



Wetlands Ecological Integrity Monitoring Protocol for Sierra Nevada Network

Narrative Version 2.1

Natural Resource Report NPS/SIEN/NRR—2018/1601



ON THE COVER

Corie Cann, Biological Technician, assessing a wetland soil profile in the Blue Canyon area, Kings Canyon National Park.
Photograph by: Talia Chorover, NPS

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Change History

Original Version #	Date of Revision	Revised By	Changes	Justification	New Version #
1.4	Jan. 2014	J. Nesmith	❖ Removed all index sites from the protocol except DEPO ❖ Re-designed sample site selection procedure and re-did GRTS draw for SEKI ❖ Expanded methods for field sampling of bare ground and peat depth to develop thresholds for management action ❖ Many other minor changes to address reviewer comments	Changes made to respond to reviewer comments and to account for reduced funding.	2.0
2.0	Oct. 2015 – Jun. 2017	J. Nesmith and others	❖ Included YOSE Site selection procedure and GRTS Draw results in Narrative and Appendix 3 ❖ Updated Data dictionary to reflect changes in Access Database ❖ Added rationale for similar sampling frequency among different parameters in section 2.5	Changes made to respond to reviewer comments	2.1

1. Version numbers increase incrementally by tenths (e.g., version 1.1, version 1.2, ...etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.
2. Notify the Network Data Manager of any changes to the Protocol Narrative or SOPs so that the new version number can be incorporated in the Metadata of the project database.
3. Post new versions on the internet and forward copies to all individuals with a previous version of the Protocol Narrative or SOPs. A list will be maintained in an appendix at the end of this document.

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Standard Operating Procedures

The standard operating procedures (SOPs) are provided separately in the NPS Data Store at: <https://irma.nps.gov/DataStore/Reference/Profile/2245848>.

SOP 1. Sample Event Preparation

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SOP 3. GPS Use: Navigation, Data Collection, and Downloading

SOP 4. Electronic Data Entry

SOP 5. Equipment Decontamination Procedures

SOP 6. Determining Target Status of a Site in the Field

SOP 7. Site Establishment and Assessment

SOP 8. Groundwater Monitoring Well Installation

SOP 9. Measuring Groundwater Monitoring Wells

SOP 10. Laying Out a Site

SOP 11. Photo Point Documentation

SOP 12. Vegetation Sampling

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SOP 14. Collecting Voucher Specimens

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SOP 21. Training

SOP 22. Safety

Standard Operating Procedures (continued)

SOP 23. Field Communications for Wilderness Travel

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SOP 29. Data Analysis and Reporting

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SOP 31. Protocol Revisions

Acronyms and Abbreviations

CRAM	California Rapid Assessment Method
DEPO	Devils Postpile National Monument
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Geographic Positioning System
GRTS	Generalized Randomized Tessellated Stratification
FIA	Forest Inventory and Analysis Program
FHM	National Forest Health Monitoring program
I & M	Inventory and Monitoring Program (NPS)
MFR	Margalef's Family Richness
MMU	minimum mapping unit
NAIP	National Agricultural Imaging Program
NPS	National Park Service
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NRDT	Natural Resource Database Template
NWI	National Wetlands Inventory
PD	percent dominance
POC	point of contact
PP	percent predators
SEKI	Sequoia and Kings Canyon National Parks
SIEN	Sierra Nevada Network

Acronyms and Abbreviations (continued)

SOP	Standard Operating Procedure
USDA	United States Department of Agriculture
WEI	Wetland Ecological Integrity
YOSE	Yosemite National Park

Abstract

The National Park Service, through its Vital Signs monitoring program, has been charged with developing a series of monitoring protocols to evaluate the condition and trend of key ecological resources in national parks. The Sierra Nevada Network identified 13 vital signs for long-term monitoring. Three of these pertain to wet meadow and fen ecosystems and include macroinvertebrate assemblages, wetland plant communities, and surface/groundwater dynamics. In this document, we present a protocol for monitoring these vital signs in wet meadows and fens, which we will refer to hereafter in the document as “wetlands”. The Sierra Nevada Network parks where this protocol is implemented include Yosemite National Park, Sequoia and Kings Canyon National Parks, and Devils Postpile National Monument.

Following a standard format used by monitoring programs nationally, the protocol consists of two parts, a narrative section and a series of standard operating procedures (SOPs). The protocol narrative provides an overview of the vital signs monitoring program and detailed treatments of topics specific to the wetland monitoring protocol including specific monitoring objectives, statistical design, field data collection methods, crew safety, data management, and basic analysis and reporting. SOPs provide more specific guidance for protocol tasks, and are presented as a simplified series of steps intended to facilitate the task completion.

The Wetlands Ecological Integrity monitoring project is designed to provide basic information on the condition of targeted wetlands (wet meadows and fens) and to allow for the evaluation of long-term trends of key ecological variables in Sierra Nevada parks. Biotic and abiotic variables are measured, with the expectation that some variables will react differently to potential anthropogenic stressors than others, thereby more effectively characterizing wetland ecological integrity. The protocol outlines field methods for sampling vascular and nonvascular plants, terrestrial and aquatic macroinvertebrates, and the groundwater hydrologic regime. Additional approaches including selected quantitative and qualitative condition assessment metrics, and the collection of photo points are also described.

A spatially randomized survey design (Generalized Randomized Tessellated Stratification or GRTS) is used to develop park-wide inferences regarding fen and wet meadow ecological integrity (Stevens and Olsen 2004). Within watersheds, analysis of aerial photographs and existing data sets, such as the NPS vegetation map coverage and National Wetlands Inventory, are used to develop a sampling frame for wet meadows and fens across Park landscapes. GRTS is then used to select individual wetland points for site level evaluation. Sample sites selected through the GRTS design represent what we refer to as “extensive” sites that will be used to make inferences about the status and trend of wetland ecological integrity of SIEN park fens and wet meadows.

One additional hand-picked “index” site in a prominent riparian meadow within Devils Postpile National Monument (DEPO) will be monitored by SIEN. This site will not be used in the analysis to assess wetland ecological integrity within the network parks, but will serve as an important case study of the largest and most visible wetland within DEPO. Similar index sites, which are not the responsibility of SIEN, have been established within the other SIEN parks because they represent

areas of particular interest for the parks, such as areas that currently or historically experience high levels of use or have a history of previous research. Because index sites are often more accessible than extensive sites, they lend themselves to more frequent or intensive monitoring. The objectives and sampling procedures for these sites, however, are left up to the individual parks and these procedures are not discussed in this document.

Acknowledgments

This protocol benefited from the hard work and extensive technical input of numerous individuals. We thank NPS staff at the Rocky Mountain Network-- Brent Frakes, Billy Schweiger, and Mike Britten, for technical assistance and advice.

We gratefully acknowledge the insights provided by previously produced I&M protocols. Certain sections (e.g. data management, statistical design) borrowed heavily from other protocols, in particular, the SIEN Lakes Protocol, the Rocky Mountain Network Wetland Ecological Integrity Protocol, the Central Alaska Network Vegetation Structure and Composition Monitoring Protocol, and the North Coast and Cascades Network Forest Vegetation Monitoring Protocol.

We thank SIEN Physical Scientist Andi Heard for her advice regarding sample design issues and decisions, and her willingness to share her expertise. SIEN Biological Science Technician Sandy Graban provided both GIS and field data collection support. Jutta Schmidt-Gengenbach (White Mountain Research Station) spent many hours sampling, sorting, and identifying invertebrates, and occasionally brought fine chocolate to meetings. Meryl Goldin Rose, former SIEN Ecologist, provided critical support during the first pilot data collection season in Yosemite, and participated in many early protocol work group meetings and conference calls. Lisa Acree, Yosemite Botanist, provided logistic support during pilot data collection efforts, participated in the wetlands work group, and wrote the Wilderness Minimum Requirement Analysis for the wetlands pilot work in Yosemite. Jason Love and Lyra Pierotti (White Mountain Research Station) provided excellent field and lab support for the invertebrate portion of the protocol. Georgia Doyle lent her expert botanical skills to the 2008 field data collection effort, and Erik Frenzel (SEKI Plant Biologist) provided critical field and database assistance. Liz Ballenger (former YOSE Botanist) and Martin Oliver (former YOSE Biological Technician) provided field support and helpful reviews of the SOPs. Jim Roche, YOSE Physical Scientist, participated in wetlands work group meetings, reviewed and revised wetland well and data logger installation and monitoring SOPs, and provided guidance for index site location at Devils Postpile. Patrick Flaherty, on detail from Appalachian Highlands Network, completed the draft MS Access database. Tani Meadows (former SIEN Administrative Assistant), provided administrative support and assisted with SOPs, appendices, and citations.

Kathren Murrell Stevenson and Michael Barbour co-authored a report providing a literature review and evaluation of existing montane meadow monitoring programs that informed some of the early decisions for our protocol approach (Murrell-Stevenson et al. 2006).

This report was greatly improved from previous versions due to thorough and thoughtful comments provided by multiple reviewers including Protocol Review Coordinators Dr. James Agee and Dr. Jonathan Bakker, Inventory and Monitoring Pacific Northwest Regional Program Managers Dr. Penny Latham and Lisa Garrett, and external reviewer Dr. Dennis Whigham, administrative reviewer Joel Siderius, and two anonymous reviewers. We thank Editors Kris Freeman, Ann Huber, and Jenny Matsumoto for assisting us with formatting this document.

1 - Background and Objectives

1.1 Introduction

Ecological monitoring is a key element of park stewardship. Effective monitoring allows managers to identify and track the status and trend in the condition of key park resources, evaluate the efficacy of resource management activities, improve understanding of natural variation in ecological patterns and processes, and provide an early warning of potential threats to ecological integrity and sustainability. Through its vital signs monitoring program, the National Park Service (NPS) has begun numerous initiatives across the country aimed at tracking key physical, chemical, and biological elements and processes in park ecosystems (Fancy et al. 2009). A vital sign can be any measurable feature of the environment that provides insight into the condition and functioning of an ecosystem. Vital signs are selected to provide a measure of the overall condition of park resources and to help elucidate possible effects of known or hypothesized stressors.

To achieve greater efficiency in the design and implementation of inventory and monitoring work, and to foster the exchange of ideas and information among parks in a similar ecoregional context, the NPS has grouped parks and monuments into monitoring networks. The NPS Sierra Nevada Network (SIEN) parks included in the protocol are: Devils Postpile National Monument (DEPO), Sequoia and Kings Canyon National Parks (SEKI), and Yosemite National Park (YOSE) (Figure 1).

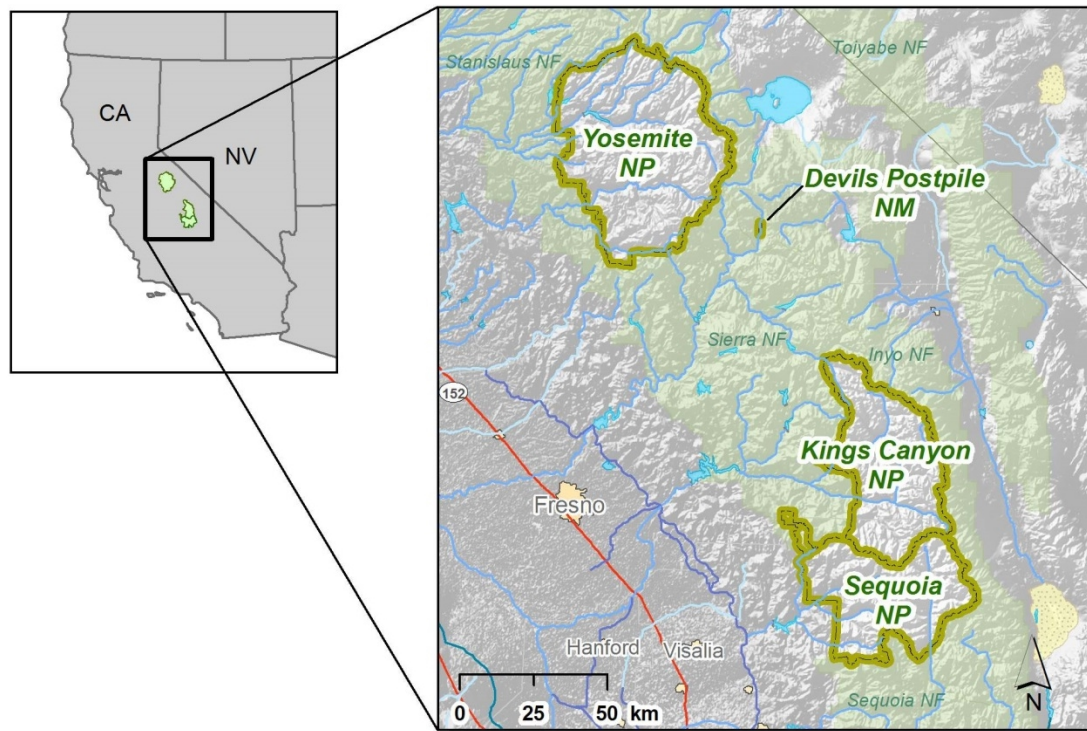


Figure 1. The four NPS units in the Sierra Nevada Network and the surrounding region.

Through a collaborative and multi-step process, NPS managers, SIEN staff, and outside scientists created a list of high-priority vital signs and selected from the list 13 vital signs for long-term monitoring in the SIEN (Table 1; Mutch et al. 2008a).

Table 1. Vital signs that were selected for protocol development by the Sierra Nevada Network, organized according to the NPS Inventory and Monitoring Program framework.

Level 1	Level 2	Vital Sign
Air and Climate	Weather and Climate	Weather and Climate
		Snowpack
Water	Hydrology	Surface water dynamics
		Wetland water dynamics**
	Water Quality	Water chemistry
	Invasive Species	Non-native invasive plants
Biological Integrity	Focal Species or Communities	Wetland plant communities**
		Macroinvertebrates (wetlands)**
		Amphibians
		Birds
		Forest population dynamics
*Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire regimes
	Landscape Dynamics	Landscape mosaics

*Draft protocol developed, but implementation not funded.

** Vital signs are those included in the wetlands ecological integrity protocol (also in bold font).

Although a separate monitoring protocol could have been developed for each of the 13 vital signs, there is considerable overlap among them in terms of topical focus and specific physical or ecological systems involved. For example, “wetland plant communities” intersects with several wetland water dynamics, macroinvertebrates, and nonnative invasive plants, thus providing an opportunity to monitor an integrated set of vital signs in a single monitoring protocol. Thus the wetland ecological integrity protocol will provide information about a primary physical driver (water) and the responses of both plant and animal communities to ecosystem change.

In this document we present a protocol that will serve as the initial basis for the long-term monitoring of wetland plants, macroinvertebrates, and groundwater hydrologic regimes in SIEN parks. However, due primarily to budget constraints, the protocol is restricted to two types of wetlands: wet meadows and fens. These wetland types often occur together as integrated components of wetland complexes (Benedict 1983). Together they form a subset of what are commonly referred to as ‘meadows’ in the Sierra Nevada. The term ‘meadow,’ however, is rather expansive and includes multiple ecosystem

types with significant functional differences. Thus, throughout this protocol we will refer to the more specific terms used to describe the component target wetlands – fens and wet meadows.

This protocol does not describe methods for monitoring riparian ecosystems, which often occur within or adjacent to wet meadows and fens, nor does it provide for monitoring marshes, which are scarce in the Sierra Nevada except where associated with the margins of lakes, ponds, and some streams. While both riparian wetlands and marshes were considered for inclusion in the protocol, the rarity of marsh habitat within the SIEN parks made this wetland type ill-suited for capturing landscape level change. Riparian areas were not included in the protocol due to cost, but if additional funding becomes available in the future, the methods outlined in this protocol could be used to develop a riparian sampling scheme that could complement the existing monitoring.

The protocol is organized following standards established by the NPS Inventory and Monitoring program (Oakley et al. 2003), and comprises two parts:

1. The protocol narrative (this document) provides an overview of the monitoring protocol, the monitoring objectives, the rationale for the specific design elements and monitoring components, and a detailed examination of statistical and field methods.
2. The standard operating procedures (SOPs) are in a separate document (Gage et al. 2017b). These provide straightforward, yet detailed instructions for executing specific components of the protocol.

Although considerable effort has been made to provide the most defensible and effective monitoring approach possible given time and resource constraints, future modifications of specific methods may be needed. Therefore, a change history log is presented for both the narrative section and each individual SOP in the protocol, where all modifications and their rationale are recorded. In addition, an administrative history of the protocol development is given in Appendix 1 of the narrative.

1.2 Rationale and Justification

The National Park Service has a legal mandate “to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations” (The National Park Service Organic Act, 16 USC § 1). Fulfilling this mandate requires knowing the condition of park resources, a task that can be aided by an effective natural resources monitoring program. To gain the most benefit of monitoring with limited fiscal resources, individual NPS units were grouped into networks. SIEN is one of 32 networks throughout the NPS. The Sierra Nevada Network Inventory & Monitoring (I&M) Program has a legal mandate to monitor the ecological condition of constituent parks. The vital signs program has been developed in response to the long recognized need for better tools to characterize and evaluate trends in the condition of ecosystem elements.

Parks may be vulnerable to multiple anthropogenic stressors originating outside of their boundaries such as air and water pollution, wildfire, changing land use patterns, invasive species, and climate change (Figure 2). Other stressors, such as recreation and development are also important, though they can be more easily controlled through management and policy decisions. To effectively address

the effects of anthropogenic stressors on park resources in managing and planning activities, it is essential that the NPS be able to characterize the current conditions and trends of key ecosystem parameters. Monitoring approaches that emphasize multiple physical and biotic elements are needed because no single approach or scale is appropriate for all system components and processes. Wetlands fulfill these criteria, integrating a range of physical and biotic processes that are potentially useful as indicators of broader ecological change (Figure 2).

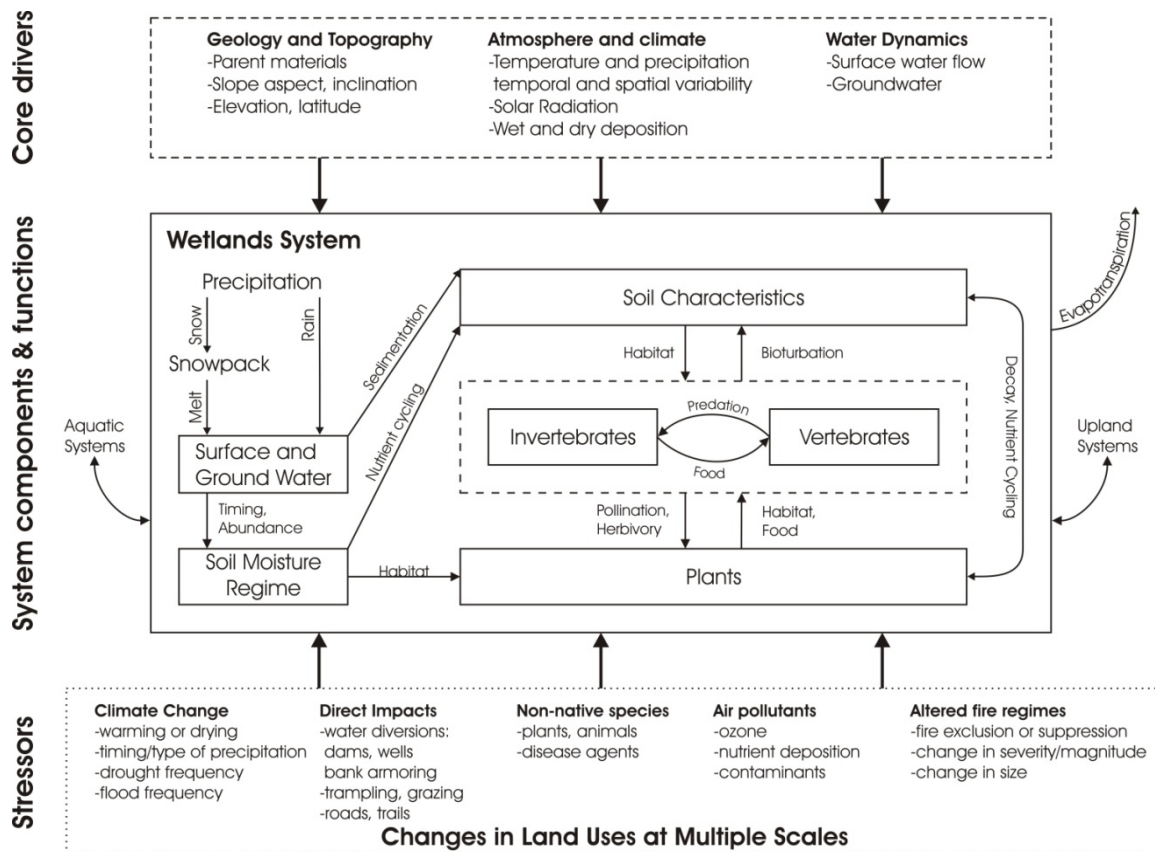


Figure 2. Wetland ecosystem conceptual model (from Mutch et al. 2008b).

In California's Sierra Nevada range, wet meadows and fens occupy <10 % of the total land area (Davis and Stoms 1996, Moore et al. 2000). Despite comprising such a small area, wetlands are widely recognized for the numerous important functions they provide. They are local and regional centers of biodiversity, and support species found nowhere else across western landscapes (Ratliff 1982, Debinski et al. 2000). Wetlands provide critical habitat for a variety of wildlife, play an important role in the life cycle of many invertebrate and amphibian species, and provide a wide variety of ecosystem services such as nutrient retention, flood control, and sediment storage (Johnston 1991, Richardson 1994, Smith et al. 1995, Semlitsch and Bodie 1998, Zedler and Kercher 2005). Wet meadows and fens are also important aesthetic elements of Sierra Nevada landscapes and provide important forage for wildlife and recreational and administrative pack stock (Moore et al. 2000).

While wet meadows and fens superficially appear similar and can occur adjacent to one another, they are driven by different hydrologic processes. Fens are perpetually saturated or flooded from various sources of groundwater (Bedford and Godwin 2003). Wet meadows often depend on precipitation, and they can appear dry for much of the year. Fens accumulate peat, sequestering carbon; wet meadows do not. The accumulation of organic matter in soils can lead to distinct plant community assemblages in fens and differences in soil chemistry. Differences in hydrology, soil chemistry, and plant community assemblages underlying these two wetland types are likely to result in different responses to stressors that affect the delivery of water, either as snow or rain. For example, small changes in the timing and rate of groundwater drawdown may have a larger effect on plant respiration and carbon dynamics in fen systems (Estop-Aragonés and Blodau 2012) compared to wet meadows. Alternatively, fens may be more resistant to change than wet meadows due to more stable hydrologic regimes associated with springs and other hydrogeomorphic features. Thus, more can be learned about the effects of ecosystems stressors on ecological integrity by sampling within each of these distinct wetland types.

The Wetland Ecological Integrity (WEI) Monitoring Protocol addresses three of the vital signs selected for monitoring in the Sierra Nevada Network: wetland water dynamics, wetland plant communities, and macroinvertebrates. By incorporating plant composition and structure, groundwater and surface water hydrology, and macroinvertebrate composition and abundance, the monitoring project can assess stressor impacts on wetlands at individual trophic levels and at a community level. Each component alone has utility for monitoring, reflecting different environmental gradients and stressors to yield information regarding ecological integrity. Variables can also be analyzed together to yield secondary indicators for monitoring effects from stressors (Fore et al. 1996, Jones 2004, Niemi and McDonald 2004, Faber-Langendoen et al. 2006, Miller et al. 2006).

The key physical driver influencing wetland plant and animal communities is the hydrologic regime (Figure 2). Water table gradients strongly influence vegetation composition and structure in wetlands (Allen-Diaz 1991, Svejcar and Riegel 1998, Dwire et al. 2004). Spatial and temporal variability in hydrologic characteristics also strongly controls basic ecological processes such as plant production and decomposition (Thormann and Bayley 1997, Thormann et al. 1999, Martin and Chambers 2001, Chimner and Cooper 2003). Saturated environments are also critical to the biogeochemical transformation of key elements such as nitrogen in the landscape (Zak and Grigal 1991).

Wetland plants are important indicators of basic physical processes such as hydrologic regime, site productivity, and water/soil chemistry (Cooper 1990, Goslee et al. 1997, Dwire et al. 2006, Cook and Hauer 2007, Mitsch and Gosselink 2007). The presence of hydrophytic plants is one of the defining characteristics of wetlands (Cooper et al. 2005) and is often used as an indicator of ecosystem function and condition (McClaran and Cole 1993). In the Sierra Nevada, wetlands are often dominated by perennial graminoids including species of *Carex*, *Deschampsia*, *Calamagrostis*, *Juncus*, *Danthonia*, and *Eleocharis*. Wetland vegetation is also responsive to natural and anthropogenic disturbance and can provide important insights into the effects of ecological stressors (Cole et al. 2004). Wetland plants play key roles in influencing water flow regimes by intercepting

and slowing the release of water to streams and improving water quality by removing or trapping nutrients, toxins, and sediments (Williams 1990, Mitsch and Gosselink 2007). They also serve as core habitat for wildlife (US EPA 1995) and are highly valued by people for their aesthetic and recreational value (Mitsch and Gosselink 2007). In addition, bryophytes are sensitive to environmental change including the frequency of rain events and distance to the groundwater table, as well as changes to water and air quality due to pollution, making them useful as indicators for environmental change (California Native Plant Society 2001).

Invertebrates are useful as vital signs because of their abundance, species richness, ubiquitous presence, and importance in ecosystem function (Holloway 1980, Rosenberg et al. 1986). Sampling invertebrate fauna directly provides a more complete picture of wet meadow and fen condition than sampling vegetation alone (Holmquist and Schmidt-Gengenbach 2006). Invertebrates influence productivity, decomposition, nutrient cycling, physical processes, and disturbance regimes (Coleman and Hendrix 2000). Invertebrates are essential prey for many vertebrate species and exert a strong influence on plant community dynamics as seed dispersers, seed predators, and pollinators (Janzen 1987). They provide important linkages between the soil, litter, and plant canopies, as well as between aquatic and terrestrial systems (Holmquist et al. 1998, Coleman and Hendrix 2000). Invertebrates are dominant wetland ecosystem components in terms of biodiversity, abundance, and trophic web structure. Wetland invertebrates are important food resources and processors of organic material and represent a “crossroads” for ecological flows between aquatic and terrestrial realms; disturbances can be transferred among habitats by this important invertebrate linkage. Invertebrate fauna produced by wetlands also subsidize upland assemblages. In addition to their ecological significance, invertebrates can be extremely sensitive to anthropogenic disturbance (Holmquist and Schmidt-Gengenbach 2004, Holmquist and Schmidt-Gengenbach 2008), expressed both by mortality and emigration. Therefore, they are a useful indicator of the impact of stressors on ecological integrity (Guntenspergen et al. 2002, Angeler and Garcia 2005, Holmquist and Schmidt-Gengenbach 2006, Dziok et al. 2006). Invertebrates are also excellent rapid response “sentinel species” owing to their high reproductive potential (New 1995) and variety of trophic levels they represent even within a given taxon (Samways 1994).

1.2.1 Threats to Wetland Ecological Integrity

Wetlands are among the most significantly altered ecosystems in North America (Mitsch and Gosselink 2007). Recognizing the effects of historic and contemporary anthropogenic stressors on the structure and function of fens and wet meadows can provide important contextual information useful for understanding the current status of wetlands, monitoring trends in their condition over time, and providing adaptive management solutions. Anthropogenic impacts, including changes in hydrology due to flow regulation, pumping, fill placement, historical grazing by domestic livestock, atmospheric deposition of pollutants, and exotic species invasion, have drastically altered the structure and function of many wetlands (Patten 1998, Zedler and Kercher 2005). In the Sierra Nevada, historic impacts to wet meadows and fens from sheep grazing have likely pushed species assemblages and ecosystem dynamics outside of their natural range of variability in many areas (Dull 1999). In addition, wet meadows and fens may be particularly vulnerable to forecasted changes in climate (Weltzin et al. 2000, Winter 2000, Poff et al. 2002, Baron et al. 2002, Weltzin et al. 2003).

POLLUTION – Nitrogen pollution from atmospheric deposition has the potential to affect productivity and species composition of wetland vegetation (Morris 1991), and depending on seasonal timing, may affect aquatic organisms such as algae and microbes. Effects to the primary producers of the aquatic food chain have the potential to significantly alter all wetland biota. Atmospheric contaminants even at low concentrations have the potential to adversely impact aquatic biota through estrogenic effects and bioaccumulation (Landers et al. 2008, Nowell et al. 2010). Currently, this protocol is not designed to specifically address impacts of pollution by, for example, coupling water chemistry analyses with changes in macroinvertebrate composition. However, the protocol design allows for easy modification (i.e., additional sampling) if funding and priorities change in the future.

FIRE REGIME CHANGES – Many areas within the Sierra Nevada have experienced prolonged periods without fire due to fire suppression, which has altered ecosystem structure and function (Scholl and Taylor 2010, Stephens et al. 2015). Fire can have direct impacts on wetlands through the combustion of plant material and changes in soil properties, as well as indirect effects by altering stream flow and nutrient inputs (Chorover et al 1994, Moore 2000, Boisramé et al. 2016). Fire can also facilitate the establishment of exotic species such as cheat grass (*Bromus tectorum*) that can further alter fire regimes and ecosystem function (Lambert et al. 2010).

LAND USE CHANGES – Direct impacts to wetlands affect their structure and function via on-site effects on vegetation, macroinvertebrates, or hydrologic regime. Alteration of hydrologic regime due to the effects of compaction, ditching, or ground water pumping can deleteriously impact biota and alter fundamental ecosystem processes such as production and decomposition (Cooper 1990, Cooper et al. 1998, Cooper and Wolf 2006b, Patterson and Cooper 2007). Indirect hydrologic impacts can also occur due to changes in land cover in surrounding watersheds (Troendle and King 1987, Stednick 1996).

GRAZING – Livestock use in the Sierra Nevada was historically concentrated in wetlands, with very heavy stocking rates of both cattle and sheep in the late 19th and early 20th centuries leading to severe degradation (Ratliff 1985, Dull 1999). Many wetlands still show evidence of these effects nearly a century later. For example, overgrazed wet meadows may support greater cover of herbaceous dicots and fewer grasses and sedges than ungrazed meadows (Cooper et al. 2006). Impacts on wetlands is one of the main confounding variables of this study as potential legacy effects from historic 19th century grazing likely resulted in changes in plant communities that are still present today. Therefore, some changes detected by this protocol may in fact be caused by ecosystem adjustment to historic grazing impacts.

Sheep and cattle grazing are now prohibited in SIEN parks, but pack stock use has the potential to cause severe impacts to wet meadows and fens (Cooper et al. 2005). Pack stock impacts include physical changes to wetlands, such as soil compaction or erosion, as well as impacts to vegetation and macroinvertebrate communities (Cooper et al. 2005, Holmquist et al. 2013). Pack stock selectively graze, and can change plant community composition as well as meadow wetland productivity (Cole et al. 2004).

Despite the potential consequences of grazing to wetland ecosystems, this protocol is not designed to address these impacts. Profound differences among the network parks in intensity and spatial distribution of pack stock grazing and the documentation of pack stock use within wetlands preclude our ability to investigate grazing effects at a network-wide level. Furthermore, natural resource personnel within the SIEN parks are engaged in park-specific studies to assess grazing impacts (Ostoja et al. 2014, National Park Service 2015). The sample frame from which study sites were chosen, therefore, excludes wet meadows and fens that have experienced moderate to heavy grazing (>0.5 stock use nights/ha/year) within the past 20 years (1993 – 2012) at SEKI and the past 10 years in YOSE (2004 – 2013).

RECREATION – Wetlands such as wet meadows and fens serve as important destinations for visitors to SIEN parks due to their many wildflowers, opportunities for viewing wildlife, and other aesthetic qualities (Hopkinson et al. 2013). For those who are visiting these areas using pack stock, meadows can serve as important sources of forage as well. Impacts from recreation include roads, developed and social trails, campsites, grazing, and water diversion (Ratliff 1985, Cole et al. 2004, Cooper and Wolf 2006b). These uses can create areas of localized erosion (Poff et al. 1997), lowered water tables (Ratliff 1985), soil compaction, loss of hydrologic function (Viers 2012), and altered plant and animal communities (Galatowitsch et al. 2000, Rocchio 2006a, Long 2013). Visitation has been increasing in SIEN parks, and while recreational stock use has been decreasing, administrative use in support of recreation has remained stable (National Park Service 2015). These changing use patterns have the potential to alter wetland condition, especially in areas where use patterns are changing rapidly.

INVASIVE NON-NATIVE SPECIES – Non-native plants pose a tremendous threat to many Sierra Nevada ecosystems. Although high elevation wet meadows and fens in the Sierra Nevada have a low incidence of invasive non-native plant species, the threat of invasion is present (D’Antonio et al. 2004) and likely increasing. For example, lower elevation wetlands (particularly those on the drier end of the hydrologic gradient) often support dense swards of naturalized non-native pasture grasses such as Kentucky bluegrass (*Poa pratensis*) and redtop (*Agrostis gigantea*) (Gerlach et al. 2003). In recent years a number of montane wet meadows in Kings Canyon, Sequoia, and Yosemite National Parks have also been successfully invaded by velvet grass (*Holcus lanatus*) and reed canary grass (*Phalaris arundinacea*). Velvet grass was first discovered in Kings Canyon in 1998 and has spread to occupy 20.4 acres within SEKI as of 2013 (Athena Demetry, Sequoia & Kings Canyon NP Restoration Ecologist, personal communication, 28 August 2013). Invasive animal species also pose a threat to wetland community integrity (e.g. *Harmonia axyridis*; Reynolds 2013). This protocol, while not designed to serve as a comprehensive monitoring effort to detect exotic plant and macroinvertebrate species invasions within the parks, will be able to document temporal changes in associated community composition and structure within wet meadows and fens as well as partially serve as a mechanism for early detection of invasive species within the parks.

CLIMATE CHANGE – Continued atmospheric warming poses a particularly pernicious threat to fen and wet meadow communities primarily by modifying the timing, duration, and magnitude of precipitation and snow melt in the Sierra Nevada (Lowry et al. 2011). Changes in precipitation

patterns will affect hydrologic regimes and the underlying hydrology of local systems, through changes in the timing and amount of snowmelt. This has the potential to cause dramatic shifts in species composition and abundance within mountain wetlands. Experimental manipulations in the Rocky Mountains demonstrate that increased temperatures can lead to a general drying down of mountain wetlands with subsequent invasion by woody species such as sagebrush (Saleska et al. 1999), and changes to the phenology of wetland species (Dunne et al. 2004). Another example is that after only three years of pilot data collection for both this vital sign effort and for a parallel effort in the White Mountains as part of the Global Observation Research Initiative in Alpine Environments, we believe that we are seeing rapid response of wetland arthropod abundance, richness, evenness, and dominance metrics to changes in snow water equivalent (Holmquist and Schmidt-Gengenbach 2008). By measuring groundwater depth over time, this protocol will provide site-level hydrologic data that can be compared with local precipitation data. Thus, causal relationships of climate-hydrology-species composition can be explored.

1.2.2 Historical Monitoring

Wet meadows and fens are a conspicuous component of Sierra Nevada landscapes; however, there has been relatively little historical monitoring. Long-term monitoring, as part of programs such as the Forest Inventory and Analysis Program (FIA) and National Forest Health Monitoring program (FHM) (McRoberts et al. 2005, USDA Forest Service 2005), poorly capture wetlands. Survey sampling designs such as the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) (Ernst et al. 1995, Urquhart et al. 1998, Whigham et al. 2007) have focused on wetlands, but extensive sampling has not occurred in Sierra Nevada parks.

Over the past decade there have been significant strides made to map and assess the condition of meadows (and fens in particular), but these efforts have occurred largely outside of SIEN parks. A majority of this work has occurred on USDA Forest Service Lands (Cooper and Wolf 2006a, Weixelman and Cooper 2009, Sikes et al. 2011, Sikes et al. 2013). During this time, the Forest Service and cooperating partners have surveyed over 800 fens and developed standardized procedures to conduct surveys and monitoring, many of which have been incorporated into this protocol.

Rapid assessment approaches such as the California Rapid Assessment Method (CRAM) have been implemented on a limited scale within the Sierra Nevada (Collins et al. 2006, Sutula et al. 2006, Denn and Shorrock 2009). However, no systematic assessments using a rigorous statistical design have been done in SIEN parks, limiting inferences that can be made regarding wetland condition at broad spatial scales. The approach presented in this protocol differs from most rapid assessment techniques by emphasizing the collection of quantitative data from long term, fixed-area plots to maximize the precision of data collection and the ability to detect change over time.

There is a long history of terrestrial vegetation inventory, research, and monitoring work in SEKI and YOSE. Most work has focused on evaluating the effects of management such as fire, non-native plant control, restoration, recreation (especially pack stock grazing), and air pollution (Goldin Rose 2008). Although the SEKI fire ecology program has provided DEPO support for fire history and fire

effects monitoring, the monument has otherwise lacked the staffing or resources to carry out extensive long-term vegetation monitoring.

Vegetation maps of SIEN parks provide general baseline data for monitoring (Aerial Information Systems 1997, National Park Service 2007). Additional vascular plant and rare plant surveys have occurred in SEKI and YOSE (Graber et al. 1993, Moore et al. 2005, Goldin Rose 2008, Huber et al. 2013), and a vascular plant inventory has been completed in DEPO and YOSE (Arnett and Haultain 2004, Arnett et al. Moore and Johnson 2010). None of these efforts have focused specifically on wet meadows or fens. However, a wetlands inventory and condition assessment was recently completed for DEPO (Denn and Shorrock 2009) that will inform consideration of additional wetland monitoring needs specific to management objectives for the monument.

In the Sierra Nevada Network parks, only a limited amount of work in wetlands has been done. In SEKI, most of this has been focused on monitoring the effects of pack stock grazing on vegetation in wilderness meadows, and has been conducted in a limited number of sites (Haultain 2008, Haultain 2009, Goldin Rose 2008). In YOSE, several wetland restoration projects have involved the collection of monitoring data, but again, only for a limited number of sites (Goldin Rose 2008).

Relatively few site-level studies of wet meadows and fens have been conducted in SIEN parks. Detailed groundwater data are limited, for example, to only a handful of sites in Yosemite National Park such as Yosemite Valley, Crane Flat, and Tuolumne Meadows (Cooper et al. 2006, Cooper and Wolf 2006b, Cooper et al. 2015). In Sequoia National Park, detailed groundwater data are available from a small number of montane meadow sites in the Giant Forest and Halstead Creek areas (Cooper et al. unpublished data) and from subalpine meadows in the Rock Creek drainage (Leonard et al. 1969, Giffen et al. 1970). These sites are neither numerous enough nor distributed in a sufficiently rigorous statistical design to allow park-level inferences of wetland resources.

1.3 Ecosystem types and Key Ecological Characteristics

1.3.1 Wetland Definitions and Classification

As noted earlier, this protocol has been developed for application to two kinds of wetlands: wet meadows and fens. Note that this usage differs from some commonly used definitions of meadows, which may also include non-wetland ecosystems (Ratliff 1982, Ratliff 1985). Upland meadow community types are not covered by the protocol, nor are riparian areas, which often occur as part of wetland complexes. To minimize the variation in data sets and allow for maximum inferential ability, field crews must be able to distinguish between uplands and wetlands, and between individual wetland types. Because individual indicators may not always be reliable, multiple characteristics such as plant species composition, soil characteristics, and depth of peat within the soil horizon should be used to differentiate wetland types in the field (Weixelman and Zamudio 2001, Weixelman et al. 2011). For example, vegetation is generally indicative of wetland type but not always, particularly in marginal or disturbed settings. Careful evaluation of soils and species composition by trained botanists, however, has proven to be an effective and reliable method for distinguishing wetland types in the field and this sort of classification has been conducted by multiple agencies and organizations throughout the southern Sierra Nevada (Cooper et al. 2005, Weixelman et al. 2011,

Sikes et al. 2013). More detailed information about differentiating wetland types in the field is presented in SOP 6.

A variety of definitions have been developed for wetlands as a result of their high ecological diversity, special legal status, and their intersection with different scientific fields (National Research Council 1995, Tiner 1999, Mitsch and Gosselink 2007). The general characteristics of different definitions are driven in large part by their purpose. For example, the definition used by the U.S. Army Corps of Engineers to administer section 404 of the Clean Water Act aims to provide consistent and uniform criteria for field delineation (Environmental Laboratory 1987), while the Cowardin et al. (1979) classification was developed for national wetland inventory and mapping efforts. The definition used by the National Research Council (NRC 1995) is relatively broad in scope, emphasizing the unique suite of hydrological, chemical, and biological characteristics which differentiate wetlands from uplands. The definition used by National Wetlands Inventory (NWI) program contains elements found in both the Corps of Engineers and NRC definitions (Cowardin et al. 1979). All definitions recognize, to one degree or another, the key role of hydrologic processes in wetland formation and the resulting suite of soil and vegetation characteristics. In practice, precise wetland boundaries can be difficult to identify. The timing and duration of soil saturation may vary among years and plant species may have individualistic responses to the changing environmental conditions, producing complex distribution patterns (Tiner 1991).

Wetlands vary widely in their functional and structural characteristics (Mitsch and Gosselink 2007). Terminology is often ambiguous, with different classifications variably lumping different ecosystem types together. Although this protocol is concerned with fens and wet meadows, it is important to realize that other wetland types such as marshes and riparian wetlands occur in SIEN parks. Each type differs in basic hydrologic characteristics, in turn driving differences in floristic composition, vegetation structure, biogeochemical functioning, and presumably, response to natural or anthropogenic stressors.

Various classification schemes have been applied to wetlands, and the criteria used to classify features differ among classification systems. Examples include dominant vegetation, hydrologic characteristics, geomorphic setting, and water chemistry. Classifications based on vegetation include the National Vegetation Classification System used by state Natural Heritage programs across the U.S. and form the basis of many mapping efforts (Grossman et al. 1998).

National Wetlands Inventory data are widely available and provide a useful base for understanding the broad distributional patterns of wetlands. However, maps in many areas are decades old and were drawn using relatively poor imagery. In addition, the Cowardin system used by NWI is of limited utility for discriminating functional wetland types. Most wetlands are classified in the palustrine system, and depending upon their vegetation may be placed in the moss-lichen, forested, emergent, or scrub-shrub class. Various hydrologic regime and chemistry modifiers can also be added (e.g. Weixelman et al. 2011), although, in practice, these data are not always available or accurate for maps (Cowardin et al. 1979).

One classification system that has been developed specifically for the classification of Sierra Nevada meadows and will be used in this protocol relies on a combination of plant species composition and hydrogeomorphic characteristics to differentiate meadow types (Weixelman et al. 2011). This key splits meadow types into peatlands (basin, mound, or discharge slope depending on landscape context), wet meadows (seasonal depressional, perennial depressional, lacustrine fringe, discharge slope, subsurface low gradient, subsurface middle gradient, sub-surface high gradient), dry meadows, and riparian meadows (low gradient, middle gradient, high gradient). These classifications can be used to aid in condition assessment, mapping and classification, and restoration efforts.

1.3.2 Main Wetland Types

Different wetland types such as fens, marshes, and wet meadows function within a range of hydrologic, geomorphic, and chemical characteristics, although there can be high variability within each type in response to localized landforms, elevation and temperature gradients, and available species pools (Windell et al. 1986, Mitsch and Gosselink 2007). These functional differences are important determinants of the sensitivity of wetlands to natural and anthropogenic disturbances and are important to consider when evaluating wetland condition (Bedford 1996, EPA 2002a, Johnson 2005). Wetland ecosystem functions are influenced by processes occurring across spatial and temporal scales, with large-scale processes such as climate and geology acting to constrain small-scale processes such as disturbance or seasonal water table fluctuations (Frissell et al. 1986, Imhof et al. 1996, Stendera and Johnson 2006). Several general wetland types occur in the Sierra Nevada including riparian wetlands, marshes, wet meadows, and fens. We describe these four wetland types below, although the protocol is only focused on fens and wet meadows.

RIPARIAN – The main characteristic of riparian ecosystems is the presence of unidirectional moving water, which has the potential to erode and transport sediment. The potential energy contained in flowing water is a key variable influencing ecosystem structure and function of this wetland type, as they are strongly influenced by fluxes of energy and materials from upstream systems (Mitsch and Gosselink 2007).

MARSHES – Marshes are characterized by highly variable hydrologic regimes whose inputs are surface water-dominated and often include periods of moderate to deep inundation. Some examples are cattail-dominated basins at low to mid elevations, and emergent grass or sedge dominated communities fringing lakes, ponds, or artificial reservoirs (Windell et al. 1986, Mitsch and Gosselink 2007).

FENS – Fens, also known as peatlands, are distinguished from other wetland types by the dominance of peat soils, and are among the most common wetland types globally. However, outside of boreal landscapes, they typically represent a small proportion of total wetland area. In the Sierra Nevada, all fens are maintained by groundwater hydrology (Benedict and Major 1982, Drexler et al. 2013). Fens have been classified using a variety of criteria such as vegetation, water chemistry, and hydrology (Wheeler and Proctor 2000). The depth of peat required to be classified as a fen is not consistently defined in the literature. To be classified as a Histosol (organic soil type) by the Natural Resources Conservation Service (NRCS) in its soil taxonomy system (USDA NRCS 2005), there must be 40 cm of peat in the upper 80 cm of the soil profile. However, wetlands not strictly satisfying this criterion

may still function as fens and support fen biota (Weixelman et al. 2011). Therefore, wetlands with at least 20 cm of peat within the top 40 cm in soil profiles were classified as peat-accumulating wetlands in this protocol, and will be categorized as fens rather than wet meadows. The use of 20 cm of organic matter within the top 40 cm of soil is a definition that has been used to classify peat accumulating wetlands in other areas of the Sierra Nevada and seems to more accurately identify wetlands with ecological characteristics and functions typified by fens (Weixelman et al. 2011).

Fens have stable water supplies with water tables at or close to the ground surface for most of the growing season (Windell et al. 1986, Winter et al. 2001, Chimner and Cooper 2003). While fens often occur in stream valleys as part of larger wetland complexes, fens do not experience high velocity surface flows or sediment deposition from fluvial processes like riparian ecosystems. In contrast to marshes, fens do not experience deep inundation, although some microsites can have over 20 cm of standing water (Cooper 1990). A distinction within peat-accumulating wetlands is that of bogs versus fens. Bogs are hydrologically supported exclusively by precipitation, while fens are supported primarily by groundwater (Cooper and Wolf 2006a, Mitsch and Gosselink 2007). Because of higher evapotranspiration rates in the Sierra Nevada compared to boreal regions, true bogs do not occur and all peatlands in the range are properly classified as fens. Fens in the Sierra Nevada network parks are placed into the Mediterranean California Subalpine-Montane Fen ecological system type by NatureServe (NatureServe 2015).

Using the Cowardin classification, fens would generally be classified as either (1) palustrine, emergent, persistent, with a saturated water regime and peat soils, or (2) palustrine, scrub-shrub with a saturated water regime and peat soils where multi-stemmed woody species dominate. Wet meadows also fall within the palustrine system, and, depending upon their vegetation, may be placed in the emergent or scrub-shrub class (Cowardin et al. 1979). Fens have stable groundwater driven hydrologic regimes with high water tables that retard organic matter decomposition and promote peat accumulation (Cooper 1990, Bedford and Godwin 2003, Cooper and Wolf 2006a).

In the Sierra Nevada, fens develop in several geomorphic settings (Weixelman et al. 2011). Basin fens are typically flat and are associated with open water features such as small lakes or ponds. They may support floating mats that rise and fall with fluctuating water levels, maintaining contact between the peat surface and the water level. Sloping fens form at the base of hills or on hillslopes where ground water discharges from alluvial fans, glacial moraines, and other aquifers (Cooper and Wolf 2006a). Constant groundwater flow is needed to maintain soil saturation due to high drainage rates. Fens may also develop in association with distinct springs. These spring mound fens are typically small but are morphologically and ecologically distinct from slope or basin fens. Spring mound fens may form within a sloping fen complex, and indicate the presence of localized groundwater discharge (Cooper and Wolf 2006a, Weixelman et al. 2011).

Multiple factors affect fen formation and function, with the relative importance of each varying depending on the spatial and temporal scale. At the broadest scales, the regional flora, climate, and geology are most important (Major 1951), while at intermediate and fine spatial scales, chemical and hydrological gradients, as influenced by geomorphic setting, are key (Cooper and Andrus 1994,

Tahvanainen et al. 2002). Biotic interactions, microtopography, and disturbance processes also all influence patterns of vegetation and succession (Kennedy et al. 2000, Mulligan and Gignac 2002).

Fens support a wide variety of vegetation types. Vascular species may include clonal monocots such as sedges (*Carex* spp.) or herbaceous dicots such as *Oxypolis* spp. Fens commonly support a well-developed bryophyte flora. Fens with basic or circum-neutral water chemistry typically support species in “brown moss” genera such as *Drepanocladus* and *Aulacomnium*. In fens with more acidic water chemistry, species in the *Sphagnum* genus may dominate. Clonal sedges are among the most common fen dominants. Grasses and rushes are less common, and are often most prevalent along fen margins, particularly where fens abut other wetland types such as wet meadows. Dicots such as *Oxypolis* spp. are dominants in certain community types, as are shrub-dominated communities, sometimes referred to as carrs. Forested fens (“treed fens”) also occur in some environments (Zoltai and Johnson 1985, Johnson 1996, Johnson 1997).

