect size on sufficient sample size is nonlinear. Sufficient sample size decreases at a decreasing rate as the effect size becomes larger (Figure 2).

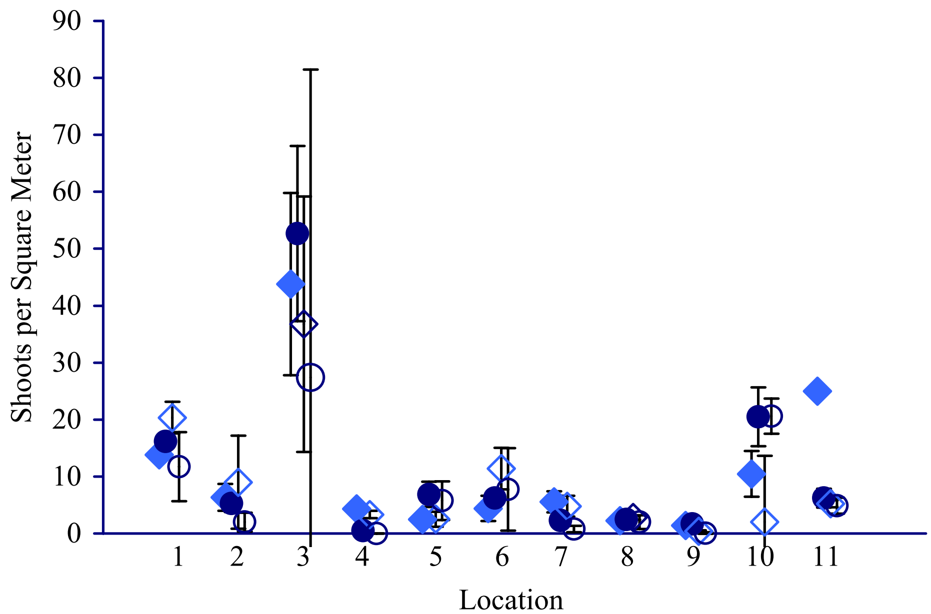

Figure 1. Mean and 95% CI of eelgrass density at before (Filled) and after (Unfilled) treatments at control (Diamond) and impact (Circle) sites at 11 locations in Puget Sound.

