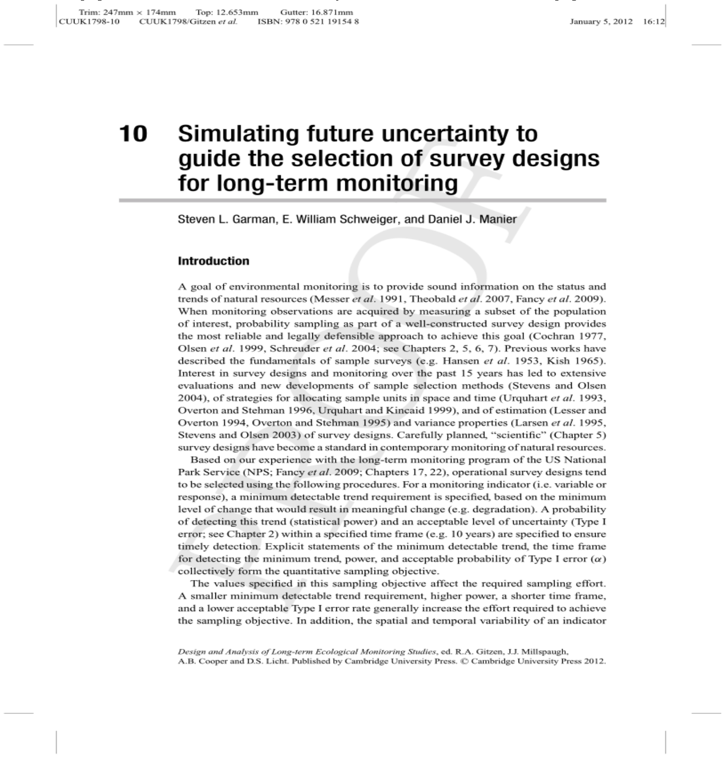
Design And Analysis Of Long-term Ecological Monitoring Studies



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10 Simulating future uncertainty to guide the selection of survey designs for long-term monitoring

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Introduction

A goal of environmental monitoring is to provide sound information on the status and trends of natural resources (Messer *et al.* 1991, Theobald *et al.* 2007, Fancy *et al.* 2009). When monitoring observations are acquired by measuring a subset of the population of interest, probability sampling as part of a well-constructed survey design provides the most reliable and legally defensible approach to achieve this goal (Cochran 1977, Olsen *et al.* 1999, Schreuder *et al.* 2004; see Chapters 2, 5, 6, 7). Previous works have described the fundamentals of sample surveys (e.g. Hansen *et al.* 1953, Kish 1965). Interest in survey designs and monitoring over the past 15 years has led to extensive evaluations and new developments of sample selection methods (Stevens and Olsen 2004), of strategies for allocating sample units in space and time (Urquhart *et al.* 1993, Overton and Stehman 1996, Urquhart and Kincaid 1999), and of estimation (Lesser and Overton 1994, Overton and Stehman 1995) and variance properties (Larsen *et al.* 1995, Stevens and Olsen 2003) of survey designs. Carefully planned, "scientific" (Chapter 5) survey designs have become a standard in contemporary monitoring of natural resources.

Based on our experience with the long-term monitoring program of the US National Park Service (NPS; Fancy *et al.* 2009; Chapters 17, 22), operational survey designs tend to be selected using the following procedures. For a monitoring indicator (i.e. variable or response), a minimum detectable trend requirement is specified, based on the minimum level of change that would result in meaningful change (e.g. degradation). A probability of detecting this trend (statistical power) and an acceptable level of uncertainty (Type I error; see Chapter 2) within a specified time frame (e.g. 10 years) are specified to ensure timely detection. Explicit statements of the minimum detectable trend, the time frame for detecting the minimum trend, power, and acceptable probability of Type I error (α) collectively form the quantitative sampling objective.

The values specified in this sampling objective affect the required sampling effort. A smaller minimum detectable trend requirement, higher power, a shorter time frame, and a lower acceptable Type I error rate generally increase the effort required to achieve the sampling objective. In addition, the spatial and temporal variability of an indicator

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