Hydrologic regimes within individual fens can be variable, and differences in the amplitude and timing of water table fluctuations can occur within sites such as fen margins, spring discharge zones, or on floating mats (Demars et al. 1997, Bragazza and Gerdol 1999, Drexler et al. 1999). While hydrologic processes vary widely among fens as a function of factors such as geologic and geomorphic setting, overall hydrologic regimes are relatively similar across floristic and geographic gradients.

Water tables may drop in the mid to late summer in many fens, although it is rare for them to drop below a meter (Cooper 1990, Cooper and Wolf 2006a). Water tables may decline more steeply during extreme droughts. If such conditions persist for extended periods of time, soils will dry and oxidation of peat will occur, eventually leading to the loss of peat. Many wetland types have high water tables through June; however, only sites with a water table within 20 – 30 cm of the soil surface during early summer accumulate peat (Cooper 1990, Chimner and Cooper 2003). This may represent a hydrologic threshold distinguishing wet meadows from fens.

Because of climatic constraints and the small size of many contributing fen watersheds, the most important source of water to fens is groundwater. Groundwater in the peat bodies of fens is hydraulically connected to underlying mineral soils resulting in elevated mineral ion concentrations compared to either surface water or precipitation (Siegel 1983, Siegel 1988). Aquifers supporting fens can be local to regional in size and the specific flow paths taken by groundwater can be complex, influenced by factors such as the lithology and physiography of contributing watersheds (Winter 2001, Chapman et al. 2003). Fractures in bedrock may lead to spring formation, and coarse glacial deposits with high permeability can link recharge and discharge areas, transmitting ground water to fens (Almendinger and Leete 1998).

Secondary water sources to fens include direct precipitation and surface water runoff. Accumulated snow pack overlying some fens may be an important source of water to subalpine fens, particularly in the Sierra Nevada with its deep snowpacks. However, much of this may be lost through evapotranspiration (Gorham and Hofstetter 1971). Surface water inputs to fens can occur as sheet flow or channelized flow. However, large channelized streams are not observed in fens because high

energy streams erode peat, preventing any significant organic matter accumulation. Sheet flow from seasonal snow melt may contribute a significant amount of water to fens and may coalesce to form water tracks around the margins of peat bodies (Heinselman 1970, Crum 1988).

Because fens rely on stable water tables near the ground surface for peat accumulation, fens may be sensitive to shifts in climate (Weltzin et al. 2000, Bubier et al. 2003, Weltzin et al. 2003). Precipitation, temperature, and evapotranspiration vary as a function of elevation (Hauer et al. 1997), and fens are typically more abundant at higher elevations. Species diversity is also thought to increase with elevation within Sierra Nevada fens (Carl Wishner, Consulting Biologist, personal communication, August 18, 2012). Physiography can also be important, with watershed characteristics indirectly influencing hydrologic processes such as snow accumulation and the rate of melting.

Geologic factors such as bedrock geology and glacial history can influence fen abundance, distribution, biota and functions. Because fens receive inputs of ground water, the mineralogy of watersheds can be an important influence on water chemistry, thereby affecting biotic composition (Cooper and Andrus 1994, Cooper 1996) and ecological processes such as productivity and decomposition (Verhoeven and Arts 1992, Szumigalski 1995, Chapin et al. 2004). As groundwater-driven ecosystems, the chemical content and pH vary considerably depending upon the source water and geological characteristics of the watershed (Chapman et al. 2003, Tahvanainen 2004). Areas with bedrock dominated by granitic and metamorphic rocks often support fens with acidic pH, while watersheds composed of limestone, dolomite, or shale produce circum-neutral to basic pH and higher concentrations of mineral ions (Windell et al. 1986). The mineralogy of surrounding landscapes also affects the pH of fens through the ability of mineral bases to neutralize organic acids produced by decomposing organic matter (Shotyk 1988, Tahvanainen 2004). Differences in the quality and quantity of groundwater entering fens drive much of the spatial and temporal variability in water as organic acids found in surface water mix with inorganic solutes contributed by ground water discharge, often with a significantly different pH (Chapman et al. 2003, Siegel et al. 2006). In microsites dominated by *Sphagnum* species, processes of active cation exchange are important (Clymo 1963, Spearing 1972).

The primary sources of nitrogen (N) to fens are wet and dry atmospheric deposition and the mineralization of organic matter (Bayley et al. 2005), while the primary losses of N from the fen ecosystem are denitrification and leaching. Processes dominating N cycling within the fen ecosystem include mineralization, nitrification, biotic uptake, and nitrate reduction. Atmospheric inputs have increased relative to historic conditions as a result of increased industrial, agricultural, and urban inputs (Bytnerowicz and Fenn 1996, Vitousek et al. 1997, Baron et al. 2000, Kittel et al. 2002, Fenn et al. 2003, Landers et al. 2008).

The predominant organic matter input in fens is from vegetation growing on-site, although surrounding areas can also contribute large amounts of organic matter (e.g. trees falling in from the margins; cones and needles transported downslope). Factors like basin size, stability of the water level, slope processes, and landform morphology may influence fen development and succession and the developmental trajectory of fens in larger basins can differ from those in smaller basins, even

within the same watershed (Cooper et al. 2002). As a result, the sensitivity of fens to environmental change likely varies (Bauer et al. 2003). Differential production and decomposition in fens can result in the formation of distinct microtopographic features that strongly influence fine-scale vegetation patterns. Commonly, different suites of species are observed among these different landform types.

Disturbances are relatively rare in fens compared to other wetlands types such as riparian areas. Although fire and grazing may affect fens, there are few historical data available to describe these effects. These can include plant mortality, as well as indirect effects through changes in hydrologic or chemical characteristics of surrounding watersheds. Fire, though uncommon, can maintain open conditions in some fens by selectively killing woody species (Jacobson et al. 1991). However, under dry conditions, fire can consume the peat layer, resulting in a type conversion. The frequency of this type of event has increased in many peatland systems throughout the boreal region and may have significant impacts on the global carbon cycle (Turetsky et al. 2002). Subsequent increases in water and sediment yield may affect fen function, as a flush of nutrients such as nitrogen following fire (Anderson and Menges 1997, Dikici and Yilmaz 2006).

WET MEADOWS – Wet meadows are abundant in western North America, occurring across a broad elevation gradient (Windell et al. 1986, Mitsch and Gosselink 2007). They are characterized by seasonally saturated soils, but lack the perennial high water tables and peat soils of fens or the large seasonal and inter-annual water table fluctuations characteristic of marshes. Wet meadows lack peat soil but have significantly more organic matter than soils in surrounding forests. NatureServe places most Sierra Nevada wet meadows into the Temperate Pacific Subalpine-Montane Wet Meadow ecological system type (NatureServe 2015).

Wet meadows, like fens, are important breeding grounds for invertebrates, which are key elements of many food chains (Holmquist and Schmidt-Gengenbach 2006). Wet meadows provide important food and habitat for vertebrate species such as small mammals. These, in turn, provide an important prey base for raptors and other predators (van Riper and van Wagtendonk 2006).

Temperature generally declines with increasing elevation, although aspect and rugged topography create a great deal of spatial variability in temperature in mountainous areas. In alpine meadows, temperatures may be relatively stable near freezing for much of the spring and autumn, with water availability limited more by freezing than drying (Costello and Schmidt 2006). Strong winds and complex topography create variable patterns of snow accumulation (Billings and Bliss 1959). Differences in the timing of melt are important for plants, influencing key phenological events like the initiation of growth (Galen and Stanton 1995, Walker et al. 1995, Yamagishi et al. 2005).

Summer precipitation is an important driver of hydrologic regimes in wet meadows of the Rocky Mountains, but likely of less importance in the Sierra Nevada due to the relatively low frequency of summer rain events. Flood frequency in wet meadows is low, with hydrologic regimes influenced more by groundwater than surface water (Mitsch and Gosselink 2007). Wet meadows typically occur in sites where soils are seasonally saturated, but unlike fens or marshes, lack perennially high water tables or seasonally deep water.

Wet meadows frequently occur in stream valleys as part of larger wetland complexes, but unlike riparian ecosystems, are not subject to high velocity surface flows or sediment deposition from fluvial processes. High water tables early in the summer are maintained in part by snowmelt, but water tables may drop to a meter or more below the soil surface in July and August, in contrast to fens, where they typically remain within 20-40 cm of the soil surface (Cooper 1990, Chimner and Cooper 2003).

As with fens, plant species distribution in wet meadows varies along hydrologic and edaphic gradients (Benedict 1983, Allen-Diaz 1991, Dwire et al. 2006). In the wettest wet meadow communities, obligate hydrophytes tolerant of seasonal flooding, shallow water table depths, and anaerobic soil conditions generally dominate. In contrast, competition and other biotic interactions likely play a greater role in determining species composition and vegetation structure in the more diverse moist and dry meadow communities (Dwire et al. 2004). Wet meadow communities dominated by sedges (*Carex* spp.) may have lower species richness and diversity compared to dry meadow communities, which are composed of a mix of mostly grasses and herbaceous dicots (Dwire et al. 2006).

Palynological and stratigraphic evidence suggests that many wetlands are relatively stable elements of Sierra Nevada landscapes, although composition of plant communities has varied in relation to natural and anthropogenic factors such as 19th century grazing and shifts in climate (Koehler and Anderson 1994, Dull 1999, Kim and Rejmankova 2001). Fens and wet meadows in particular, have unique characteristics such as the accumulation of fine textured materials that create a stratigraphic record that is strongly influenced by variations in watershed hydrology (Wood 1975). This allows for historic analysis of hydrologic and vegetative change over time, which can provide an important historic perspective to their stability. This strong connection with watershed hydrology also allows fens and wet meadows to serve as ecosystem gages of groundwater recharge (Drexler et al. 2013).

Soils in wet meadows are often fine textured and have high organic matter content. Anaerobic conditions lead to the formation of hydric soil indicators such as mottles and oxidized root channels, and these features can be used to distinguish wet meadows from dry meadows, particularly where vegetation has been disturbed (Tiner 1999, USDA NRCS 2006). Because water and nutrients are generally more abundant than in adjacent uplands, wet meadows tend to be highly productive.

Soil pH and the concentration of cations and nutrients vary within and among sites in relation to factors such as mineral soil particle size distribution, organic matter content, and hydrologic regime (Johnston et al. 1995, Blank et al. 2006). In watersheds where relatively soluble minerals are dominant, groundwater may contain abundant dissolved solids, while areas composed of relatively insoluble minerals will typically have lower concentrations of ions.

Compared to riparian areas or marshes, abiotic disturbances such as floods are less important in wet meadows. Fires can affect meadow vegetation, leading to short-term instability in community composition, but promoting their long-term stability by reducing the encroachment of forests (DeBenedetti and Parsons 1979, DeBenedetti and Parsons 1984).

Biotic disturbances from small mammals can be significant. Through their burrowing and foraging, pocket gophers and other small mammals can affect patterns and rates of soil development, nutrient availability, microtopography, demography and abundance of plant species, and plant diversity (Ellison and Aldous 1952, Ward and Keith 1962, Huntly and Inouye 1988, Sherrod and Seastedt 2001). Pocket gophers can restrict the expansion of woody plants into meadows (Cantor and Whitham 1989). Other mammals such as marmots or voles can also influence wet meadows through herbivory and soil disturbance (del Moral 1984, Austin and Pyle 2004, Howe and Lane 2004).

1.4 Monitoring Questions and Measurable Objectives

1.4.1 Network-Level Monitoring Questions Relevant to Wetland Communities

This section provides the broader context for the wetland monitoring protocol. In the Sierra Nevada Network Vital Signs Monitoring Plan (Mutch et al. 2008a), SIEN articulated a set of broad monitoring objectives and related questions to be addressed by SIEN's long-term monitoring program, which includes this wetlands protocol. Broader questions that may be addressed by this protocol include:

- How resistant to change are Sierra Nevada wet meadow and fen ecosystems?
- How do concentrations of persistent organic pollutants vary spatially in aquatic systems?
- How are water dynamics changing in response to climate and fire regimes?
- How are surface water volumes changing in wetlands?
- How are height and supply of shallow groundwater and flow regimes changing in wet meadows and fens?
- How are plants and animals responding to changes in nutrient concentrations, heavy metals and toxins, sediment loads, and water temperature? What effects are these responses having on aquatic food chains and biological diversity?
- How do the structure, composition, and distribution of plant communities change in response to variation in climate, fire regime, and human use?
- How are abundance and distribution of non-native plant species changing, and what impacts are these having on native plant and animal communities?
- How are wetlands and wet meadows changing in species composition and productivity in relation to changes in human use and climate? How are associated animal communities affected by these changes?
- How is net primary productivity changing in aquatic and terrestrial systems in relation to changes in climate, fire regime, and human use?

1.4.2 Ecosystem Stressors

Wetland communities in the Sierra Nevada Network are susceptible to the same stressors implicated in altering the state of other network vital signs. The working systems-level conceptual relationship is given by:

Stressor → Major Ecological Driver → Vital Sign

The main Sierra Nevada Network stressors are 1) climate change, 2) altered fire regimes, 3) invasive species, 4) air pollution, 5) habitat fragmentation and 6) changing land use patterns.

Due to contemporary constraints on funding, this protocol was not designed to address how stressors influence the major ecological driver–hydrologic regime. Instead, it aims to identify relationships among several vital signs (wetland plant communities and wetland macroinvertebrates) with the hydrologic regime. If additional resources become available in the future, careful attention should be given to modifying the present protocol to accommodate additional measurements of other ecological drivers. For example, air pollution and deposition into wetland systems could greatly influence the persistence and composition of the biotic community, as well as alter species interactions. Measuring water and sediment quality would allow for analysis and interpretation of putative relationships. The second stressor addressed by the protocol is invasive species (plant and animal). It is not anticipated that invasive species will affect the other vital signs by altering local hydrology. Changes in local hydrology could, however, increase the likelihood of specific species invasions, as could changes in the other stressors. Impacts of invasive species will most likely result from site-level interspecific interactions, structural and compositional change, and modification of edaphic conditions.

1.4.3 Specific Monitoring Questions and Hypotheses

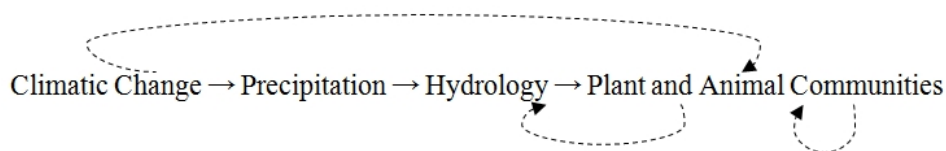
Simulation models of climate change suggest that predicted warmer temperatures will alter water availability due to changes in the type of precipitation and timing of snowmelt in the Sierra Nevada (Knowles and Cayan 2001, Dettinger et al. 2004). Such changes would affect the underlying hydrologic regime of local systems and potentially shift composition and relative abundance of wetland species. Specific questions addressed by this protocol are listed below.

Monitoring Questions:

1. Are hydrologic processes (e.g., duration, depth, and timing) in wetlands changing?
2. Are there changes in wetland plant communities (e.g., structure, composition, and abundance)?
3. Is the composition, abundance, or trophic structure of aquatic or terrestrial invertebrate communities changing in wetland ecosystems?
4. Are invasive species (plants and invertebrates) expanding or declining in wetlands?
5. Are observed changes in flora or fauna correlated with changes in water table depth?

Hypotheses:

An example of our specific systems-level conceptual relationship is:



where dashed arrows indicate the direction of diffuse interactions. In this protocol we will be investigating the relationships between Hydrology and Plant and Animal Communities. Our specific hypotheses are:

Hypothesis 1: Changes in wetland hydrology will alter species composition and relative abundance within vascular and non-vascular plant, as well as macroinvertebrate communities.

Hypothesis 2: The rate and magnitude of changes to wetland hydrology will differ between wet meadows and fens, leading to divergent responses of the wetland flora and fauna between wetland types.

1.4.4 Monitoring Objectives

For wet meadow and fens in Yosemite, Sequoia and Kings Canyon we will:

1. Determine temporal changes in hydrology by:
 - measuring the distance between the ground surface and top of the water table (cm) through time
2. Estimate temporal changes in species composition and abundance of wetland vascular and non-vascular plants by quantifying:
 - relative ground cover composition and abundance
 - woody plant invasion
 - vascular and non-vascular plant species richness
3. Evaluate temporal changes in the composition and relative abundance of wetland macroinvertebrate (arthropods and mollusks within size constraints) populations by measuring:
 - aquatic macroinvertebrate abundance and Family richness
 - terrestrial macroinvertebrate abundance and Family richness
 - ant (Family Formicidae) abundance and species richness
4. Quantify changes in bare ground frequency and abundance and determine the most likely causal agents (e.g., rodent activity, pack stock disturbance, human disturbance, etc.) of the observed bare areas. Bare ground will be used to define thresholds for recommending management action.
5. Determine temporal changes in exotic plant species cover and dominance and document their location and extent within the wetlands and surrounding area

6. Quantify and compare the status of fens and wet meadows by measuring water table depth, peat depth, plant species composition and abundance, bare ground, and aquatic and terrestrial macroinvertebrate abundance and richness
7. Compare rates of change in wetland community characteristics between fen and wet meadow sites

The same objectives will be assessed for one riparian influenced meadow in Devils Postpile National Monument. Because this is only a single site that was subjectively chosen, inference to the larger population of meadows within DEPO cannot be drawn. However, this index site will serve as an important case study for DEPO and provide valuable information about the hydrology, vegetation, and macroinvertebrates for this important meadow. For more information on other index sites within SEKI and YOSE, see Appendix 2.

1.5 Overview of Monitoring Approach

The wetland ecological integrity protocol seeks to monitor changes in the structure and composition of wet meadows and fens as they are influenced by natural and anthropogenic system drivers. This protocol incorporates measures of invertebrate community composition and abundance, plant community composition and abundance, groundwater and surface water hydrology, non-native plants, indicators of disturbance such as bare ground, and landscape context. The protocol narrative and associated SOPs include descriptions of activities related to site selection and instrumentation, field data collection, and basic data analysis and management.

The emphasis is on the measurement of community level floristic composition and abundance, terrestrial and aquatic invertebrate community composition, hydrologic metrics, and qualitative or categorical indicators of land use and wetland condition. Individual data sets can be analyzed for trends. In addition, data can be used to generate multi-metric indices of wetland ecological integrity, which facilitates comparisons of ecosystems with dissimilar species composition (EPA 2002b, Jones 2004, Faber-Langendoen et al. 2006, Rocchio 2006a, Rocchio 2006b, Rocchio 2007, Schweiger et al. 2016).

The survey design underlying the selection of sites will allow valid statements of status and trend at the network level. Vegetation will be assessed using a series of nested plots centered on a groundwater monitoring well. Vegetation data can be analyzed in a variety of ways to evaluate trends. For example, changes in species richness or species dominance can be analyzed in terms of individual species or functional types, such as wetland indicator status (Reed 1997) or seral status (Weixelman 2013). Similar kinds of approaches can be taken with invertebrate data. As with vegetation, diversity metrics may be useful for contrasting sites. Functional groups of species can be evaluated as indicators of condition (Scrimgeour and Kendall 2003, Whiles and Goldowitz 2005). In addition, diagnostic or indicator species may also present useful tools for inferring condition.

Because hydrologic regime is so important to the function of wetlands, the protocol calls for explicit evaluation of hydrologic regime through the use of ground water monitoring wells. The use of continuous data loggers will provide higher resolution data useful for understanding seasonal

variation in water table elevations. These data will allow for improved quantification of important hydrologic thresholds influencing wetland condition and ecological processes such as peat accumulation.

2 - Sample Design

2.1 Introduction

Inference regarding park- and network-level response of wetland ecological integrity will be made from future analyses of the extensive sites, which represent a probabilistic sample of wetland vegetation, hydrologic regime, and macroinvertebrates. These sites will be visited periodically (annually or every 4th year), and each sampling visit should be completed in less than 1 day. Site-level sampling uses a nested plot design centered on a groundwater monitoring well, which is randomly located within the target wetland type (fen or wet meadow) in a selected wetland. In addition to the core set of metrics (vegetation, hydrology, macroinvertebrates) that are recorded at each site, a set of semi-quantitative rapid wetland condition indicators are also recorded for the surrounding area and a set of photo points are collected to provide additional information about the condition of the target wetlands throughout the network.

In this chapter, we describe our sampling frame, the site selection procedure, the response and revisit design, and analytic approaches for trend detection, with specific procedures presented in the SOPs. A few protocol elements vary somewhat between parks due to differences in available data (e.g. historical grazing patterns, soils map, etc.), park management priorities, and logistical issues. These differences will be explained in detail within this narrative and associated SOPs.

2.2 Spatial Design

A spatial design, also referred to as the membership design, refers to how sample sites are selected and defines the area of statistical inference. We used a probabilistic design to ensure that extensive sites in YOSE and SEKI are randomly distributed across park landscapes. This approach will allow design-based analysis of data with an inference level at the scale of entire park and network landscapes (Dixon et al. 1998, Edwards 1998, McDonald 2003).

2.3 Target Population and Sample Frame

The goal of this protocol is to obtain inference on the condition of fens and wet meadows within the Sierra Nevada Network. The large parks (SEKI and YOSE) each have a sufficiently large number of wet meadows and fens such that a probabilistic sampling design is appropriate. However, Devils Postpile National Monument (DEPO), does not have a significant population of fens or wet meadows as defined in this protocol; instead, it has predominantly riparian wetlands that are small in size (Denn and Shorrock 2009). Thus, wetland sampling at DEPO will consist of one index site at the monument's largest wetland (Soda Springs Meadow). This index site will be visited on an annual basis by SIEN staff, and the types of data that are recorded will be identical to other extensive sites.

To develop the sampling frame for each park, we first prepared a comprehensive map of target wetlands (wet meadows and fens) and then filtered for wetlands of an appropriate size and grazing history (defined separately for each park). We used this approach in 2013 to develop the map and select sites at SEKI, and we subsequently used the same approach to develop a map and select sites at YOSE in 2014. To produce the map of fens and wet meadows at SEKI and YOSE, we mapped features using multiple years of both true color and color infrared aerial photographs (National Agriculture Imagery Program [NAIP], www.apfo.usda.gov), taken at a 1 meter or less resolution, and

data from existing GIS layers as reference (e.g. NPS vegetation maps, NWI data; Figure 3). We incorporated spatial data from our wetland protocol pilot study (2007-2009), which mapped wetlands in selected YOSE and SEKI watersheds (Jones 2011). We used a minimum mapping unit (MMU) of 0.5 ha to be consistent with the SEKI and YOSE vegetation maps (Aerial Information Systems and Environmental Systems Research Institute 2007). Each wetland polygon was classified as fen, wet meadow, or fen-meadow complex based on color signature, vegetation texture, landscape context, and local knowledge of the area (Table 2).

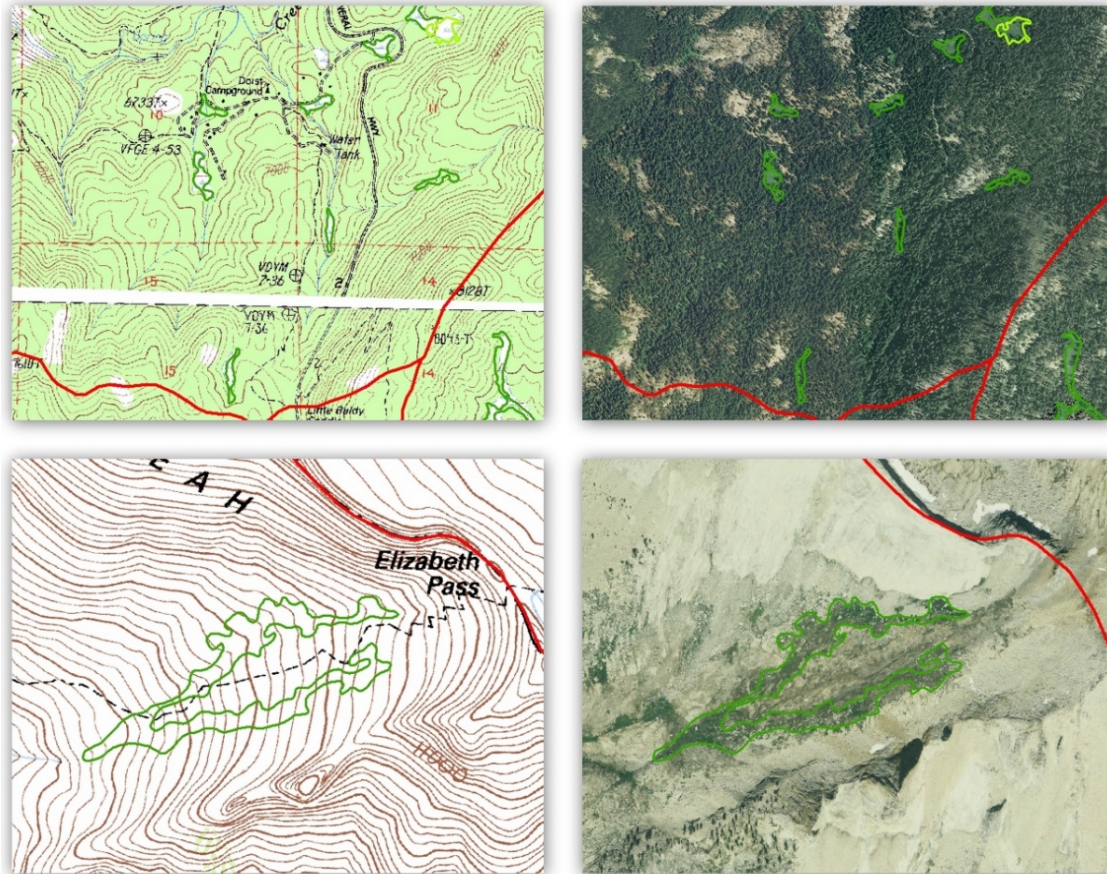


Figure 3. Example portions of the SEKI sampling frame. Digital Raster Graphics (DRGs; left panels) and Natural Agriculture Imagery Program (NAIP) imagery (right panels) for two areas illustrate delineated wetlands (green polygons). Red lines indicate watershed boundaries (Calwater 1999).

Table 2. Diagnostic characteristics used to differentiate wetland types in aerial photographs and the field.

Sample Type	Category	Wetland Characteristics	Wet Meadow	Fen
Aerial Photos	n/a	Geomorphic context	Moderate slopes, valley bottoms, saddles	Glacial lake basins, potholes, slopes associated with springs, toeslope settings
	n/a	Imagery characteristics	Difference in tonal characteristics from dry meadows and fens, landscape position	Difference in tonal characteristics from other wetland types; presence of hummocks or other microtopographic features
Field	Hydrologic	Mean water table depth	-30 to -150 cm	-30 cm to slightly inundated
	Hydrologic	Seasonal variation in water table depth	Low to moderate	Low to moderate
	Hydrologic	Primary hydrologic source	Groundwater	Groundwater
	Vegetation	Physiognomy	Herbaceous, shrub	Herbaceous, low shrub, forested
	Vegetation	Structural characteristics and species composition	High cover of facultative hydrophytes, often perennial grasses, sedges, and rushes; variable herbaceous dicot cover	High cover of obligate hydrophytes, typically clonal sedge.; bryophytes common
	Soils	Soils	Hydric mineral, often redoximorphic features indicative of fluctuating water tables, upper soils may or may not be saturated	Peat soils (histosols) containing 20 cm of peat in upper 40 cm of profile
	Other Characteristics	Other characteristics	Pocket gopher mounds	Microtopographic features (flarks, strings, water tracks)

After developing the comprehensive map of fens and wet meadows, we evaluated the classification accuracy of our map by verifying the assigned wetland type (fen or wet meadow) of 137 wetlands at SEKI (Pyrooz et al. 2015). This field work was performed by SEKI staff during summer 2013. The field component of the accuracy assessment of the wetland map began in YOSE in 2015 and was completed in 2017. Overall classification error rates in SEKI were low, and less than 20% of all meadows were misclassified. Initial results in YOSE indicate similar accuracy rates for distinguishing target vs. non-target wetlands, though accuracy rates among target wetland types (fen-meadow vs wet meadow) appear to be lower. Our classification accuracy rates exceed the minimum requirement of the National Map Accuracy Standards threshold of 80% across all map classes (Aerial Information Systems and Environmental Systems Research Institute 2007). The largest percentage of misclassifications occurred in areas that were mapped as fen-wet meadow complexes by the SEKI wetland map project, but were classified as wet meadow in the field. These fen-wet meadow complexes were correctly classified by the mapping project 69% of the time, illustrating the difficulty in identifying fen area from aerial imagery. The project to identify the target population of wetlands within SIEN parks is discussed in greater detail in: Wet Meadow and Fen Mapping of Sequoia and Kings Canyon National Parks: A Photo Interpretation Mapping Project of the Parks' Wetland Resources (Pyrooz et al. 2015).

To create our sampling frame from the comprehensive map, we filtered for wetlands of a minimum size and particular grazing history. At SEKI, we filtered for wetlands that are ≥ 0.5 ha and have been grazed less than an average of 0.5 nights/ha over the past 20 years (1993 – 2012). This reduced the sample size from 2307 to 1582 target wetlands (Appendix 3). We eliminated substantially grazed wetlands from the sampling frame because these sites would not yield valid information for monitoring because of their potential to confound trend analysis with grazing effects. To distinguish between grazed and ungrazed meadows at SEKI, we used data collected by the meadow monitoring program. These stock use data were summarized for the 2013 Wilderness Character Mapping Project (Tricker et al. 2014), which is part of the SEKI Wilderness Stewardship Plan (National Park Service 2015).

The YOSE sampling frame includes those wetlands that are ≥ 0.5 ha and have not been significantly altered by recent human activity based on expert opinion from YOSE NPS and USGS staff. The wetlands that were excluded from the YOSE sample frame were identified as part of a workshop held in Yosemite during the spring of 2014. Specific meadows were excluded from the sample frame based on whether they had experienced high recent stock use or extensive human impacts such as alterations in hydrology due to roads or dams. Only 5 % of the identified target wetlands were removed from the sample frame due to human impacts. The size and disturbance history filters reduced the sample size in YOSE from 1605 to 1379 target wetlands (Appendix 3). As a result of the different filters used to create the final sampling frames, the scope of inference differs slightly between SEKI and YOSE and is restricted to the population of ungrazed to lightly-grazed wetlands (SEKI) or wetlands with without significant known human impacts (YOSE) that are ≥ 0.5 ha in size. This means that results from this protocol will apply to a slightly different population of wet meadows and fens between parks because of the different criteria used to define these target wetlands.

Within each park, individual sites for field sampling were selected from the sampling frame using the Generalized Randomized Tessellated Stratification (GRTS) design (Urquhart et al. 1998). The GRTS sample was drawn using an unequal probability sampling design based on classes formed by wetland type (fen-wet meadow complex and wet meadow). This was done to ensure that a roughly equal number of fens and wet meadows were included in the selected sites. All wetlands within a specific wetland type had the same probability of inclusion, but fen-wet meadow complexes had a higher probability of inclusion than wet meadows due to their relative scarcity (11% and 19% of target wetlands were classified as fen-wet meadow complexes in SEKI and YOSE, respectively) within the target population. The mapping efforts at SEKI and YOSE revealed that pure fens are rare (2 of 1582 polygons in SEKI, 8 of 1379 in YOSE). Most fens in the Sierra Nevada are integrated with wet meadows forming fen-wet meadow complexes. Therefore, these pure fen sites were categorized as fen-meadow complexes and not treated as a separate wetland type for the sample site selection. Appendix 3 provides greater detail on the site selection process, including R code and data used to select sites, as well as a map and list of coordinates for the selected sites.

During the first visit to each wetland, we verify that the selected plot area contains an adequate percentage (>80 %) of the targeted wetland type. This ensures that the data that are being collected are representative of that target wetland type. For each selected wetland, we used GRTS to generate an ordered list of thirty sampling points. We refer to this second GRTS draw that identifies 30 random locations within the selected wetlands as the second stage GRTS draw. Each individual point is visited sequentially and classified as fen or wet meadow, or non-target vegetation. A groundwater monitoring well and associated monitoring plot is established at the lowest numbered point of the targeted type. For example, if it is a fen-wet meadow complex, the area around the lowest numbered point (of the 30 points) that is wet meadow is sampled and the lowest numbered point that is fen is sampled. If only one target type exists within the wetland, then only one plot is installed. If the area around the selected point contains <80% of the target type, crews must move to the next point in the list. If none of the 30 points in the GRTS list is found to contain >80% of the target wetland type, the crews evaluate whether shifting the sampling point a short distance would resolve the issue. Starting with the lowest of the 30 GRTS points, crews determine whether the criteria (>80% target wetland) can be met by moving the point up to 20 meters away (SOP 6). If this approach is unsuccessful for all 30 points, the wetland will be dropped and replaced with the next polygon from the GRTS order. R code for the second stage GRTS draw to determine plot location within selected sites is given in Appendix 3.

2.4 Response Design

A response design describes how to best record information from sample locations and includes metrics of the sample unit such as its shape, size, and number (Stevens and Urquhart 2000). Data are collected using a site-level response design developed to measure plant and macroinvertebrate community characteristics and water table depth. Our site-level sampling involves using randomly generated points to select locations for objective sampling. The reader is referred to Chapter 3 and associated SOPs for more detailed descriptions of the procedures involved in the extensive site response design.

2.5 Revisit Design

The revisit design outlines the pattern of temporal sampling for the selected sites (McDonald 2003). Sites are randomly assigned into groups called panels. Panels may be visited annually, visited a specific number of times and then dropped, or visited on an alternating schedule. Panel designs provide balanced replication of sites over time so that spatial and temporal effects may be modeled and trend may be accurately estimated. All sites within a panel are visited on the same schedule and within the same year.

Notation for panel designs will be as defined by McDonald (2003). Revisit schedules are summarized by the number of consecutive visits followed by the number of years the panel is not visited. Multiple revisit patterns are separated by a comma. For example, a revisit schedule of [1-0] indicates that the sites within the single panel will be revisited each year and never rotated out of the schedule. A revisit schedule of [(1-0), (2-3)] indicates that the revisit design includes an annual panel that is visited every year as well as a set of panels that are visited for two consecutive years then not visited for the following three years before being rotated back into the design. Several revisit designs were considered for this monitoring project and are described in Figure 4.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	48	48	48	48	48	48	48	48	48	48	48	48
ANNUAL TOTAL	48	48	48	48	48	48	48	48	48	48	48	48

a) Design [(1-0)]. Of the 48 total sites, 48 sites are visited annually.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	12	12	12	12	12	12	12	12	12	12	12	12
2	18		18		18		18		18		18	
3		18		18		18		18		18		18
ANNUAL TOTAL	30	30	30	30	30	30	30	30	30	30	30	30

b) Design [(1-0),(1-1)]. Of the 48 total sites, 30 sites are visited annually.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	12	12	12	12	12	12	12	12	12	12	12	12
2	9				9				9			
3		9				9				9		
4			9				9				9	
5				9				9				9
ANNUAL TOTAL	21	21	21	21	21	21	21	21	21	21	21	21

c) Design [(1-0),(1-3)]. Of the 48 total sites, 21 sites are visited annually.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	12	12	12	12	12	12	12	12	12	12	12	12
2	6						6					
3		6						6				
4			6						6			
5				6						6		
6					6						6	
7						6						6
ANNUAL TOTAL	18	18	18	18	18	18	18	18	18	18	18	18

d) Design [(1-0),(1-5)]. Of the 48 total sites, 18 sites are visited annually.

Figure 4. Four revisit designs (a-d) that were considered for this monitoring project. The total number of plots (48) visited across all panels is the same in each revisit design.

Revisit designs should be chosen by considering the outcome of interest and the time frame within which a trend estimate is desired. Periodicity in the response variables should be considered when

determining the time between survey visits for a panel. If measurements from sites are highly correlated between consecutive years, one might consider greater spacing between survey revisits to avoid this duplication of information, unless the measurement of that correlation meets a specific monitoring goal. If trend is more desirable than status, sites should be visited more often. If status is more important, then more sites should be visited each year. McDonald (2003) cited several sources indicating that the annual revisit panel should use roughly 50% of annual resources. However, Urquhart et al. (1993) found that 10-20% of annual resources could be used for sites visited every year.

There are several reasons why we decided on the same sampling frequency for most of the parameters in this protocol. The main reason is that, regardless of which revisit design was selected, the vast majority of the effort involved in sampling a site is in traveling to it, given the remoteness of most target wetlands within SIEN parks. Therefore, cost savings associated with not sampling certain parameters every time a site is visited are quite minimal compared to the benefits of reduced time to detect trend and consistency in data collection across sampling events. For some variables, such as groundwater depth where we are interested in not only changes in average water level through time, but changes in the rate and timing of drawdown throughout the growing season, we have chosen to sample a subset of sites (annual panel) more frequently by using data loggers that can record information hourly instead of annually. For other parameters where more frequent sampling would be beneficial (such as different measures of plant phenology), we have strived to find a balance between sampling frequency (the number of times we visit a site during a year or full panel rotation) and sample size (the number of sites we visit during the year or across all panels).

Preliminary power analysis of multiple WEI indicators demonstrated that the power to detect trend is similar for the revisit designs described in Figure 4 (Appendix 4). Revisit designs incorporating alternating panels produce tests of trend that are nearly as powerful as tests based on revisit designs for which sites are visited every year, the most powerful revisit design for trend detection (Urquhart and Kincaid 1999). Of the four revisit designs that were considered, the [1-0] and [(1-0),(1-1)] designs required substantial annual effort to obtain a total sample of 48 sites. These revisit designs would also incorporate fewer unique sites for estimation of annual status. The [(1-0),(1-5)] design would require six years to complete a full cycle. Up to 15 years would be necessary to complete data entry, data analysis, and reporting for trend estimation of two complete replications of the [(1-0),(1-5)] revisit design (Urquhart et al. 1993).

We chose the [(1-0),(1-3)] design because it optimized a shorter reporting cycle (4 years) and larger sample for status estimation. Figures 5 and 6 illustrate the final revisit design for the total SIEN sample, the annual sample across wetland types, and the annual sample within each park. This design results in a total sample of 60 unique sites across wetland types and parks. The total sample is split equally among YOSE and SEKI, with 30 sites in each park. Each park has one annual panel of 6 sites that are visited each year (i.e., annual panel) and four panels of 6 sites that are visited every fourth year (i.e., alternating panels). Each year, we sample the annual panel (12 sites across parks) and one of the four alternating panels (12 sites across parks) for a total of 24 sites. Figures 7 and 8 display a

map showing the selected sites distributed into panels for SEKI and YOSE, respectively. Sampling began in SEKI and DEPO in 2014 and in YOSE in 2015.

Panel	Year							
	1	2	3	4	5	6	7	8
1	12	12	12	12	12	12	12	12
2	12				12			
3		12				12		
4			12				12	
5				12				12
ANNUAL TOTAL	24	24	24	24	24	24	24	24

Figure 5. Final [(1-0),(1-3)] SIEN revisit design across parks and wetland types.

Panel	Year							
	1	2	3	4	5	6	7	8
1	6	6	6	6	6	6	6	6
2	6				6			
3		6				6		
4			6				6	
5				6				6
ANNUAL TOTAL	12	12	12	12	12	12	12	12

Figure 6. Final [(1-0),(1-3)] SIEN revisit design within each park.

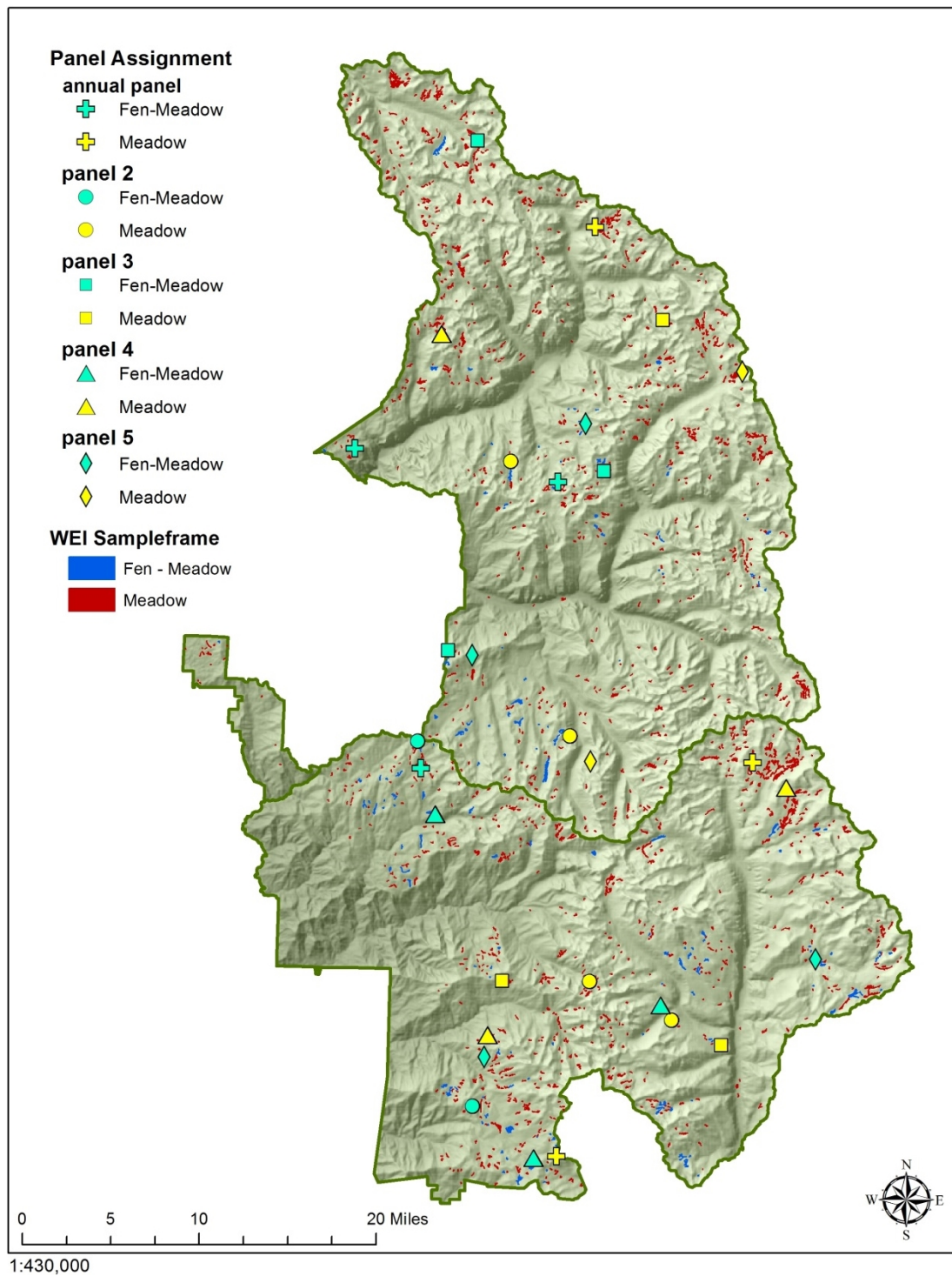


Figure 7. Distribution of extensive wetland sites in SEKI. Blue symbols indicate fen-wet meadow complexes and yellow symbols indicate wet meadows. Points in the “Annual” panel indicate sites that will be sampled every year. Points in panels 2 through 5 are rotating panels that will be sampled every 4 years. The sample frame used to select the sites is also shown by designated wetland type.

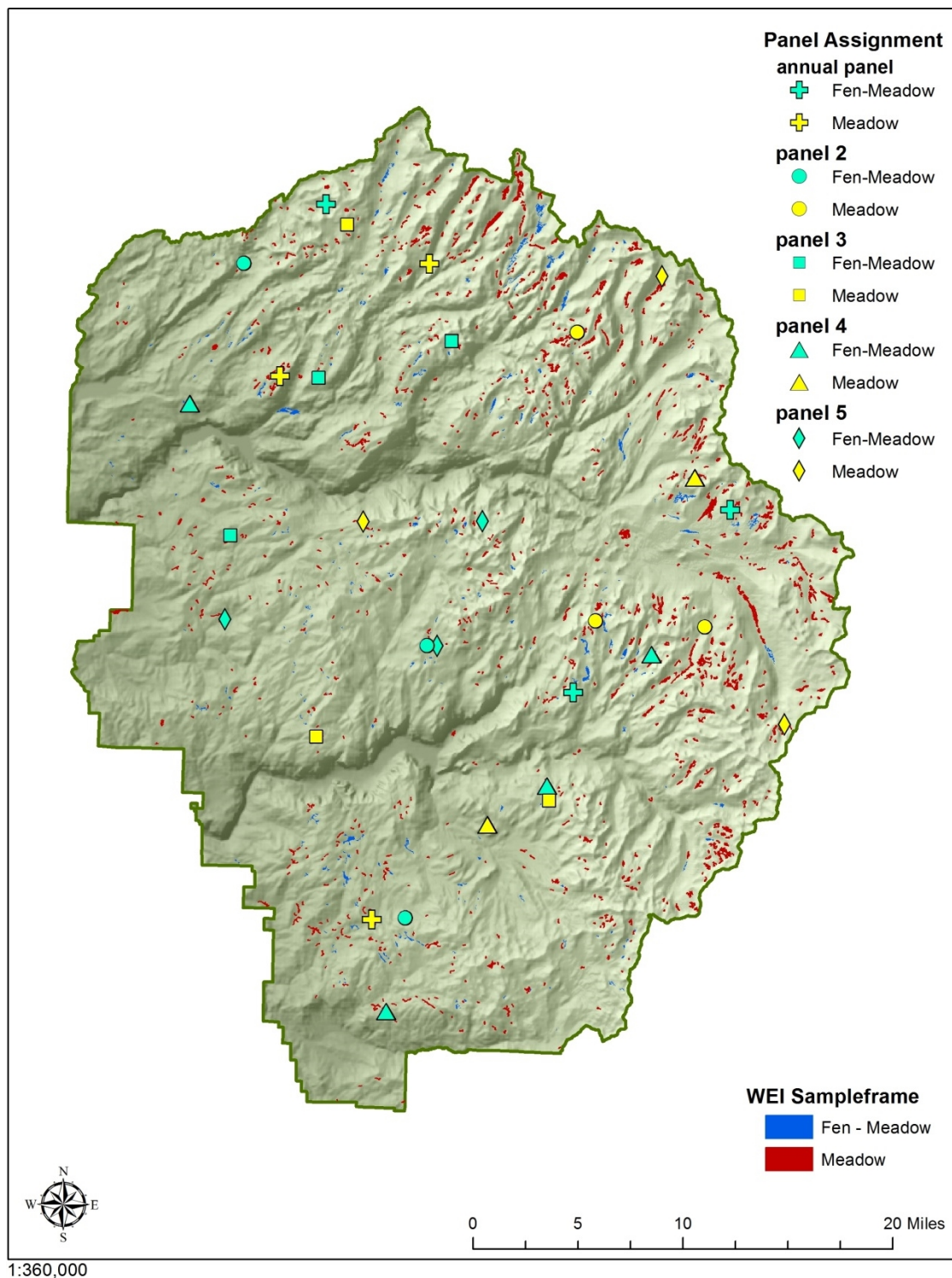


Figure 8. Distribution of extensive wetland sites in YOSE. Blue symbols indicate fen-wet meadow complexes and yellow symbols indicate wet meadows. Points in the “Annual” panel indicate sites that will be sampled every year. Points in panels 2 through 5 are rotating panels that will be sampled every 4 years. The sample frame used to select the sites is also shown by designated wetland type.

2.6 Hypothesis Tests for Trend Detection

The power to detect trends in vegetative, invertebrate, and hydrological outcomes was computed to inform decisions regarding the survey design, sample size, effect size, and Type I error rate. SIEN ecologists are most interested in testing the null hypothesis $H_0:\beta=0$ versus the alternative hypothesis $H_0:\beta\neq 0$. Hypothesis testing is subject to two types of errors: Type I errors and Type II errors. The Type I error rate is the probability that the null hypothesis is rejected when it is actually true. The Type II error rate measures the probability that a false null hypothesis is not rejected. Power is generally denoted as $1 - \beta$, where β is the probability that a Type II error is made. The power of a trend test measures the probability of detecting a significant trend given that a trend actually exists. Power may be calculated as a function of the Type I error rate, the precision of the tested estimate, and the desired effect size (Cohen 1988).

A number of nonparametric techniques are available for testing trend (Theil 1950, Yue and Pilon 2004) and are useful for providing a range of trend estimates for comparison, but these approaches do not allow estimation of components of variance that affect the ability to detect trend. Variance component estimation will be helpful if power is reassessed in the future using data obtained from the probabilistic survey design. The linear mixed model is used to estimate and test the significance of linear trend as well as to estimate the variance components across time and space.

The linear mixed model is a versatile modeling tool that incorporates fixed effects of the mean structure and random effects that form the variance structure. Variance sources may include site-to-site variation, year-to-year variation, random slopes over time for each site, and site-by-year interactions. We use the linear mixed model that omits within-year revisits as proposed by Piepho and Ogutu (2002):

$$Y_{ij} = \mu + W_j\beta + b_j + a_i + w_it_i + e_{ij},$$

where $i=1, \dots, m_a$; $j=1, \dots, m_b$; and

m_a = the number of sites in the sample;

m_b = the number of consecutive years in the sample;

w_j = constant representing the j^{th} year (covariate);

μ and β = fixed intercept and slope of the linear time trend;

b_j = random effect of the j^{th} year;

a_i = random intercept of the i^{th} site, independent and identically distributed as $N(0, \sigma_a^2)$;

t_i = random slope of the i^{th} site, independent and identically distributed as $N(0, \sigma_t^2)$;

e_{ij} = unexplained error, independent and identically distributed as $N(0, \sigma_e^2)$.