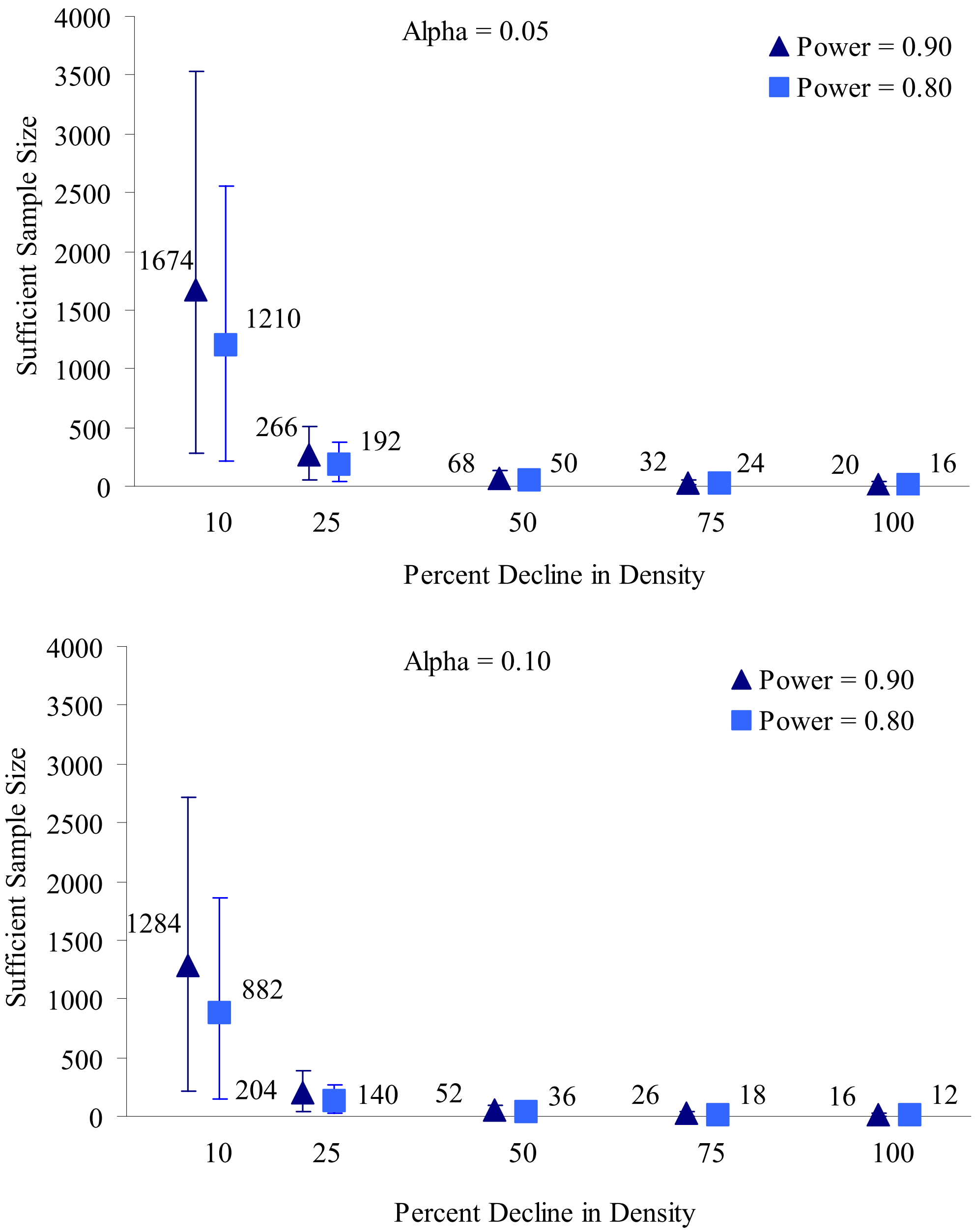

Figure 2. Mean and range of estimates of sufficient sample sizes to detect declines in mean eelgrass density of 10%, 25%, 50%, 75%, and 100% using a BACI design, critical values of 0.05 and 0.10, and statistical power of 0.90 and 0.80.

Discussion

Variation in eelgrass density within locations can dramatically increase the sample size necessary to reliably detect changes in eelgrass density. We emphasize the importance of carefully developing experimental designs and the possibility of conducting studies of eelgrass that have low statistical power. That is, without sufficient sampling studies are likely to fail to detect a decline in eelgrass density when one has occurred. Variation in sufficient sample size among locations suggests that sampling protocols should be specifically designed for each survey or experiment. A sampling protocol sufficient for most locations may excessively sample many locations. Carefully selecting critical values and statistical power can reduce sufficient sample size (Peterman 1990). We suggest that given the cost of sampling and the range of sample sizes sufficient to detect changes in eelgrass density (see Figure 2), scientists should conduct preliminary surveys that estimate variability in eelgrass density and conduct a priori power analyses prior to designing and implementing studies.

Power analyses that estimate sufficient sample size using pre-study data can facilitate efficient surveys (Green 1979, Peterman 1990, Taylor and Gerrodette 1993). Using a BACI design with several controls (Green 1979, Stewart-Oaten et al. 1986, Underwood 1991) can account for regional changes in density that can be misinterpreted as effects. Using paired samples and repeated measurements can also reduce the sufficient sample size (Green 1979, Quist et al. 2006). Variability in eelgrass density estimates can necessitate very large sample sizes that may render some studies infeasible (Krueger et al. 1998, Rodgers et al. 1992).

Literature Cited

Burdick, D.M. and F.T. Short. 1999. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. Environmental Management 23: 231-240.

Dowty, P., B. Reeves, H. Berry, S. Wyllie-Echeverria, T. F. Mumford Jr., A. Sewell, P. Milos, and R. Wright. 2005. Puget Sound Submerged Vegetation Monitoring Project 2003-2004 Monitoring Report. Department of Natural resources, Nearshore Habitat Program, Olympia, WA.

Fresh, K. L., T. Wyllie-Echeverria, S. Wyllie-Echeverria, and B. Williams. 2006. Using light-permeable grating to mitigate impacts of residential floats on eelgrass Zostera marina L. in Puget Sound, Washington. Ecological Engineering 28: 354-362.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. Wiley, publishers. New York.

Krueger, K. L., W. A. Hubert, R. M. Price. 1998. Tandem-set fyke nets for sampling benthic fish in lakes. North American Journal of Fisheries Management 18: 154-160.

Peterman, R. M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences 47: 2-15.

Quist, M. C., K. G. Gerow, M. R. Bower, and W. A. Hubert. 2006. Random versus fixed-site sampling when monitoring relative abundance of fishes in headwater streams of the upper Colorado River basin. North American Journal of Fisheries Management 26: 1011-1019.

Short, F.T. and S. Wyllie-Echeverria. 1996. Natural and human-induced disturbance of seagrasses. Environmental Conservation 23: 17-27.

Stewart-Oaten, A., W. M. Murdoch, and K. Parker. 1986. Environmental impact assessment: 'pseudo-replication' in time? Ecology 67: 929-940.

Taylor, B. L., and T. Gerrodette. 1993. The uses of statistical power in conservation biology: the vaquita and northern spotted owl. Conservation Biology 7: 489–500.

Underwood, A.J. 1991. Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research 42: 569-87.

Kirk L. Krueger[1]
Research Scientist
Habitat Program
Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, WA 98501-1091
kruegklk@dfw.wa.gov

Timothy Quinn, Ph.D.
Chief Scientist
Habitat Program
Washington Department of Fish and Wildlife
600 Capitol Way North
Olympia, WA 98501-1091
quinntq@dfw.wa.gov

Randy E. Carman
Fish and Wildlife Biologist
Habitat Program
Washington Department of Fish and Wildlife
600 Capitol Way N, NRB
Olympia, WA 98501-1091
carmarec@dfw.wa.gov

Sandy Wyllie-Echeverria, Ph.D.
Research Scientist
Friday Harbor Laboratories and UW Botanic Gardens
University of Washington
Seattle, WA 98195
zmseed@u.washington.edu

Tina Wyllie-Echeverria, Ph.D.
Wyllie-Echeverria and Associates
Shaw Island, WA 98286
tinawe@fidalgo.net

Kurt Fresh
Research Fishery Biologist
NOAA Fisheries
Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, WA 98112
Kurt.Fresh@noaa.gov

Brian Williams
Fish and Wildlife Biologist
Habitat Program
Washington Department of Fish and Wildlife
PO Box 1100
La Conner, WA 982571
willibww@dfw.wa.gov