The outcome of interest, y_{ij} , is calculated as the natural logarithm of the outcome at site i and year j . The logarithmic transformation allows straightforward calculation of multiplicative annual change and net change. Variance components are estimated from this model. For some indicators, site-to-site variation is measured from a pilot data set with good spatial coverage, and year-to-year variation is modeled from pilot data with replication over time. The use of multiple pilot data sets may result in estimates of total error that exceed the true amount for more conservative power approximations.

However, the relative sizes of spatial and temporal variance components are important factors affecting power to detect trend, so this conservative approach was deemed appropriate.

The hypothesis test for trend detection is the F-test (or corresponding t-test) of the linear fixed slope estimate. When data are unbalanced as in a serially-augmented panel design, Spilke et al. (2005) recommend using Kenward-Rogers (1997) degrees of freedom with restricted maximum likelihood estimation.

2.6.1 Power Analyses

Network and park staff are interested in monitoring changes in wetland indicators over time. In addition to estimating the multiplicative trend of an indicator, SIEN staff plan to test a two-sided alternative hypothesis to determine if the estimated change is statistically significant. Power analyses were conducted to inform the selection of the preferred revisit design and to determine sample size (Appendix 4). Estimated variance components were used in large-sample power approximations for the [(1-0),(1-3)] revisit design over a 30-year monitoring period for increasing trends of 1%, 2%, 3%, and 4% annually. Code for approximating power was provided by Tom Kincaid of the Environmental Protection Agency and modified to include a random slope effect. The Type I error rate was set at 0.2 because the cost of taking management action based on erroneously detecting a trend that does not exist is less expensive than missing a real trend and incurring potentially long-lasting or permanent damage to wetland resources. A Type I error level of this size is reasonable for long-term monitoring of resources (Mapstone 1995, Buhl-Mortensen 1996, Gibbs et al. 1998).

Since the spatial distribution of the outcomes is unknown, incorporating GRTS into the power analysis would require simulating each outcome in space and drawing spatially-balanced samples from this surface for analysis. This approach would introduce unnecessary error into the power analysis, so the GRTS membership design was not incorporated into the power analysis. Because GRTS variance estimates should be smaller than variance estimates from simple random sampling (Stevens and Olsen 2003), variances obtained under the assumption of simple random sampling design provide conservative power approximations.

2.6.2 Pilot Data for Power Analyses

Two pilot data sets were used to estimate variance components affecting power to detect trend in a single hydrological indicator, well depth. One pilot data set was obtained from a three-year study in Tuolumne Meadows, YOSE, and the other pilot data set resulted from a four-year study of six meadows in SEKI (Table 3). Data used in the power analyses are provided in Appendix 4.

Table 3. Summary of hydrology pilot data used in power analysis.

Dataset characteristics	YOSE Meadows	SEKI Meadows
Years	2006-2008	2005-2008
Number of meadows	1 (Tuolumne)	6 (Cabin, Crescent, Dorst, Halstead, Log, Round)
Total number of wells	47	45

Vegetation indicators of interest included percent cover, species richness, and prevalence. Percent cover was measured for bare ground, bryophytes, perennial and herbaceous dicots, non-graminoid monocots, annual dicots, graminoids, and NWI wetland species categories. Pilot data for vegetation indicators were obtained from the initial pilot surveys conducted in YOSE and SEKI in 2007 and 2008, respectively (Jones 2011). These data provided the basis for estimates of site-to-site variation. A second data set taken from a long-term study of three SEKI meadows allowed estimation of temporal random effects variances for percent bare ground and overall species richness. NWI vegetation categories are provided in Table 4.

Table 4. NWI wetland plant indicator categories*.

Wetland Type (Indicator Code)	Definition
Obligate Wetland (OBL)	Occurs almost always (estimated probability 99%) under natural conditions in wetlands
Facultative Wetland (FACW)	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands
Facultative (FAC)	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%)
Facultative Upland (FACU)	Occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%)
Obligate Upland (UPL)	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.

*Accessed from <http://plants.usda.gov/wetinfo.html>.

Three indicators are of interest for invertebrate monitoring in SIEN wetlands: Margalef's family richness (MFR), percent dominance (PD), and percent predators (PP). All three indicators are measures for terrestrial invertebrates, while only MFR and PD are measured for aquatic invertebrates. Variance components affecting trend detection for these three indicators were estimated from SIEN pilot data. Surveys conducted in Tuolumne Meadows from 2004 through 2007 were used to estimate the variation of year random effects. Probabilistic surveys of 48 fens and 71 wet meadows conducted in YOSE and SEKI in 2007 and 2008, respectively, were used to estimate site-level random effects and their variances (Jones 2011). Different survey methods were used during this period in Tuolumne Meadows (Table 5), and any added variability in the outcomes of interest between the two methods will result in a conservative power approximation.

Table 5. Summary of invertebrate pilot data locations and methods by year.

Year	Location	Aquatic Survey Methods	Terrestrial Survey Methods
2004	Tuolumne Meadows	Throw-trapping	Vacuum netting
2005	Tuolumne Meadows	Throw-trapping	Vacuum netting
2006	Tuolumne Meadows	Throw-trapping	Vacuum netting
2007	YOSE (including Tuolumne Meadows)	D-frame netting	Sweep-netting
2008	SEKI	D-frame netting	Sweep-netting

2.6.3 Power Analysis Results

The variance components estimated from the pilot data described above provide the basis for large-sample power calculations. Several indicators demonstrated exceptional power for trend detection. These indicators include well depth; the NWI prevalence index; and percent cover of perennials, herbaceous dicots, and non-graminoid monocots. Power to detect trends as low as 1% annually may reach 80% in less than 15 years for these indicators (Appendix 4). Indicators that appear highly variable for long-term monitoring include percent of predatory terrestrial invertebrates and visual estimates of percent bare ground for vegetation surveys. Power of 80% or more is achieved for these and other indicators by sampling consecutive years over a 20 to 30 year period (Appendix 4).

This power analysis underscores the need for consistent sampling over a long time period for powerful trend detection. The most effective approach for achieving high power to detect trends over time is to ensure that at least the annual panel is surveyed each year using methods that are consistent over time.

3 - Field Methods

3.1 Introduction

This section provides an overview of field season preparation, sampling methods, and post-season processing of samples and data. More detailed descriptions of procedures are provided in individual SOPs.

3.2 Pre-Season Preparation

There are a wide variety of logistical issues related to protocol implementation that require significant preplanning if a sampling season is to be successful (For a detailed description of pre-season preparation activities see SOP 1). For example, hiring of personnel must generally begin months before the actual start of field sampling. Housing is generally competitive and must be secured well in advance. However, factors such as snowpack depth and the rate of melt, which influence accessibility and the appropriate time period for sampling vegetation and macroinvertebrates, can vary widely from year to year, necessitating a certain amount of flexibility in scheduling.

Given these issues, it is important that all appropriate preseason preparations be made as far ahead of time as feasible. Some important considerations include effective communication with park staff. Specific issues that may need to be addressed include housing for personnel, logistical support in the form of assistance from park employees, access to radios or other communication equipment, and any special access issues. The field readiness review, research permits and Wilderness compliance approval must be obtained prior to the start of field work. Note that these internal approvals require precise documentation of the number and location of proposed sampling sites. Any changes to plot locations should be relayed to the appropriate park staff as soon as is feasible.

3.3 Sampling Strategy and Response Design

The ideal field sampling strategy is one that allows for the collection of accurate and unbiased data in the most efficient manner possible. No single sampling design is the best in all environments and for all types of data. Factors such as vegetation type influence the performance of different plot types for the collection of vegetation data. In addition, different sampling methods are needed for different organisms and functional groups (e.g. terrestrial versus aquatic insects).

Our goal of providing network and park level inferences necessitates random placement of plots throughout the parks' wet meadow and fen habitat. Accessing these sometimes remote sites on foot is extremely time-consuming and thus limits the amount of time (sampling effort) that can be expended in any particular site. As a consequence, there are unavoidable limits to features included in the site level response design. The minimum required sample sizes, the need for revisits for QA/QC purposes and model parameterization, and the logistical limitations imposed by working in large, wilderness parks, all contribute to the critical need that the response be simple to lay out and conducive to efficient, accurate, and repeatable data collection.

The response design that was selected after extensive review entails the establishment of long-term, nested plots centered on a groundwater monitoring well (Figure 9). To minimize variability and

ensure the greatest statistical power for trend detection, it was decided that fixed plots were preferable to designs involving new plots for future revisits. A nested plot design was selected because no single plot size is ideal for all organism types. Achieving consistency and precision when making cover measurements in smaller plots is typically easier than in large plots; however, large plots are more efficient at capturing species diversity, especially when travel time is considered as part of the sampling effort (Barnett and Stohlgren 2003). Thus, a nested plot design is used, combining the desirable features of both small and large plots (Stohlgren et al. 1997).

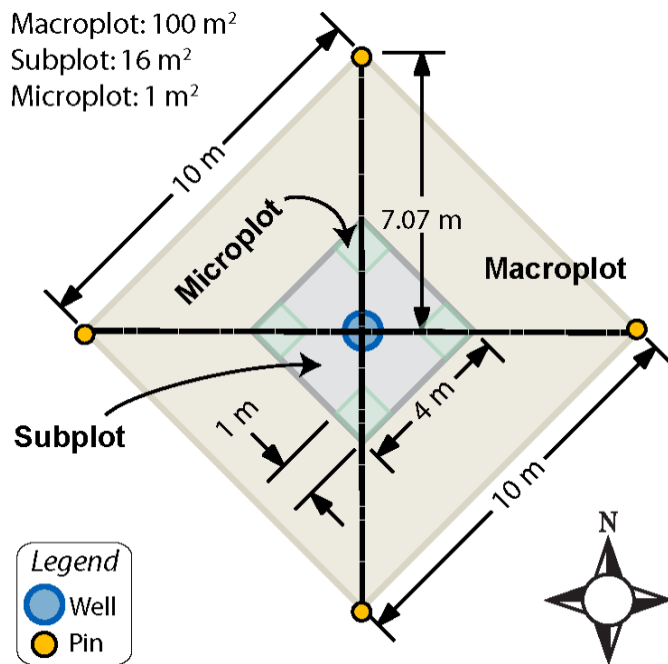


Figure 9. Layout of nested plots centered on a groundwater well.

There are many examples of nested plot designs in the ecological literature. For example, the modified Whittaker design has been widely used in vegetation studies (Stohlgren et al. 1995, Stohlgren et al. 1997, Stohlgren et al. 1999). However, the time required to lay out the modified-Whittaker design in the field and to collect data from all the different subplots made the design impractical. Other sampling strategies, such as the use of transects, were rejected, in part to maintain focus on the groundwater monitoring well and facilitate the integration of vegetation, hydrology, and invertebrate data.

The final plot design that was selected incorporates three plot sizes (Figure 9). The largest plot, which we refer to as the “macroplot”, is square in shape and has an area of 100 m². Contained within it is a 16 m² “subplot”, and, lastly, four 1 m² “microplots”. Long-term monumenting of the plot is achieved via four capped rebar placed in the corners of the subplot and the capped groundwater monitoring well. Pin-flags are placed temporarily at the macroplot corners as well as the microplot corners to aid in plot layout, then removed following sampling, leaving only the rebar marking the subplot and the well as permanent installations. More details regarding the site level design are presented in SOP 10.

The general sampling procedure is consistent, regardless of wetland type. The sampling schedule for extensive sites will be spread over several years using a panel design. Basic information regarding each extensive site including maps, directions, and general descriptions of wetlands will be recorded. In addition, during the process of site selection (Appendix 3), a list of “over sample” wetlands will be prepared, for instances of sample frame error or inaccessibility.

3.4 Overview of Workflow at a Site

A standard workflow will be followed when collecting data in the field (Figure 10). This will help ensure that all data are collected and that they are of the highest quality possible. Crews must take particular care to minimize disturbance in the course of laying out plots and collecting data to try and minimize any effects from the sampling itself (Wolski et al. 2004). There are several additional steps involved in the initial site establishment, including well installation and the establishment of plot monuments that occur only during the initial visit. However, data collection methods such as vegetation and invertebrate sampling are the same whether a site is newly established or being revisited. Figure 10 illustrates the general sequence of events upon visiting a site, and Figure 11 illustrates the sequence of events for determining the location of a new plot. Specific procedures for each step in these figures (e.g. plot establishment, plot layout) are described in detail in SOPs 7, 8, and 10. Data collection procedures are detailed in SOPs 9, 11 - 13, and 15 - 19.

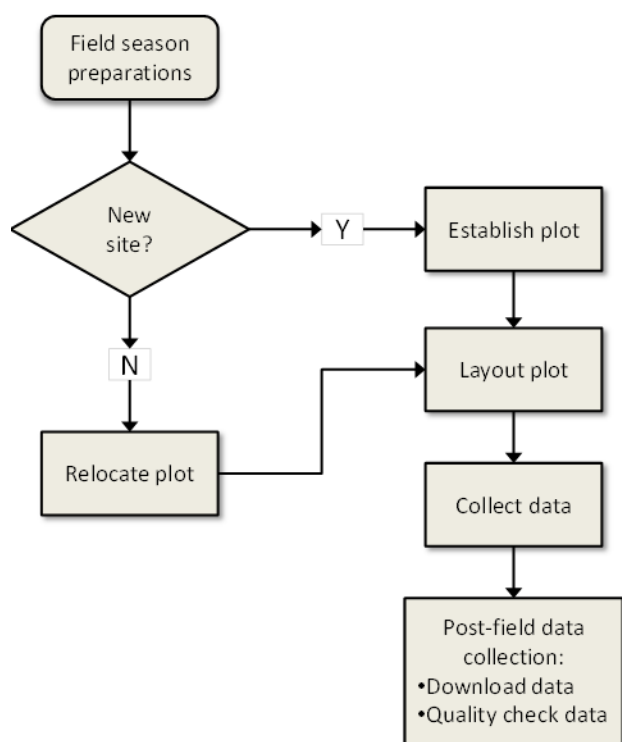


Figure 10. General sequence of events upon visiting a site.

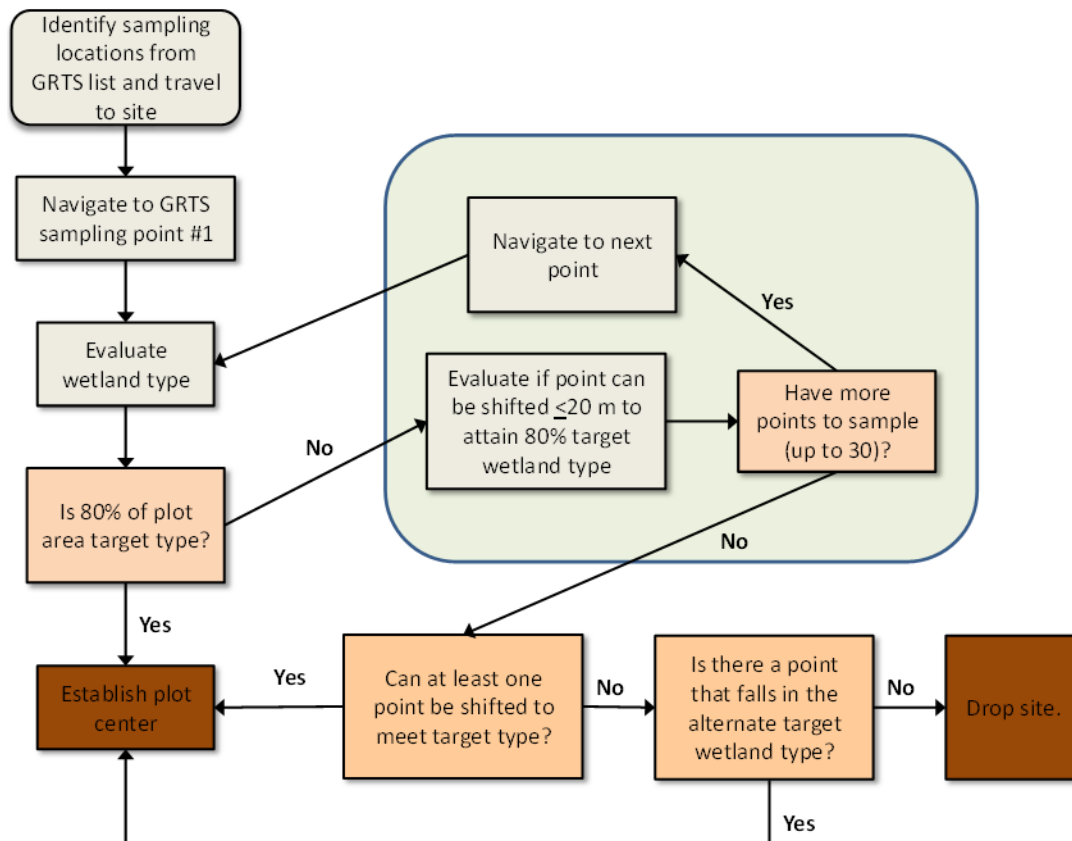


Figure 11. General sequence of events for determining the location of a new plot.

3.5 Resource Protection Overview

All efforts aimed at minimizing the impact of crew members on SIEN wetlands must be taken. The following guidelines will be implemented to ensure that no impacts to important cultural or biological resources occur during sampling:

- No historical or prehistorical archeological artifacts or historical features will be disturbed. Archeological clearance will be obtained from the parks prior to any planned installations.
- Wells will be installed with minimal soil disturbance using an auger.
- When wells are installed, soil will be placed on a polytarp and returned to holes with any excess scattered following installation.
- Well casings will be cut within 6" of ground surface, capped and camouflaged with earth-toned spray paint.
- Vouchers will be collected from outside the plot boundaries whenever possible (SOP 14). If <20 individuals of the plant are noted within the area, plants will be photographed rather than collected.
- No flagging or other markers beyond those specified by the protocol will be left on site.

- All staff and volunteers will be instructed in appropriate safety and Leave-no-trace© practices of wilderness travel and camping.
- Proper precautions, specified by the network or individual parks, will be taken to minimize transfer of organisms among wetlands (SOP 5). Boots and gear will be examined for seeds or other propagules between visits to different sites. Decontamination procedures aimed at preventing the spread of chytrid fungus will be followed.

The groundwater monitoring well serves as the main plot marker, indicating the macroplot center, with additional plot markers used to ensure plots revisited in the future are set up in the same location, reducing variability. Data loggers, where used, will be installed within well casings with no additional installation required to support them. The protocol allows for adoption of methods with fewer impacts if new technologies become available. Should any sites be omitted from sampling in the future, the Network commits to removing all plot markers and the well.

Crews will be made aware of any threatened, endangered, or rare species that may be in the vicinity of sampling locations. During plot establishment, care will be taken to ensure that no sensitive resources are negatively impacted. Where potentially important or sensitive resources have been encountered, the location is recorded with a Global Positioning System (GPS) waypoint and a photo taken. The location of any sensitive resources should not be communicated to anyone other than official NPS staff.

3.6 Data Management in the Field

3.6.1 Use of Forms

A variety of field data forms are provided for field data collection. Electronic versions have been developed to facilitate data collection using a hand-held computer and will be the primary method used by field crews. Even though the use of a hand-held computer for data collection is preferred, an adequate supply of paper forms will be carried by crews so that sampling is still possible if circumstances prevent use of electronic equipment. A portion of field data forms should be copied to waterproof (e.g. Write-in-the-Rain©) paper in case of inclement weather. More specific instructions for completing data forms are provided in SOP 4 and in the individual SOPs describing protocol metrics. Copies of the paper forms are provided in SOP 4.

3.7 Establishing/Relocating Sites

Dossiers, which include maps of each site and relevant metadata such as driving directions and estimated travel time, will be prepared for sites prior to the start of field work. Along with the sampling schedule, these will be used to generate the list of points for upload into a GPS unit. Driving directions to park study areas are discussed in SOP 1. Travel times can be substantial and should be carefully planned. Access to sampling areas may require hiking across rugged terrain, backcountry camping, and field teams must be prepared for challenging weather conditions, including extreme heat, cold, rain, and snow. Each team member should maintain a supply of warm clothes and rain gear, clothing that limits exposure to the sun, and plenty of water. Safety procedures outlined in SOP 22 and the SIEN Safety Plan (Chung-MacCoubrey et al. 2012) should be adhered to, including maintaining close communication with office-based park and network points-of-contact,

such as park resource managers, regarding field schedules and check-in/check-out times. Park hazards, including emerging threats such as extreme weather or fire hazards, should be discussed with network and park staff during a debriefing prior to initiation of field work, and throughout the duration of sampling, as necessary. First aid and other safety equipment must be kept in project vehicles and easily available at all times.

Once all pre-visit tasks are taken care of, the crew will use the GPS to navigate to the first target point in the GRTS sample point list when establishing a site or to the coordinates of the previously established site when revisiting. Once on site, the crew will navigate to the first GRTS point and evaluate whether the point falls within the target wetland type (i.e. fen or wet meadow; Figure 11). Methods for determining the target status are presented in SOP 6. If at least 80% of the area within a macroplot is of the target type and the plot is contained within the wetland boundaries, the point is marked as the plot center and sampling is conducted. If the point does not meet these criteria, the next point on the numbered list is selected and evaluated using the same steps described above. If no points meeting the criteria for inclusion are encountered, and no points can be shifted a small distance (≤ 20 m) to meet these criteria, the wetland is rejected.

If selected for sampling, the crew will follow a standardized set of procedures to monument the plot and collect the required information (Figure 12). First, plot center and well location are temporarily marked. Distinctive witness features such as large trees or rock outcrops on the margins of the wetlands are identified and their coordinates are recorded using a GPS. The azimuth and distance from the well to witness features is determined using a compass and by pacing, or if practicable, running a tape. Distances and azimuths are recorded on a sketch map and any supplemental photographs useful for documenting site location are taken. If points are rejected, the reason why is recorded.

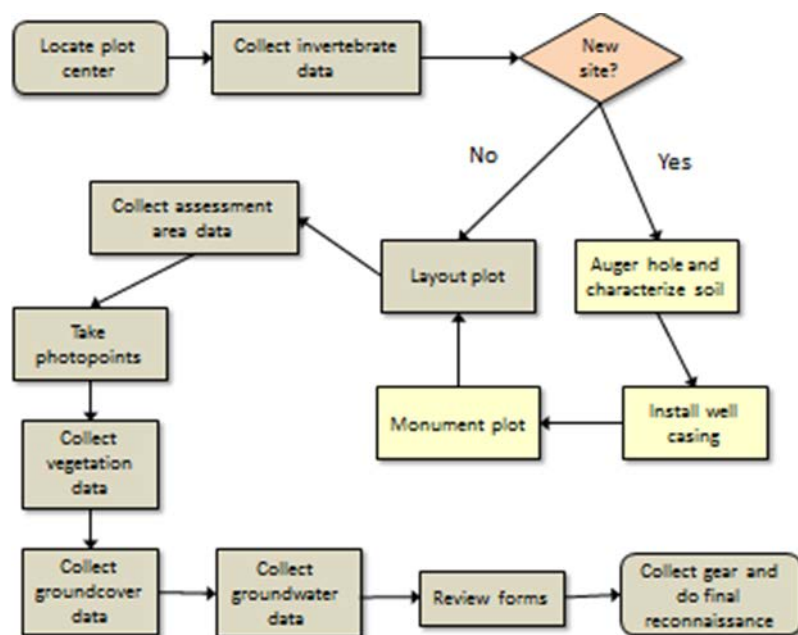


Figure 12. General sequence of events for monumenting a new plot and collecting data.

As part of the initial assessment of the site during establishment, general soil characteristics (e.g. texture, color, etc.) and presence of hydric soil indicators of soils excavated from the well hole are recorded. Soils develop certain diagnostic characteristics when subject to extended periods of saturation and/or inundation. Termed hydric soil indicators, they are a primary indicator used to evaluate soil saturation and water table depth for wetland assessment and delineation procedures (Environmental Laboratory 1987, USDA NRCS 2006). Examples include gleyed soils or soils with abundant redoximorphic features such as oxidized root channels or mottles (Tiner 1999).

The crew member responsible for soil descriptions will create a sketch of the soil stratigraphy, noting the depth, texture, matrix color, presence and type of hydric soil indicators, and, in peat soils, the depth and degree of decomposition of peat layers. In fens, the degree of humification (decomposition) in peat soils is evaluated using the von Post scale (Ekono 1981), described in detail in SOP 8. The higher the value on the von Post degree of decomposition scale, the greater degree of decomposition. Hydraulic conductivity of peat soils decreases with greater levels of decomposition, influencing hydrologic patterns (Malterer et al. 1992).

3.7.1 Rejecting or Moving Sites

When first visited, sampling points are evaluated to confirm that they are of the target wetland type (Figure 11) using information in SOP 6. If the point appears to be of the target type, but cannot be sampled because of shallow soils that prevent the installation of a well (soils < 1 m), safety, or accessibility issues, then the point can be rejected. Crews must record why the site was rejected on the Site Establishment Form, and select a replacement site from the list of “oversample sites.” Sites should generally not be dropped unless extenuating circumstances exist, such as the lack of target wetland habitat, safety, or resource protection issues.

3.8 Site Reconnaissance and Rapid Assessment Metrics

Once a point has been selected for sampling, and the plot center temporarily marked, invertebrate sampling is conducted. The crew then performs an initial site assessment and reconnaissance. The objective is to record data useful for classifying and characterizing sites, note the presence of stressors or disturbances including invasive species, and record broad indicators of condition. These include the presence/absence of point source discharge, ditches/diversions, current signs of pack stock grazing, trash, roads or trails, and evidence of fire or flood. These assessment metrics include both site-level data and information gained through analysis of maps or GIS data and are largely derived from the California Rapid Assessment Method (CRAM; information found at <http://www.cramwetlands.org>). Land use within a 1-ha circle (56.4 m radius) centered on the groundwater monitoring well is also assessed. This includes estimates of the assessment area used for dispersed recreation, developed recreation, urban/suburban development, and in a natural condition (SOP 7). Crews will record the presence and condition of buffers while conducting site assessments. The presence and integrity of natural buffers around the margins of wetlands can be used as an indicator of wetland condition (Fennessy et al. 2004). Buffers may mitigate anthropogenic effects to wetlands by helping attenuate overland flow, filter sediments and pollutants, and by providing important habitat features for wildlife species (Semlitsch and Bodie 2003, Miller et al. 2006, Liu et al. 2008). The shortest straight-line distance between a sampling point (well) and human disturbance

(e.g. road, trail, ditch, etc.) and the slope is measured and recorded for each of the four plot quadrants. This must be done in the field but may be informed through the use of maps or aerial photographs. In addition to buffer width and the occurrence of different land use types, presence of different structural patch types found within the 1-ha assessment area are recorded. These include hummocks/strings, pools/flarks/water tracks, floating mats, cobbles and/or boulders, unvegetated flats, animal mounds or burrows, and standing snags. Each of these metrics can be used to inform both historical and current condition of the wetland. Finally, plant layer information related to canopy height, and the estimated cover (m²) of invasive species is recorded within the assessment area.

3.9 Plot Layout

Once the plot center point/well location is established (or relocated for revisits) and the invertebrate sampling has been completed, the crew lays out the measuring tapes using a compass and establishes the boundary of the macroplot. The general steps in plot layout are presented in Figure 13. Detailed instructions for plot layout are provided in SOP 10.

Set-up sequence

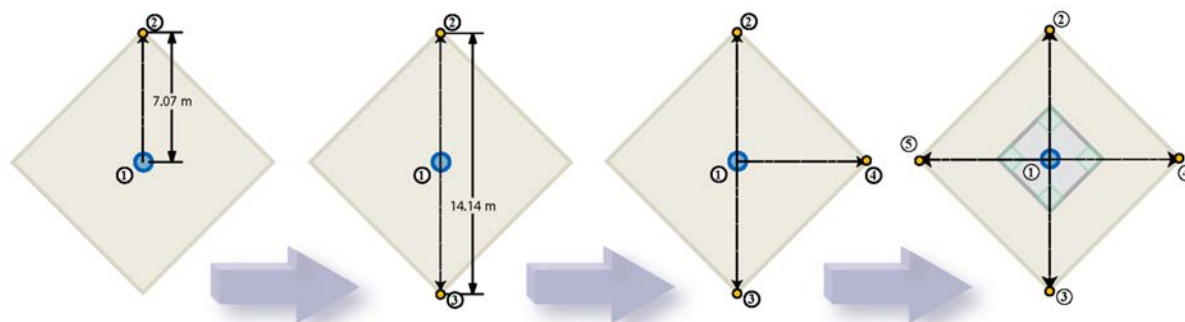


Figure 13. Overview of steps in laying out a plot. Tapes are laid orthogonal to one another along cardinal directions. Once corners are established, tapes can be used to define the edges of the macroplot. Distances to subplot corners/microplot corners are measured from the well using tapes.

3.10 Site Photos

Although they have definite limitations, photographs provide a valuable tool for evaluating ecological change (Mast et al. 1997, Bradford 1998, Horsted and Grafe 2002). For example, processes such as tree or shrub invasion are readily visible on photographs (Jakubos and Romme 1993, Vale and Vale 1994, Zier and Baker 2006). Properly framed and documented images also can be useful for relocating monitoring sites.

The protocol involves collecting one photo of the entire macroplot 2-5 meters from the south corner of the plot (Figure 14A), a downward looking photo taken roughly 0.5 m above each 1x1 m microplot (Figure 14A), eight photo points at fixed azimuths from the center of the plot module (Figure 14B), and a photo from plot center of any landmarks used to help locate the plot (Figure 14C). A detailed discussion of photo points is presented in SOP 11. Specific methods for camera use will vary depending on model. Manufacturer instructions must be reviewed and followed.

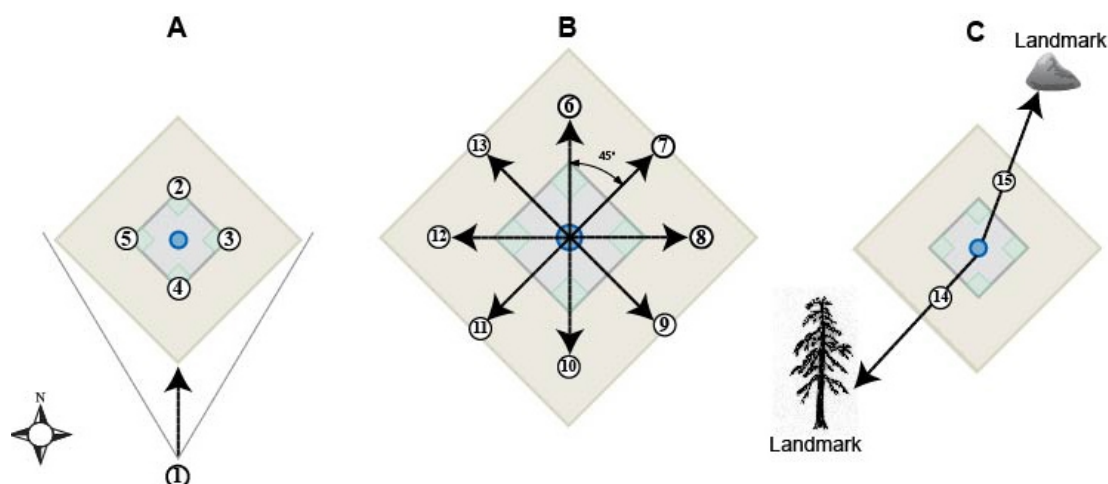


Figure 14. Overview of photo points taken at sampling sites. One photo is taken 2–5 meters south of the south plot corner and one downward-looking photo is taken over each microplot (A). Photos are taken in sequence clockwise from due north from the macroplot/subplot center (B). Photos are taken from the well of landmarks used to relocate plot (C).

3.11 Macroinvertebrates

The techniques that we are using to sample macroinvertebrates integrate over a relatively large sampling area. Macroinvertebrate sampling occurs immediately after arriving at the plot so that there is as little disturbance of the insect communities as possible before sampling occurs. A single sweep net sample (SOP 17) covers an area that is 20% greater than the associated macroplot, i.e., all of the macroplot, plus some habitat that directly adjoins the macroplot and is used to sample terrestrial macroinvertebrates. Baits (SOP 18) are also used to attract ants and other fauna from the same area. Aquatic sampling (SOP 16) collects fauna from a 1.5 m² area and occurs at the nearest location of seasonal standing water to the macroplot. Once the samples have been collected and returned to the lab, they are sorted and processed for identification by subject matter experts (SOPs 16 – 18).

3.12 Groundwater

One of the first tasks following macroinvertebrate sampling is the installation of a groundwater monitoring well at the center of the macroplot (SOP 8). During well establishment, soil characteristics from the soil core augured for the well casing will be described on site. Variables of particular interest include gross stratigraphy and make-up of the soil profile (e.g. texture, color, organic matter content) and the presence of hydric soil indicators.

Once the well is installed data loggers are used to measure water table levels on an hourly basis (SOP 15). Continuous data is far more useful than isolated measurements, as seasonal fluctuations in water tables are often more important than mean, min, or max levels. These data loggers must be downloaded and maintained on a regular basis (every subsequent visit to the site). Each data logger needs to have adequate battery life and memory to store hourly measurements for several years. At this time, data loggers will be at the annual panel sites only, though they may be expanded to alternating pane sites in the future if funding allows. At all sites, manual measurements of water table depth will be recorded during each site visit following procedures outlined in SOP 9. For well

measurements taken during the same visit as well installation, measurements will be made as long after well installation as possible to allow time for groundwater equilibration.

3.13 Vegetation

Vegetation can be an excellent indicator of changes in key environmental drivers such as hydrologic regime (Cooper 1990, Ahn et al. 2004, Auble et al. 2005). Given the objectives of the wetland monitoring protocol, we selected a sampling design using nested plots of varied size for sampling vegetation. Because hydrologic regime is such an important driver of vegetation in wetlands, plots are centered on the groundwater monitoring well. A fixed plot design is used, regardless of vegetation type, providing the largest plot and nested subplots fall within the target wetland type. Ideally, stratification would also be done by vegetation community, allowing for the sampling of more homogeneous vegetation units (e.g. Sikes et al. 2011). However, due to practical and statistical constraints, the protocol does not stratify at a finer scale than wetland type.

Percent cover of woody and herbaceous species is visually estimated to the nearest percent in the small microplots (1 m²). In the 100 m² macroplot percent cover is visually estimated using a modified Daubenmire cover class (<1, 1-5, 6-25, 26-50, 51-75, 76-95, 95-100; Daubenmire 1959). Species are defined as woody or herbaceous based on the USDA NRCS PLANTS Database definition (USDA NRCS 2013). Bryophyte percent cover species is estimated in the microplots only and species presence/absence is recorded at the macroplot scale. During dry periods, mosses are difficult to observe, reducing the accuracy of cover measurement. Therefore, sampling will be scheduled to occur as early in the growing season as feasible given environmental and logistic constraints. The procedure for sampling bryophytes in the protocol employs an approach whereby samples of mosses are collected from outside of the macroplot, packaged, and sent for outside identification by bryological experts (Doubt and Belland 2000). Voucher specimens of all vascular and non-vascular plants recorded in plots will be collected off-plot and submitted to herbaria for subsequent identification and archiving (SOP 14, SOP 20).

3.14 Auxiliary Plot Data

Several additional metrics including tree seedling composition and abundance, type and percent cover or non-vegetation groundcover, and average peat depth within the macroplot are recorded (SOP 19). Live tree seedlings (<1.37 m) are counted by species and size class within the subplot and recorded. The count and total percent cover class of all mature trees by species is also estimated within the macroplot. If a majority of the tree's base is within the plot, it is included in the count. Any tree cover that is within the plot is included in the estimate of percent cover, regardless of whether an individual is rooted in the plot or not.

The frequency of occurrence of all types of ground cover within the macroplot is recorded using a point intercept sampling method. Within each macroplot a 10 x 10 m grid of 100 points is established using string and pin flags. The number of pin hits of each ground cover type is recorded. Only one type can be recorded at each location. Types of groundcover include:

- Live vegetation

- Rock: rock fragments larger than 6.4 cm (~2.5 inches) diameter
- Gravel: rock fragments between 2 mm - 64 mm diameter
- Bare Ground: bare mineral soil less than 2 mm diameter (not rock or gravel)
- Bare Peat: in practice, this is usually peat that has been exposed by disturbance, such as being dug up by animal activity
- Litter: in the context of this protocol, litter includes all downed dead plant herbaceous material laying on the soil surface plus all woody material less than 1 cm diameter
- Standing Dead: standing dead plant material
- Wood: dead, down wood that is greater than 1 cm diameter

Peat depth is measured at five randomly selected points from the 100 point grid used to estimate ground cover within the macroplot. A random number table is used to select the five points and peat depth up to 1.5 m is estimated using a soil probe (Lindsay 2010). Another commonly used approach to measure peat depth is through the use of ground penetrating radar (Rosa et al. 2009). However, given the remoteness of our sites and the cost of this type of equipment, this option was not feasible for this protocol. The spatial and temporal variability of the peat measurements will be assessed to determine whether they can provide an accurate and repeatable estimate of average peat depth within a plot and whether a detectable trend can be measured over time or among sites.

3.15 End-of-Season Procedures for Processing Data and Samples

To establish and preserve data integrity, it is essential that field crews follow a basic set of procedures for processing samples and data collected in the field. Upon completion of sampling and prior to departing the field site, all electronic and paper data forms must be examined for completeness. A reconnaissance of the site must be conducted by crews to ensure that no equipment is left behind.

Field crews will follow a rigorous set of procedures to ensure that all data are properly downloaded, archived, and fully documented. All relevant metadata needs to be completed and included with the data sets (see SOPs 4, and 24 – 26 for details). All specimens that have been collected and identified must be properly catalogued. Unknown specimens need to be sent to experts for taxonomic identification as soon as feasible.

Plants must be transferred from field presses to a wooden plant press promptly for proper storage and mounting. Specific guidelines for voucher specimen collection, preparation, identification and storage are detailed in SOP 14. The standards followed for archiving plant materials will vary by institution, but all labels must include details regarding the collector, date, and place of collection, purpose of collection, and other information as required. More detailed descriptions are presented in SOPs 16 – 18 (invertebrates) and 20 (plants).

Vegetation and invertebrate databases need to be updated to account for the identification of unknowns. For all vouchers, specimens need to be properly prepared and labeled for accession to

herbaria or museum collections. Plant specimens collected for identification should be identified as soon as possible. Voucher specimens require long-term storage and cataloging. Long-term storage of the plant vouchers will be in the YOSE herbarium or the SEKI herbarium, depending on where they were collected. Vouchers collected at DEPO will be accessioned at SEKI. Any macroinvertebrate specimens not destroyed during identification will be stored as part of the respective Parks' museum collections.

At the end of the field season, all equipment needs to be cleaned and inventoried for winter storage. Broken or obsolete equipment needs to be identified and repaired or replaced. Soil must be removed from shovels, augers, and other tools and lubricant (e.g. WD-40) applied to metal fittings to inhibit rust formation. Batteries must be removed from all electronic equipment prior to storage during the off-season.

4 - Data Management, Analysis and Reporting

This chapter describes the data management procedures for the Wetlands Ecological Integrity monitoring protocol, including the data management roles and responsibilities for various staff involved with the protocol. Additional details and context for this chapter can be found in the SIEN Data Management Plan (Cook and Lineback 2008), which describes the overall information management strategy for the network.

4.1 Information Management Life Cycle

Data go through successive stages as a project progresses. These stages can be viewed as a cyclic process tied to the annual collection and management of wetlands monitoring data. The major stages in this cycle are described and summarized below (Table 6) and illustrated in Figure 15.

Table 6. Data management activities and responsibilities associated with Wetland Ecological Integrity monitoring.

Activity	Description	Responsibility
Acquire data	Data are acquired in digital or analog form. Digital data can be recorded on handheld computers, tablets, or laptop computers. Analog data are entered on field data sheets.	Project Lead, Crew Lead, Crew Members
Archive raw data	Copies of all raw data files are archived intact. Digital files are copied to the digital library (the set of LAN folders created for the project); hard copy forms are either scanned and placed in the digital library (preferred) or are copied and placed in the archives. Archiving or scanning of hard copy data forms may occur at the end of a season as a means of retaining all marks and edits made during the verification and validation steps.	Crew Members, Crew Lead, Data Manager
Enter/import data	Analog data are entered manually and digital data files are uploaded to the working database.	Crew Members, Crew Lead
Verify, process, and validate	Accurate transcription of the raw data is verified; data are processed to remove missing values and other flaws; and data are validated through visual inspection and queries to identify missing data, out-of-range values, and logical errors.	Project Lead, Crew Lead, Crew Members, Data Manager
Documentation and certification	Develop or update project metadata and certify the data set. Certification is a confirmation by the Project Lead that the data have passed all quality assurance requirements and are complete and documented. It also means that data and metadata are ready to be posted and delivered.	Data Manager, Project Lead

Table 6 (continued). Data management activities and responsibilities associated with Wetland Ecological Integrity monitoring.

Activity	Description	Responsibility
Upload data	Certified data are uploaded from the working database to the master project database. This step might be skipped for short-term projects where there is no need to distinguish working data for the current season from the full set of certified project data.	Data Manager
Archive versioned data set	The SIEN Project Data Certification Form is completed (SOP 28). Copies of the certified data and metadata are placed in the digital library. This can be accomplished by storing a compressed copy of the working database or by exporting data to a more software-independent format (e.g., ASCII text).	Data Manager
Disseminate data and update national databases	Certified data and metadata, and digital image products are posted to national repositories (the NPS Data Store, Biodiversity Data Store, NPS Focus) to make them more broadly available to others. National databases, including NPSpecies, NPSTORET, and ANCS+ are updated with data obtained from certified data sets.	Data Manager
Reporting and analysis	Certified data are used to generate data products, analyses, and reports, including semi-automated annual summary reports for monitoring projects. Depending on project needs, data might be exported for analysis or summarized within the database.	Project Lead, Data Manager
Distribute information products	Information products such as reports, maps, and checklists are disseminated to the public through the SIEN website and NPS Focus, and catalogued in NatureBib.	Data Manager
Share data and information	Data, metadata, reports and other information products can be shared in a variety of ways – by FTP or mailing in response to specific requests, or by providing direct access to project records to park staff and cooperators.	Project Lead, Data Manager
Track changes	All subsequent changes to certified data are documented in an edit log, which accompanies project data and metadata upon distribution. Significant edits will trigger reposting of the data and products to national databases and repositories.	Data Manager, Project Lead
Store products	Reports and other data products are stored according to format and likely demand, either in the digital library, on off-line media, or in the document archives.	Data Manager
Catalog project products	Catalog products and all information associated with a project, including results of analyses and paths of dissemination. Project tracking databases can be useful tools for this purpose.	Data Manager, Project Lead

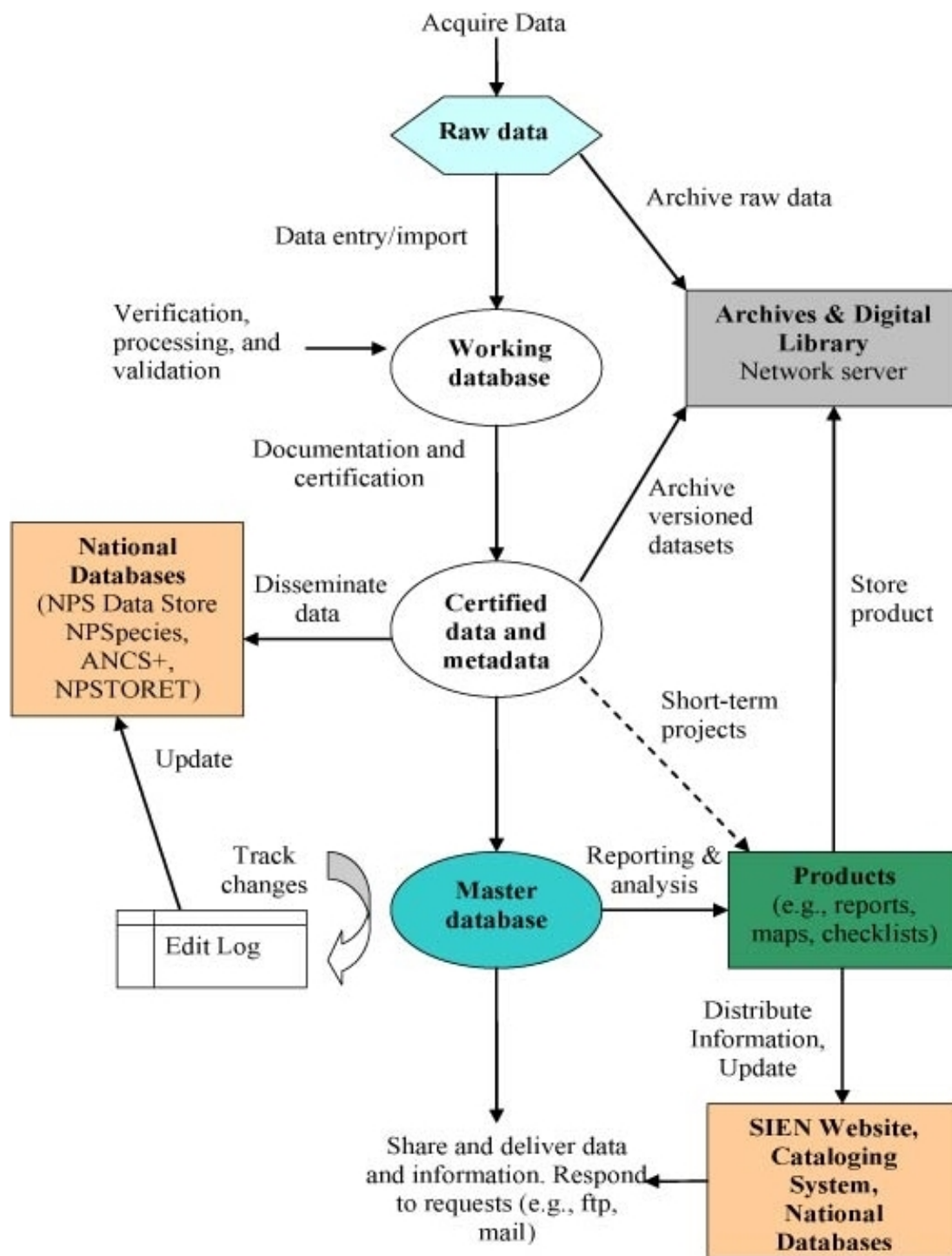


Figure 15. Flow diagram of the information management life cycle for Wetlands Ecological Integrity monitoring in Sierra Nevada Network parks (from Cook and Lineback 2008).

4.2 Database Design

The SIEN WEI monitoring database is a Microsoft Access application. Its design is based on the NPS I&M Natural Resource Database Template (NRDT) version 3.1 and is consistent with database standards described in the SIEN Data Management Plan (Cook and Lineback 2008). Two tables, tblSites and tblSiteVisit, form the core of the database. They correspond to the core tables of the NRDT, which are tblLocation and tblEvents, respectively. TblSites stores the location information for each sampling unit while tblSiteVisit stores data associated with individual sampling events at those sampling units. The remaining data tables in the database characterize wetland vegetation, hydrology, and invertebrates at the sampling unit for each sampling event. For a full description of table relationships and a complete data dictionary, please see Appendix 5.

The SIEN strategy for maintaining the integrity of the WEI database uses the “working copy/master copy” model adopted by other I&M networks. The data models for the “working copy” and the “master” (archive version) are identical. The “working copy” is used to store the current season’s data while the “master copy” serves as a data archive suitable for multi-year analyses. Queries in the front-end working database application are used to validate and verify the data before it is certified and appended to the master copy of the database. The master copy of the database incorporates a front-end user interface with additional tools for generating summary information, reports and formatted export files.

In general, project staff has read/write access to the working copy of the database to perform data entry and data verification procedures. Read/write access to the master copy of the database is limited to the Database Manager and Project Lead. Access rights to both copies of the database are controlled by network level directory and file permissions.

4.3 Pre-Season Preparations

4.3.1 Set Up Project Workspace

A section of the networked file server at each host park is reserved for this project, and access permissions are established so that crew members have access to needed files within this workspace. Prior to each season, the Project Lead should make sure that network accounts are established for each new crew member, and that the Data Manager is notified to ensure access to the project workspace and databases.

4.3.2 GPS Loading and Preparation

The Logistics Tech and Crew Lead should work together to ensure that target coordinates are loaded into the GPS units prior to the onset of field work, and that GPS download software is available and ready for use. Additional details on GPS use and GPS data handling may be found in SOP 3.

4.3.3 Implement Working Database Copy

Prior to the field season, the Data Manager will implement a new copy of the working database and ensure proper access on the part of the crew members. Refer to Appendix 5 for additional information about the database design and implementation strategy.

4.4 Data Entry

The working copy of the database includes a front-end client application with tools and forms for uploading and entering the current field season's data (SOP 4). Before each field season, the Data Manager installs a copy of the working database on a network server, places a copy of the front-end database application in the project workspace on a network client computer accessible to crew members, and links the front and back ends. Crew members use the front end application on the client to upload electronic data from a handheld computer and enter data manually into the working copy of the back-end database on the server. Once data from a field season have been entered, validated, and certified, the Data Manager transfers it to the master copy of the database on the network server.

4.5 Data Backup

Both the working copy and master copy of the database are backed up as part of the nightly network server backup. SIEN also manages two additional backups: weekly backups that are retained for a minimum of a year and an off-site copy of the master database archived to CD or DVD.

In addition to procedures for backing up digital data, another vital step in ensuring the integrity of the WEI data is making backup copies of all original field forms and storing copies at off-site locations to prevent data loss. Specific procedures for handling originals, making copies, and storing both analog and digital data are discussed in SOP 28.

4.6 Quality Assurance and Quality Control (QA/QC)

Field data are currently recorded using a combination of handheld computers, paper datasheets, and automated data loggers. Data are recorded on the handheld computer in an MS Access compatible application that employs electronic data entry forms. These forms incorporate validation rules, range limits, and pick lists that promote consistent and accurate data entry. Added advantages of entering data on handheld computers include reducing the burden of subsequent data entry and minimizing the potential for data transcription errors.

In some cases, paper field forms are more suitable than electronic forms for recording data like sketches and lengthy narrative descriptions. When data must be transcribed from paper forms to digital format, they undergo rigorous data verification and validation procedures that are summarized below.

4.7 Data Verification and Validation

Data quality is appraised by applying verification and validation procedures. *Data verification* checks that the transcribed data match the source data. All data recorded on paper datasheets are subject to verification. Once data entry is complete, the Project Lead or a designee must verify the data to assure consistency between field forms and the database. This is accomplished by comparing the analog data to the digital version and resolving discrepancies.

Once verification is complete, the data set undergoes validation. *Data validation* checks that the data make sense. Although data may be correctly transcribed from the original field forms, they may not be accurate or logical. The process of reviewing computerized data for range and logic errors is one

step in the validation stage. Validation procedures also seek to identify generic errors (e.g. missing, mismatched or duplicate records). Certain components of data validation are built into data entry forms (e.g. range limits). Validation can also be extended into the design and structure of the database through the use of look-up tables. Subsequent data validation is accomplished by a combination of visual inspection and queries in the database front end that are structured to find duplicates and logical inconsistencies. Although data entry and verification can be handled by project staff who are less familiar with the data, validation requires in-depth knowledge about the data and primary responsibility for validation is borne by the Project Lead. Verification and validation procedures are described in detail in SOP 27.

4.8 Data Documentation

Data documentation is an essential component of sound data management. Thorough documentation is essential for preserving the integrity and longevity of data and the products of its analysis. From project development through final delivery of information products, the Data Manager and Project Lead will place a high priority on documenting the aims, quality, and meaning of WEI data.

The process of documenting data creates a description of the data, how it was collected, and what it means. This information is collectively known as metadata. Wetlands Ecological Integrity metadata will adhere to content standards set by the Federal Geographic Data Committee and NPS policy. The Project Lead will begin creating metadata at the onset of the project and set the tone for record-keeping throughout the course of the project. Crews will be trained to record decisions made in the field that affect data quality or meaning. The creation of WEI metadata will be guided by the practices described in SOP 26.

4.9 Data Archival Procedures

Data sets are rarely static. Changes, improvements, or updates to the data may be required once a dataset has been archived. However, archived data can be changed only if three safeguards are in place: 1) data integrity must be maintained; 2) once archived, all changes to the data set must be documented; and 3) mistakes made during editing must be recoverable.

To maintain data integrity, original field forms should not be altered. Original entries on the data sheet are never erased. If corrections are needed, they are written in the margins with the date and initials of the person making the correction. Corrections on field forms can be reconciled with the database through the use of an edit log. Every change must be documented in an edit log and accompanied by an explanation that includes pre- and post-edit data descriptions.

Prior to any major changes in a digitally archived data set, a copy is stored with the appropriate version number, which allows for the tracking of changes over time. Versioning of archived data sets involves adding a decimal version number to the file name, with the first version being numbered 1.00. Each major version is assigned a sequentially higher whole number. Each minor revision is assigned a sequentially higher 0.1 number. With proper controls and communication, versioning ensures that only the most current version is used in any analysis. Frequent users of the data are notified of the updates and provided with a copy of the most recent archived version.

Any editing of archived data is accomplished jointly by the Project Lead and Data Manager. The reader is referred to Tessler and Gregson (1997) for a complete description of prescribed data editing procedures and an example edit log.

Secure data archiving is essential for protecting data files from corruption. Once a data set has passed the QA/QC procedures specified in the protocol, a new metadata record is created. Subsequently, an electronic version of the data set is maintained in a read-only format on the SEKI GIS server in the SIEN directory. Backup procedures for the WEI protocol follow those described in the Sierra Nevada Network Data Management Plan (Cook and Lineback 2008).

4.10 Data Dissemination

Currently, data are available for research and management applications on request for database versions where all QA/QC has been completed and the data have been archived. Data can also be transferred using e-mail (most Access files are smaller than 10 Mbytes or can be compressed into .zip files) or ftp where available. Eventually, Wetland Ecological Integrity monitoring data will be available for download directly from IRMA and the NPS I&M Monitoring webpage. In addition, metadata will become available directly from the NPS I&M Data Store, the NPS I&M data and metadata server. Data requests should be directed to the SIEN Data Manager and Project Lead.

4.11 Data Analysis: Overview

Data summaries and analyses will be incorporated into annual reports and periodic trend analysis reports. Detailed descriptions of data analysis procedures are provided in SOP 29.

Data collected at the extensive sites are used to estimate status and trend at park and network levels (Table 7). Two types of wetlands are considered: fens and wet meadows. Three distinct data sets are collected within each of the two wetland types: vegetation, invertebrate, and hydrology. This structure allows for analyses of each of these components, as well as community level analyses.

Table 7. Number of extensive sample sites (fen-meadow and wet meadow sites combined) by park unit and network. Total sites per year is the sum of sites in the annual panel and the single alternating panel sampled that year. Total sites per rotation is total number of site visits after completion of the 4-year cycle, which includes four (annual) visits to sites in the annual panel and one visit to sites in each of the four alternating panels (SEKI= Sequoia Kings Canyon NP, YOSE=Yosemite NP, SIEN=Sierra Nevada Network).

Park unit	Annual panel sites	Alternating panel sites/year	Total sites visited per year	Total sites visited per rotation	Total unique sites
SEKI	6	6	12	48	30
YOSE	6	6	12	48	30
SIEN	12	12	24	96	60

4.12 Annual Status Summary

Status results will be summarized after each year of data collection. Standard summary statistics will be presented with content similar to that shown in Table 8, and will include measures of central tendency ($\bar{x}$), and spread (s) for vegetation, invertebrate, and hydrologic data. Within each wetland type, data will be summarized by park-unit and network levels. Graphical analysis of plots and maps will be performed as part of exploratory data analysis. This will be particularly important in the early years of the project to identify a workable set of variables or metrics that best explain the status of wetlands among the vast possible sets, and to aid in the refinement of existing hypotheses and generate new hypotheses about pattern and process.

Table 8: Relationship among the protocol objectives, data, and inference. The overarching objective is to describe and compare the status of wet meadow and fen wetlands and to compare rates of change in wetland characteristics between fen and wet meadows. $\bar{x}$ is the sample mean; p is the sample frequency (proportion of total); MFR is Margalef's Family richness; PI is National Wetland Inventory prevalence index; sp is species (singular); spp is species (plural); Y is yes; N is no.

Objective	Raw Data	Summarized Data	Inference Goal	
			Trend	Statistic(s) for status
Identify temporal change in wetland hydrology	Groundwater	–	Y	$\bar{x}$ depth (cm)
Estimate temporal change in wetland plant communities	Herbaceous spp	–	Y*	$\bar{x}$ % cover/sp; p plots/sp
		spp richness	Y	$\bar{x}$ richness
		Total herbaceous	Y	$\bar{x}$ % cover
		PI	Y	$\bar{x}$ index value
	Non-vascular spp	–	Y*	$\bar{x}$ % cover/sp; p plots/sp
		spp richness	Y	$\bar{x}$ richness
		Total non-vascular	Y	$\bar{x}$ % cover; p plots
	Woody spp	–	Y*	$\bar{x}$ % cover/sp; p plots/sp; $\bar{x}$ no./m ²
		Total woody	Y	$\bar{x}$ % cover; p plots; $\bar{x}$ no./m ²
		Total gymnosperms	Y	$\bar{x}$ % cover; p plots; $\bar{x}$ no./m ²
		Total angiosperms	Y	$\bar{x}$ % cover; p plots; $\bar{x}$ no./m ²

* Trend may be evaluated on key species for which necessary abundance values are known.

Table 8: Relationship among the protocol objectives, data, and inference. The overarching objective is to describe and compare the status of wet meadow and fen wetlands and to compare rates of change in wetland characteristics between fen and wet meadows. $\bar{x}$ is the sample mean; p is the sample frequency (proportion of total); MFR is Margalef's Family richness; PI is National Wetland Inventory prevalence index; sp is species (singular); spp is species (plural); Y is yes; N is no.

Objective	Raw Data	Summarized Data	Inference Goal	
			Trend	Statistic(s) for status
Estimate temporal change in wetland macroinvertebrate communities	Exotic spp	–	Y*	$\bar{x}$ % cover/sp; p plots/sp
		spp richness	Y	$\bar{x}$ richness
		Total exotics	Y	$\bar{x}$ % cover; p plots
	Litter	–	Y	$\bar{x}$ % cover
	Bareground	–	Y	$\bar{x}$ % cover; p points/subplot
	Top canopy	–	Y	$\bar{x}$ ht (cm)
	Vertical structure	–	N	$\bar{x}$ & mode (3 classes)
	Peat	–	N	$\bar{x}$ depth (cm)
	Terrestrial macroinvertebrate Families	–	Y*	$\bar{x}$ no. indiv./Fam; p plots/Fam
		MFR	Y	$\bar{x}$ MFR
	Aquatic macroinvertebrate Families	–	Y*	$\bar{x}$ no. indiv./Fam; p plots/Fam
		MFR	Y	$\bar{x}$ MFR
	Ant spp	–	Y*	$\bar{x}$ no. indiv./sp; p plots/sp
		spp richness	Y	$\bar{x}$ richness

* Trend may be evaluated on key species for which necessary abundance values are known.

4.13 Trend Analyses

Analyses of trend will be conducted following completion of each full panel rotation (SOP 29). The null hypothesis that no change in a given metric has occurred at the network level ($H_0: \beta_1=0$) will be tested using a mixed linear model with $\alpha=0.10$. The model was developed by VanLeeuwen et al. (1996) and Piepho and Ogutu (2002) specifically to address trend estimation for correlated data. The mixed model allows for consideration of both fixed and random effects. Fixed effects contribute to the mean of the outcome and random effects contribute to the variance. Random effects are used to estimate variation of linear trends among units (wetland sites) and over time (years).

4.14 Reporting

Detailed reporting guidelines and table structures are provided in SOP 29. The Sierra Nevada Network will produce two types of reports for the Wetland Ecological Integrity project. Annual summaries will be produced following each field season, and more comprehensive status and trend reports will be produced every four years following a full panel rotation.

Annual reports will:

- List project personnel and their roles
- List sites sampled during the current year (and any sites that were missed)
- Provide a summary history of the number of sites, their panel membership, park unit, and wetland type during each year of the project
- Identify any data quality concerns and/or deviations from the protocol that affect data quality and interpretability
- Include information on any rare native species or early invasive species detected, or other information that could be of immediate interest to park managers
- Evaluate and identify suggested or required changes to the protocol
- Provide tables of measured variables summarized by wetland type, park unit, and network
- Briefly discuss results, including management implications
- During the plot installation and site establishment years, annual reports will document additional information, such as rejected sites, challenges to site installation, solutions, and other methodological details

A detailed analysis and report will be produced after each of the alternating panels has been visited. In addition to the above, the four-year report will:

- Document in-depth status and trend analysis results
- Provide an overview of the protocol status and major accomplishments
- Give recommendations for future improvements
- Discuss in detail the results and implications to park management of wetlands
- Identify any changes in spatial patterns of wetlands

Annual reports and four-year status and trend reports should use the NPS Natural Resource Publications template, a pre-formatted Microsoft Word template document based on current NPS formatting standards. Annual reports will use the Natural Resource Data Series template, and comprehensive status and trend analysis reports will use the Natural Resource Report template.

These templates and documentation of the NPS publication standards are available at:

<http://www.nature.nps.gov/publications/NRPM/index.cfm>.

4.15 Management Thresholds

In this section, specific measurable objectives related to wetland condition or ecological change, such as thresholds or trigger points for management actions are identified and discussed. Changes in the abundance or conditions of several metrics will be used to inform resource managers of the potential need for management action to maintain ecological integrity within the SIEN parks' wetlands. These metrics include the presence and abundance of invasive species, rare or sensitive species, and the extent of bare ground due to anthropogenic disturbance from recreational or administrative use. The benchmarks presented below serve only as thresholds that would require the Project Lead to inform the park point of contact (POC) of the observed changes in wetland condition and do not imply that any management actions are required. In addition, we recognize that attempting to apply a uniform set of metrics to a diverse assemblage of wetlands arrayed across hundreds of thousands of hectares should serve only as a coarse early warning system of wetland ecological integrity and that the potential management actions that are appropriate will depend on management objectives and the unique characteristics of each individual wetland including ecological condition, management history, social values, access, and many other factors. If and when the parks set management thresholds through the Resource Stewardship Strategies or other planning efforts, we will revise values in our protocol to be consistent with park guidelines.

4.15.1 Rare, Sensitive, and Invasive Species

The Project Lead will inform the park point of contact of the location and abundance of any rare, sensitive, or invasive species found within the WEI plots or associated assessment areas. The POC will be informed as soon as is feasible upon the detection of newly discovered populations and on an annual basis for existing/previously documented populations. As part of the field sampling that occurs as part of this protocol, the species name, abundance (m²), and location (UTM coordinates) of all rare, sensitive, and invasive species will be recorded within the assessment area and stored in the WEI database. If a new species is found within the park, the Project Lead and Data Manager will work with the appropriate park staff to update NPSpecies and other relevant park species lists.

4.15.2 Bare Ground

The quantity of bare ground has often been used as a metric of meadow condition, primarily when assessing the effects of livestock grazing (Weixelman et al. 1997, Weixelman and Zamudio 2001, Cole et al. 2004). A threshold of 10% bare ground is one trigger point for possible management action used by resource managers, though this number must be considered in combination with other factors such as hydrogeomorphic setting, species composition, cause, and other variables (David Weixelman, USFS Range Ecologist, personal communication 9/17/2013). A threshold of 10% bare ground will be adopted by the WEI protocol and any time a macroplot exceeds this value and is believed to be attributed to anthropogenic disturbance, the park POC will be notified.

Both YOSE and SEKI are currently assessing the ability to correlate bare ground to multiple metrics of meadow condition and as that work is developed, any metrics and thresholds that are identified will be considered for inclusion as part of the WEI protocol. The inclusion of multiple estimates of bare ground (percent cover estimates within the microplots and point counts within the macroplot) in the sampling methods of the WEI protocol were developed to be consistent with the YOSE bare

ground assessment project methodology so that the transferability of the findings from their report to this protocol would be possible.

4.16 Index Sites

A second design type is also specified by the protocol. “Index” sites are hand-picked sites that can be sampled more intensively than extensive sites. The goals of index site sampling include providing an improved understanding of the natural range of variability and key physical and ecological processes in wetlands. Index site data can also be used in interpretation and hypothesis generation regarding patterns and trends in data from the extensive design. Index sites may be used in the future to provide additional data to refine models relating vegetation and invertebrate communities to key site-level ecological drivers such as hydrologic regime or water chemistry. However, these procedures are not in place and are not discussed in this document.

One key difference between index sites and the extensive sites that are the main focus of the WEI protocol is that index sites are subjectively chosen and inference from status estimation and trend analyses is limited to these specific sites. Any monitoring and reporting of index sites (except for the site at DEPO) is the responsibility of Resource Management Staff from the park in which they are located. SIEN will summarize and report on the DEPO site in the WEI annual reports following the same procedures described above for the extensive sites. This will include summary metrics of hydrology, plant species composition and abundance, and measures of macroinvertebrate diversity. Data from the DEPO index site will be entered into the SIEN WEI database and will undergo the same QA/QC and archiving procedures as that of the extensive sites. The DEPO site will not be used for status and trend estimation of SEIN wet meadows and fens, however. Additional information related to the potential analysis and reporting for the index sites can be found in Appendix 2.

5 - Personnel Requirements and Training

The wetlands monitoring protocol requires effective management and oversight from core network staff as well as support from local park staff to assist with crew training, logistics, permitting, and sampling. Outside experts are also used for taxonomic expertise for invertebrates and some plant taxa (bryophytes). In addition to the key roles for long-term network staff and park staff, seasonal employees will be needed to accomplish field sampling. Considerable care needs to be taken to ensure that seasonal hires have the necessary field skills and subject matter expertise to successfully accomplish the required tasks.

5.1 Roles and Responsibilities

The wetlands ecological integrity Project Lead is the SIEN Ecologist, supervised by the Network Program Manager. Field monitoring is conducted by field technicians (biological science technicians) with support from SIEN staff.

Extensive site sampling will be conducted by a three person crew of technicians. This crew can be augmented by an additional technician when funding allows. The crew will sample all extensive sites across SEKI and YOSE, as well as the index site at DEPO. Table 9 summarizes the broader roles and responsibilities of SIEN, Park, and seasonal staff and cooperators in the wetlands monitoring program. Should budget resources improve in the future, there would be many advantages to converting the GS-07 seasonal botanist position to a permanent subject to furlough GS-07/09 Botanist/Ecologist to help with crew hiring and training, logistics support, field work supervision, data management, and other standard tasks associated with multiple I&M protocols. While there are no plans for this in the next several years, it is an option that should be considered should funding allow.

The Wetlands Work Group composed of, but not restricted to, the SEKI Plant Ecologist (Erik Frenzel), YOSE Botanist (vacant), USGS WERC Plant Ecologist (Peggy Moore), and UCLA White Mountain Research Center Research Scientist (Jeff Holmquist), has been instrumental in the development of this protocol, and will continue to be involved in advisory and support roles. Some members will participate more actively, assisting with protocol development, revisions, crew training, and acting as a park POC. The network will continue to consult and work with experts from universities and federal and state agencies who are engaged in wetland monitoring such as the USFS and USGS to build collaborative relationships that foster sharing of information and subject matter expertise.

Table 9. Roles and responsibilities for SIEN staff, park staff, and cooperators for WEI protocol.

Role	Responsibilities
Project Lead (SIEN Ecologist)	Oversee all protocol activities; supervise field crews; train crews; support field sampling; verify, validate, and analyze data; write annual and comprehensive monitoring reports; manage protocol budget; work w/ Coordinator and Data Manager to meet I&M program level reporting requirements; manage database; revise protocol, as needed.
Data Manager	Maintain database; provide technical support for database management, data quality assurance/quality control, data storage and dissemination, and data analysis procedures; provide GIS technical support.
Program Manager	Coordinate with Project Lead to meet I&M Program requirements (e.g. budget, reporting, education/outreach); administer contracts & agreements, review reports; integrate wetlands monitoring with rest of Vital Signs program.
Park Point of Contact	Provides basic information about the protocol field work to other park staff; meets with the field crew at the beginning of the field season to provide a basic orientation, and make acquaintance with individuals working on the SIEN project; provides information on how to navigate park-specific processes (e.g., arranging administrative campsites, compliance and permit requirements); notifies SIEN Project Lead of Park orientation opportunities and safety-related training.
Park Ecologists	Assist with oversight, training, and support of field crew(s) in respective park; conduct index site sampling (optional).
Logistics Technician (SIEN staff)	Provide logistical support for field sampling; order and track supplies; assist with field season prep; provide GIS support; participate in field sampling when needed; provide support for crew training (radio, GPS, map and compass training).
Crew Members (SIEN staff)	Prep for field sampling and wilderness travel; collect vegetation, invertebrate and hydrologic data following protocol procedures; fully document procedures and anomalies; enter field data into database; perform end-of-season procedures; ensure safety of self and crew members.
Crew Lead (SIEN staff)	All crew member responsibilities, plus: communicate with Project Lead regarding crew concerns and needs; ensure crews have all equipment before going into field; submit wilderness travel plans; take lead on decisions in the field regarding safety, logistics, and sampling; manage plant and invertebrate collections; sort and organize collections; and prepare voucher specimens.
Subject matter experts (cooperator or contractor)	Invertebrate taxonomy, assistance with invertebrate data processing and analyses. Plant identification and taxonomy (some sedges, bryophytes).
Wetland Work Group	Provide technical guidance; coordinate with Project Lead on park-level logistics (e.g., Wilderness Minimum Requirement Analysis, research permitting, housing); assist in disseminating information as appropriate; provide review and evaluation.
Local area Experts	Provide guidance and technical assistance as needed – recommending cross-country hiking routes, permitting, Wilderness Minimum Requirement Analysis, etc.

5.2 Desirable Skills and Qualifications for Core Protocol Staff

The Project Lead will meet basic requirements for a GS-11 Ecologist position and will have education or experience in vegetation sampling, research or monitoring sample designs and analytical methods, strong communication skills, and ability to manage projects and field crews.

Essential field staff includes a lead botanist (GS-07) competent in plant identification, particularly grasses and sedges, and at least one other biological technician (GS-05) capable of sampling invertebrates for export to a cooperator for identification and assisting with vegetation sampling and identification. The third technician would also participate in field sampling as well as manage the lab/office related tasks including keying out unidentified species, mounting voucher specimens for submission to herbaria, and processing macroinvertebrate samples. The duties of the two GS-05 technicians are interchangeable and each technician would likely perform all the required field and lab/office related tasks at some point during the field season. Field crews need to be healthy and physically able to manage the work, which will include frequent travel to remote backcountry locations. They must be able to perform work independent of direct supervision, given proper guidance and training. The senior crew member must have experience working in field settings and leading others. This individual must also be competent using spreadsheets, GIS, and database programs, as they will be primarily responsible for field data quality control.

Collectively, crews will need to have the following skills or qualifications:

- B.S. or higher degree in botany, entomology, wetland ecology, field biology, geology, or related field
- Strong plant identification skills, including sedges
- Invertebrate sampling skills; some basic invertebrate identification skills helpful, but the emphasis for crew members will be on plant taxonomy
- Ability to use dichotomous keys
- Familiarity with Sierra Nevada flora
- Familiarity with soil profiles and soil properties characteristic of wetlands
- Ability to conduct field work safely, under strenuous circumstances, in remote backcountry areas (Wilderness first aid or first responder training is recommended, but not required)
- Ability to work independently and follow detailed, complex protocols
- Good map reading, compass, and route-finding skills for off-trail hiking
- Strong hiker with physical stamina
- Excellent oral and written communication skills
- Strong proficiency in Microsoft Office Word, Excel; basic skills in MS Access and ArcGIS are helpful

The skills needed by cooperators who provide taxonomic expertise will be detailed in contract or task agreement documents.

5.3 Training

Proper training in protocol-specific SOPs and safe work practices is critical to the success of this monitoring project. The safety philosophy of SIEN is grounded in Operational Leadership concepts and crews will be hired early enough to allow time for detailed training that gives them context and a basic understanding of how these concepts should be applied to the work they are doing, familiarizes them with the protocol methods, and gives them the information and tools they need to conduct work safely in our large predominantly wilderness parks.

The SIEN Safety Plan (Chung-MacCoubrey et al. 2012), SOP 21, and other sampling and data management SOPs provide more detail on specific training needs and procedures for crews.

Safety is a central aspect of seasonal crew training (SOP 22) and a Field Readiness Review must be completed and then signed by the Project Lead, Program Manager, and Park superintendent prior to each field season (Chung-MacCoubrey et al. 2012). The Field Readiness Review identifies the project specific park point of contact, outlines the locations where the field work will be performed, and documents the responsibilities of SIEN and Park staff related to the safe implementation of a field project. It addresses the following components of seasonal training and communication:

- Participation in local park seasonal training with the Resources Management and Science Divisions
- Introduction to I&M program and the specific monitoring project(s) that crew will be involved with (including information about why we are monitoring specific resources and discussing the bigger picture of why what they are doing is important)
- Discussion of our vision and philosophy for safety and wellness at work, the roles and responsibilities each person has to create and maintain a safe work environment, and the fact that there are no I&M data worth risking injury to collect
- Review and discussion of Job Hazard Guidelines related to working in the parks and to the specific protocol(s) they will be working on
- Introduction to radio system and communications in parks (including hands-on training); review of wilderness communication and check-in procedures
- Maintaining vigilance about safety – use of safety tailgate sessions, the action review cycle, staying focused and mindful while working and traveling in the parks, communicating openly with supervisor and team members when you have a safety concern
- Provision of safety-related supplies and equipment, with clear instruction on how/when they are to be used, if appropriate (first aid supplies, radios, hiking poles, bear-proof food canisters, camping gear, etc.)
- Reporting of accidents and injuries, if they do occur

- Providing NPS emergency contact information, and obtaining emergency contact information from crew members, along with any concerns such as allergies to medications
- Hands-on training with the protocol (and safety issues) in the field
- First Aid and CPR training if feasible

For the wetlands protocol, crews will be given training and guidelines in the safe and proper use of specific sampling equipment and hand tools used in the protocol, such as soil augers and soil probes. Checklists will be provided for appropriate gear and field clothing for safe wilderness travel, and to the extent possible, SIEN will provide and check out work gear (such as bear canisters, tents, sleeping bags, hiking poles) to crew members for the season.

Other specific information and guidance are provided on:

- Trip plans: At a minimum, a trip plan for each field trip must be completed and sent to the primary and secondary SIEN Emergency contacts listed on the trip plan, as well as the Park POC and Dispatch office (SOP 23). The trip plan should include the following information:
 - Field trip participants, including guests and observers, with emergency contact information
 - Departure and expected return time(s) and date(s)
 - Basic itinerary, including where and when sampling will occur
 - Phone numbers for cellular or satellite phones, radio frequencies or repeaters to be used
- Field communications (radio use, satellite phones if available)—see SOP 23
 - provide park-specific instructions, call numbers, phone numbers
 - check-in procedures for field crews doing wilderness travel
- Handling medical emergencies
 Emergency communication guidelines and incident response are outlined in SOPs 2 and 3 of the SIEN Safety plan (Chung-MacCoubrey et al. 2012). These guidelines are consistent with “Call, Contact, Care” and describes the required immediate response to an emergency. Crews are advised of the following:
 - Always call 911 or Park Dispatch first if the situation warrants.
 - Contact colleagues in the field, supervisor, and park staff to alert them to the incident and any relevant danger.
 - Care for injuries by getting or providing prompt medical treatment. All injuries that warrant compensation require paperwork.
 - Report all incidents of any type to supervisor

6 - Operational Requirements

The wetlands monitoring protocol requires support from both Network and local Park staff as well as expertise from cooperators or contractors for specialized taxonomy (invertebrates, sub-sets of plant taxa). Network staff is duty-stationed in SIEN parks, which facilitates coordination of logistics, training, and field support with local Park staff.

6.1 Annual Workload and Field Schedule

The field sampling season is from approximately June through September (Table 10). Extensive sites and the DEPO index site are sampled annually from June through early September. Exact timing is dependent upon plant phenology and travel logistics. Data entry or upload occurs throughout the season and is completed by the end of October for most data. Some additional data entry will be finalized later in the fall/winter after specimen determinations have been completed. Data analysis and reporting occurs during the winter months. Annual and comprehensive reports are submitted to the Network Program Manager and Park staff by the end of April.

Table 10. Annual work schedule.

Event	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
End of season wrap-up	✓	–	–	–	–	–	–	–	–	–	–	✓
Field data entry	✓	–	–	✓	–	–	–	–	✓	✓	✓	✓
Sample processing and ID	✓	✓	✓	–	–	–	–	–	–	–	–	–
Data analysis/reporting	–	–	–	✓	✓	✓	–	–	–	–	–	–
Pre-season field prep	–	–	–	–	–	✓	✓	✓	–	–	–	–
Extensive site sampling	–	–	–	–	–	–	–	–	✓	✓	✓	✓

6.2 Facility and Equipment Requirements

Equipment inventory and checklists are located in the individual field sampling SOPs. A comprehensive list of required field gear is given in SOP 1. Additional equipment required for office and lab related tasks are listed in the individual SOPs.

Wetlands protocol personnel use office space in both Sequoia (Ash Mountain) and Yosemite (El Portal). Parks provide office space at both Yosemite and Sequoia so crews may organize field gear, access email and phones, copy and file field forms, and complete data entry tasks. Staff also require use of the microscopes and lab space in SEKI to sort and organize invertebrate samples for shipment to specialists and to identify plant specimens and prepare vouchers for herbaria. The SIEN Ecologist's primary office is located in Sequoia; temporary office space is available when working in Yosemite. Facilities are provided by the parks.

The field crews will be primarily in the wilderness for the field season; so they may or may not have seasonal housing. For the limited time they are in the front-country they may be housed at the Ash Mountain Dormitory, Yosemite Bug Hostel, or park seasonal housing, if available.

The field crews will require the use of a vehicle throughout the field season to allow for travel from their assigned duty station (Ash Mountain, SEKI) to the various trailheads. This will be arranged through the General Services Administration by the SIEN Program Manager and Project Lead prior to the start of the field season. It is the responsibility of the crew to maintain the vehicle in good working condition and to follow safe driving practices outlined in the SIEN Safety Plan (Chung-MacCoubrey et al. 2012). To reach sampling locations at some parks, field crews may have to travel on secondary roads that are graveled or dirt and may be poorly maintained. Drivers should be keenly aware of risks. Jeep roads can also pose serious fire hazards when hot vehicle engines pass over top of dry vegetation. Late season access, which could begin as early as June in some drought years, may be prohibited if fire risk is too high. Vehicle fire prevention and response kits per park instruction should also be available at all times. The crew will check with parks regularly for updates on fire weather and road closure information.

Due to the large amount of gear required for plot installation and monitoring and the rugged and remote nature of many of the sample locations, stock support will be arranged prior to the field season whenever feasible. This is an important mitigating factor for crew safety as reducing pack weight helps prevent work related injuries and reduce fatigue. Stock support will be coordinated by the SIEN Project Lead and Logistics Technician through both commercial pack operators and administrative stock prior to the start of the field season. Caches will be arranged at ranger stations in SEKI when feasible, but this option is not possible in YOSE. In YOSE, crews will arrange to meet the stock at a specified time and location for the transfer of food and equipment.

6.3 Partnerships

Partnerships, such as with the University of California White Mountain Research Station for assistance with invertebrate specimen identification and support with data analysis and interpretation are an important component of this protocol. Some continued statistical support from a university or consultant may also be needed through the first years of protocol implementation to assist with refining data analysis methods. Other partnerships may include projects with wetlands specialists with the USDA Forest Service or other agencies to answer questions that the monitoring data will generate or to assist us in defining thresholds for key metrics. Establishing working relationships with regional experts affiliated with the Jepson Herbaria at UC Berkeley or California Native Plant Society to assist with voucher identification will also be important.

6.4 Budget

The total cost of the WEI Monitoring Protocol is \$115,742, which includes staff salaries plus annual operating costs (Table 11). The annual operating budget of \$56,553 includes wetlands seasonal technician salaries, their travel, macroinvertebrate and plant identification, and supplies. It does not include costs absorbed at the program-level, such as field vehicles, backpacking and camping supplies, stock support for placement of backcountry caches (food and equipment), office supplies, and periodic equipment maintenance. Network staff primarily address field crew training, project

management, and reporting costs, with some in-kind support from park staff. The budget in Table 11 is divided into two sections: 1) Network and Park staff salaries that are contributed to the project by the Network and Parks, and 2) Annual Operating Budget (which comes from the Network). Additional in-kind support from the parks occurs in the form of project work space.

Significant portions of the wetlands protocol resources are put towards data management (35% of total budget), primarily time from the Ecologist, Data Manager, and crew members. The SIEN Program Manager and Logistics Technician also contribute time to the wetlands protocol and contribute to data management, logistics support, report preparation, and outreach and communication needs.

A key component to the success of this protocol is involvement and support from park staff. However, due to current budget restraints and already more than full workloads, staff contributions to this protocol are mostly limited to the Plant Ecologist and affiliated biological technicians in Sequoia and Kings Canyon National Parks. These staff will coordinate sampling index sites in those parks when possible and will participate in field crew training when possible. Other Park staff contributions will primarily be through participation in the Wetlands Work Group, assisting with park-level logistical support as their time permits, and coordinating with Network staff to cost-share seasonal crews or other staff. Parks also provide significant resource support by providing office, herbaria, and housing facilities. The Work Group hopes that as the program continues to develop, park contributions will increase through time.



Peggy Moore and Evan Wolfe reading a groundwater monitoring well near Gin Flat, Yosemite National Park, August 8, 2006. Photograph by Linda Mutch.

Table 11. Total and annual operating budget for the wetlands protocol, as well as staff time and funding devoted to data management. Values presented are in 2014 dollars.

Expense Type	Expense	Project Costs				Data Management	
		Number	Rate	#	Cost (\$)	% of time	Cost (\$)
SIEN and park staff*	SIEN Ecologist- GS-11	10.0 pp	3,361	1	33,610	50	16,805
	YOSE & SEKI Ecologists GS-11	0.5 pp	3,361	2	3,361	—	—
	YOSE & SEKI Technicians GS-07	0.5 pp	2,302	2	2,302	—	—
	Park Crew Lead GS-06 (SEKI)	0.5 pp	1,455	1	728	—	—
	Data Manager	2.0 pp	3,692	1	7,384	100	7,384
	Logistics/Data Technician	3.0 pp	2,302	1	6,906	20	1,381
	SIEN Program Manager	1.0 pp	4,898	1	4,898	50	2,449
Subtotal	n/a	—	—	—	59,189	—	—
WEI seasonal technicians	GS-07 seasonal botanist	9.5 pp	1,600	1	16,459	30	5,486
	GS-05 seasonal biotechs (2)	7.5 pp	1,291	2	20,828	30	6,943
Subtotal	n/a	—	—	—	37,287	—	—
Services	Plant identification	1	1,500	—	1,500	—	—
	Invertebrate id**	48 samples	242	—	11,616	—	—
Subtotal	n/a	—	—	—	13,116	—	—
Travel	Wilderness per diem/seasonals	70 days	20	3	4,335	—	—
	Wilderness per diem/others	10 days	20	1	215	—	—
Subtotal	n/a	—	—	—	4,550	—	—

* salary rates for current individuals

**includes 2 samples (terrestrial and aquatic) per site for the 24 sites visited each year

Table 11 (continued). Total and annual operating budget for the wetlands protocol, as well as staff time and funding devoted to data management. Values presented are in 2014 dollars.

Expense Type	Expense	Project Costs				Data Management	
		Number	Rate	#	Cost (\$)	% of time	Cost (\$)
Operations/Supplies	Supplies	1 season	1500	–	1,500	–	–
	Shipping (plant/inverts)	–	100	–	100	–	–
Subtotal	n/a	–	–	–	1,600	–	–
ANNUAL OPERATING BUDGET					56,553	n/a	–
TOTAL BUDGET (STAFF PLUS ANNUAL OPERATING)					115,742	n/a	40,448 (35%)

* salary rates for current individuals

**includes 2 samples (terrestrial and aquatic) per site for the 24 sites visited each year

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Appendix 1: Administrative Record

March 2017

Prepared by Sylvia Haultain, Jonathan Nesmith, and Alice Chung-MacCoubrey

The purpose of the Administrative Record is to provide a history of protocol development and refinement. A timeline of events is presented in Table A1.1. The Project Lead should update the record as major changes are made or milestones are achieved.

Table A1.1. Timeline of key protocol development events.

Date	Event
2003	Funds obligated for cooperative agreement with Dr. Jeff Holmquist, White Mountains Research Station (WMRS), to initiate a pilot study to determine the efficacy of invertebrates as indicators of change in mountain meadows
Winter/Spring 2004	Series of meetings and conference calls to discuss invertebrate sampling objectives and design issues with SIEN staff and WMRS cooperators
Summer 2004	Weekly to bi-weekly invertebrate samples collected from Tuolumne Meadows (YOSE)
Fall 2004	Literature review received from Holmquist: <i>Terrestrial invertebrates: functional roles in ecosystems and utility as vital signs in the Sierra Nevada</i>
Winter 2005	Series of meetings and conference calls to discuss second year goals, design, methods and collaboration on invertebrate study with SIEN staff, USGS, NPS and WMRS collaborators
Summer 2005	Expanded invertebrate sampling to include montane meadows in SEKI. In addition to weekly to bi-weekly samples from Tuolumne Meadows (YOSE), collected bi-weekly to monthly samples from flooded and dry portions of Crescent, Log, and Huckleberry Meadows (SEKI)
Fall 2005	Funds obligated for cooperative agreement with Dr. Michael Barbour and Dr. Kathren Murrell Stevenson, UC Davis, to conduct a synthetic review and evaluation of mountain meadow monitoring protocols to support development of the SIEN wetland ecological integrity vital sign
Winter/Spring 2006	Series of meetings and conference calls to discuss mountain meadow monitoring review, sampling methodology, and protocol development. Draft protocol development summary and monitoring objectives prepared.
Spring 2006	SIEN enters into cooperative agreement with ROMN wetland protocol development group and wetlands ecologist Dr. David Cooper, CSU for development of vegetation and hydrology protocols. Agreement with Holmquist/WMRS modified to include development of SOPs for monitoring invertebrates in mountain meadows
June 2006	Final report received from Holmquist <i>et al.</i> : <i>A pilot study and assessment of the efficacy of invertebrates as indicators of meadow change in Sierra Nevada Network Parks</i>
Sept 2006	Final report received from Murrell Stevenson <i>et al.</i> : <i>Mountain Meadow Monitoring Across The Western United States: A Synthesis With Implications For The Monitoring Of Vital Signs In Devils Postpile, Kings Canyon, Sequoia And Yosemite National Parks</i>
Dec 2006	First version of protocol development summary completed
Winter/Spring 2007	Main protocol development period
Summer 2007	Leigh Ann Starcevich (statistician) begins working on wetland ecological integrity protocol design issues and power analysis
Summer 2007	Survey sites selected and pilot data collection conducted in YOSE
Fall 2007	2007 field season reviewed and evaluated. Wetlands conceptual model revised.

Date	Event
Fall 2007	Draft database developed by detail Data Manager Patrick Flaherty
Winter/Spring 2008	Main protocol development period. Results of pilot data collection incorporated. SOPs for sampling terrestrial invertebrates using sweep nets, aquatic invertebrates using D frames and ants using baits finalized by Holmquist/WMRS. Pilot data summarized and provided to statistician for power analysis.
Summer 2008	Survey sites selected and pilot data collection conducted in SEKI
Fall 2008	2008 field season reviewed and evaluated.
Winter/Spring 2009	Main protocol development period, with a series of meetings and conference calls regarding the narrative, SOPs, and power analysis conducted between SIEN, NPS, USGS and university cooperators.
May 2009	Draft protocol narrative and SOPs received from Cooper <i>et al.</i>
July 2009	Final power report complete
Summer 2009	Wetland Ecological Integrity narrative and SOPs reviewed and revised by NPS and USGS working group members
September 7, 2009	Protocol development summary revised and submitted to Jim Agee with letter listing suggested peer reviewers
September 14, 2009	Draft protocol submitted to University of Washington and PWR I&M for peer review
January 6, 2010	Peer reviews received back from University of Washington – ‘Acceptable with Minor Revision’.
September 29, 2010	Meeting with SIEN Steering Committee, I&M staff, and other park staff to prioritize protocols. Wetlands protocol still ranked high, but cost reductions are needed.
October 2010	Results of 3-year Start-Up Review of SIEN program. Review Panel stated “that too few protocols are about to be implemented, and that sample sizes or spatial or temporal sampling designs may need to be scaled back on several protocols to allow additional resources to be monitored”. Consequently, SIEN examined various cost reduction strategies to allow implementation of six protocols (4 field-based, 2 mostly data summaries). Reaffirms need for cost reduction on wetlands protocol.
Summer 2011	Jennifer Rains Jones completes her M.S. thesis, based on data collected in SIEN wetlands: Patterns of Floristic Diversity in Wet Meadows and Fens of the Southern Sierra Nevada, California, USA
Summer 2011	Shawn McKinney and Leigh Ann Starceвич discuss sample size reduction options and Leigh Ann conducts additional power analyses – “Power Analysis to Detect Trend for a Reduction in Sampling Effort for the SIEN WEI Protocol” (Sept. 9, 2011).
November 2011	Holmquist et al. publish paper in <i>Arctic, Antarctic, and Alpine Research</i> based on pilot invertebrate data collected during the wetland protocol development: Terrestrial and aquatic macroinvertebrate assemblages as a function of wetland type across a mountain landscape.

Date	Event
Summer/Fall 2011	Conference calls with Shawn McKinney, Alice Chung-MacCoubrey, Sylvia Haultain, Jeff Holmquist, Peggy Moore, and Lisa Acree to review alternatives and make decisions on approaches to reduce protocol cost. The selected alternative kept the revisit design intact, as well as continued to monitor wetlands in both YOSE and SEKI in both fen and wet meadow areas, but reduced the number of annual panel and alternating panel sites from 5 and 6 to 3 and 3, respectively.
September 2011	Shawn McKinney and Alice Chung-MacCoubrey prepared a revised WEI budget for the smaller sample size, and the SIEN Steering Committee approved the modifications.
Spring 2012	New SIEN Ecologist Jonny Nesmith assumes responsibility as the WEI protocol project lead and begins a review of the current status of the protocol and associated subject matter.
Summer 2012	Laura Jones, Plant Ecologist, is appointed as the Yosemite point of contact for the WEI protocol and is added to the WEI working group.
August 2012	Jonny Nesmith, Erik Frenzel (SEKI NPS), and Dave Weixelman (USFS) meet in the Crabtree area of SEKI to discuss grazing effects on meadows, methods for assessing meadow condition, and potential revisions to the WEI protocol methods.
September 2012	WEI working group (Sylvia Haultain, Jeff Holmquist, Peggy Moore, Laura Jones, Jonny Nesmith) and SIEN staff (Alice Chung-MacCoubrey, Linda Mutch) participate in a conference call to update everyone of the current status of the WEI protocol and discuss proposed revisions to the protocol and sampling methods recommended by Jonny Nesmith. These include revising the sample site selection process from a 2 stage GRTS design to a 1 stage design due to major flaws in the implementation of the GRTS draw during the pilot data phase of the project, brainstorm possible alternatives to deal with a reduction in crew size from 4 to 3, and incorporate measures of bare ground that are consistent with ongoing work being conducted in Yosemite.
Nov. 2012	Jonny Nesmith, Sylvia Haultain, Jeff Holmquist, and Peggy Moore meet in the Crane Flat area in YOSE to discuss potential changes to WEI sampling methods and wetland classification.
Winter/Spring 2013	Jonny Nesmith, Alice Chung-MacCoubrey, Sylvia Haultain, and Erik Frenzel implement a wetland mapping project through the U. Idaho to map and classify wet meadows and fens throughout SEKI. This information is used to identify the target population for the revised WEI sample frame.
May 2013	Jonny Nesmith, Peggy Moore, Sylvia Haultain, Jeff Holmquist, and Laura Jones participate in a conference call to discuss results from the wetland mapping project in SEKI, plan for continuing the project in Yosemite, and discuss results from the GRTS draw to identify extensive panel sites in SEKI.
June 2013	Jonny Nesmith, Alice Chung-MacCoubrey and Jeff Holmquist finalize a multi-year CESU Task agreement to identify macroinvertebrate samples collected as part of the WEI protocol in 2014 – 2016. Macroinvertebrate identification and analyses during establishment of wetlands monitoring in Sierra Nevada Network
Summer 2013	The SEKI Plant Ecology Program performed the field accuracy assessment of the wetlands map by evaluating ~100 target and non-target wetlands throughout SEKI. These data were used to produce a type I and II error rate in the aerial interpretation that was performed as part of the Wetlands Mapping Project.
Summer 2013	Laura Jones and Jonny Nesmith collaborate on a proposal to the Yosemite Conservancy seeking funding to initiate the second phase of the wetland mapping project in Yosemite (Not selected for funding).

Date	Event
Summer/Fall 2013	Substantial revisions to the WEI protocol narrative, appendices, and SOPs begin to address reviewer comments and incorporate changes to the sample design and data collection procedures.
January 24, 2014	Revised protocol narrative and SOPs re-submitted to peer review coordinator (Dr. Jon Bakker) and PWR Program Manager (Dr. Penny Latham) for review and approval.
October 29, 2014	Reviewer comments are received and protocol is APPROVED pending minor revisions.
January 20, 2015	Meeting in El Portal with Tim Kuhn (YOSE NPS), Laura Jones (YOSE NPS), Martijn Ouborg (YOSE NPS), Peggy Moore (USGS), and Jonny Nesmith (SIEN) to discuss candidate sites for removal from the YOSE sampleframe due to human impacts.
May 2015	Sequoia and Kings Canyon Wetland Mapping Project Report is published in the NRR series (Pyrooz et al. 2015)
July 2017	Protocol revisions are completed and revisions submitted to PWR Program Manager Lisa Garrett.
September 6, 2017	Final approval of the SIEN Wetland Ecological Integrity Protocol received from PWR Program Manager Lisa Garrett.

Appendix 2: Index Sites

November 2013

Prepared by Jonathan Nesmith and Alice Chung-MacCoubrey

Change History

Revision Date	Rev. No.	Author	Changes Made	Reason for Change
None	–	–	–	–

Add more rows as needed.

Executive Summary

The Wetlands Ecological Integrity (WEI) monitoring protocol was initially designed to use two complementary methods for selecting sample sites: randomly-selected “extensive” sites and subjectively-chosen “index” sites. Extensive sites are chosen randomly as part of a probabilistic sampling design used to allow inference of wetland condition at the park and network scale. In contrast, index sites are chosen subjectively based on factors such as the presence of data from historical monitoring, representativeness, or ease of access. An advantage of index sites is that their proximity to roads and trails facilitates repeated sampling, resulting in more spatially and temporally intensive sampling than is possible for extensive sites. This greater intensity of sampling can lead to greater understanding of natural variability, provide a link to existing long term monitoring data, and facilitate the development of more detailed models of drivers, anthropogenic stressors, and condition metrics. Several criteria used to select index sites in Sierra Nevada Network (SIEN) parks included the availability of existing data, management priority, elevation, vegetation types present, and access.

A total of 10 index sites were established in SIEN parks during the pilot work for the WEI protocol (Table A2.1). Five index sites were identified and established in YOSE in 2007. In Sequoia and Kings Canyon National Parks (SEKI), four sites were identified, two of which were established in 2008, and two in 2009. In Devils Postpile National Monument (DEPO), one index site was established in 2009. Multiple plots were installed in most sites and there locations are listed in Table A2.1.

Although SIEN originally intended to monitor both index and extensive sites, it became clear during protocol development that this was not possible due to funding constraints. As the result of subsequent decisions by the wetland working group and SIEN Steering Committee, SIEN will only monitor the extensive sites, and the WEI protocol has been updated to reflect this change. Monitoring of index sites within Yosemite National Park (YOSE) and SEKI will be the responsibility of the natural resource staff of each respective park. Although index sites were designed to share the same basic methods as the extensive sites for assessing invertebrate community composition, vegetation composition and structure, and supporting habitat information (e.g. water table dynamics), park staff may choose to adapt the methods and reporting schedules to suit their site-specific objectives. To the degree that they are still compatible, data may be stored along with extensive site data in the WEI database. The one exception is the index site at DEPO, which will remain the responsibility of SIEN staff and will be re-visited annually.

Table A2.1. Plot location information for index sites located in SIEN Parks. UTM Zone for all locations is 11N recorded in NAD83.

Park	Site Name	Plot Name	UTM (E)	UTM (N)	Wetland Type
DEPO	Soda Springs	DEPO_Index_409	315925	4166629	Wet meadow
SEKI	Dorst	SEKI_Index_401	339027	4056440	Wet Meadow
SEKI	Dorst	SEKI_Index_402	339003	4056404	Fen
SEKI	Rock Creek	SEKI_Index_403	381286	4039617	Wet Meadow
SEKI	Rock Creek	SEKI_Index_404	381337	4039666	Fen
SEKI	Log meadow	SEKI_Index_405	344023	4047335	Wet Meadow
SEKI	Log Meadow	SEKI_Index_406	344038	4047039	Fen
SEKI	Charlotte Lake	SEKI_Index_407	373001	4070736	Wet Meadow
SEKI	Charlotte Lake	SEKI_Index_408	373042	4070611	Fen
YOSE	Crane Flat	YOSE_Index_201	253058	4182639	Wet Meadow
YOSE	Crane Flat	YOSE_Index_202	253147	4182766	Wet Meadow
YOSE	Mono Meadow	YOSE_Index_203	272258	4172879	Fen
YOSE	Mono Meadow	YOSE_Index_204	272203	4172949	Fen
YOSE	Drosera	YOSE_Index_205	256722	4183544	Fen
YOSE	Bridal Veil	YOSE_Index_206	265538	4177701	Wet Meadow
YOSE	Bridal Veil	YOSE_Index_207	265487	4177798	Wet Meadow
YOSE	Tuolumne Meadows	YOSE_Index_208	289899	4194932	Wet meadow
YOSE	Tuolumne Meadows	YOSE_Index_209	290240	4195042	Wet meadow
YOSE	Tuolumne Meadows	YOSE_Index_210	292080	4194591	Wet meadow
YOSE	Tuolumne Meadows	YOSE_Index_211	292102	4194800	Wet meadow

Devils Postpile National Monument Index Site

The index site at DEPO will be monitored annually by SIEN because the site is of high management importance to the park and because there are no extensive sites at DEPO. The DEPO index site (Figure A2.1) will serve as a case study for DEPO and provide valuable information about the hydrology, vegetation, and macroinvertebrates for this important meadow. The objectives for this site mirror the basic objectives of the extensive sites and are:

1. Determine temporal changes in hydrology by measuring ground water table depth through time and associate these measures with stream flow using data from a near-by stream gage.

2. Estimate temporal changes in species composition and abundance of wetland vascular and non-vascular plants by quantifying relative ground cover composition and abundance, woody plant invasion, vegetation structure, and vascular and non-vascular species richness.
3. Evaluate temporal changes in the composition and relative abundance of wetland macro-invertebrate populations by measuring aquatic and terrestrial macro-invertebrate abundance and Family richness, and ant abundance and species richness.
4. Quantify changes in bare ground frequency and abundance and determine the most likely causal agents (e.g., rodent activity, pack stock disturbance, human disturbance, etc.) of the observed bare areas.
5. Determine temporal changes in exotic plant species cover and dominance and document their location and extent within the meadow and surrounding area.

Plot installation, monitoring, and reporting for the DEPO site will follow the same guidelines outlined in the WEI narrative and associated SOPs. DEPO index site data will be stored along with extensive site data in the WEI database according to the same procedures described in the data management and reporting chapter.



Figure A2.1. J. Nesmith at WEI index site in Soda Springs Meadow, Devils Postpile National Monument. Photo: J. Skancke.

Appendix 3: Site Selection

March 2017

Prepared by Jonathan Nesmith and Alice Chung-MacCoubrey

Change History

Revision Date	Rev. No.	Author	Changes Made	Reason for Change
None	–	–	–	–

Add more rows as needed.

Executive Summary

This appendix documents the final site selection process and presents the sites selected for monitoring by the Sierra Nevada Network (SIEN) wetland ecological integrity protocol. Each year 24 wetlands across the network will be visited – of which twelve are in the annual panel and 12 are in an alternating panel. Thus across four years a total of 60 unique sites across the network, plus one additional Index Site located at Devils Postpile National Monument will be sampled. Of these 60 sites, half will be located in Sequoia and Kings Canyon National Parks (SEKI) and half will be in Yosemite National Park (YOSE). Short-hand for the revisit design at each park is [(1-0),(1-3)], which indicates that one panel of sites are sampled annually and remaining panels (‘alternating’ panels) are sampled once and then rested for 3 years before being sampled again (McDonald 2003). Figure A3.1 illustrates the revisit design for the 30 sites to be sampled at SEKI; an identical design will be used for the 30 sites at YOSE.

Panel	Panel type	Year							
		1	2	3	4	5	6	7	8
1	Annual	6	6	6	6	6	6	6	6
2	Alternating	6				6			
3	Alternating		6				6		
4	Alternating			6				6	
5	Alternating				6				6
ANNUAL TOTAL		12	12	12	12	12	12	12	12

Figure A3.1. Annual visitation schedule for a [(1-0),(1-3)] revisit design across wetland types at SEKI. This design will be replicated at YOSE.

Sites were probabilistically selected from the target population using a generalized random tessellation stratified (GRTS) design that incorporated unequal inclusion probabilities (Stevens and Olsen 2004). The sample frame was defined as all ungrazed or lightly grazed fen and wet meadows >0.5 ha within SEKI and sites without significant known human impacts (primarily recent grazing or alteration to meadow hydrology) in YOSE. Wetlands within the sample frame were derived from a comprehensive map of wet meadows and fens that was developed using aerial imagery interpretation, local site knowledge, and other available topographic and environmental data such as slope, aspect, elevation, and watershed size (Pyrooz et al. 2015). This approach was favored over other possible methods of identifying target wetlands such as statistical modeling of wetland locations based on environmental data or reliance on the existing park vegetation maps because we felt that the

relatively subtle environmental differences between wetland types could only be accurately classified using expert local knowledge of the characteristic signatures of these systems. We felt that these often subtle differences would be missed by modeling approaches or were not adequately defined among existing vegetation classes within the park vegetation maps. In general aerial photo interpretation is viewed to be more accurate than remote sensing or other modeling approaches to classify wetlands, especially at a fine scale (Wright and Gallant 2007; Harvey and Hill 2001).

We used an unequal probability design to increase the inclusion probability for fens in the sample draw, ensuring that a roughly equal number of fens and wet meadows would occur in each panel. This approach was important because one of our goals is to assess the ecological condition of fens, and fens are relatively rare compared to wet meadows within the network parks.

Please refer to the Protocol Narrative (Chapter 2) for a complete description of the sampling design. We drew the GRTS sample using the R workspace ‘spsurvey version 2.5’ (Kincaid and Olsen 2012). Original files, including the R code, sample frame data, input files, model output, GRTS output, etc., along with metadata will be stored in the appropriate folders under the I&M directory structure. The R code used for the GRTS draw and the panel assignment including oversample are given at the end of this appendix (Attachment A2.A and Supplementary Table A2.S1).

Site Selection at Sequoia and Kings Canyon

The sampling frame for the GRTS draw within SEKI included all wet meadows and fens >0.5 ha that had received an average grazing intensity of <0.5 grazing nights/ha/year over the past 20 years. A grazing night is defined as one animal for one night where they were allowed to forage. Data for the sampling frame were derived from a map of wet meadows and fens produced by the SEKI Wetland Mapping Project during the spring of 2013 (Pyrooz et al. 2015). Development of the sampling frame was a three-step process, including 1) development of the SEKI Wetland Map, 2) consolidating the number of wetland types from three to two to meet the objectives of the Wetlands Ecological Integrity (WEI) protocol, and 3) filtering to select wetlands of the appropriate size and level of grazing intensity. Below are details on sample frame development and the GRTS draw in SEKI.

Sample Frame Development

A new personal geodatabase called *GrazingIntensityWildCharMapping_Spatial.gdb* was created to attribute the mapped wetland polygon features with grazing intensity. Grazing intensity was calculated as the 20-year average number of stock nights per hectare per year using data that were summarized in 2013 for the Wilderness Character Map (Tricker et al. 2014). This was done using the model builder within ArcMap 10.1. The feature class was called *WetMdwsFens_py_Grazing* and included all 2307 polygons from the Wetland Mapping project and associated grazing intensity (Figure A3.2).

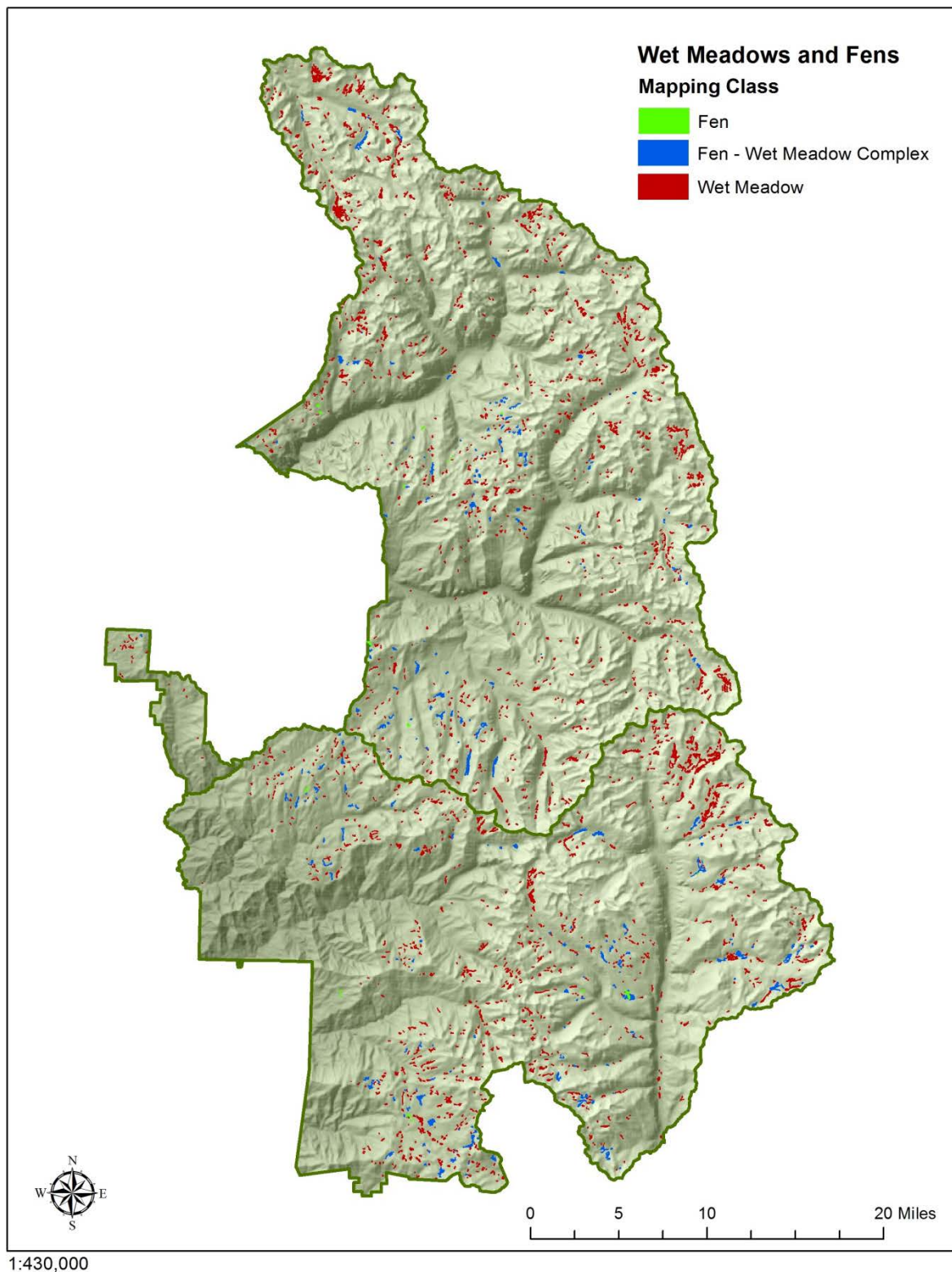


Figure A3.2. Mapped wetlands in Sequoia and Kings Canyon National Parks. The figure includes a total of 2307 mapped wetlands: 17 fens, 260 fen - wet meadow complexes, and 2030 wet meadows.

For the SEKI Wetlands Mapping project, wetlands were grouped into three types: Fens, fen - wet meadow complexes (FenMeadow), and wet meadows (Meadow). Due to the extreme rarity of sites classified as Fen (17 of 2307) and the fact that a majority of these did not meet the 0.5 ha size cut-off, we reduced the number of wetland groups from three to two for the WEI protocol GRTS Draw. Specifically, we eliminated the separate Fen category and included Fen polygons in the FenMeadow group. The total number of polygons classified by wetland type, average grazing intensity, wetland size, and average percent peat accumulating area within each wetland polygon are given in Table A3.1.

Table A3.1. The first step in developing the WEI protocol sampling frame consolidated groups to two types of wetlands (Fen_Meadow and Meadow). Listed are the number of polygons for each type and averages (SE) for percent of the meadow that was estimated to be peat accumulating wetland, 20-year average grazing intensity per hectare (grazing nights/ha/year), and average wetland size (ha).

Meadow Type	Number	Ave. Peat	Ave. Grazing	Ave. Size
Fen_Meadow	277	25.0 (1.3)	2.3 (0.6)	3.5 (0.3)
Meadow	2030	0.3 (0.03)	1.0 (0.1)	1.6 (0.1)
Grand Total	2307	3.3	1.2	1.8

Next, a filter was applied to remove wetlands <0.5 ha and with grazing intensity >0.5 grazing nights/ha/year (20 year avg.). This reduced the number of meadows included in the WEI sample frame to 1582. The removal of small and grazed meadows did little to alter average wetland size or estimated percent peat accumulating area of the target wetlands compared to the total wetland population (Table A3.2). The filtered feature class was called *WEI_GRTS_sampleframe* and was copied into a new file geodatabase called *WEI_GRTS_SEKI.gdb*.

Table A3.2. Composition of the final sampling frame for the WEI protocol GRTS draw. Listed are the number of polygons for each type and averages (SE) for percent of the meadow that was estimated to be peat accumulating wetland, 20-year average grazing intensity per hectare (grazing nights/ha/yr), and average size (ha).

Meadow Type	Number	Ave. Peat	Ave. Grazing	Ave. Size
Fen_Meadow	175	22.5 (1.4)	0.04 (0.007)	3.5 (0.3)
Meadow	1407	0.2 (0.03)	0.02 (0.002)	1.9 (0.1)
Grand Total	1582	2.7	0.02	2.1

A point feature class called *WEI_GRTS_sampleframe_pt* was created from *WEI_GRTS_sampleframe* using XTools Pro:Convert Feature to Point tool. This feature class was saved within the *WEI_GRTS_SEKI* geodatabase as a shapefile. The shapefile *WEI_GRTS_Sampleframe_SEKI_pt* was used to run the sample site selection GRTS draw using the package *spsurvey* within R (Kincaid and Olsen 2012).

Site Selection and Panel Assignment Using GRTS

The R code and data are provided at the end of this appendix (Attachment A3.A and Table A3.S1). Code was based on Kincaid (2012) for an unstratified, unequal probability, GRTS survey design with an oversample. This approach was selected because it allows for a spatially balanced sampling design that retains many of the statistical properties of a simple random sample, which is an implicit assumption of many statistical tests (Stevens and Olsen 2004). Another key advantage of using a GRTS design for long term monitoring is that it can provide a framework for replacement of selected sites. Inclusion probabilities were based on wetland type classification and were adjusted to produce a roughly equal number of selected wetlands from each classification type within the overall sample. All wetlands in the sampling frame have a nonzero probability of inclusion so that inference may be made to the larger population. Wetlands classified as wet meadow – fen complexes had a higher inclusion probability than wetlands classified as wet meadows due to their relative rarity across the parks. All wetlands within a specific wetland type had the same probability of inclusion.

The results of the GRTS draw were saved as a text file called GRTS_Order_SEKI_FINAL.txt. This file was converted to an excel file and imported into WEI_GRTS_SEKI.mxd. The xy data were displayed and the results were saved as a shapefile called GRTS_Order_SEKI_FINAL.shp. The results of the panel assignments by wetland type from the GRTS draw are shown in Table A3.3 and their location within SEKI is shown in Figure A3.3.

Table A3.3. Number of sites in each panel by meadow type. Total sample size (across meadow types) for each of the 5 panels was six, and total sample size for the oversample was 60. An unequal probability survey design was used where the targeted sample size for each meadow type was set at 15 (See Attachment A3.A that includes the R code at the end of this appendix).

GRTS Seed #	Meadow Type	Panel 1 Annual	Panel 2 (Alternating)	Panel 3 (Alternating)	Panel 4 (Alternating)	Panel 5 (Alternating)	OverSamp
5152	Fen_Meadow	3	2	3	3	4	31
5277	Meadow	3	4	3	3	2	29

Plot Location Assignment Using GRTS

Once all the target wetlands have been selected for sampling using GRTS, the specific locations of the macroplots within them must be identified. This is also accomplished using a GRTS design where 30 points are randomly selected within the wetland polygon and then visited in ascending order with the lowest point that falls within the target wetland type being used to establish the plot. For additional information on plot establishment criteria see SOP 6. For sites that comprise both fen and wet meadow, two locations are selected using the lowest GRTS numbers within the respective wetland types. R code for this GRTS draw is included at the end of this appendix.

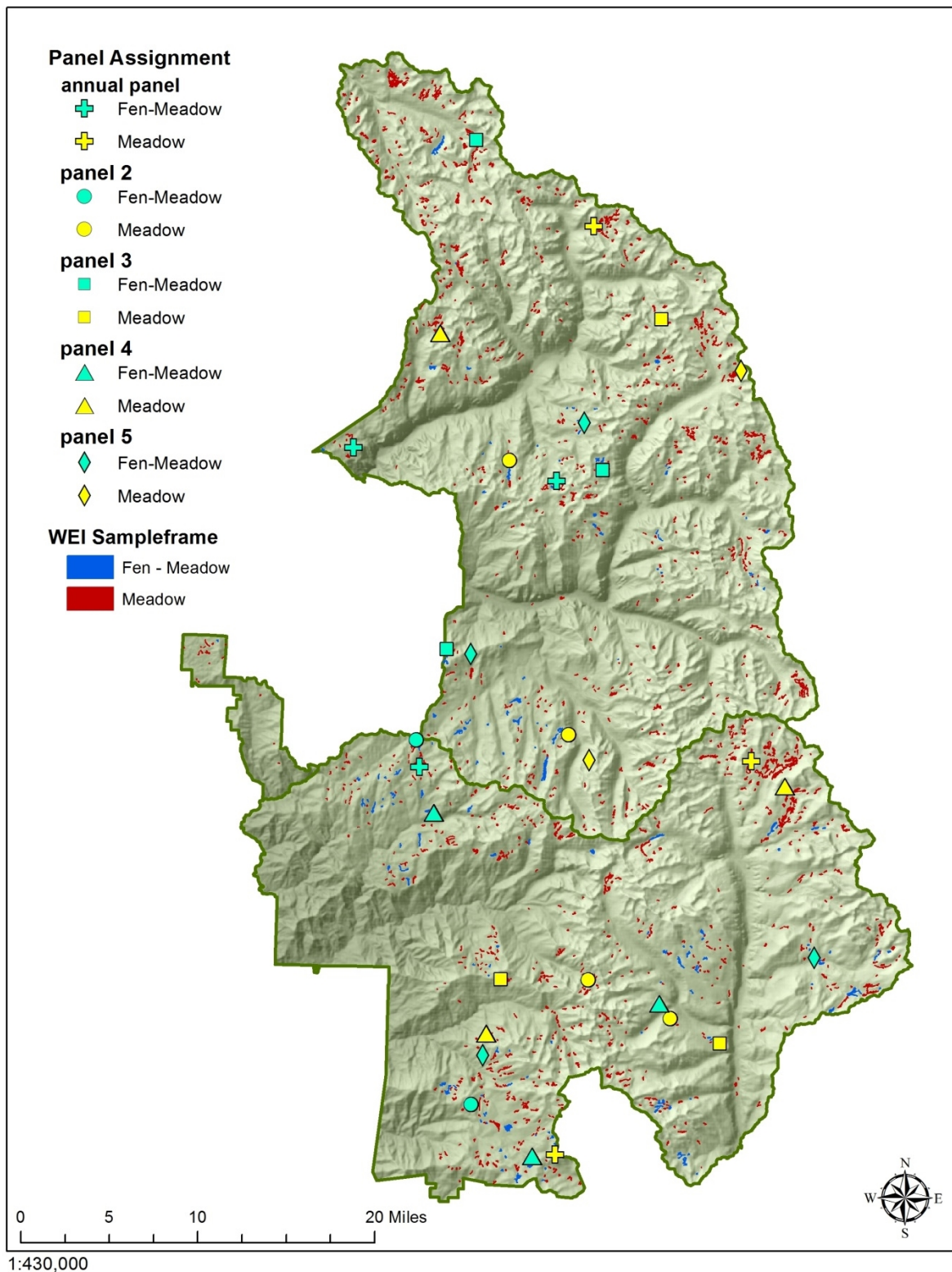


Figure A3.3. WEI panel assignments and plot locations at Sequoia and Kings Canyon National Parks.

Site Selection at Yosemite

The sampling frame used for the GRTS draw included all wet meadows and fens >0.5 ha within the park boundary that have not been significantly altered by recent human activity (n=1,379). These data were produced from aerial imagery and other sources and the process is documented in the Yosemite Wetland Mapping Project Report (Pyrooz et al. *In prep*). Specific meadows were excluded from the sample frame based on subject matter expertise provided by Yosemite NPS and USGS staff to remove meadows that had experienced high recent stock use or extensive human impacts such as alterations in hydrology due to roads or dams. Only 5 % of the identified target wetlands were removed based on these opinions. A list of wetlands that were removed from the wetland map to produce the sample frame are listed in Supplementary Table S2 at the end of this appendix. Results of the GRTS draw and the steps that were followed to produce the panel assignments are described below.

Sample Frame Development

The original YOSE wetlands mapping project identified 1605 target wetlands that were classified into three types: Fens, Fen_Meadow, and Wet_Meadow (Figure A3.4). These data were created in a versioned SDE environment and are housed on the SEKI GIS server (SEKIGIS.DBO.WetlandsProject) in a layer file called “SEKIGIS.DBO.YOSE_WetMeadowFen_py”. These data were copied into a separate shapefile called WetMaP_polygons_20150309.

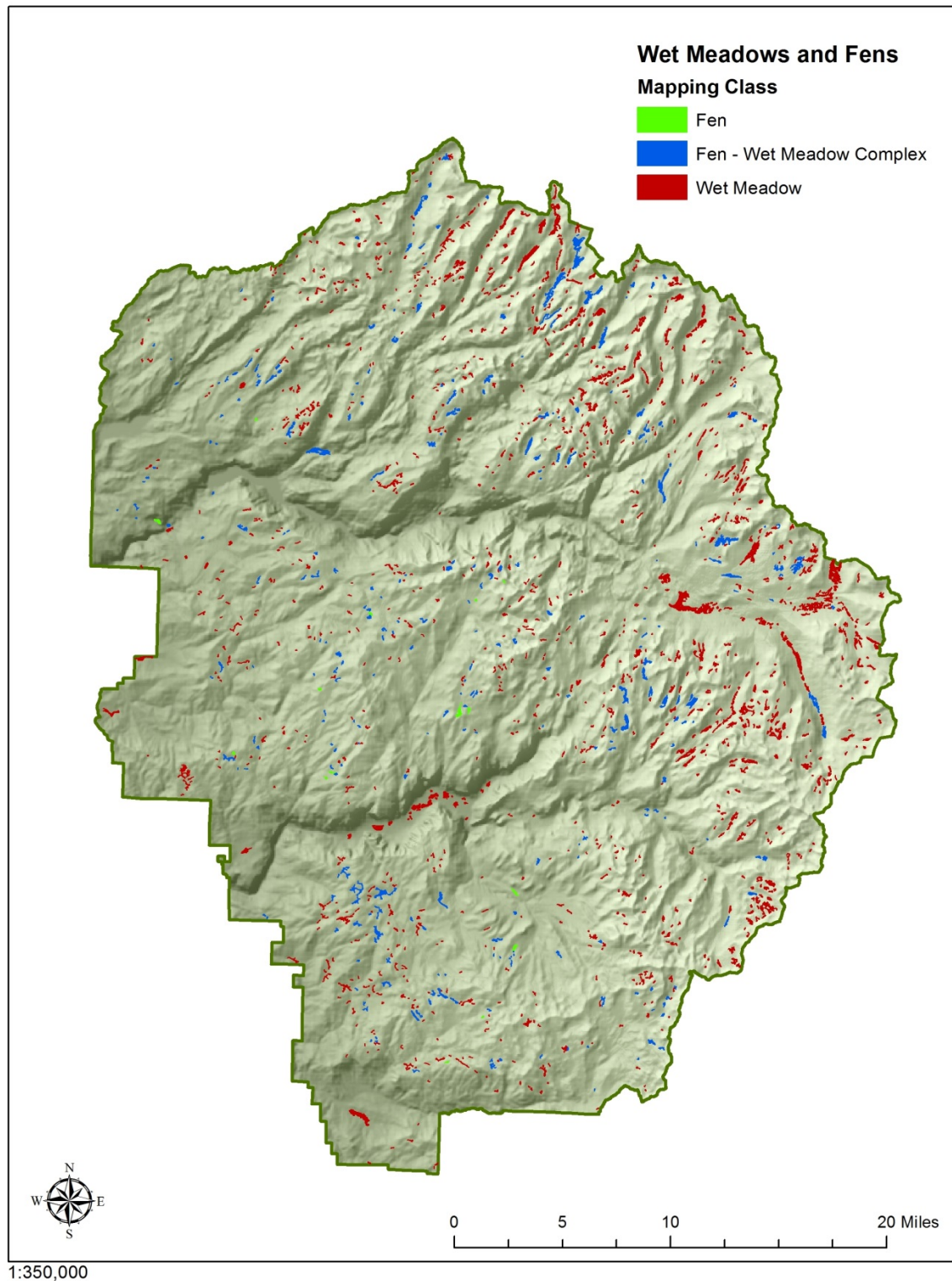


Figure A3.4. Mapped wetlands in Yosemite National Park. The figure includes a total of 1605 mapped wetlands: 17 fens, 297 fen - wet meadow complexes, and 1291 wet meadows.

For the WEI protocol GRTS Draw, wetlands that were projected to contain peat during the wetland mapping project that were assigned by photointerpreters as “Fen” or “Fen_meadow” were lumped into a single group within the field called “Fen_Meadow” due to the scarcity of sites classified as Fen (17 out of 1605 target wetlands) and to be consistent with the SEKI GRTS Draw process (Table A3.4). These data were added to the shapefile in a new field called “WEI_WetTyp”.

Table A3.4. Summary of estimated percent of the meadow that is peat accumulating wetland and average size (ha) by meadow type for the original WetMaP project polygons.

Row Labels	Average percent peat	Average size (ha)	Count
Fen_Meadow	30.2	4.07	314
Meadow	0.3	2.35	1291
Grand Total	6.1	2.68	1605

The 1605 target wetlands identified in the WetMaP project were then filtered to apply the minimum size threshold of 0.5 ha. This reduced the sample frame to 1463 sites. An additional 84 sites were removed based on expert opinion (one sight recommended for removal had already been removed by the size requirement; Supplementary Table A3.S2). Reasons for removal included: heavy stock use within the last 5 years, high visitor use (e.g., Tuolumne meadow), or human caused alterations to meadow hydrology from infrastructure such as buildings, wells, campgrounds, golf courses, dams, or paved roads. Specific justifications for the removal of individual meadows from the sample frame are provided in Supplementary Table A3.S2. Sites that were removed based on expert opinion were indicated by a new field called “Disturbed” in WetMaP_polygons_20150309. The final number of target wetlands included in the WEI sample frame was 1379 and these were saved in a separate shapefile called WEI_GRTS_Sampleframe_YOSE_20150310.shp (Table A3.5) using a definition query to select only the target polygons.

Table A3.5. Summary of estimated percent of the meadow that is peat accumulating wetland and average size (ha) by meadow type for the YOSE WEI sample frame wetland polygons.

Row Labels	Average percent peat	Average size (ha)	Count
Fen_Meadow	28.6	4.40	267
Meadow	0.3	2.17	1112
Grand Total	5.8	2.60	1379

A point featureclass was created from WEI_Sampleframe_20150310 using XTools Pro:Convert Feature to Point. The featureclass was saved as a shapefile called *WEI_Sampleframe_20150309_pt_Final.shp* and was used to run the GRTS draw using the package *spsurvey* within R (Kincaid and Olsen 2012).

Site Selection and Panel Assignment using GRTS

R code was based on Kincaid (2012) for an unstratified, unequal probability, GRTS survey design with an oversample and followed the same procedures described above for SEKI. The results of the draw were saved as a text file called YOSE_WEI_GRTS_ORDER_20150310_Final.txt. This file was converted to an excel file and the xy data were displayed within the ArcMap project and saved as a shapefile called GRTS_Order_YOSE_Final_20150309.shp. Summary statistics are given in Table A3.6 and the R code used to produce the panel assignments is given in Attachment A3.A.

Table A3.6. Summary of estimated percent of the meadow that is peat accumulating wetland and average size (ha) by meadow type for the selected WEI wetland sites by panel assignment (n = 30).

Row Labels	Average percent peat	Average size (ha)
Fen_Meadow	37.9	3.35
Annual	21.7	1.59
Year1	63.3	1.28
Year2	9.0	5.68
Year3	51.3	5.76
Year4	40.0	1.64
Meadow	0.4	2.24
Annual	1.7	1.00
Year1	0	1.97
Year2	0	0.57
Year3	0	3.90
Year4	0	4.29
Grand Total	20.4	2.83

The spatial distribution of sites from the draw is shown in Figure A3.5 and the distribution of sites among panels is given in Table A3.7. The GRTS order of all sites and their UTM's are provided in Table A3.S2. The same procedure of selecting 30 potential plot locations within each wetland using GRTS was employed at YOSE and the R code is included in Attachment A3.A.

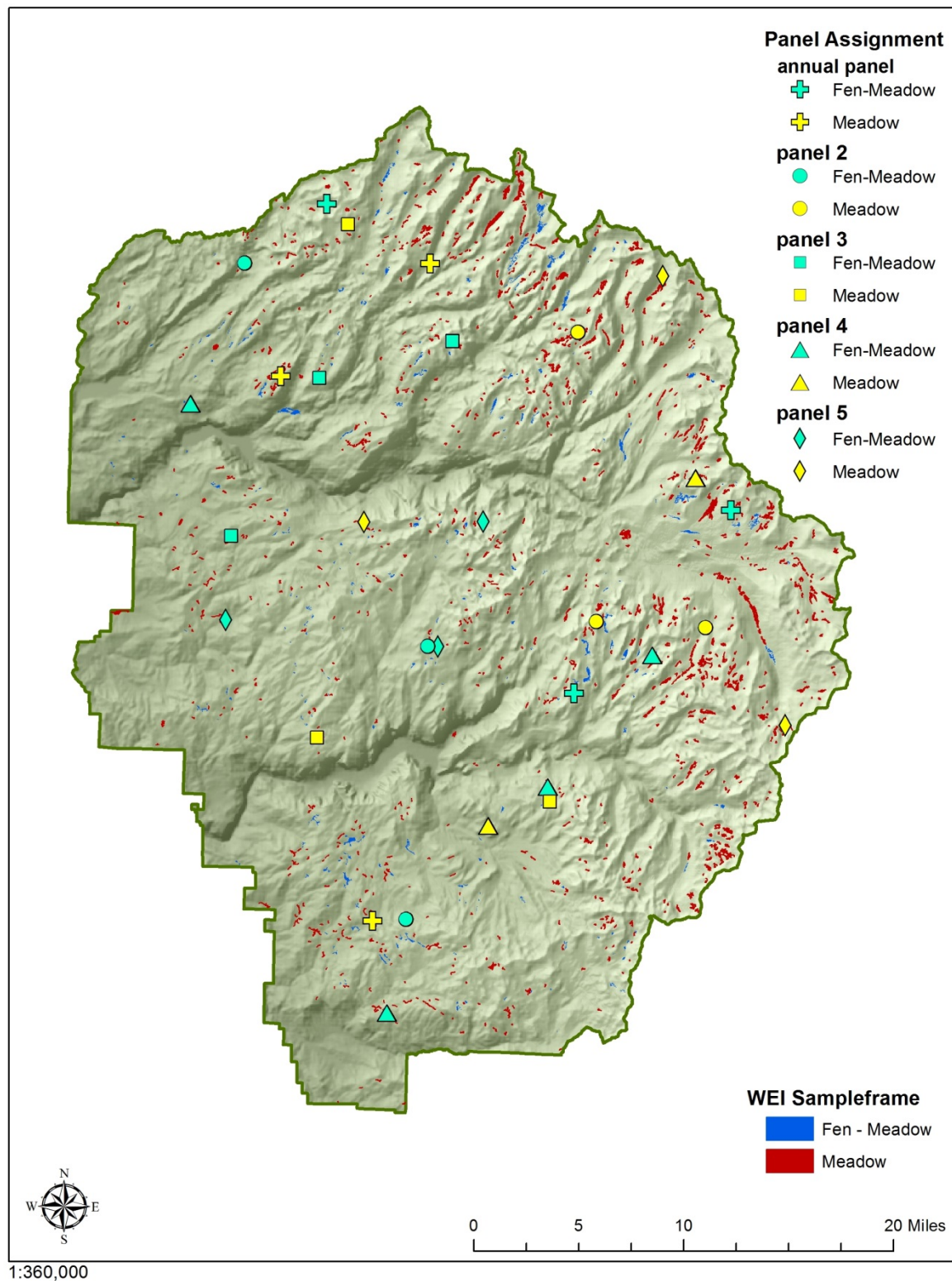


Figure A3.5. WEI panel assignments and plot locations at Yosemite National Park.

Table A3.7. GRTS Draw panel assignment by meadow type. Each of the 4 panels was set at 6 and the oversample was set at 60. An unequal probability survey design was used where the targeted sample size for each meadow type was set at 15.

Meadow Type	Annual	Year1	Year2	Year3	Year4	OverSamp
Fen_Meadow	3	3	3	4	3	33
Meadow	3	3	3	2	3	27

Literature Cited

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Attachment A3.A. R Code for Site Selection and Plot Location for Sequoia, Kings Canyon, and Yosemite National Parks GRTS Draw

```
# Wetland site selection #
#SEKI#
setwd("J:\\sien\\monitoring_projects\\wetlands\\data\\analyses\\G
RTS\\GRTS_draw_SEKI")

library(sp)
library(rgdal)
library(spsurvey)

## Code based on Kincaid 2012 #
att<-read.dbf("WEI_GRTS_sampleframe_SEKI_pt")

table("wetland"=att$WEI_Wetlan)
shp<-read.shape("WEI_GRTS_sampleframe_SEKI_pt")

Paneldsgn<-list(None=list(panel=c(Annual=6, Year1=6, Year2=6,
Year3=6, Year4=6),seltype="Unequal",
caty.n=c("Meadow"=15, "Fen_Meadow"=15),over=60))

# seed<-sample(1000000000,1) # run to get random seed
seed<-51525277 #original set seed used for all runs

set.seed(seed)

GRTSDraw <-
grts(design=Paneldsgn,DesignID="UNEQUAL",type.frame="finite",
src.frame="shapefile",
in.shape="WEI_GRTS_sampleframe_SEKI_pt", att.frame=att,
mdcaty="WEI_Wetlan",
shapefile=FALSE)

dsgnsum(GRTSDraw)
print(GRTSDraw[1:10,1:10])
write.table(GRTSDraw[1:90,],"J:\\sien\\monitoring_projects\\wetla
nds\\data\\analyses\\GRTS\\GRTS_draw_SEKI\\GRTS_Order_SEKI_2.txt"
, sep=",")

# Stage Two GRTS DRAW#
# Plot Location Selection #
```

```
Att.plot <- read.dbf("WEI_GRTS_sampleframe_SEKI")
table(Att.plot$wetland<-Att.plot$WEI_Wetlan)
shp<-read.shape("WEI_GRTS_sampleframe_SEKI")
Att.plot$Poly<-paste("polyID",Att.plot$Poly_ID, sep="_")

Wet_equal3rdstage_strata_specs <- list(
polyID_1170=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1335=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1680=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_2294=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1306=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1872=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1672=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_2145=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1312=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1711=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_769=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1958=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_74=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1496=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_2120=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_749=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_146=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1379=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1694=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_2248=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1154=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_964=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1023=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_2044=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_294=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1598=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_734=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1989=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1277=list(panel=c(Main=30), seltype="Equal", over=0),
polyID_1490=list(panel=c(Main=30), seltype="Equal", over=0))

#sample(100000000,1)
# run to get random seed
set.seed(50921794)
Wet_equal3rdstage_strata_Design <-
grts(design=Wet_equal3rdstage_strata_specs,
```

```
DesignID='SEKI_extent',
type.frame='area',
src.frame='shapefile',
in.shape='WEI_GRTS_sampleframe_SEKI',
stratum='Poly',
att.frame=Att.plot,
shapefile='seki_3rdstage_panelsites_final')

dsgnsum(Wet_equal3rdstage_strata_Design)
print(Wet_equal3rdstage_strata_Design[1:10,1:10])
write.table(Wet_equal3rdstage_strata_Design[1:900,], "J:\\sien\\mo
nitoring_projects\\wetlands\\data\\analyses\\GRTS\\GRTS_draw_SEKI
\\GRTS_Order_SEKI_Stage3_1.txt", sep=",")

#YOSE#
setwd("J:\\sien\\monitoring_projects\\wetlands\\data\\analyses\\G
RTS\\GRTS_draw_YOSE\\GRTS_Draw_Files")
## Code based on Kincaid 2012 #
att<-read.dbf("WEI_Sampleframe_20150309_pt_Final")
names(att)
table("wetland"=att$WEI_WetTyp)
shp<-read.shape("WEI_Sampleframe_20150309_pt_Final")

Paneldsgn<-list(None=list(panel=c(Annual=6, Year1=6, Year2=6,
Year3=6, Year4=6), seltype="Unequal",
caty.n=c("Meadow"=15, "Fen_Meadow"=15), over=60))

# seed<-sample(1000000000,1) # run to get random seed
seed<-62978679 #original set seed used
set.seed(seed)

GRTSDraw <-
grts(design=Paneldsgn, DesignID="UNEQUAL", type.frame="finite",
src.frame="shapefile",
in.shape="WEI_Sampleframe_20150309_pt_Final", att.frame=att,
mdcaty="WEI_WetTyp",
shapefile=FALSE)

dsgnsum(GRTSDraw)
print(GRTSDraw[1:10,1:10])
```

```
write.table(GRTSDraw[1:90,], "J:\\sien\\monitoring_projects\\wetlands\\data\\analyses\\GRTS\\GRTS_draw_YOSE\\GRTS_Draw_Files\\Yose_GRTS_Draw\\GRTS_Order_YOSE_Final_20150309.txt", sep=",")  
#Stage two GRTS Draw#  
# Plot Location Selection #
```

```
Att.plot <- read.dbf("WEI_GRTS_sampleframe_YOSE_20150310")  
table(Att.plot$wetland<-Att.plot$WEI_WetTyp)  
shp<-read.shape("WEI_GRTS_sampleframe_YOSE_20150310")  
Att.plot$Poly<-paste("polyID",Att.plot$Poly_ID, sep="_")
```

```
YOSE_WEI_equal3rdstage_strata_specs <- list(  
  polyID_49=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_394=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1384=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1067=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_68=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_695=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1388=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_958=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_132=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_234=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_901=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_870=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_434=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_663=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1165=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1603=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_99=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_409=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1476=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1310=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_473=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_579=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1241=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1055=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_591=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_338=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_903=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_1104=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_551=list(panel=c(Main=30), seltype="Equal", over=0),  
  polyID_807=list(panel=c(Main=30), seltype="Equal", over=0))
```

```
# run to get random seed
seed<-sample(100000000,1)
seed

set.seed(1115086)
YOSE_WEI_equal3rdstage_strata_Design <-
grts(design=YOSE_WEI_equal3rdstage_strata_specs,
  DesignID='YOSE_extent',
  type.frame='area',
  src.frame='shapefile',
  in.shape='WEI_GRTS_sampleframe_YOSE_20150310',
  stratum='Poly',
  att.frame=Att.plot,
  shapefile='YOSE_WEI_3rdstage_panelsites_final')

dsgnsum(YOSE_WEI_equal3rdstage_strata_Design)
print(YOSE_WEI_equal3rdstage_strata_Design[1:10,1:10])

write.table(YOSE_WEI_equal3rdstage_strata_Design[1:900, ], "J:\\sien\\monitoring_projects\\wetlands\\data\\analyses\\GRTS\\GRTS_draw_YOSE\\GRTS_Draw_Files\\YOSE_GRTS_Draw\\GRTS_Order_YOSE_Stage3.txt", sep=",")
```

Table A3.S1. GRTS order for selected sites in SEKI. Thirty sites were selected as part of the main panel design (See Table A3.3 in this appendix) and an additional 60 were selected as part of an oversample. Poly_ID is a unique identifier for each wetland from the total population of mapped wetlands.

Poly_ID	SiteID	Xcoord	Ycoord	Meadow_Type	Panel
1170	UNEQUAL-01	360443.7781	4106858.382	Meadow	Annual
1335	UNEQUAL-02	357042.4229	4083633.399	Fen_Meadow	Annual
1680	UNEQUAL-03	344554.6259	4057556.188	Fen_Meadow	Annual
2294	UNEQUAL-04	356905.3344	4022190.116	Meadow	Annual
1306	UNEQUAL-05	338555.6739	4086687.895	Fen_Meadow	Annual
1872	UNEQUAL-06	374798.3306	4058056.665	Meadow	Annual
1672	UNEQUAL-07	344284.2171	4060007.957	Fen_Meadow	Year1
2145	UNEQUAL-08	367399.82	4034565.55	Meadow	Year1
1312	UNEQUAL-09	352747.3379	4085492.309	Meadow	Year1
1711	UNEQUAL-10	358139.2385	4060468.389	Meadow	Year1
769	UNEQUAL-11	349249.477	4026745.714	Fen_Meadow	Year1
1958	UNEQUAL-12	359940.9305	4038111.362	Meadow	Year1
74	UNEQUAL-13	366579.0962	4098351.574	Meadow	Year2
1496	UNEQUAL-14	347022.454	4068310.99	Fen_Meadow	Year2
2120	UNEQUAL-15	351943.1367	4038173.283	Meadow	Year2
749	UNEQUAL-16	371915.5053	4032318.503	Meadow	Year2
146	UNEQUAL-17	349736.0852	4114724.476	Fen_Meadow	Year2
1379	UNEQUAL-18	361224.3815	4084622.118	Fen_Meadow	Year2
1694	UNEQUAL-19	345859.138	4053365.933	Fen_Meadow	Year3
1154	UNEQUAL-21	346467.6785	4097077.849	Meadow	Year3
964	UNEQUAL-22	377851.1836	4055764.578	Meadow	Year3
1023	UNEQUAL-23	350645.9882	4033226.082	Meadow	Year3
2044	UNEQUAL-24	366421.7081	4035975.342	Fen_Meadow	Year3
294	UNEQUAL-25	373854.5357	4093636.036	Meadow	Year4
1598	UNEQUAL-26	360024.8168	4058125.675	Meadow	Year4
734	UNEQUAL-27	350357.0827	4031232.308	Fen_Meadow	Year4
1989	UNEQUAL-28	380529.714	4040130.847	Fen_Meadow	Year4
1277	UNEQUAL-29	359597.1602	4088890.959	Fen_Meadow	Year4
1490	UNEQUAL-30	349266.4266	4067829.652	Fen_Meadow	Year4

Poly_ID	SiteID	Xcoord	Ycoord	Meadow_Type	Panel
1769	UNEQUAL-31	354561.0306	4050680.453	Fen_Meadow	OverSamp
2032	UNEQUAL-32	382101.364	4035374.656	Fen_Meadow	OverSamp
132	UNEQUAL-33	346706.6611	4117840.23	Meadow	OverSamp
1421	UNEQUAL-34	366454.5786	4078400.051	Fen_Meadow	OverSamp
424	UNEQUAL-35	348133.2682	4060725.872	Fen_Meadow	OverSamp
1921	UNEQUAL-36	362838.8414	4040804.484	Meadow	OverSamp
1064	UNEQUAL-37	350394.3461	4101480.655	Meadow	OverSamp
939	UNEQUAL-38	380581.2221	4051942.449	Fen_Meadow	OverSamp
2173	UNEQUAL-40	355486.7102	4029261.141	Meadow	OverSamp
1242	UNEQUAL-41	360383.1222	4093592.595	Meadow	OverSamp
1524	UNEQUAL-42	376249.5461	4079002.167	Fen_Meadow	OverSamp
850	UNEQUAL-43	343550.6206	4047129.359	Fen_Meadow	OverSamp
1849	UNEQUAL-44	376479.9898	4045850.804	Meadow	OverSamp
1273	UNEQUAL-45	360624.5903	4090189.41	Fen_Meadow	OverSamp
564	UNEQUAL-46	339857.6263	4054482.218	Fen_Meadow	OverSamp
2260	UNEQUAL-47	351966.4703	4022579.63	Fen_Meadow	OverSamp
698	UNEQUAL-48	386555.3108	4042521.794	Meadow	OverSamp
53	UNEQUAL-49	349402.2323	4113240.852	Meadow	OverSamp
1594	UNEQUAL-50	362672.2868	4067343.897	Fen_Meadow	OverSamp
1553	UNEQUAL-51	347517.1643	4061956.501	Meadow	OverSamp
1975	UNEQUAL-52	366920.3768	4040683.544	Fen_Meadow	OverSamp
1314	UNEQUAL-53	351044.16	4087089.521	Fen_Meadow	OverSamp
1707	UNEQUAL-54	356869.4737	4060105.911	Fen_Meadow	OverSamp
787	UNEQUAL-55	351969.9589	4028398.132	Meadow	OverSamp
758	UNEQUAL-56	356672.7821	4035237.958	Meadow	OverSamp
187	UNEQUAL-57	358054.895	4104857.351	Meadow	OverSamp
1489	UNEQUAL-58	373946.9209	4077588.839	Meadow	OverSamp
1698	UNEQUAL-59	347434.1904	4050953.004	Meadow	OverSamp
675	UNEQUAL-60	369048.2262	4040502.517	Fen_Meadow	OverSamp
1272	UNEQUAL-61	357334.2157	4085472.82	Fen_Meadow	OverSamp
565	UNEQUAL-62	341248.7144	4054621.651	Fen_Meadow	OverSamp

Poly_ID	SiteID	Xcoord	Ycoord	Meadow_Type	Panel
1041	UNEQUAL-63	368738.2058	4021563.528	Fen_Meadow	OverSamp
2021	UNEQUAL-64	387344.194	4040686.867	Fen_Meadow	OverSamp
1666	UNEQUAL-65	364573.9682	4054130.029	Meadow	OverSamp
1986	UNEQUAL-66	380910.096	4039842.737	Fen_Meadow	OverSamp
100	UNEQUAL-67	367059.0337	4084354.042	Fen_Meadow	OverSamp
594	UNEQUAL-68	350974.4915	4039381.031	Fen_Meadow	OverSamp
1092	UNEQUAL-69	360545.2998	4080518.069	Fen_Meadow	OverSamp
32	UNEQUAL-70	368516.0092	4024274.925	Meadow	OverSamp
1438	UNEQUAL-71	374330.6288	4080226.266	Fen_Meadow	OverSamp
2054	UNEQUAL-72	347820.3451	4028365.301	Fen_Meadow	OverSamp
1728	UNEQUAL-73	339016.1459	4056420.792	Fen_Meadow	OverSamp
2197	UNEQUAL-74	369736.2611	4027412.106	Meadow	OverSamp
1141	UNEQUAL-75	345357.3403	4107789.201	Meadow	OverSamp
1554	UNEQUAL-76	348422.9506	4061596.437	Meadow	OverSamp
1880	UNEQUAL-77	377114.3309	4052042.594	Fen_Meadow	OverSamp
2114	UNEQUAL-78	365989.238	4027263.63	Meadow	OverSamp
315	UNEQUAL-79	365136.758	4091062.08	Meadow	OverSamp
830	UNEQUAL-80	352096.3491	4020782.09	Fen_Meadow	OverSamp
542	UNEQUAL-81	378752.9677	4058925.835	Meadow	OverSamp
1896	UNEQUAL-82	362482.9266	4047381.092	Meadow	OverSamp
1409	UNEQUAL-83	353948.7932	4079639.029	Meadow	OverSamp
2284	UNEQUAL-84	350630.4074	4025975.194	Fen_Meadow	OverSamp
392	UNEQUAL-85	374336.7234	4075480.311	Meadow	OverSamp
1009	UNEQUAL-86	370380.4591	4041903.007	Fen_Meadow	OverSamp
1066	UNEQUAL-87	349436.0797	4098115.469	Meadow	OverSamp
948	UNEQUAL-88	354818.1564	4056863.881	Meadow	OverSamp
1677	UNEQUAL-89	344697.3216	4058667.716	Meadow	OverSamp
1049	UNEQUAL-90	324680.2418	4068483.621	Meadow	OverSamp

Table A3.S2. GRTS order for selected sites in YOSE. Thirty sites were selected as part of the main panel design (See Table A3.7 in this appendix) and an additional 60 were selected as part of an oversample. Poly_ID is a unique identifier for each wetland from the total population of mapped wetlands.

Poly_ID	SiteID	Xcoord	Ycoord	Wetland_Type	Panel
49	UNEQUAL-01	266123.4254	4222241.53	Fen_Meadow	Annual
394	UNEQUAL-02	262587.7214	4209045.012	Meadow	Annual
1384	UNEQUAL-03	269607.2108	4167296.447	Meadow	Annual
1067	UNEQUAL-04	285059.003	4184745.038	Fen_Meadow	Annual
68	UNEQUAL-05	274028.2693	4217664.657	Meadow	Annual
695	UNEQUAL-06	297119.6787	4198756.332	Fen_Meadow	Annual
1388	UNEQUAL-07	272175.0989	4167427.317	Fen_Meadow	Year1
958	UNEQUAL-08	295163.9745	4189760.972	Meadow	Year1
132	UNEQUAL-09	259807.3073	4217692.805	Fen_Meadow	Year1
234	UNEQUAL-10	285364.4971	4212369.609	Meadow	Year1
901	UNEQUAL-11	273847.5541	4188324.801	Fen_Meadow	Year1
870	UNEQUAL-12	286764.88	4190221.587	Meadow	Year1
434	UNEQUAL-13	275753.8657	4211715.94	Fen_Meadow	Year2
663	UNEQUAL-14	258769.7672	4196809.852	Fen_Meadow	Year2
1165	UNEQUAL-15	265333.6943	4181355.255	Meadow	Year2
1603	UNEQUAL-16	283197.4948	4176453.984	Meadow	Year2
99	UNEQUAL-17	267719.8209	4220676.793	Meadow	Year2
409	UNEQUAL-18	265543.0391	4208893.636	Fen_Meadow	Year2
1476	UNEQUAL-19	270711.106	4160256.345	Fen_Meadow	Year3
1310	UNEQUAL-20	283065.2067	4177566.348	Fen_Meadow	Year3
473	UNEQUAL-21	255650.5254	4206912.896	Fen_Meadow	Year3
579	UNEQUAL-22	294401.3852	4201235.201	Meadow	Year3
1241	UNEQUAL-23	278471.5864	4174590.804	Meadow	Year3
1055	UNEQUAL-24	291064.3805	4187664.861	Fen_Meadow	Year3
591	UNEQUAL-25	278120.9613	4197866.815	Fen_Meadow	Year4
338	UNEQUAL-26	291912.1241	4216684.377	Meadow	Year4
903	UNEQUAL-27	274636.5777	4188307.38	Fen_Meadow	Year4
1104	UNEQUAL-28	301296.1581	4182257.746	Meadow	Year4
551	UNEQUAL-29	268963.0114	4197858.281	Meadow	Year4

Poly_ID	SiteID	Xcoord	Ycoord	Wetland_Type	Panel
807	UNEQUAL-30	258375.7912	4190337.089	Fen_Meadow	Year4
812	UNEQUAL-31	264643.5964	4190240.12	Fen_Meadow	OverSamp
1580	UNEQUAL-32	294609.135	4167993.923	Meadow	OverSamp
84	UNEQUAL-33	275989.5271	4218090.694	Meadow	OverSamp
497	UNEQUAL-34	282093.341	4206049.056	Fen_Meadow	OverSamp
1506	UNEQUAL-35	279959.9242	4160583.123	Meadow	OverSamp
974	UNEQUAL-36	295253.5547	4186204.15	Meadow	OverSamp
561	UNEQUAL-37	251305.6007	4201129.038	Fen	OverSamp
255	UNEQUAL-38	283798.44	4209649.618	Meadow	OverSamp
1216	UNEQUAL-39	264736.9139	4165714.453	Meadow	OverSamp
957	UNEQUAL-40	297009.7773	4189717.501	Meadow	OverSamp
553	UNEQUAL-41	273062.6138	4197690.233	Fen_Meadow	OverSamp
356	UNEQUAL-42	294215.6557	4211210.984	Fen_Meadow	OverSamp
1166	UNEQUAL-43	265457.7915	4182136.17	Meadow	OverSamp
745	UNEQUAL-44	302531.8955	4194584.041	Meadow	OverSamp
660	UNEQUAL-45	262149.0036	4196959.659	Fen_Meadow	OverSamp
1357	UNEQUAL-46	268060.1172	4173498.485	Fen_Meadow	OverSamp
819	UNEQUAL-47	263377.4788	4192269.884	Fen_Meadow	OverSamp
1524	UNEQUAL-48	284058.9044	4157479.283	Meadow	OverSamp
35	UNEQUAL-49	270661.1207	4224358.408	Fen_Meadow	OverSamp
524	UNEQUAL-50	292865.3261	4206768.174	Meadow	OverSamp
1499	UNEQUAL-51	270735.4287	4164514.164	Fen_Meadow	OverSamp
1326	UNEQUAL-52	293020.912	4179975.558	Meadow	OverSamp
151	UNEQUAL-53	259738.1635	4211790.864	Fen_Meadow	OverSamp
218	UNEQUAL-54	282373.3481	4216176.476	Meadow	OverSamp
1219	UNEQUAL-55	266662.3841	4165320.744	Fen_Meadow	OverSamp
604	UNEQUAL-56	280428.7063	4194315.096	Fen_Meadow	OverSamp
417	UNEQUAL-57	271909.8788	4211107.232	Meadow	OverSamp
266	UNEQUAL-58	286315.4631	4218195.734	Meadow	OverSamp
1140	UNEQUAL-59	264239.8978	4182781.273	Fen_Meadow	OverSamp
766	UNEQUAL-60	302256.5148	4190949.997	Meadow	OverSamp

Poly_ID	SiteID	Xcoord	Ycoord	Wetland_Type	Panel
118	UNEQUAL-61	269057.0157	4214581.571	Fen_Meadow	OverSamp
1019	UNEQUAL-62	264770.1188	4174849.306	Fen_Meadow	OverSamp
833	UNEQUAL-63	268822.0207	4192809.218	Fen_Meadow	OverSamp
1440	UNEQUAL-64	289824.1104	4166457.475	Fen_Meadow	OverSamp
301	UNEQUAL-65	289065.1371	4216750.431	Meadow	OverSamp
1048	UNEQUAL-66	289625.331	4187124.733	Meadow	OverSamp
206	UNEQUAL-67	280066.2179	4216364.256	Fen_Meadow	OverSamp
1034	UNEQUAL-68	267330.2145	4189721.264	Fen_Meadow	OverSamp
521	UNEQUAL-69	287365.1613	4204185.31	Fen_Meadow	OverSamp
1065	UNEQUAL-70	285909.4641	4185741.487	Fen_Meadow	OverSamp
493	UNEQUAL-71	279719.4514	4204876.353	Fen_Meadow	OverSamp
841	UNEQUAL-72	279235.5158	4192784.857	Meadow	OverSamp
1114	UNEQUAL-73	256932.2636	4183888.827	Fen	OverSamp
1418	UNEQUAL-74	296902.857	4173015.517	Meadow	OverSamp
74	UNEQUAL-75	279886.0893	4223129.983	Meadow	OverSamp
1486	UNEQUAL-76	275702.0845	4163356.483	Meadow	OverSamp
260	UNEQUAL-77	280714.4982	4209172.6	Fen_Meadow	OverSamp
1554	UNEQUAL-78	287596.8107	4192762.909	Fen_Meadow	OverSamp
479	UNEQUAL-79	267705.7982	4204686.521	Fen_Meadow	OverSamp
550	UNEQUAL-80	269302.9648	4196702.177	Fen_Meadow	OverSamp
1555	UNEQUAL-81	299347.8372	4198299.032	Meadow	OverSamp
1113	UNEQUAL-82	299877.3591	4184065.85	Meadow	OverSamp
169	UNEQUAL-83	256408.4465	4211719.444	Fen_Meadow	OverSamp
846	UNEQUAL-84	276791.3002	4191138.175	Meadow	OverSamp
125	UNEQUAL-85	281280.8639	4221966.446	Meadow	OverSamp
1253	UNEQUAL-86	286099.4863	4171175.465	Meadow	OverSamp
560	UNEQUAL-87	249597.3268	4202389.425	Fen_Meadow	OverSamp
1268	UNEQUAL-88	277635.0853	4168345.123	Fen_Meadow	OverSamp
1368	UNEQUAL-89	265994.9542	4171209.872	Fen_Meadow	OverSamp
1520	UNEQUAL-90	283298.4721	4162056.962	Fen_Meadow	OverSamp

Appendix 4: Power Analysis for Selected Indicators of Wetland Ecological Integrity

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1. Introduction

The Sierra Nevada Network (SIEN) of the National Park Service is currently developing a plan for monitoring wetland ecological integrity (WEI) within SIEN parks (Gage et al. 2009). The parks included in the protocol are Yosemite National Park (YOSE), Sequoia and Kings Canyon National Parks (SEKI), and Devils Postpile National Monument (DEPO). Terrestrial and aquatic invertebrates, vegetation indices, and hydrologic measures have been chosen as important indicators of change and will be used to monitor wetland status and trends. For the large parks (YOSE and SEKI) where a sample design incorporating randomly selected sites is being developed, a power analysis was conducted to inform decisions on sample size and site revisit designs needed to accurately measure changes given sources of variation. Pilot data were used to estimate sources of variation for power simulations.

1.1 Sampling design

Aerial photography was used to identify areas likely to be wet meadows or fens. When a contiguous wetland appearing to contain both wet meadow and fen habitat was identified, both wetland types were delineated, but the entire unit was classified as *fen+wet meadow*. This classification resulted in polygons attributed with wetland types of either *fen*, *wet meadow*, or *fen+wet meadow*. Because of the extreme rarity of the pure fen wetland type (2 of 1582 mapped target wetlands within SEKI), fens were lumped in with the fen+wet meadow complexes, resulting in only two categories in the sample design. The wetland classification served as multidensity categories. Unequal probability sampling was conducted within these two categories to obtain a sample that consisted of roughly an equal number of fen and fen+wet meadows within the selected sites. GRTS sampling provided a spatially-balanced sample of wetlands within the SIEN parks.

Sample sizes for wetlands types were determined iteratively using a method suggested by Scott Urquhart for the Rocky Mountain Network wetlands sampling design. This method involves using weights to allocate the sampling effort among wetland types. Experimenting with the weights allows one to distribute the sample size such that the desired number of fens-wet meadow complexes and wet meadows may be attained.

The sampling frame in SEKI was defined as the set of wetlands within SEKI that have not received more than an average of 0.5 nights/acre of grazing over the past 20 years. A similar rule to restrict sampling to sites without significant human impacts (primarily recent grazing or alterations to wetland hydrology) in Yosemite was also applied to the sample frame in Yosemite. These rules were established so that differences in grazing pressure or human disturbance between the parks would not confound results and subsequent interpretation. These heavier grazed sites were deemed more appropriate for targeted research rather than for long-term monitoring. The differences in the

definitions of the target populations between the two parks should be explicitly stated when reporting any network-level inference from this survey design.

A total of 30 wetlands were selected for the YOSE sample with 60 additional wetlands chosen in an oversample. The SEKI sample consisted of 30 wetlands chosen for the main sample and 60 in the oversample. The wetlands protocol working group determined that a network-wide total of 24 sites could be visited in any given year.

The response design within each site consists of a dense set of points that are randomly drawn within each wetland complex using GRTS. The first randomly-located point that meets the definition of the wetland type is established as the site. If the site is the *fen+wet meadow* wetland type, then the first fen point and the first wet meadow point in the list of random points are used as sites for each type. Therefore, the wetlands classified as *fen+wet meadow* will contain two sites while wetlands classified as wet meadows will contain only one site. Other points from the GRTS sample are used for wetland extent verification. This stage of sampling is treated as the response design; sampling at this level does not affect design-based estimation.

1.2 Revisit design

Revisit designs describe the structure of a sample over time. Revisit designs are helpful in allocating effort over space and time so that sites are visited on regular schedules and samples are more balanced for estimation purposes. Four serially-alternating augmented revisit designs are examined here subject to a maximum annual sample of 48 sites. Using the revisit design parlance of McDonald (2003), these designs are referred to as [1-0], [(1-0),(1-1)], [(1-0),(1-3)], and [(1-0),(1-5)] and are represented visually in Figure 1.1. Each design is augmented by an annual revisit panel of sites visited every year. This panel improves power to detect trend. Serially-alternating revisit designs consist of a fixed set of panels visited sequentially over time with the cycle beginning again after a complete replicate is obtained. The sites in serially-alternating panels are visited every other year in the [(1-0),(1-1)] design, every four years in the [(1-0),(1-3)] design, and every six years in the [(1-0),(1-5)] design. More sampling effort expended in a given year yields a revisit design in which sites are visited more frequently and temporal replication increases more quickly. If annual samples are smaller, then sites not in the annual revisit panel are visited less frequently and true replication over time will be achieved less quickly.

Preliminary power analysis of WEI demonstrated that the power to detect trend is not highly sensitive to the revisit designs examined here. This outcome is consistent with revisit design research that states designs containing panels for which sites were sampled sequentially for all or part of the monitoring period were nearly as powerful as the design for which the same sites were visited every year (Urquhart and Kincaid 1999). Of the four revisit designs under consideration, the [1-0] and [(1-0),(1-1)] designs required too much annual effort to be feasible given current budget constraints. Furthermore, these revisit designs incorporated too few total sites for status estimation given the limitations on annual survey effort. The [(1-0),(1-5)] design would require six years to complete a full cycle. Such a long cycle is not recommended because up to 15 years (including time for data entry, screening, and analysis) would be necessary to obtain two replicates of the revisit design for trend estimation and subsequent interpretation (Urquhart et al. 1993). A shorter cycle is preferred so

that results can more rapidly inform management actions, decisions, or research that may be needed to reduce, mitigate, or better understand impacts on SIEN wetlands. Thus, the [(1-0),(1-3)] design was chosen. This cycle is only 4 years long, and more sites are incorporated into the sample annually than in the [1-0] and [(1-0),(1-1)] designs. Figure 1.2 – 1.4 demonstrate the final revisit design for the total SIEN sample, the annual sample within each wetland type, and the annual sample within each wetland and park combination. This design results in a total sample of 60 unique sites across wetland types, with 30 sites within each park. Each year a total of 24 sites will be visited with 12 sites in the annual panel and 12 sites from one of four alternating panels.

a) Design [1-0] with 48 sites visited annually.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	48	48	48	48	48	48	48	48	48	48	48	48
ANNUAL TOTAL	48	48	48	48	48	48	48	48	48	48	48	48

b) Design [(1-0),(1-1)] with 36 sites visited annually.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	12	12	12	12	12	12	12	12	12	12	12	12
2	18		18		18		18		18		18	
3		18		18		18		18		18		18
ANNUAL TOTAL	30	30	30	30	30	30	30	30	30	30	30	30

Figure 1.1. Four revisit designs examined in the preliminary power analysis, with designs a) and b) shown above.

c) Design [(1-0),(1-3)] with 21 sites visited annually.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	12	12	12	12	12	12	12	12	12	12	12	12
2	9				9				9			
3		9				9				9		
4			9				9				9	
5				9				9				9
ANNUAL TOTAL	21	21	21	21	21	21	21	21	21	21	21	21

d) Design [(1-0),(1-5)] with 18 sites visited annually.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1	12	12	12	12	12	12	12	12	12	12	12	12
2	6						6					
3		6						6				
4			6						6			
5				6						6		
6					6						6	
7						6						6
ANNUAL TOTAL	18	18	18	18	18	18	18	18	18	18	18	18

Figure 1.1 (continued). Four revisit designs examined in the preliminary power analysis, with designs c) and d) shown above.

Panel	Year							
	1	2	3	4	5	6	7	8
1	12	12	12	12	12	12	12	12
2	12				12			
3		12				12		
4			12				12	
5				12				12
ANNUAL TOTAL	24	24	24	24	24	24	24	24

Figure 1.2. Final [(1-0),(1-3)] SIEN revisit design across wetland types.

Panel	Year							
	1	2	3	4	5	6	7	8
1	6	6	6	6	6	6	6	6
2	6				6			
3		6				6		
4			6				6	
5				6				6
ANNUAL TOTAL	12	12	12	12	12	12	12	12

Figure 1.3. Final [(1-0),(1-3)] SIEN revisit design within each wetland type.

	Year							
	1	2	3	4	5	6	7	8
1	3	3	3	3	3	3	3	3
2	3				3			
3		3				3		
4			3				3	
5				3				3
ANNUAL TOTAL	6	6	6	6	6	6	6	6

Figure 1.4. Final [(1-0),(1-3)] revisit design within each wetland type and park (e.g., SEKI fens).

1.3 Response Design

The response design incorporates a nested plot design with three different plot sizes (see Figure 9 in Protocol Narrative). A larger macroplot contains a single subplot with four microplots. A well is established at the center of the macroplot and monumented for relocation in subsequent survey occasions.

Qualities of the indicators of interest dictate at what plot scale the indicator will be measured. Measurements made at the microplot level will have replication within a site while those collected within subplots and macroplots will not. Larsen et al. (1995) suggest that measurements collected from sites visited on an annual basis be "robust enough as a barometer ...to describe the condition of regional populations." Therefore, if measurements from a particular indicator are highly variable within a site, multiple measurements within a site could be taken during a single visit. Then either the mean may be used as the indicator response or the correlation among measurements may be modeled. If the indicator varies greatly over the index period of interest, multiple visits within a year may be used or annual visits may be conducted at similar times each year to explain the variability of the measurement over time. Often, multiple visits to a site within a year are inefficient for monitoring, and that effort is better spent visiting new sites (VanLeeuwen et al. 1996). If within-site and inter-annual variability does not affect the indicator, then a single measurement from each annual visit should be a sufficient index of the site condition. The ability to revisit the same plot over time is more important when only one measurement is taken for an indicator within a plot because blocking on a site over time reduces variability.

1.4 Trend Model

Preliminary data analysis indicated that measurements of WEI indicators better meet model assumptions if a logarithmic transformation is applied. The logarithmic transformation also facilitates interpretation of trend results on the scale of multiplicative change. The pilot data were modeled with mixed models proposed in VanLeeuwen, et al. (1996) and Piepho and Ogutu (2002). Mixed models include fixed effects, which contribute to the mean of the outcome of interest, and random effects, which contribute to the variance. Random effects are used to estimate variation that can affect the ability to detect trend, such as site-to-site and year-to-year variation.

The mixed model proposed for wetland monitoring outcomes is:

$$Y_{ij} = \mu + W_j\beta + b_j + a_i + w_jt_i + c_{ij} + e_{ijk},$$

where $i=1, \dots, m_a$; $j=1, \dots, m_b$; $k=1, \dots, m$ and

m_a = the number of sites in the sample;

m_b = the number of consecutive years in the sample;

m = the number of measurements taken within a site and year;

w_j = constant representing the j^{th} year (covariate);

μ and β = fixed intercept and slope of the linear time trend;

b_j = random effect of the j^{th} year, independent and identically distributed as $N(0, \sigma_b^2)$;

a_i = random intercept of the i^{th} site, independent and identically distributed as $N(0, \sigma_a^2)$;

t_i = random slope of the i^{th} site, independent and identically distributed as $N(0, \sigma_t^2)$;

c_{ij} = random effect of the site by year, independent and identically distributed as $N(0, \sigma_c^2)$; and

e_{ijk} = unexplained error, independent and identically distributed as $N(0, \sigma_e^2)$.

The fixed intercept, μ , may include related covariates that are modeled as fixed effects. Model selection was conducted using the Bayes Information Criterion (Gurka 2006). Roughly half of the selected wetlands will only contain a single site, but *fen+wet meadow* complexes will contain two

sites, which are helpful in estimating random site effects. Random effects variance components were estimated from the pilot data in SAS and used to estimate the power to detect linear trends of varying degrees in the logarithmically-transformed indicator.

When possible, only pilot data from probabilistic survey designs are used for variance component estimation. Several types of sites were omitted from pilot data sets. Index sites are judgment-selected sites that will be sampled more frequently to assist in interpretation of data from less frequently sampled extensive sites. A subset of sites was revisited to assess within site variability. However, the number of revisit sites chosen was very small and did not provide enough information to assess the interaction of random site and year effects. Diversity surveys were also conducted at several sites. These sites differed from the probabilistic survey sites by providing within-site replication for 3 rather than 4 microplots and using slightly larger microplots. Index, revisit, and diversity sites were omitted from the pilot data for trend analysis because of these differences in site selection methods and response design. Legacy data sets of index sites are used to estimate temporal variance components when probabilistic data are not available.

1.5 Power Approximation

Power is estimated using large-sample theory and the mixed model for trend proposed above. Code for approximating power was provided by Tom Kincaid of the Environmental Protection Agency. Kincaid's code was edited to include the option to model a random slope. The power to detect population increases is slightly lower than the power to detect declines, so the power results are conservative for detecting decreasing trends. Four levels of change are examined in the power analysis and include annual increases of 1%, 2%, 3%, and 4%. These annual changes represent annual multiplicative change so the corresponding net change over time increases exponentially (Table 1.1).

Table 1.1. Annual trends and corresponding net trend.

Annual trend	Years	Net trend (pct)	Net multiplicative trend (pct)
0.01	10	10%	110%
0.01	20	22%	122%
0.01	30	35%	135%
0.01	40	49%	149%
0.02	10	22%	122%
0.02	20	49%	149%
0.02	30	81%	181%
0.02	40	121%	221%
0.03	10	34%	134%
0.03	20	81%	181%

Annual trend	Years	Net trend (pct)	Net multiplicative trend (pct)
0.03	30	143%	243%
0.03	40	226%	326%
0.04	10	48%	148%
0.04	20	119%	219%
0.04	30	224%	324%
0.04	40	380%	480%

Variance components that cannot be estimated from a particular data set are accounted for in the residual error variance. When variance components are estimated from different data sets, the residual variance is not adjusted for the additional variance component. This will increase the total estimated variance slightly and is considered a conservative approach to accounting for different variation sources. Because this power analysis was used to inform decisions regarding the revisit design, the relative sizes of the variance component estimates for random site and year effects were important inputs for power calculations.

Power must be approximated assuming that tests of trend are conducted at a specific Type I error rate. The Type I error rate, designated as α , is the probability of rejecting a true null hypothesis. For two-sided tests of trend, a Type I error would mean that the population was found to be changing when it was not. A Type II error occurs by failing to reject a false null hypothesis and thus concluding no change has occurred. For long-term monitoring, the cost of a Type I error may be far less than the cost of a Type II error. Mistakenly rejecting a true null hypothesis (Type I error) may trigger a management conservation action that is not actually needed. However, failing to reject a false null when a significant trend has indeed occurred may have deleterious effects for a population that cannot be reversed by the time the trend is actually detected. A conservative approach is to use a larger α value for higher power and reduced probability of a Type II error (Buhl-Mortensen 1996; Gibbs, et al. 1998; Mapstone 1995). For this power analysis, an α value of 0.20 is used. Power does not fall below the α value assumed for the trend test.

2. Power Analysis of Invertebrate Indicators

Power to detect changes over time in indicators of macroinvertebrate populations is derived from variance components estimated from pilot data. The power analysis is conducted assuming the [(1-0),(1-3)] revisit design discussed in section 1.2. As an alternative analysis, the power analysis is conducted assuming that only the annual revisit panel is visited. Budget restrictions may limit survey resources, in which case macroinvertebrate surveys will only be conducted for this random subsample (i.e., annual panel) of the full sample. The power analysis results are compared to determine if the reduced sample is practical for long-term monitoring.

2.1 Pilot Data

Invertebrate pilot data were obtained from probabilistic surveys conducted during 2007 and 2008 surveys in YOSE and SEKI, respectively, as well as in randomly-selected sites in Tuolumne Meadows from 2004 through 2008. Data from the probabilistic survey provide information to estimate site-to-site and random slope variation, and Tuolumne Meadows data are used to estimate temporal variation among years. Pilot data collected from June through August were used to be consistent with the SIEN survey design. Table 2.1 provides the survey locations and methods used in the pilot data surveys. The 2007 data represent a much larger spatial extent than the data collected from 2004 through 2006.

Table 2.1. Summary of pilot data methods and locations by year.

Year	Location	Aquatic Survey Methods	Terrestrial Survey Methods
2004	Tuolumne Meadows	Throw-trapping	Vacuum netting
2005	Tuolumne Meadows	Throw-trapping	Vacuum netting
2006	Tuolumne Meadows	–	Vacuum netting
2007	YOSE (including Tuolumne Meadows)	D-frame netting	Sweep-netting
2008	SEKI	D-frame netting	Sweep-netting

The invertebrate pilot data were provided by Jeff Holmquist (White Mountain Research Station, University of California), and are subject to several variation sources including environmental condition, survey method, and spatial extent. For example, the 2004 survey conditions were very dry compared to very wet conditions in 2005. In addition, for both aquatic and terrestrial habitats, the sampling methods were different between the 2004-2006 and 2007-2008 sample periods (Table 2.1). These sources of variation will certainly contribute to the variance components estimated from the pilot data. However, if variance components are overestimated, then the power analysis will be conservative.

The pilot data were summarized at the site level for three outcomes: Margalef's family richness (MFR), percent dominance (PD), and percent predators (PP). Table 2.2 provides calculations used to compute the three outcomes of interest. Covariate information for driver clusters and watersheds was not significant in describing invertebrate outcomes except when modeling Margalef's family richness of aquatic invertebrates in SEKI fens and percent dominance of terrestrial invertebrates in YOSE fens.

Table 2.2. Invertebrate outcomes of interest.

Outcome	Formula	Invertebrate Species
MFR	$\frac{\# \text{ families in sample} - 1}{\ln (\text{total } \# \text{ animals in sample})}$	Aquatic and terrestrial
PD	$\frac{\# \text{ animals in dominant taxon in sample}}{\text{total } \# \text{ animals in sample}}$	Aquatic and terrestrial
PP	$\frac{\# \text{ predators in sample}}{\text{total } \# \text{ animals in sample}}$	Terrestrial

2.2 Results

The estimated variance components are given in Tables 2.3 through 2.7. Appropriate data subsets were used to estimate variance components. For example, the variance components for the analysis of trend in SEKI fens were estimated from pilot data collected only from fens in SEKI. In some cases, the within-meadow replication of meadows classified as *fen+wet meadow* were used to estimate the random effect of site to site variation across wetland types. Quantities in gray type represent variance components that were estimated from other subsets of the pilot data and used as inputs for power approximations.

Table 2.3. Estimated variance components for Margalef's family richness of aquatic invertebrates.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site-level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.0045*	—	0.0329*	0.0747
ALL	WM	0.0045*	—	0.0329*	0.0900
YOSE	F	0.0045*	—	0.0329*	0.0400
YOSE	WM	0.0045*	—	0.0329*	0.1095
SEKI	F	0.0045*	—	0.0329*	0.0564
SEKI	WM	0.0045*	—	0.0329*	0.0900
Tuolumne	—	—	—	0.0329	0.0649

*Quantities in gray type represent variance components that were estimated from other subsets of the pilot data and used as inputs for power approximations.

Table 2.4. Estimated variance components for Margalef's family richness of terrestrial invertebrates.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site-level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.0148*	—	0.0971*	0.0304
ALL	WM	0.0148*	—	0.0971*	0.0587
YOSE	F	0.0195*	—	0.0971*	0.0803
YOSE	WM	0.0195*	—	0.0971*	0.0710
SEKI	F	0.0105*	—	0.0971*	0.0214
SEKI	WM	0.0105*	—	0.0971*	0.0474
Tuolumne	—	—	—	0.0971	0.2404

*Quantities in gray type represent variance components that were estimated from other subsets of the pilot data and used as inputs for power approximations.

Table 2.5. Estimated variance components for percent dominance of aquatic invertebrates.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site-level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.1122*	—	0.001183*	0.4437
ALL	WM	0.1122*	—	0.001183*	0.1812
YOSE	F	0.1122*	—	0.001183*	0.2809
YOSE	WM	0.1122*	—	0.001183*	0.0265
SEKI	F	0.1122*	—	0.001183*	0.4600
SEKI	WM	0.1122*	—	0.001183*	0.1812
Tuolumne	—	—	—	0.001183	0.0743

*Quantities in gray type represent variance components that were estimated from other subsets of the pilot data and used as inputs for power approximations.

Table 2.6. Estimated variance components for percent dominance of terrestrial invertebrates.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site-level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.0318*	—	0.0022*	0.0733
ALL	WM	0.0318*	—	0.0022*	0.1474
YOSE	F	0.0318*	—	0.0022*	0.0199
YOSE	WM	0.0318*	—	0.0022*	0.2422
SEKI	F	0.0318*	—	0.0022*	0.0830
SEKI	WM	0.0318*	—	0.0022*	0.0604
Tuolumne	—	—	—	0.0022	0.2400

*Quantities in gray type represent variance components that were estimated from other subsets of the pilot data and used as inputs for power approximations.

Table 2.7. Estimated variance components for percent predators of terrestrial invertebrates.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site-level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	—	—	0.8252*	0.1811
ALL	WM	—	—	0.8252*	0.5896
YOSE	F	—	—	0.8252*	0.2486
YOSE	WM	—	—	0.8252*	0.8913
SEKI	F	—	—	0.8252*	0.1492
SEKI	WM	—	—	0.8252*	0.3130
Tuolumne	—	—	—	0.8252	2.3216

*Quantities in gray type represent variance components that were estimated from other subsets of the pilot data and used as inputs for power approximations.

Figures 2.1 through 2.5 provide the results of the power analysis for the full sample of the [(1-0),(1-3)] revisit design for the five macroinvertebrate indicators. The results of the power analysis indicate that, for increases in outcomes of 2% or more per year, power for testing trend in Margalef's family richness is as high as 80% for less than 20 years of consecutive sampling for aquatic invertebrates. Power to detect trend in Margalef's family richness for terrestrial invertebrates appears slightly lower. Power to detect changes in percent dominance reaches 80% within 20 years for most levels of estimation for both aquatic and terrestrial invertebrates. Trend detection in percent predators at the $\alpha=0.20$ level exhibits much lower power, with at least 30 years needed to detect increases as high as 4% per year. Variance components estimated from Tuolumne Meadows were very large compared to those estimated from YOSE surveys. When more data from the probabilistic surveys are available, variance components may be estimated and power re-evaluated.

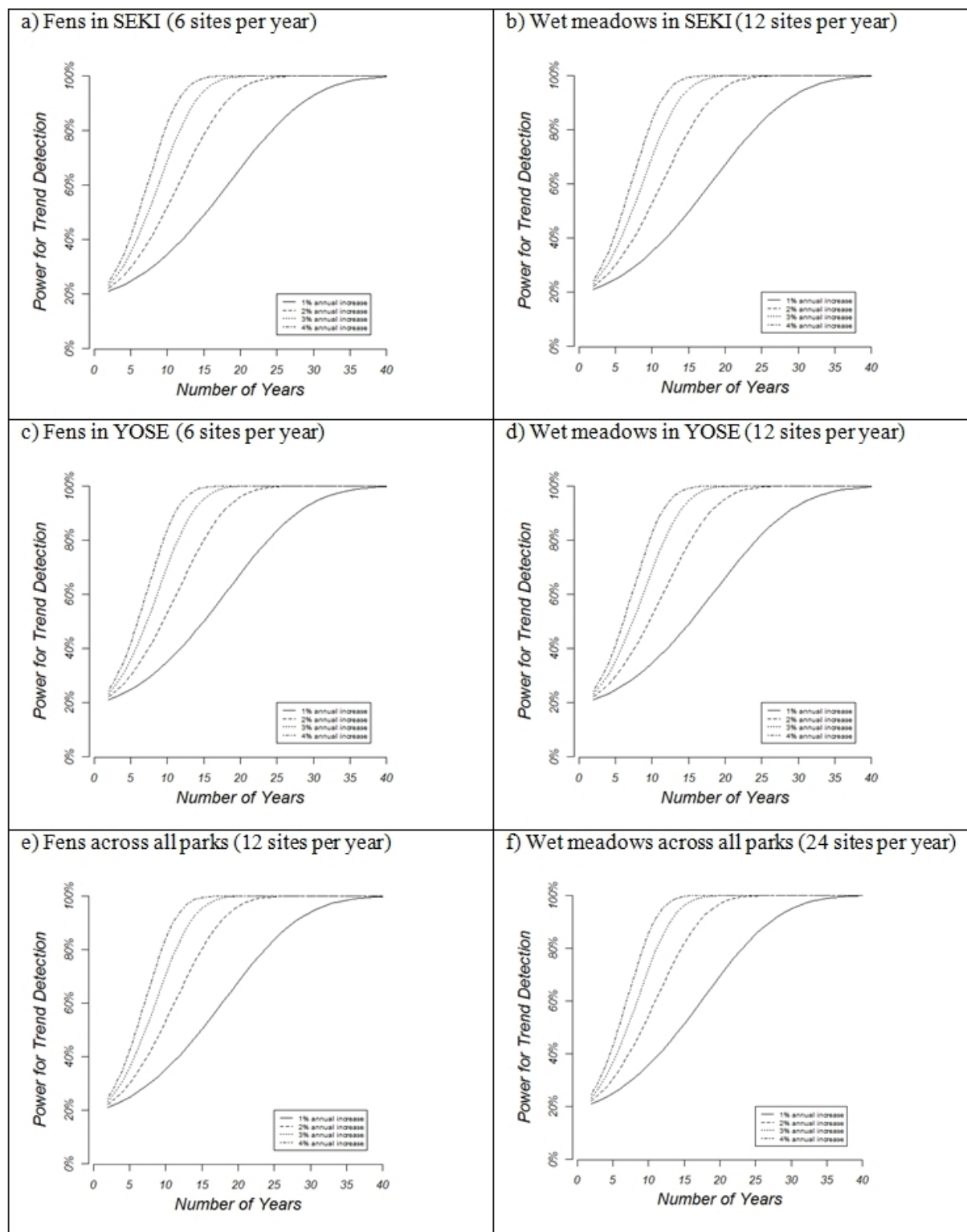


Figure 2.1. Power to detect population increases in **Margalef's family richness for aquatic invertebrates** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

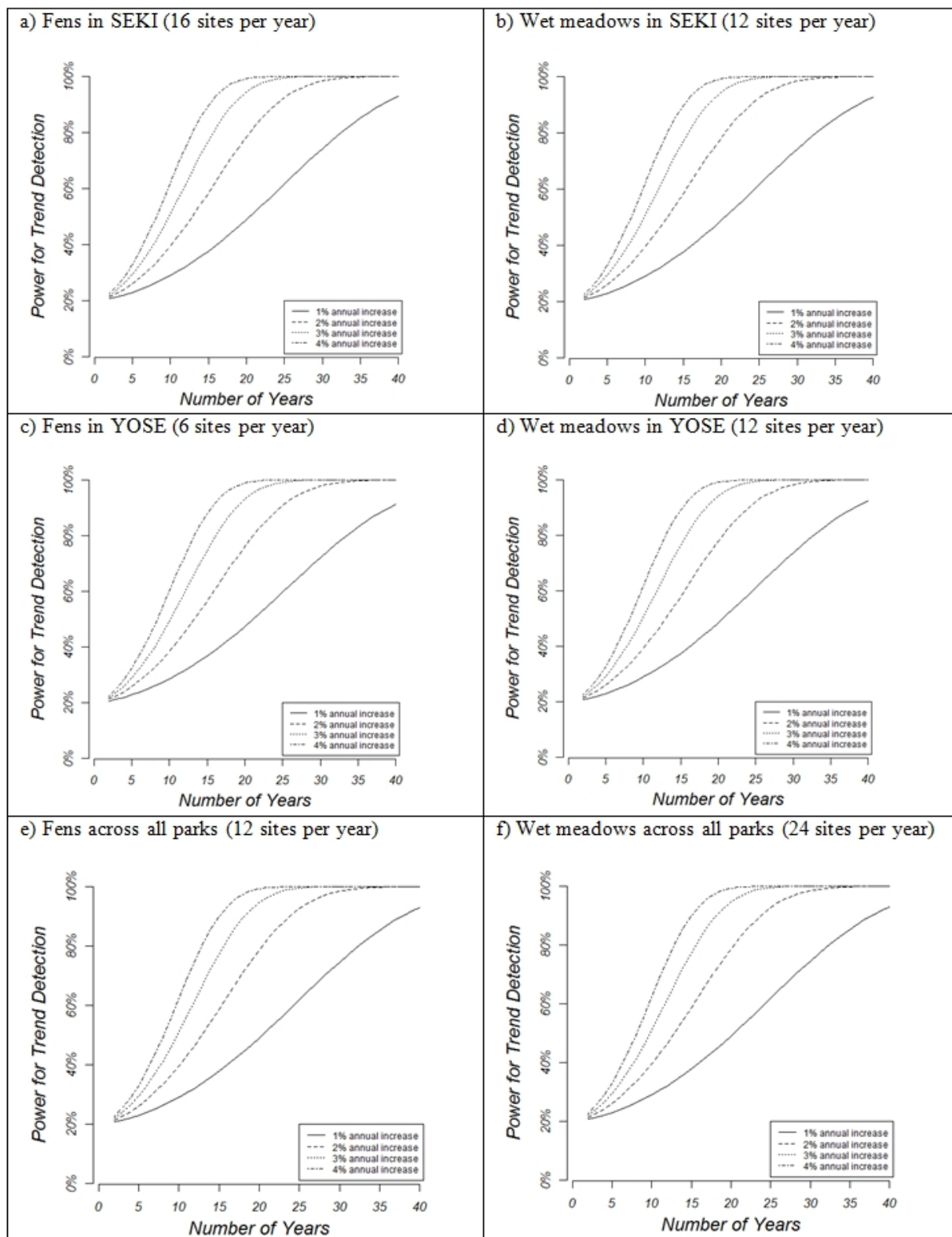


Figure 2.2. Power to detect population increases in **Margalef's family richness for terrestrial invertebrates** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

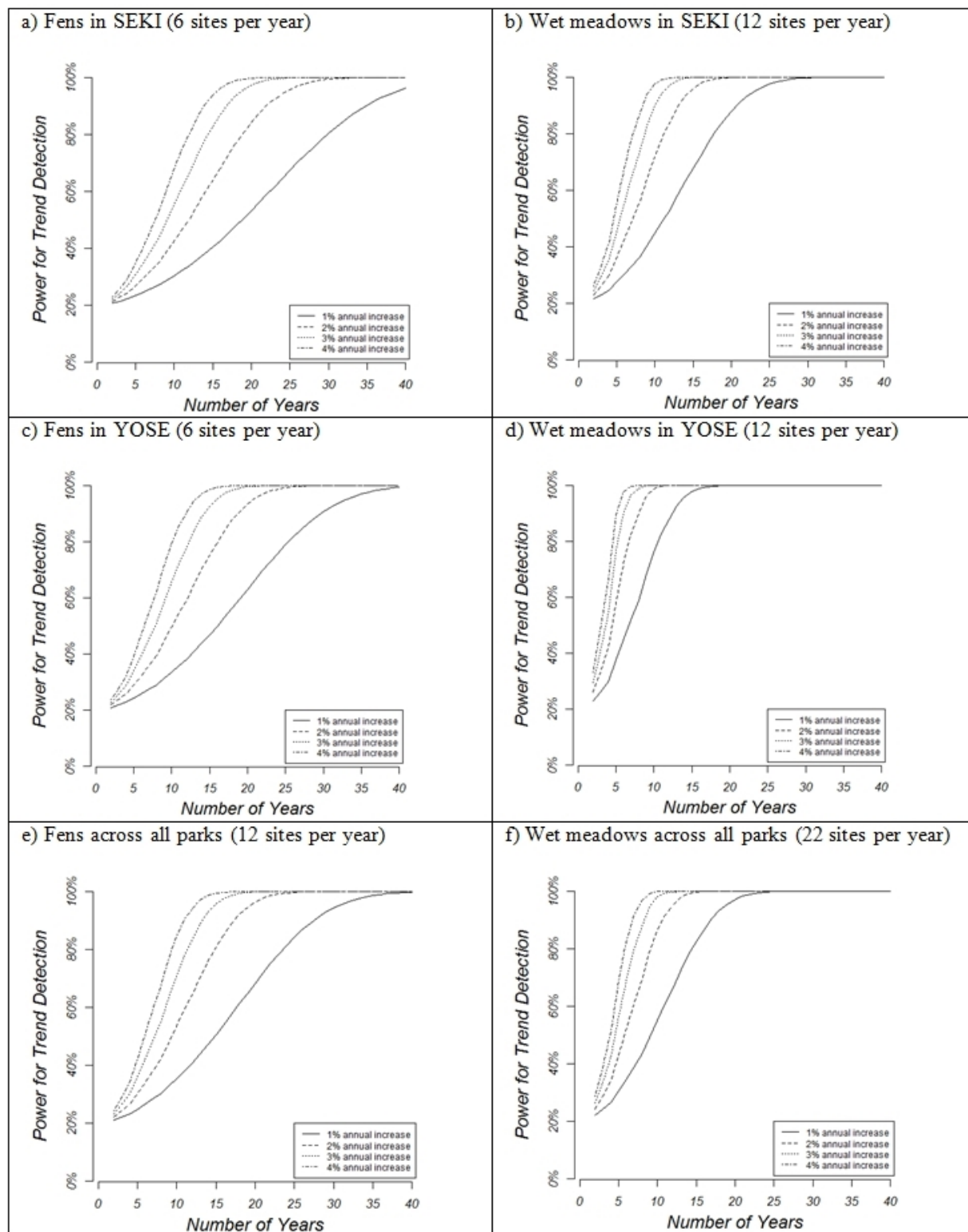


Figure 2.3. Power to detect population increases in **percent dominance for aquatic invertebrates** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

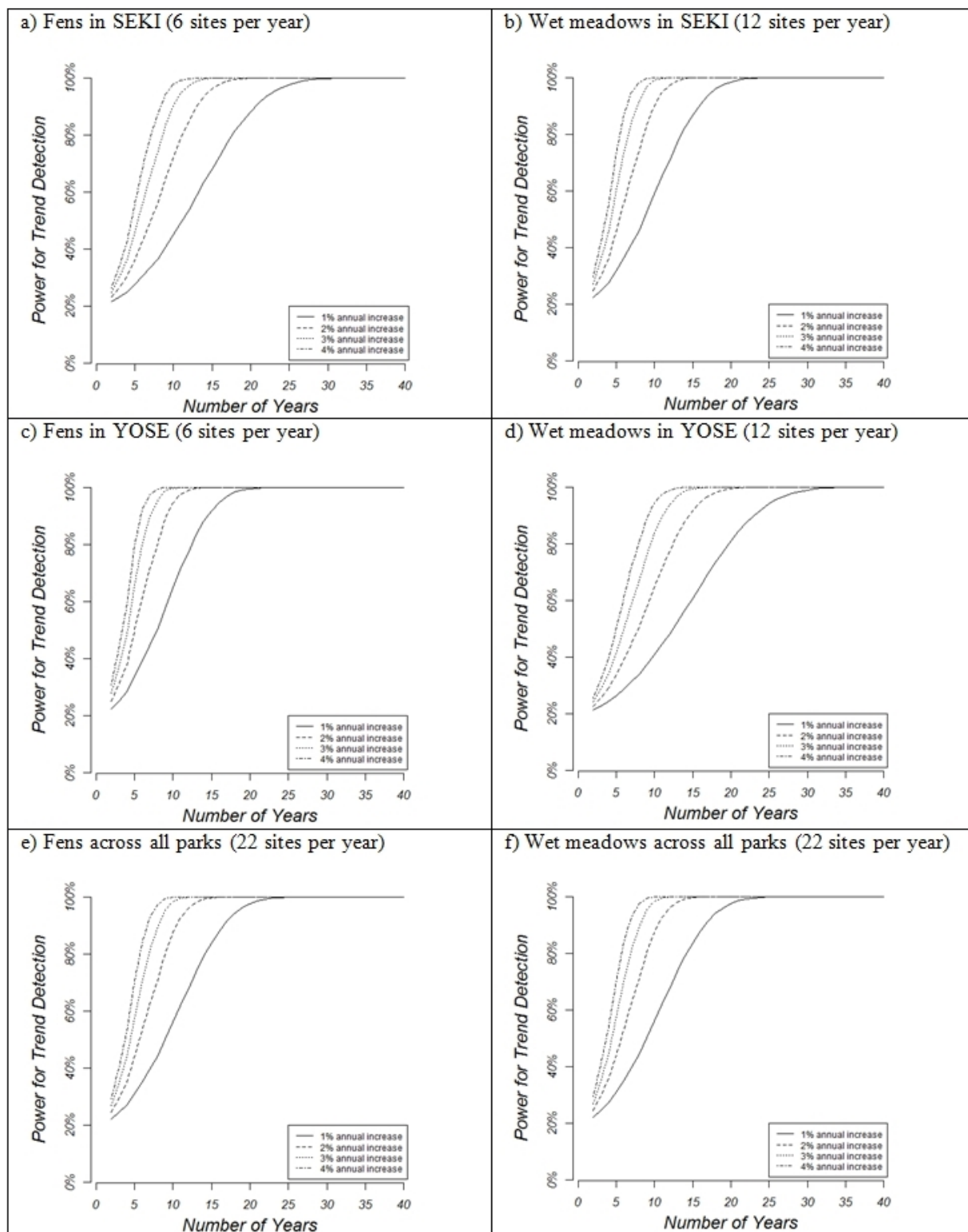


Figure 2.4. Power to detect population increases in **percent dominance for terrestrial invertebrates** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

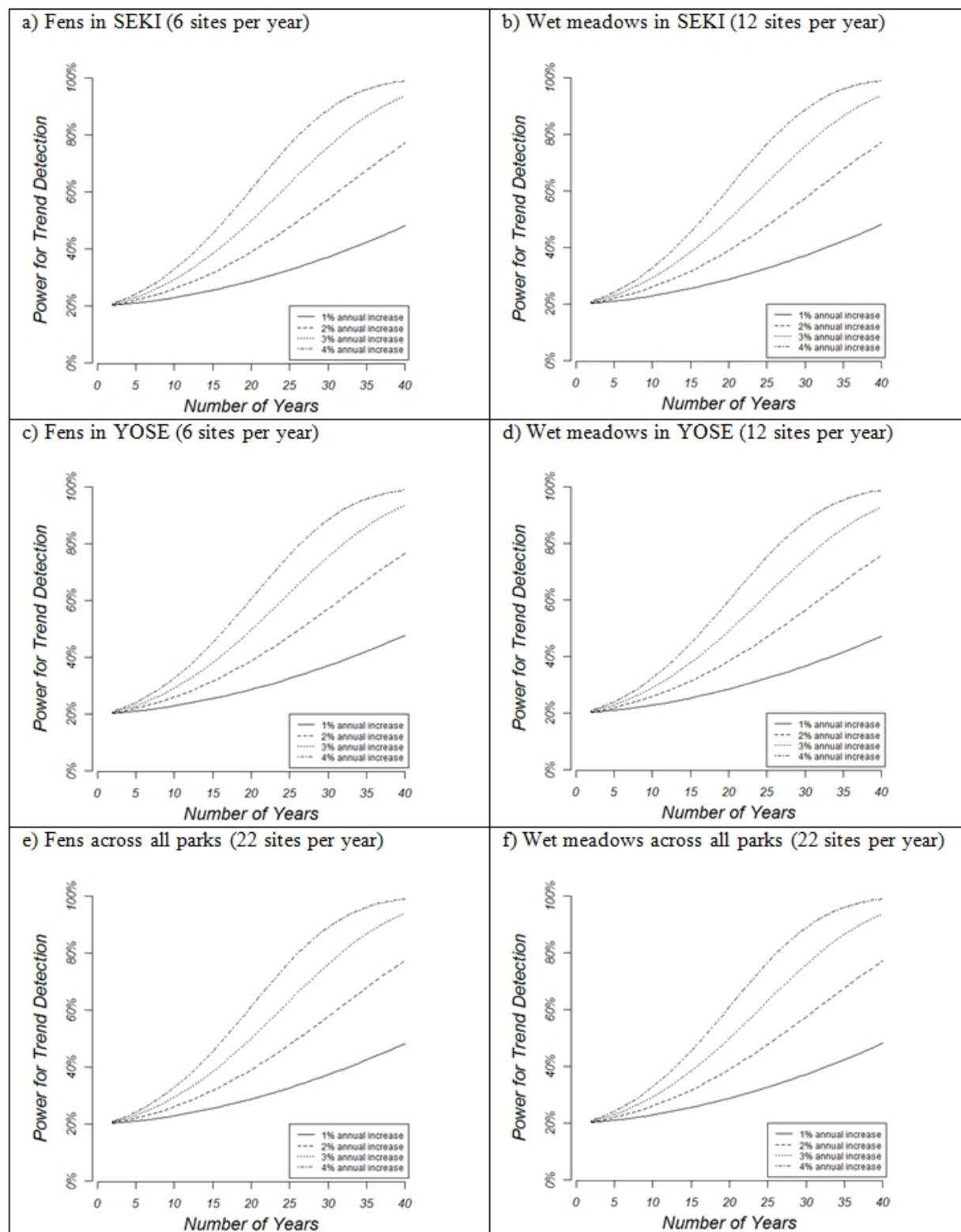


Figure 2.5. Power to detect population increases in **percent predators for terrestrial invertebrates** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

Figures 2.6 through 2.10 display the power for the same five indicators for the sampling scenario in which only the annual panel of the [(1-0),(1-3)] revisit design is visited (i.e., [(1-0)]). Comparing the two sets of plots shows that the power is only slightly less when the serially-alternating panels are omitted. This decrease in power will require a few extra survey years to compensate for the smaller sample size. Furthermore, estimates of macroinvertebrate status will be based on a sample with smaller spatial coverage than if the full sample were used. However, for the primary goal of trend, the reduced sample should not adversely affect power to a large degree.

Recall the definitions of the random effects and their respective variances:

b_j = random effect of the j^{th} year, independent and identically distributed as $N(0, \sigma_b^2)$;

a_i = random intercept of the i^{th} site, independent and identically distributed as $N(0, \sigma_a^2)$;

t_i = random slope of the i^{th} site, independent and identically distributed as $N(0, \sigma_t^2)$;

e_{ij} = unexplained error, independent and identically distributed as $N(0, \sigma_e^2)$.

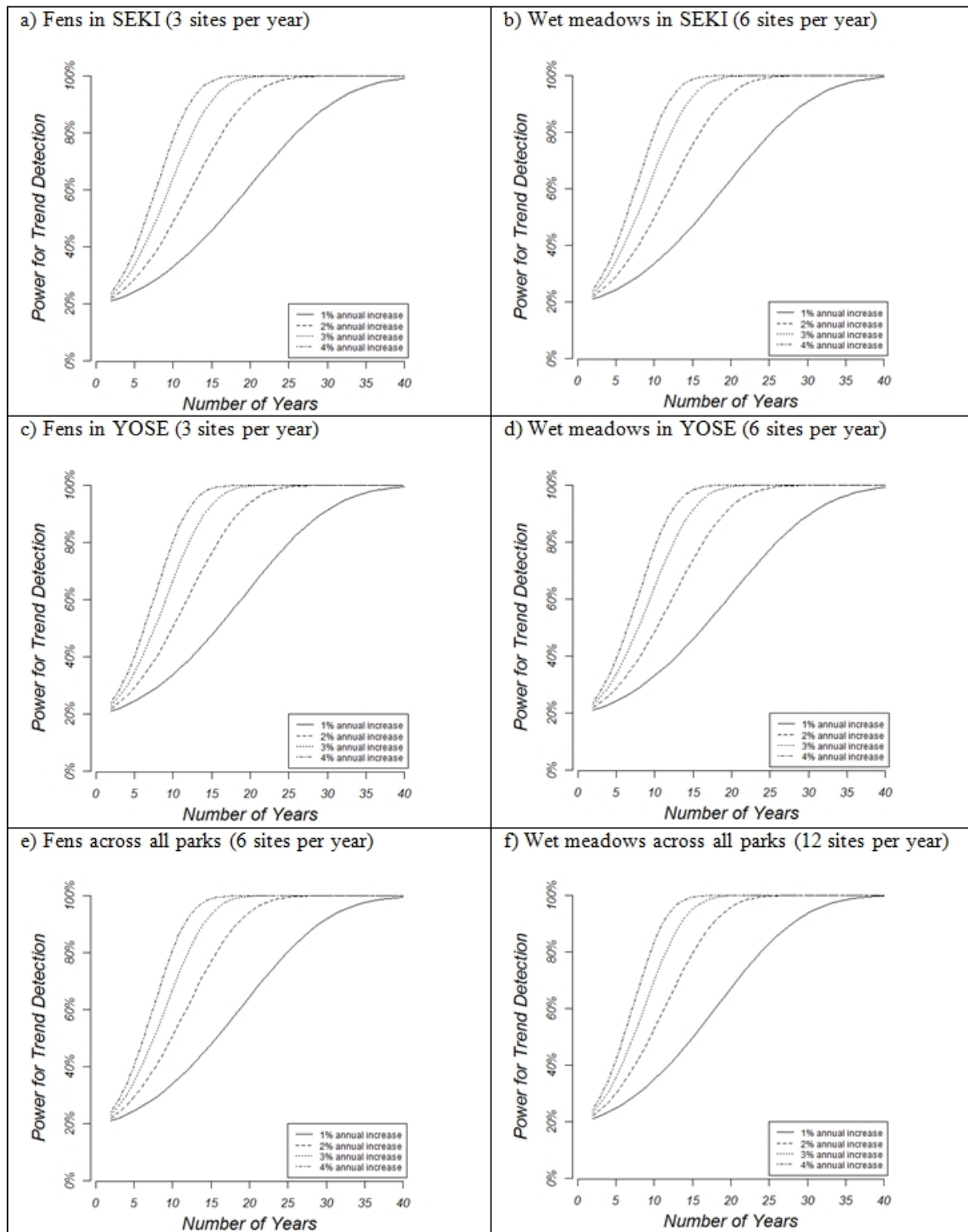


Figure 2.6. Power to detect population increases in **Margalef's family richness for aquatic invertebrates** in tests of trend computed at the $\alpha=0.20$ significance level for the **annual revisit panel only** of a [(1-0),(1-3)] revisit design.

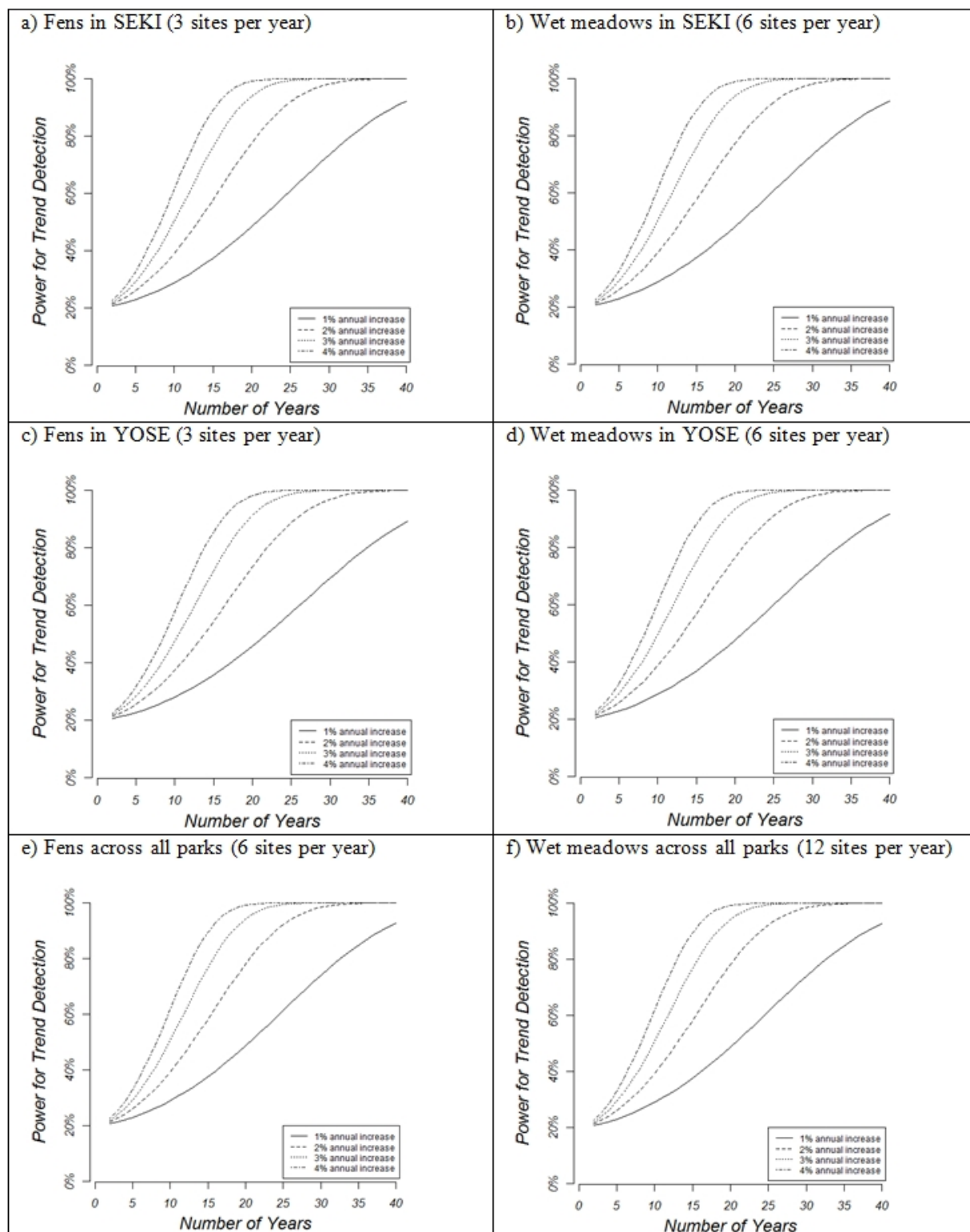


Figure 2.7. Power to detect population increases in **Margalef's family richness for terrestrial invertebrates** in tests of trend computed at the $\alpha=0.20$ significance level for the **annual revisit panel** only of a [(1-0),(1-3)] revisit design.

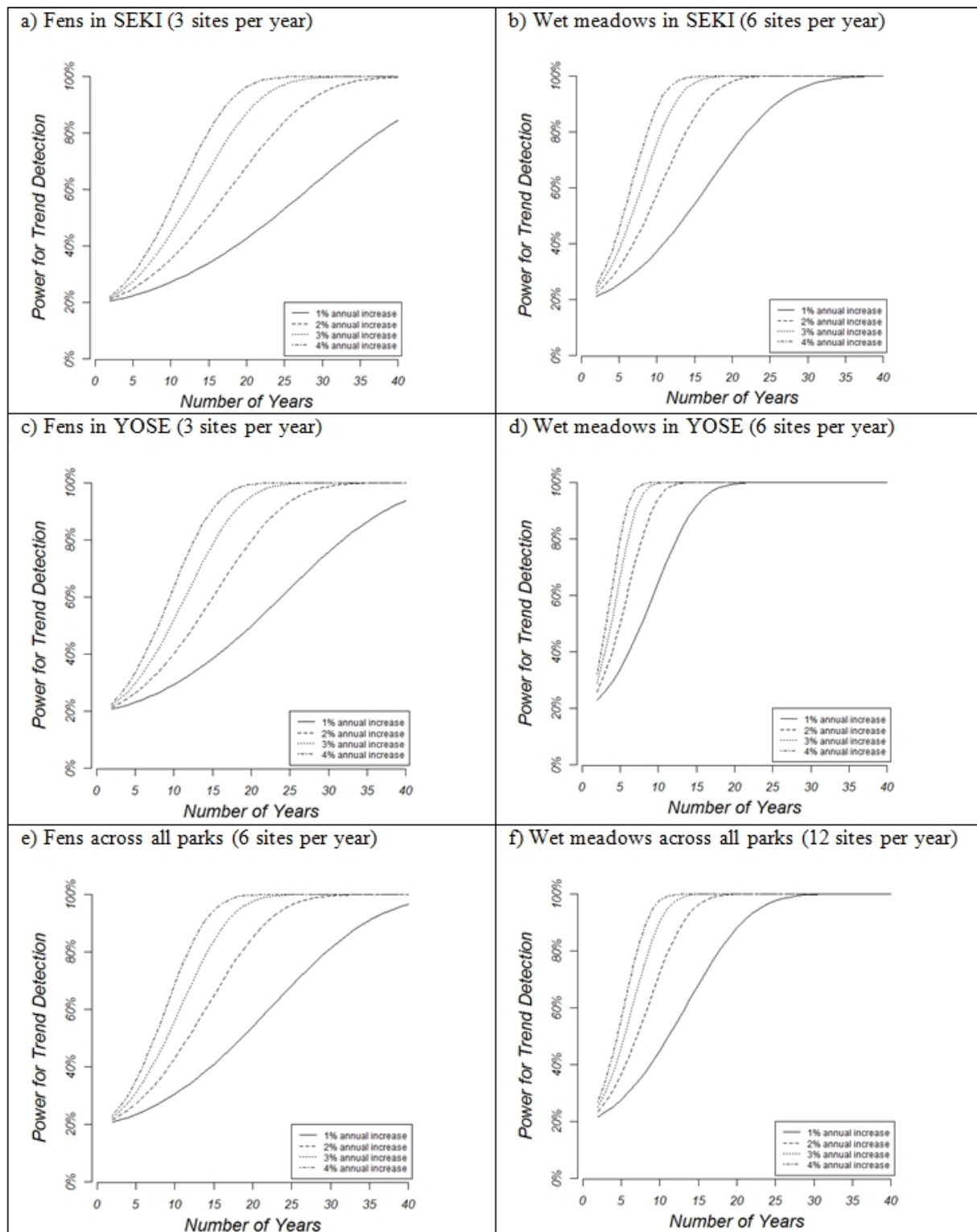


Figure 2.8. Power to detect population increases in **percent dominance for aquatic invertebrates** in tests of trend computed at the $\alpha=0.20$ significance level for the **annual revisit panel only** of a [(1-0),(1-3)] revisit design.

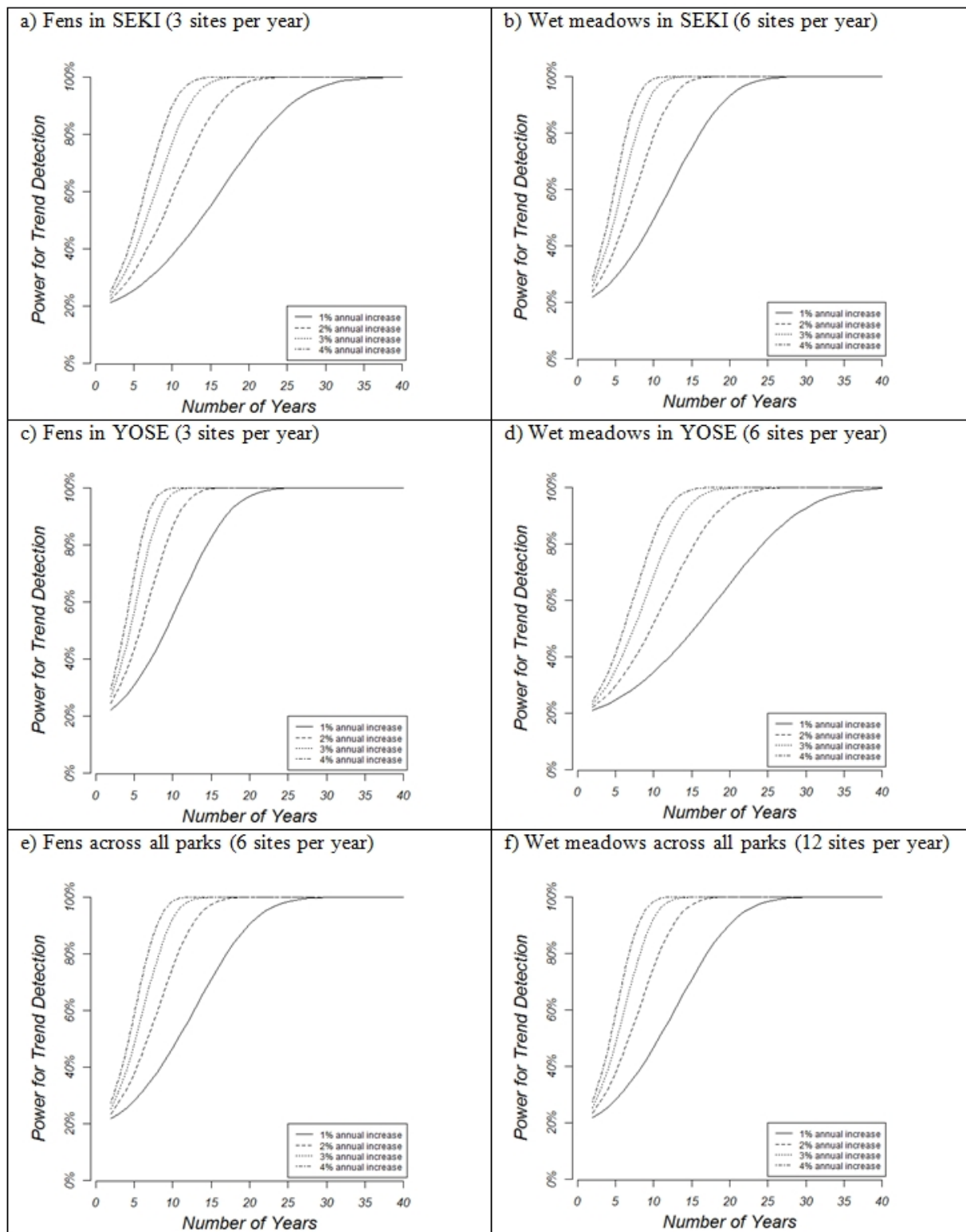


Figure 2.9. Power to detect population increases in percent dominance for terrestrial invertebrates in tests of trend computed at the $\alpha=0.20$ significance level for the annual revisit panel only of a [(1-0),(1-3)] revisit design.

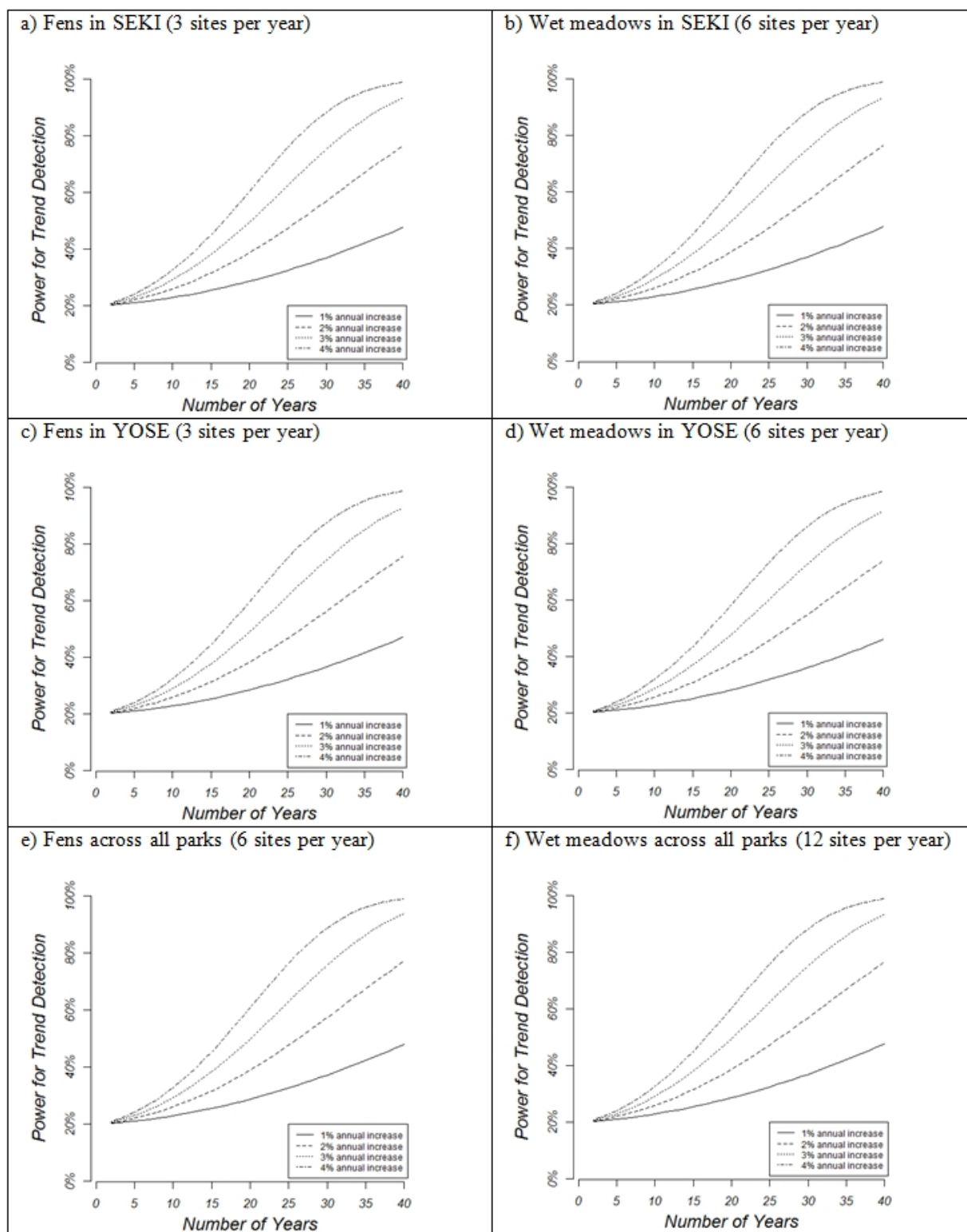


Figure 2.10. Power to detect population increases in **percent predators for terrestrial invertebrates** in tests of trend computed at the $\alpha=0.20$ significance level for the **annual revisit panel only** of a [(1-0),(1-3)] revisit design.

3. Power Analysis of Vegetation Indicators

Vegetation indices chosen for monitoring include several types of metrics. Percent cover values were used for the following indicators: bare ground; bryophytes; perennial, herbaceous dicots and non-graminoid monocots; annual dicots; and graminoids. In addition, species richness and cover sums for National Wetlands Inventory (NWI) vegetation categories (Table 3.1), the NWI prevalence index, and overall species richness were also chosen as indicators for trend estimation. Percent cover is estimated at ground level and in strata above ground level, so that total percent cover may exceed 100%. Similarly, NWI cover sums for each NWI category are sums of percentage cover across all species in the category, so cover sums may also exceed 100%.

Table 3.1. NWI vegetation categories.

NWI vegetation category	Definition*
Obligate Wetland (OBL)	Occurs almost always (estimated probability 99%) under natural conditions in wetlands
Facultative Wetland (FACW)	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands
Facultative (FAC)	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%)
Facultative Upland (FACU)	Occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%)
Obligate Upland (UPL)	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.

* Provided by Jennifer Rains Jones (02/11/09)

3.1 Pilot data

The pilot data used to estimate variance components for vegetation indices have two sources. One source is the probabilistic surveys conducted in YOSE and SEKI in 2007 and 2008, respectively. These data provide the basis for estimates of variance for site random effects. Because only two years of data are available and years are confounded with parks, fixed and random year effects could not be estimated. Percent bare ground, bryophyte, and annual dicot cover were measured at the microplot level, species richness was measured at the macroplot level, and all other indicators were measured at the subplot level, or calculated with data obtained from the subplot level. For the two indicators measured at the microplot level, the within-plot correlation was assumed to have a compound symmetric structure implying equal correlation among all microplots within a plot.

For percent cover variables, initially Daubenmire cover classes were recorded. For the first seven sites surveyed (004, 005, 006, 007, 008, 203, and 205), the midpoint of each Daubenmire cover class was used as the estimate of absolute percent cover (Table 3.2).

Table 3.2. Daubenmire cover classes and midpoints used for seven sites.

Daubenmire cover class	Percent cover range	Midpoint
1	trace	0.1%
2	1%	0.5%
3	1-2%	1.5%
4	2-5%	3.5%
5	5-10%	7.5%
6	10-25%	17.5%
7	25-50%	37.5%
8	50-75%	62.5%
9	75-95%	85.0%

A long-term study of three wet meadows in SEKI provides the basis for estimates of variance for year effects on bare ground cover and species richness. The long-term vegetation data set was collected from 1987 to 2007. Each meadow was visited every 3 to 5 years. Two meadows were surveyed each in 1987, 1990, and 1993; these data represent the only within-year replication in this data set (Figures 3.1 and 3.2). Data from 25 × 25 cm plots were used for this analysis. This plot size is considerably smaller than the 1 × 1m microplots used to measure cover in the probabilistic survey. Cover data from the smaller plots will probably tend more toward 0 % and 100 %, so variance estimates may differ from those observed in the macroplots. Bryophyte frequency was also measured in this data set, but this metric is incompatible for estimating variance components of percent cover and was omitted.

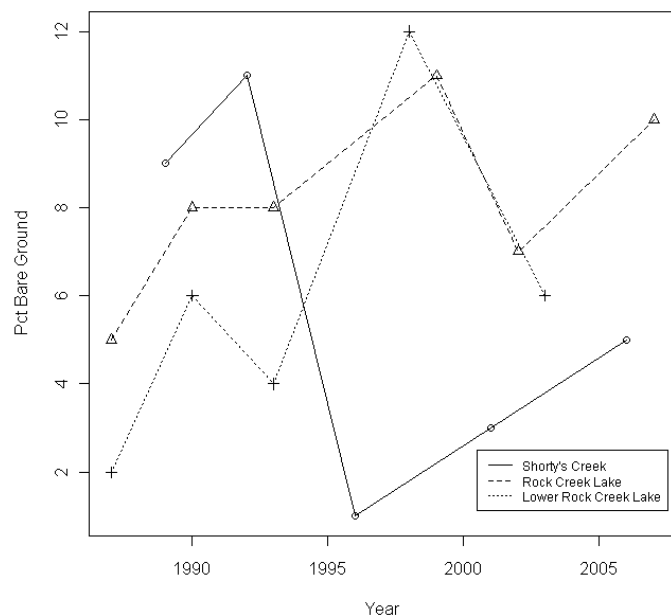


Figure 3.1. Percent bare ground for three meadows in the long-term vegetation data set.

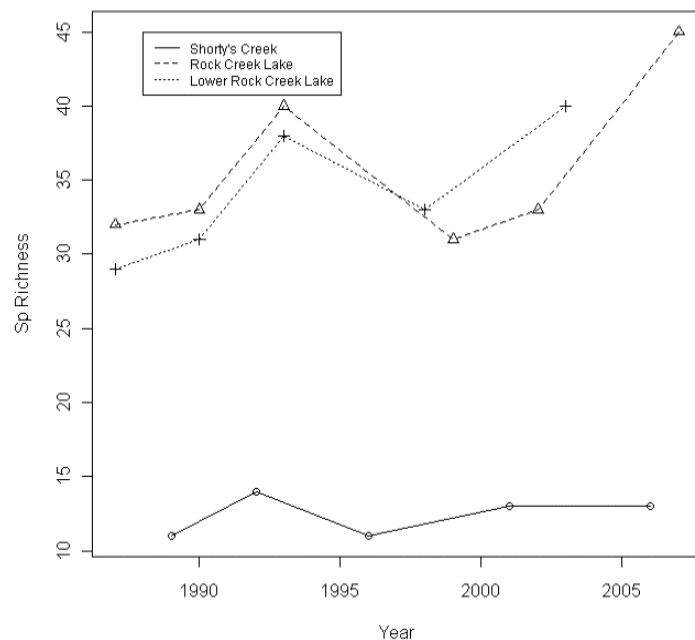


Figure 3.2. Species richness for three meadows in the long-term vegetation data set.

3.2 Results

The estimated variance components for the vegetation indicators are given in Tables 3.3 through 3.22. Approximate power is estimated with large-sample theory for the given variance components (Figures 3.3 through 3.22).

Table 3.3. Estimated variance components for percent bare ground.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.1329	0.0089*	0.2515*	0.2689
ALL	WM	0.2202	0.0089*	0.2515*	0.3369
YOSE	F	0.8337	0.0089*	0.2515*	0.6432
YOSE	WM	0.0927	0.0089*	0.2515*	0.3959
SEKI	F	0.0387	0.0089*	0.2515*	0.0906
SEKI	WM	0.3369	0.0089*	0.2515*	0.2555
SEKI (Long-term)	WM	0.9209	0.0089	0.2515	0.2357

*Quantities in gray type represent variance components that were estimated from other subsets of the pilot data and used as inputs for power approximations.

Table 3.4. Estimated variance components for percent cover of bryophytes.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.8256	—	—	0.5945
ALL	WM	0.4271	—	—	0.6188
YOSE	F	0.6464	—	—	0.5288
YOSE	WM	0.3743	—	—	0.7002
SEKI	F	0.8454	—	—	0.6271
SEKI	WM	0.5642	—	—	0.5124

Table 3.5. Estimated variance components for percent cover of perennial, herbaceous dicots and non-graminoid monocots.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.2779	—	—	0.0208
ALL	WM	0.3751	—	—	0.0313
YOSE	F	0.0386	—	—	0.0256
YOSE	WM	0.5648	—	—	0.0301
SEKI	F	0.3189	—	—	0.0193
SEKI	WM	—	—	—	0.1644

Table 3.6. Estimated variance components for percent cover of graminoids.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	–	–	–	0.1026
ALL	WM	0.4209	–	–	0.1379
YOSE	F	–	–	–	0.0070
YOSE	WM	0.5776	–	–	0.1298
SEKI	F	–	–	–	0.1217
SEKI	WM	–	–	–	0.3833

Table 3.7. Estimated variance components for percent cover of Cyperaceae.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	–	–	–	0.1495
ALL	WM	1.6531	–	–	0.0748
YOSE	F	–	–	–	0.0210
YOSE	WM	1.9720	–	–	0.0747
SEKI	F	–	–	–	0.7051
SEKI	WM	–	–	–	0.1752

Table 3.8. Estimated variance components for percent cover of Juncaceae.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.0244	–	–	0.2083
ALL	WM	0.5677	–	–	0.0473
YOSE	F	–	–	–	0.2550
YOSE	WM	0.0618	–	–	0.0476
SEKI	F	0.1490	–	–	0.0912
SEKI	WM	–	–	–	0.5636

Table 3.9. Estimated variance components for percent cover of Poaceae.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.1781	—	—	0.1717
ALL	WM	1.1819	—	—	0.0673
YOSE	F	0.3516	—	—	0.0090
YOSE	WM	1.4364	—	—	0.0672
SEKI	F	0.1491	—	—	0.2090
SEKI	WM	—	—	—	1.0129

Table 3.10. Estimated variance components for percent cover of annual dicots.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.2056	—	—	0.3697
ALL	WM	0.6812	—	—	0.3869
YOSE	F	0.6220	—	—	0.4068
YOSE	WM	0.7826	—	—	0.3341
SEKI	F	0.1287	—	—	0.3494
SEKI	WM	0.1983	—	—	0.4671

Table 3.11. Estimated variance components for cover sum of NWI obligate wetland species.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.3868	—	—	0.0946
ALL	WM	0.7425	—	—	0.1216
YOSE	F	0.3542	—	—	0.0647
YOSE	WM	0.7744	—	—	0.0975
SEKI	F	0.3883	—	—	0.1044
SEKI	WM	—	—	—	0.7363

Table 3.12. Estimated variance components for cover sum of NWI facultative wetland species.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.8714	—	—	0.0459
ALL	WM	1.0973	—	—	0.0507
YOSE	F	2.1577	—	—	0.1775
YOSE	WM	1.3437	—	—	0.0476
SEKI	F	0.2329	—	—	0.0027
SEKI	WM	—	—	—	0.7495

Table 3.13. Estimated variance components for cover sum of NWI facultative species.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.0792	—	—	0.1288
ALL	WM	1.4971	—	—	0.0713
YOSE	F	—	—	—	0.2377
YOSE	WM	2.2211	—	—	0.0720
SEKI	F	0.0501	—	—	0.1464
SEKI	WM	—	—	—	0.8284

Table 3.14. Estimated variance components for cover sum of NWI facultative upland species.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	—	—	—	—
ALL	WM	1.0064	—	—	0.1565
YOSE	F	—	—	—	—
YOSE	WM	1.0013	—	—	0.1581
SEKI	F	—	—	—	—
SEKI	WM	—	—	—	1.1474

Table 3.15. Estimated variance components for cover sum of NWI obligate upland species.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	—	—	—	—
ALL	WM	0.1098	—	—	0.0648
YOSE	F	—	—	—	—
YOSE	WM	—	—	—	—
SEKI	F	—	—	—	—
SEKI	WM	—	—	—	—

Table 3.16. Estimated variance components for NWI obligate wetland species richness.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.2323	—	—	0.0077
ALL	WM	0.1027	—	—	0.0824
YOSE	F	0.1970	—	—	0.0256
YOSE	WM	0.2002	—	—	0.0391
SEKI	F	0.1962	—	—	0.0019
SEKI	WM	—	—	—	0.1339

Table 3.17. Estimated variance components for NWI facultative wetland species richness.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.2319	—	—	0.0030
ALL	WM	0.1739	—	—	0.0014
YOSE	F	—	—	—	0.6422
YOSE	WM	0.2714	—	—	0.0014
SEKI	F	0.0898	—	—	0.0039
SEKI	WM	—	—	—	0.0782

Table 3.18. Estimated variance components for NWI facultative species richness.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.0111	—	—	0.2104
ALL	WM	0.2546	—	—	0.0599
YOSE	F	—	—	—	0.1868
YOSE	WM	0.3607	—	—	0.0605
SEKI	F	—	—	—	0.2269
SEKI	WM	—	—	—	0.1997

Table 3.19. Estimated variance components for NWI facultative upland species richness.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	—	—	—	—
ALL	WM	0.3277	—	—	0.0401
YOSE	F	—	—	—	—
YOSE	WM	0.3441	—	—	0.0410
SEKI	F	—	—	—	—
SEKI	WM	—	—	—	0.3504

Table 3.20. Estimated variance components for NWI obligate upland species richness.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	—	—	—	—
ALL	WM	—	—	—	0.0896
YOSE	F	—	—	—	—
YOSE	WM	—	—	—	—
SEKI	F	—	—	—	—
SEKI	WM	—	—	—	—

Table 3.21. Estimated variance components for overall species richness.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.1074	0.0021*	0.0123*	0.0752
ALL	WM	0.2155	0.0021*	0.0123*	0.0181
YOSE	F	0.7980	0.0021*	0.0123*	0.0148
YOSE	WM	0.3607	0.0021*	0.0123*	0.0173
SEKI	F	0.0620	0.0021*	0.0123*	0.0249
SEKI	WM	0.0026	0.0021*	0.0123*	0.0500
SEKI (Long-term)	WM	0.2787	0.0021	0.0123	0.00005

*Quantities in gray type represent variance components that were estimated from other subsets of the pilot data and used as inputs for power approximations.

Table 3.22. Estimated variance components for NWI prevalence index.

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	0.0055	–	–	0.0029
ALL	WM	0.0277	–	–	0.0025
YOSE	F	0.0229	–	–	0.0026
YOSE	WM	0.0254	–	–	0.0030
SEKI	F	–	–	–	0.0060
SEKI	WM	–	–	–	0.0255

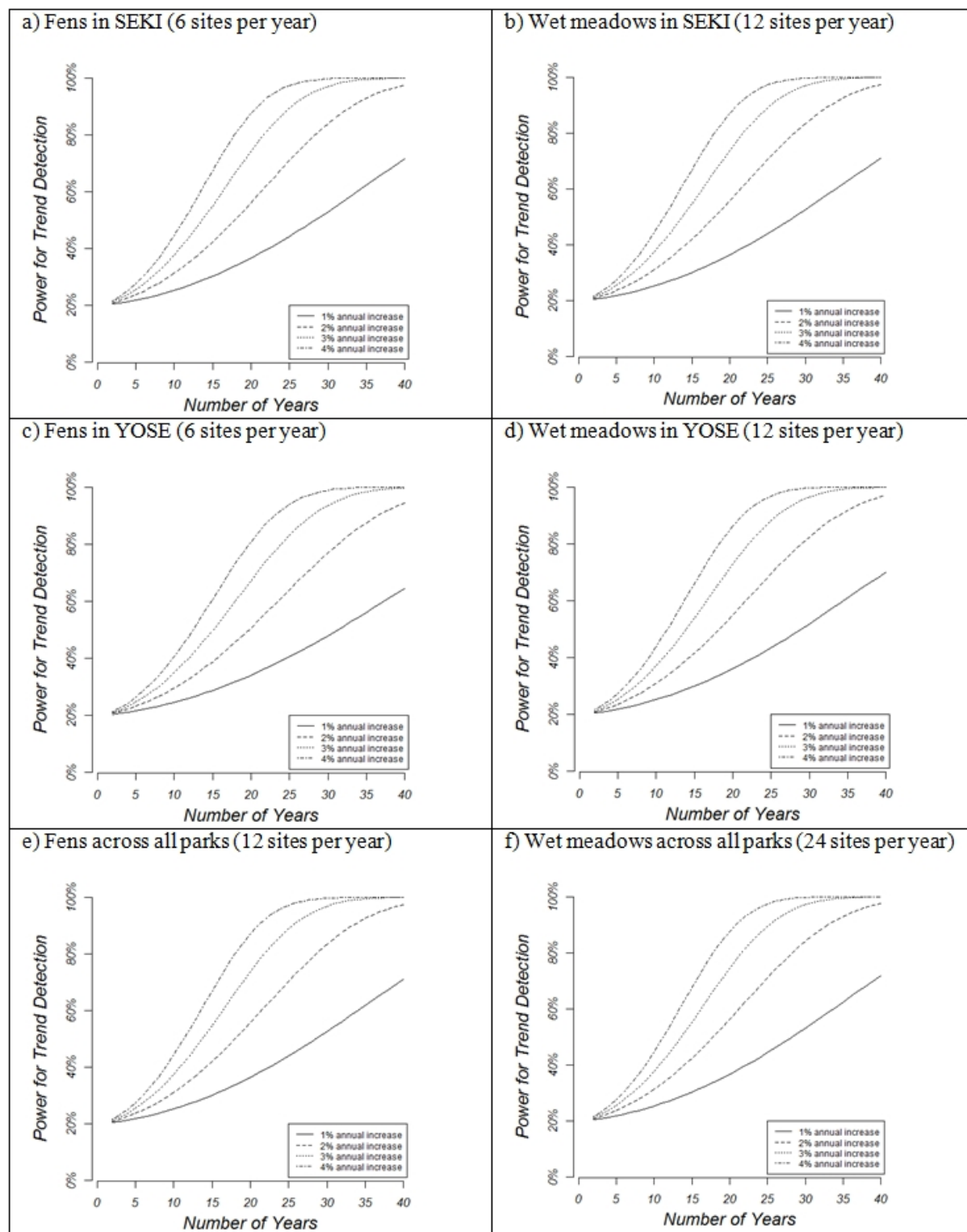


Figure 3.3. Power to detect population increases in **percent bare ground** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

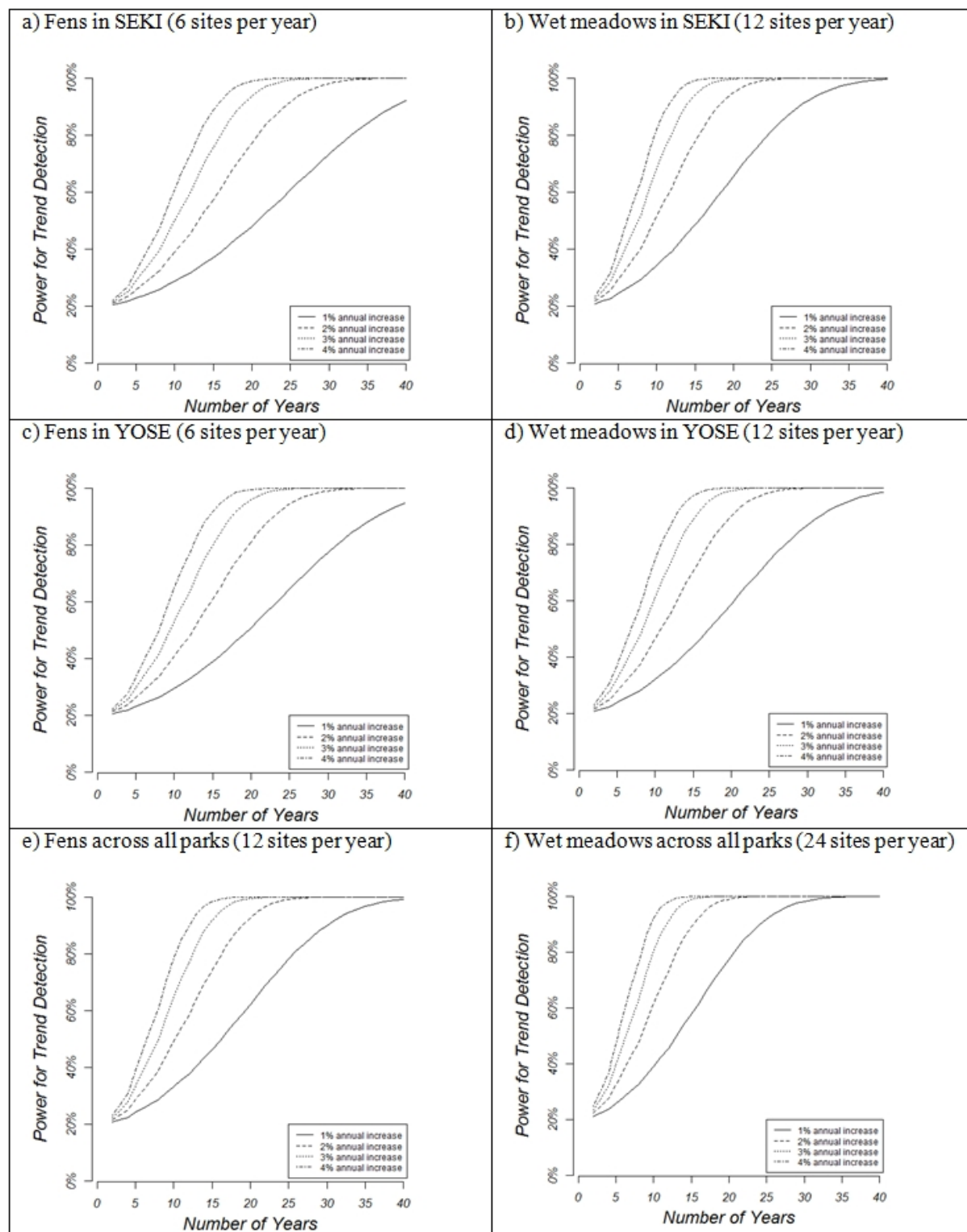


Figure 3.4. Power to detect population increases in **percent cover of bryophytes** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

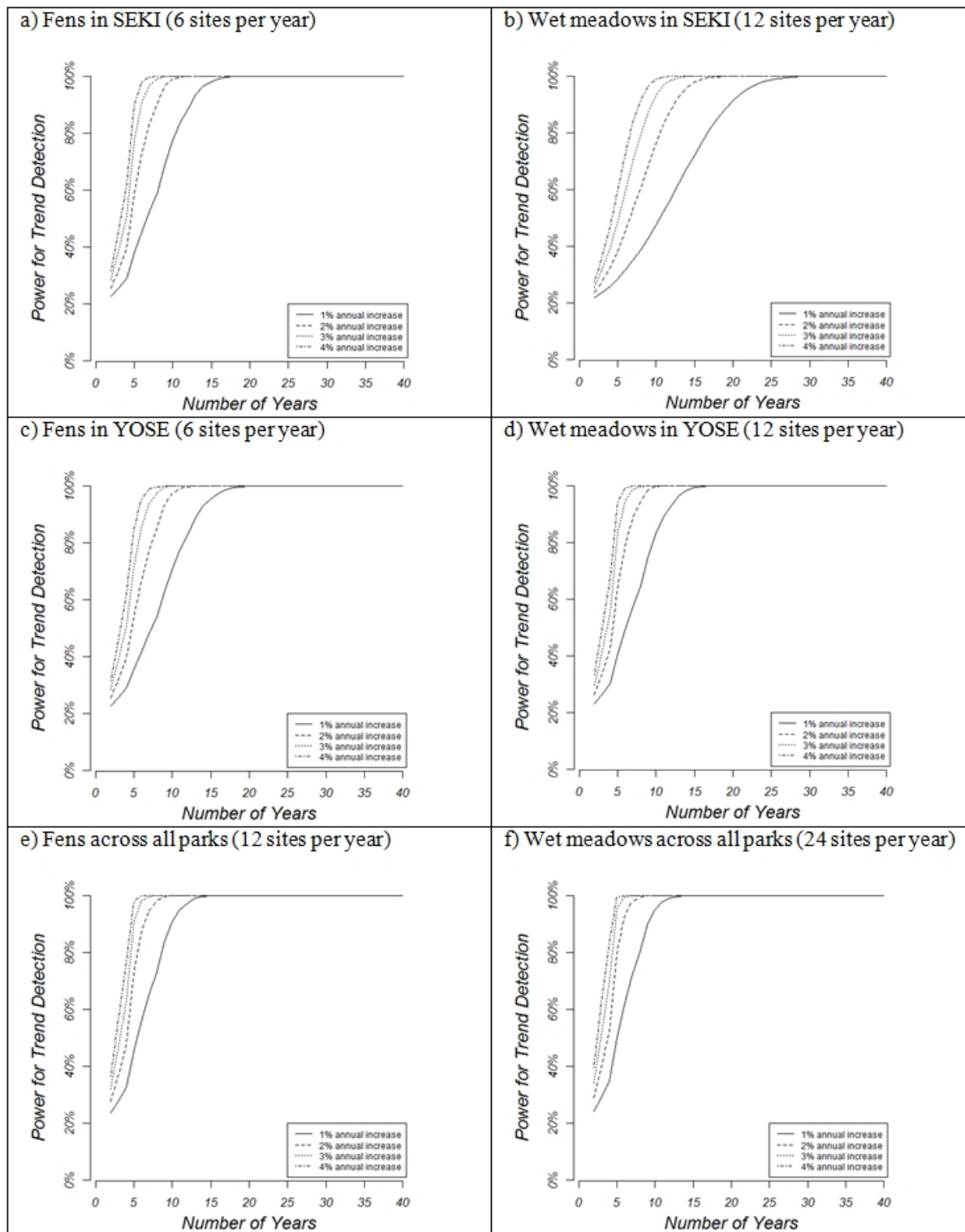


Figure 3.5. Power to detect population increases in the **percent cover of perennial, herbaceous dicots and non-graminoid monocots** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

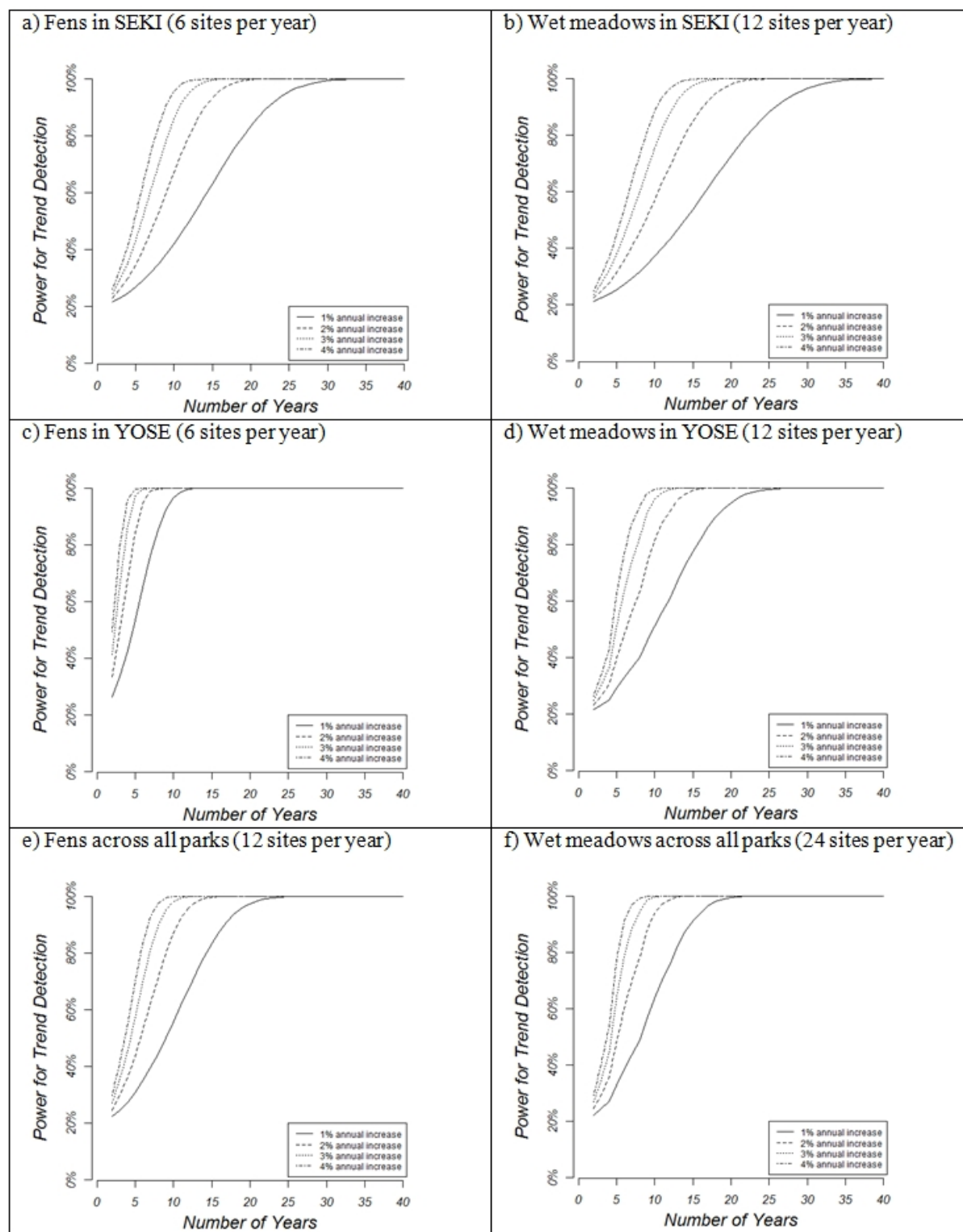


Figure 3.6. Power to detect population increases in the **percent cover of graminoids** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

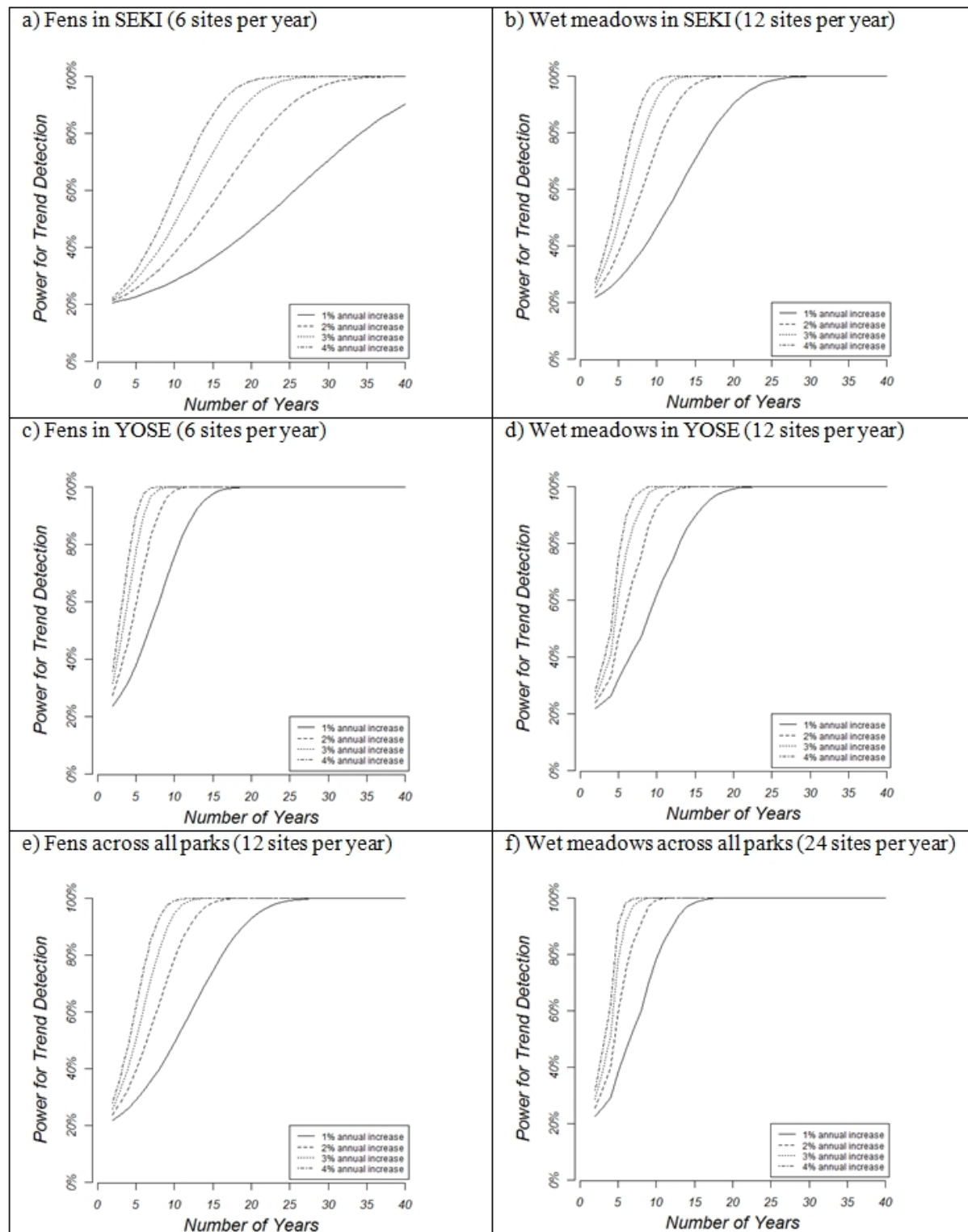


Figure 3.7. Power to detect population increases in the **percent cover of Cyperaceae** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

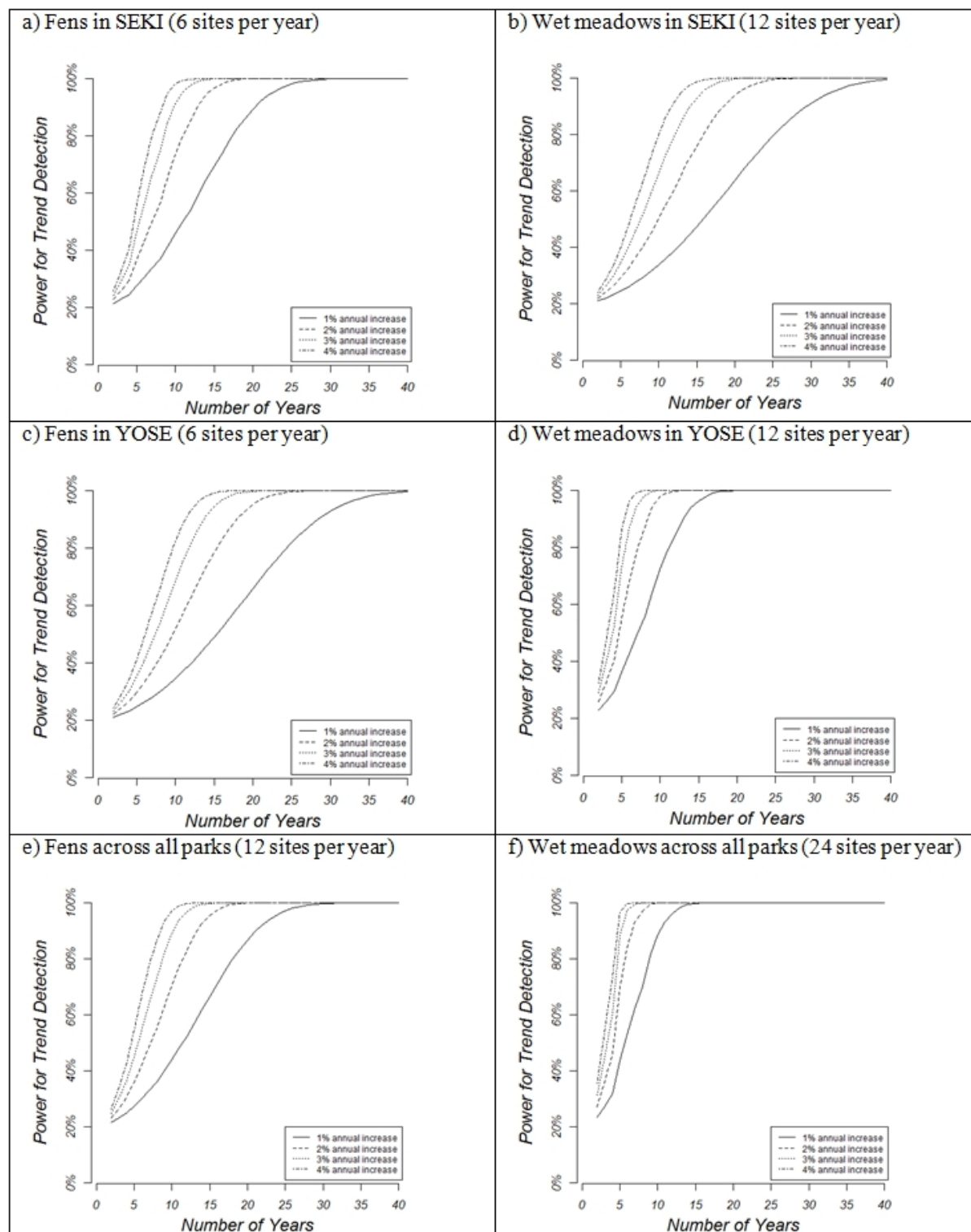


Figure 3.8. Power to detect population increases in the **percent cover of Juncaceae** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

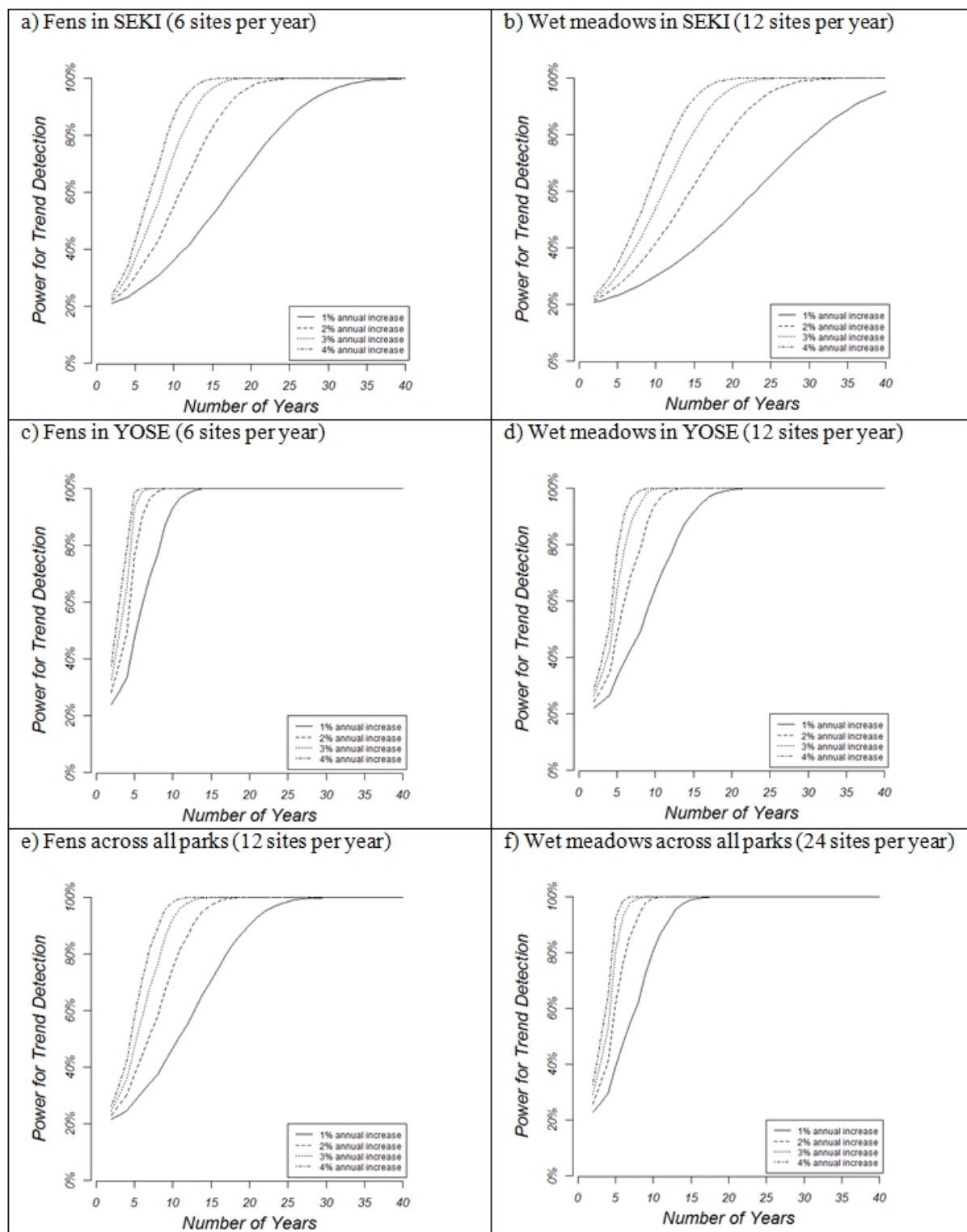


Figure 3.9. Power to detect population increases in the **percent cover of *Poaceae*** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

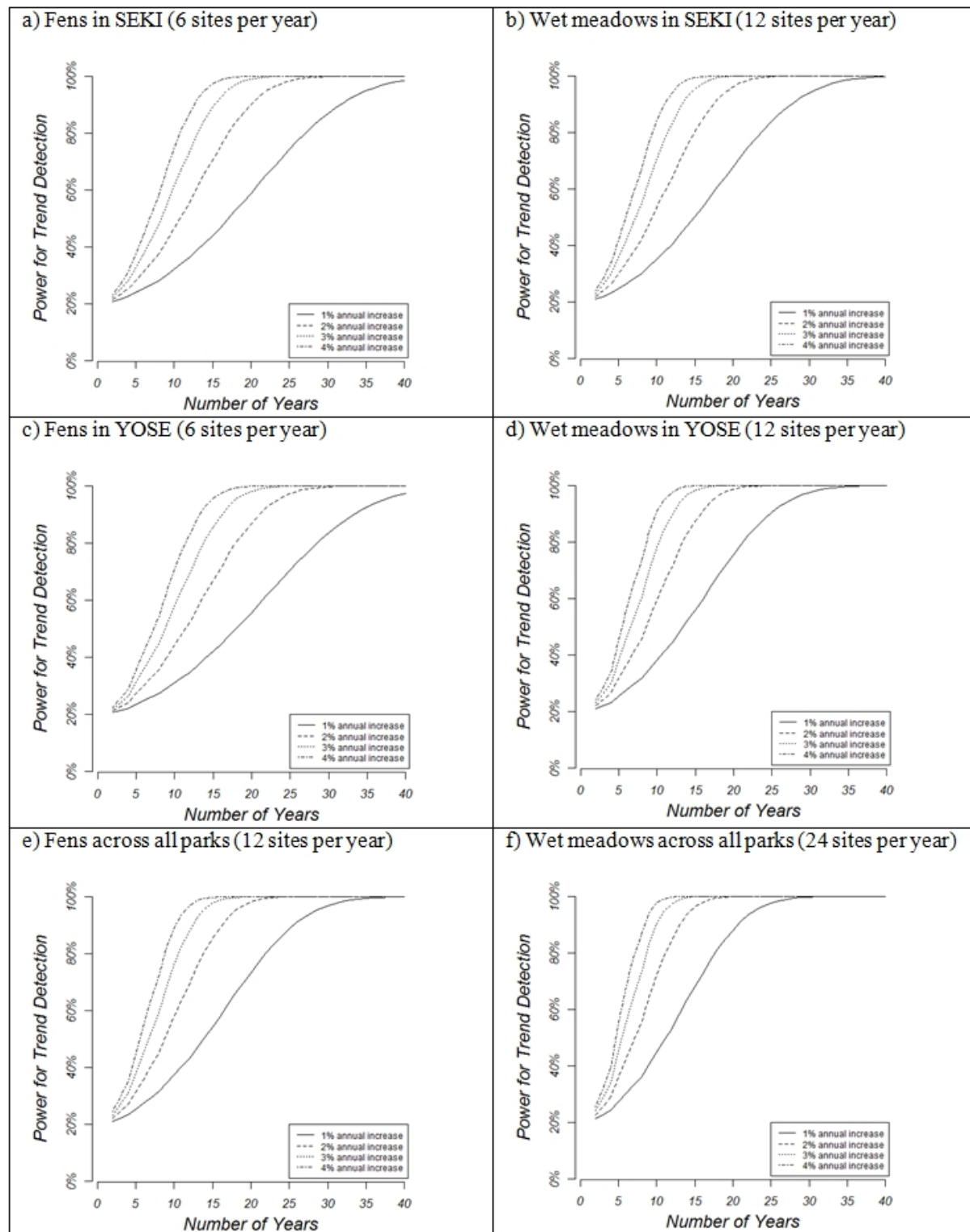


Figure 3.10. Power to detect population increases in the **percent cover of annual dicots** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

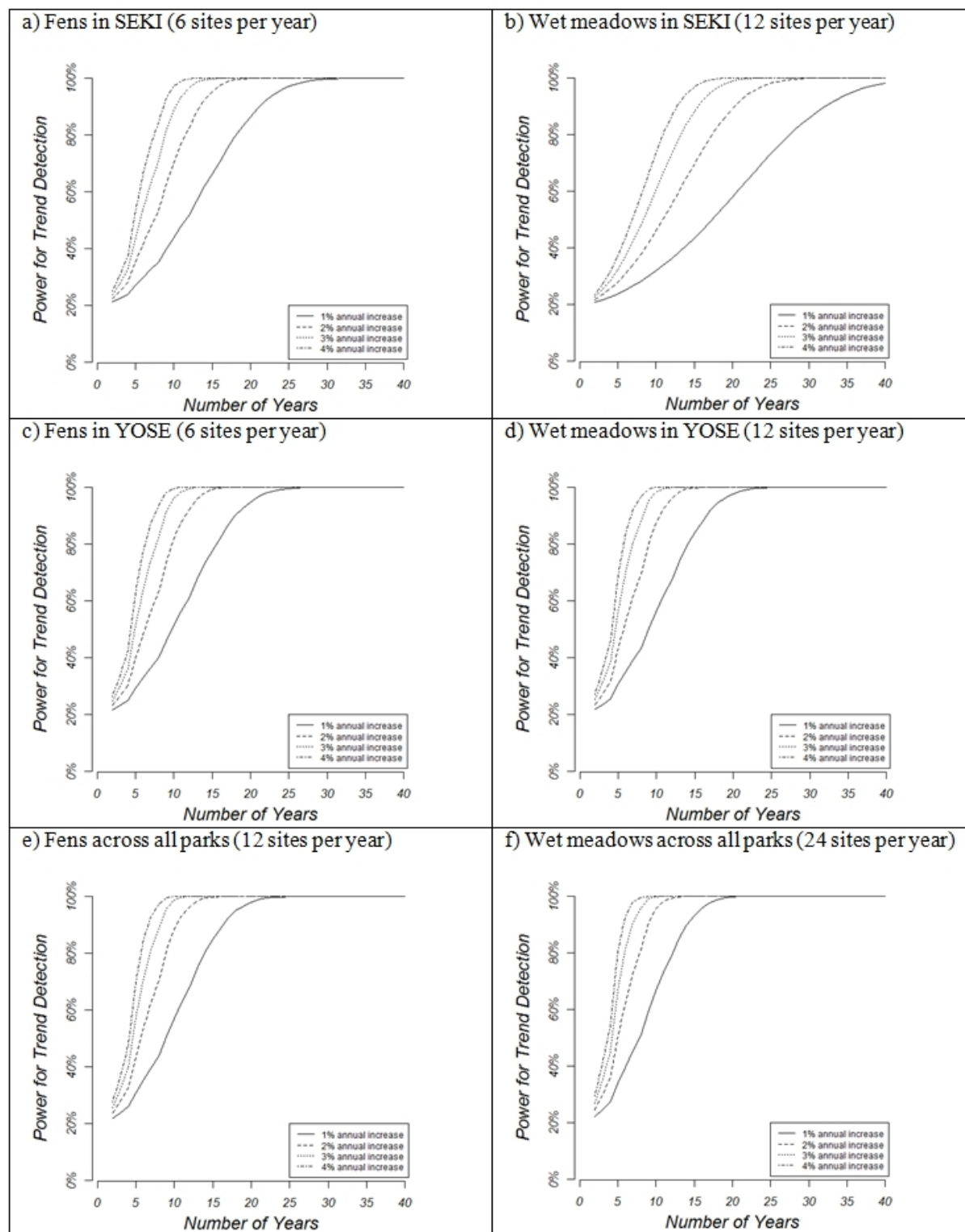


Figure 3.11. Power to detect population increases in the **cover sum of NWI obligate wetland species** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

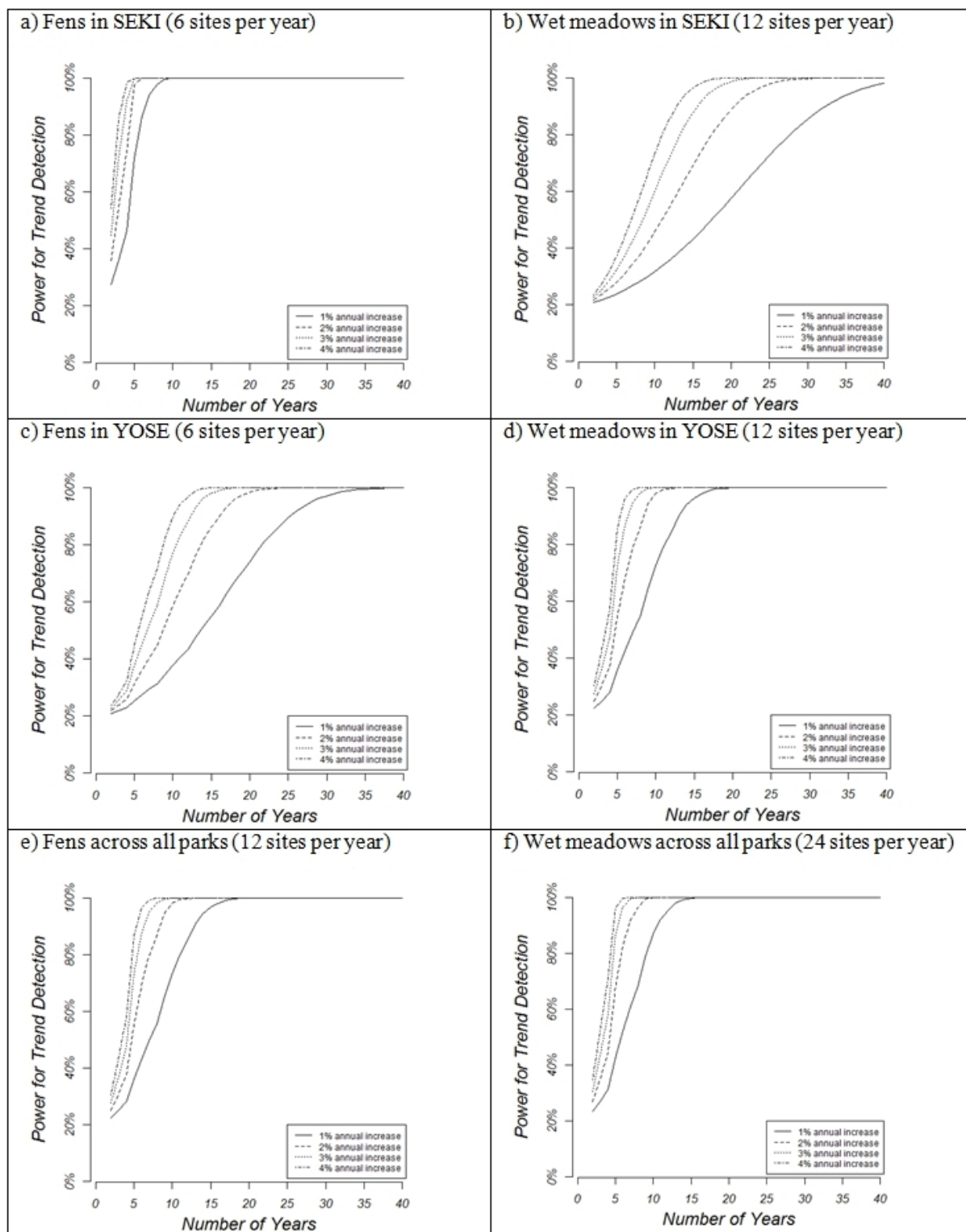


Figure 3.12. Power to detect population increases in the **cover sum of NWI facultative wetland species** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

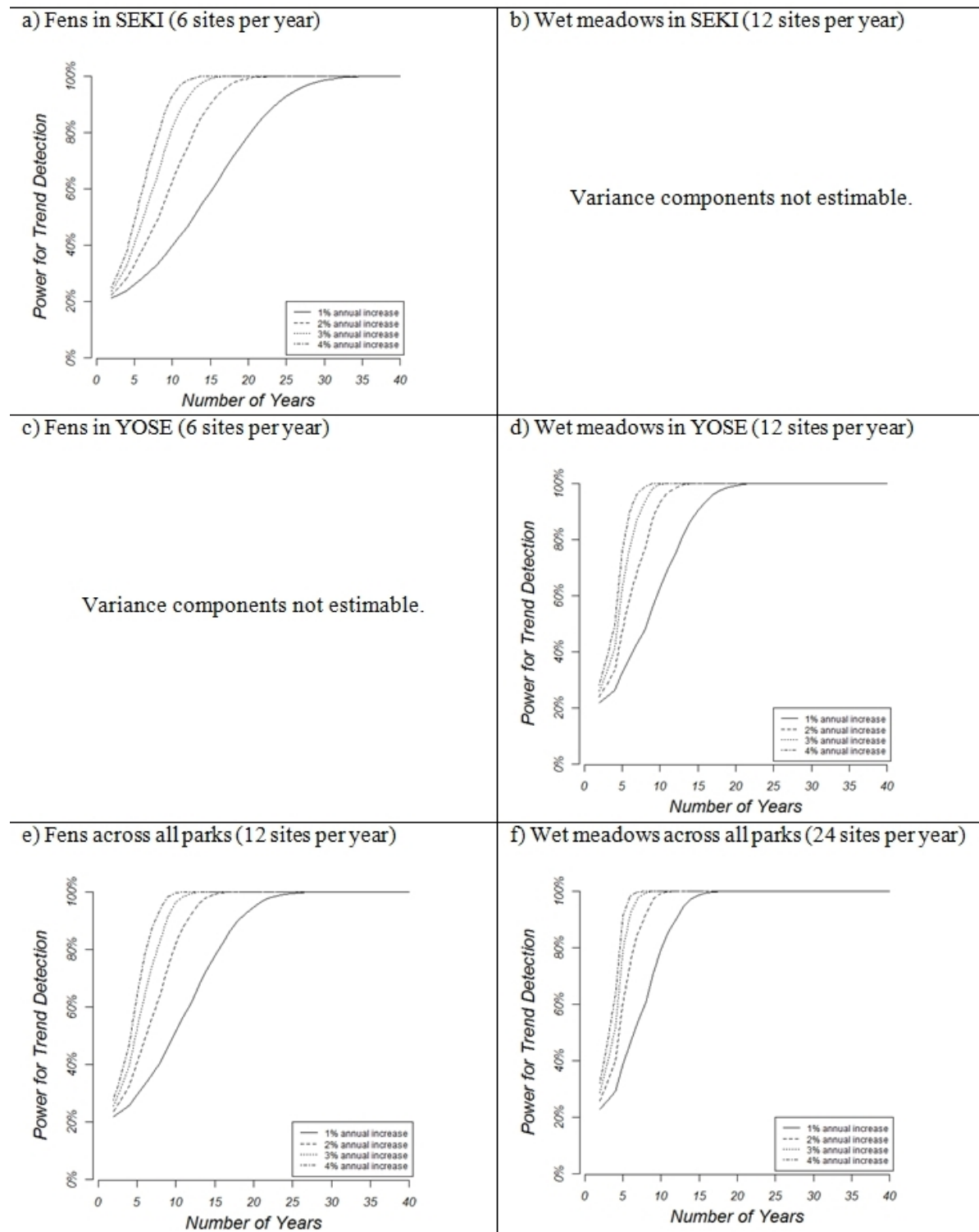


Figure 3.13. Power to detect population increases in the **cover sum of NWI facultative species** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

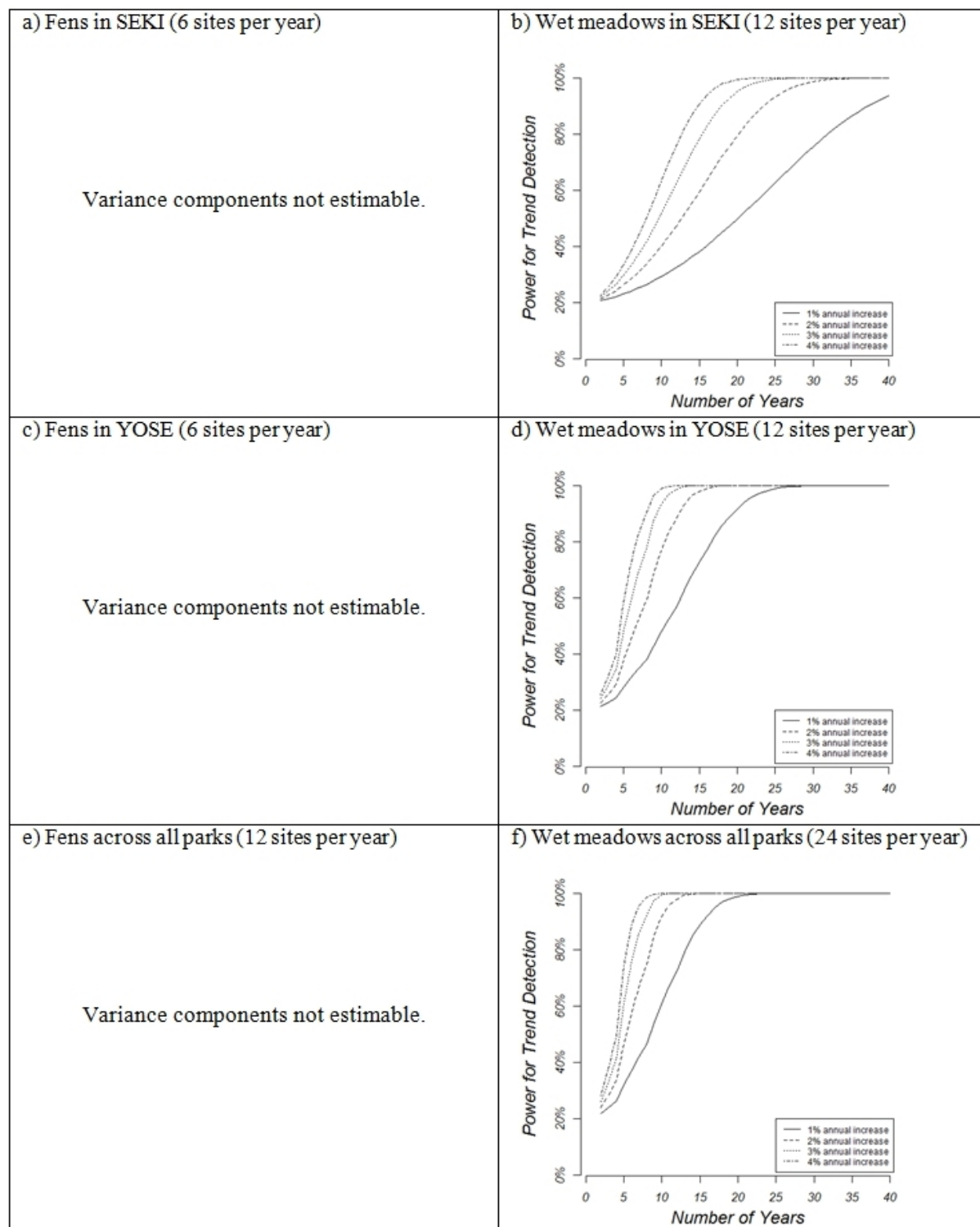


Figure 3.14. Power to detect population increases in the **cover sum of NWI facultative upland species** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

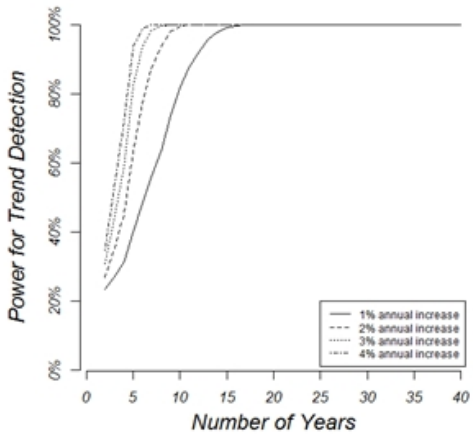
a) Fens in SEKI (6 sites per year) Variance components not estimable.	b) Wet meadows in SEKI (12 sites per year) Variance components not estimable.
c) Fens in YOSE (6 sites per year) Variance components not estimable.	d) Wet meadows in YOSE (12 sites per year) Variance components not estimable.
e) Fens across all parks (12 sites per year) Variance components not estimable.	f) Wet meadows across all parks (24 sites per year)  The graph plots 'Power for Trend Detection' (Y-axis, 0% to 100%) against 'Number of Years' (X-axis, 0 to 40). Four curves represent different annual increase rates: 1% (solid line), 2% (dashed line), 3% (dotted line), and 4% (dash-dot line). All curves start at approximately 20% power at year 0 and rise to 100% power. The 4% increase curve reaches 100% power fastest, around year 10. The 1% increase curve reaches 100% power around year 25.

Figure 3.15. Power to detect population increases in the **cover sum of NWI obligate upland wetland species** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

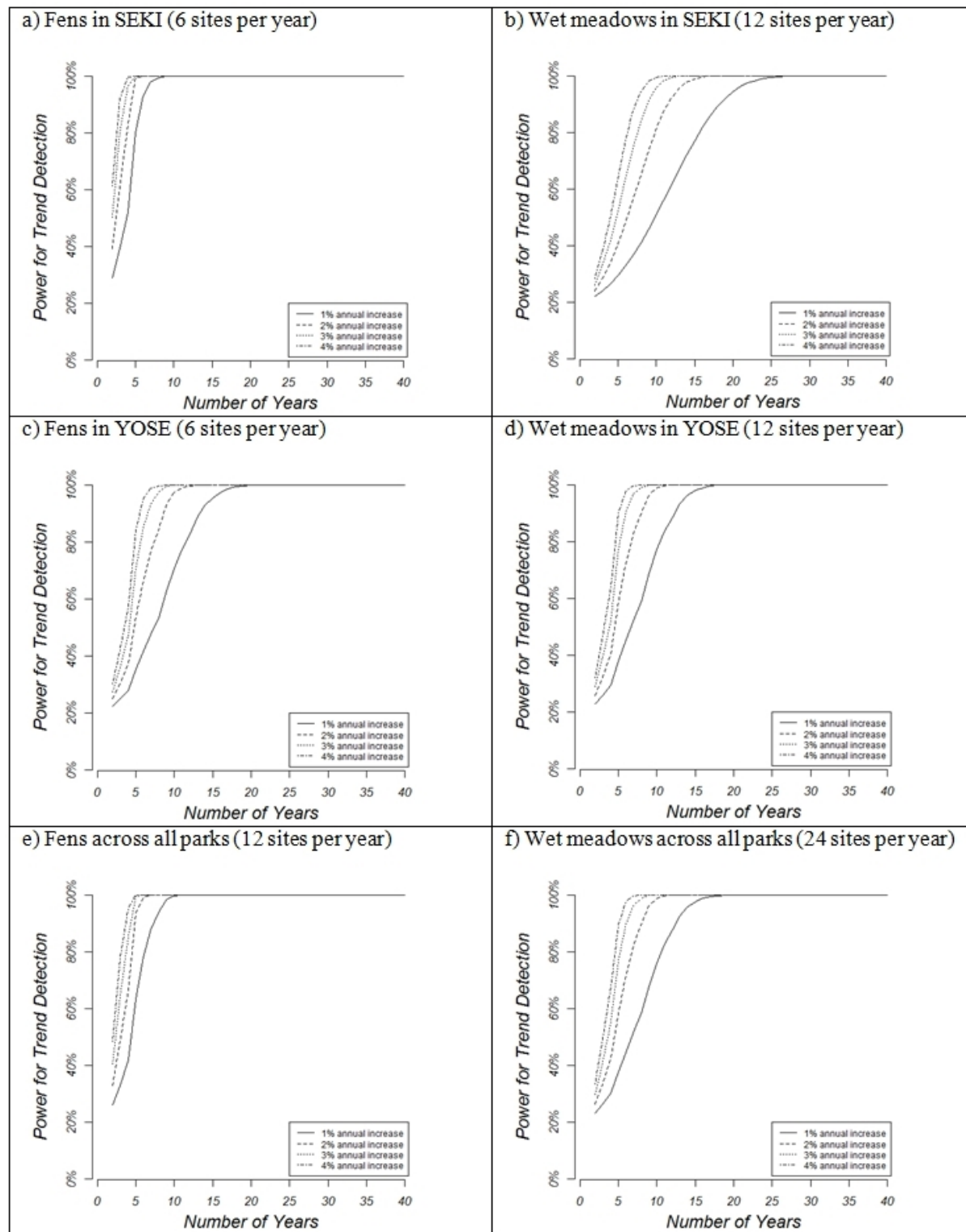


Figure 3.16. Power to detect population increases in **NWI obligate wetland species richness** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

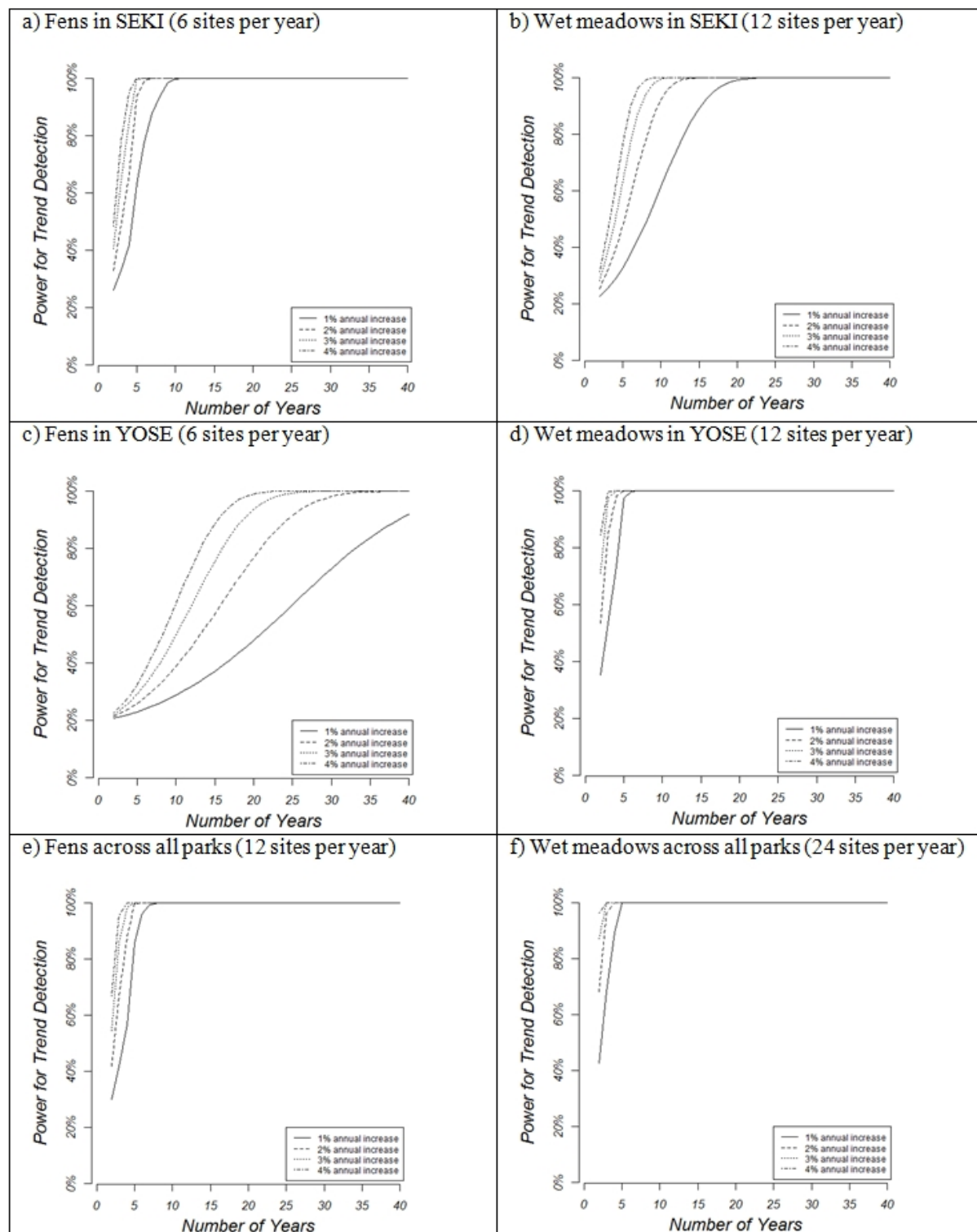


Figure 3.17. Power to detect population increases in **NWI facultative wetland species richness** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

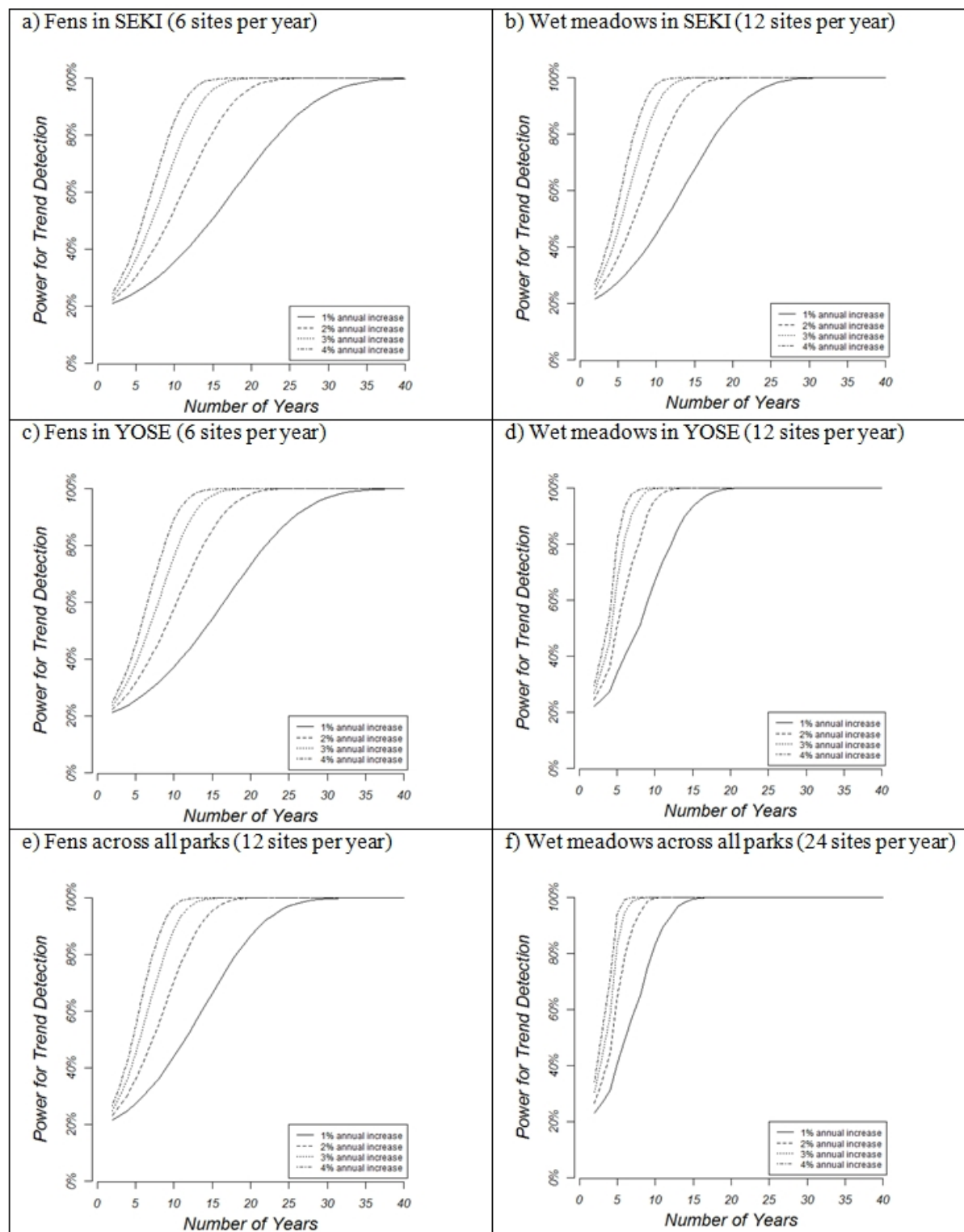


Figure 3.18. Power to detect population increases in **NWI facultative species richness** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

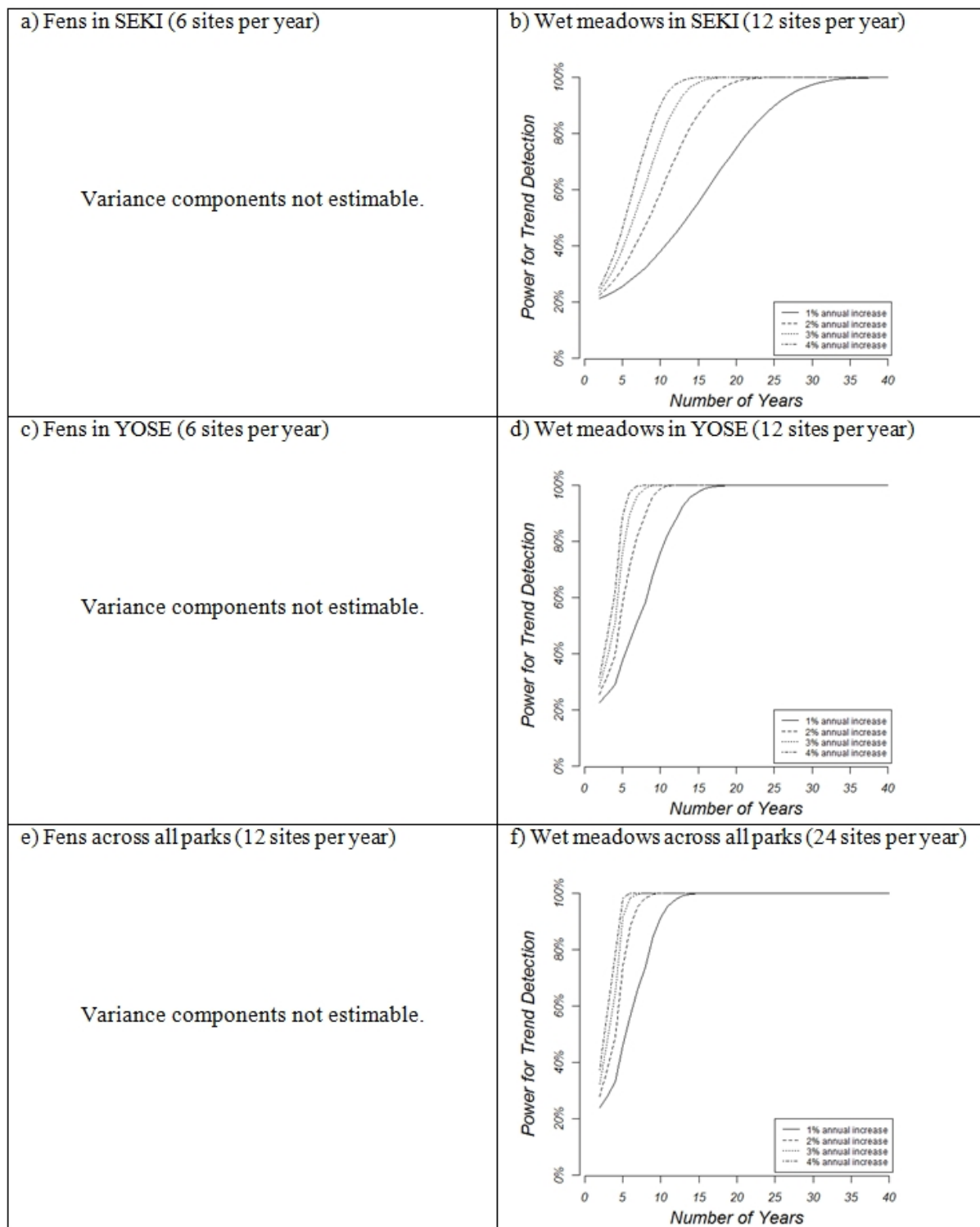


Figure 3.19. Power to detect population increases in **NWI facultative upland species richness** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

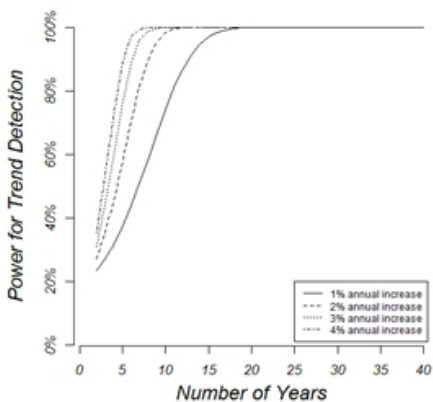
a) Fens in SEKI (6 sites per year) Variance components not estimable.	b) Wet meadows in SEKI (12 sites per year) Variance components not estimable.
c) Fens in YOSE (6 sites per year) Variance components not estimable.	d) Wet meadows in YOSE (12 sites per year) Variance components not estimable.
e) Fens across all parks (12 sites per year) Variance components not estimable.	f) Wet meadows across all parks (24 sites per year)  The graph plots 'Power for Trend Detection' (Y-axis, 0% to 100%) against 'Number of Years' (X-axis, 0 to 40). Four curves represent different annual increase rates: 1% (solid line), 2% (dashed line), 3% (dotted line), and 4% (dash-dot line). All curves start at approximately 25% power at year 0 and rise to 100% power. The 4% annual increase curve reaches 100% power fastest, around year 10. The 1% annual increase curve reaches 100% power slowest, around year 20.

Figure 3.20. Power to detect population increases in **NWI obligate upland species richness** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

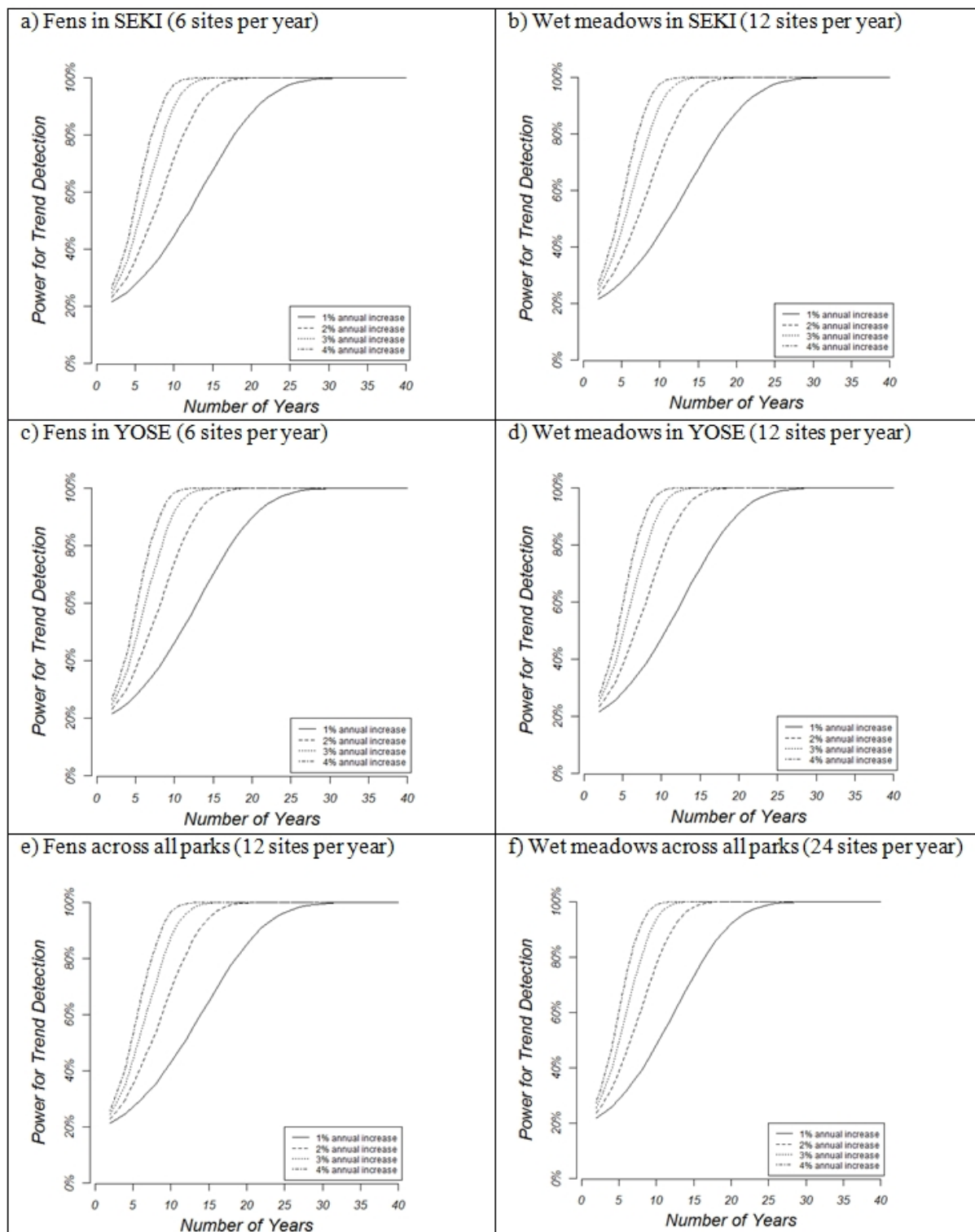


Figure 3.21. Power to detect population increases in **overall species richness** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

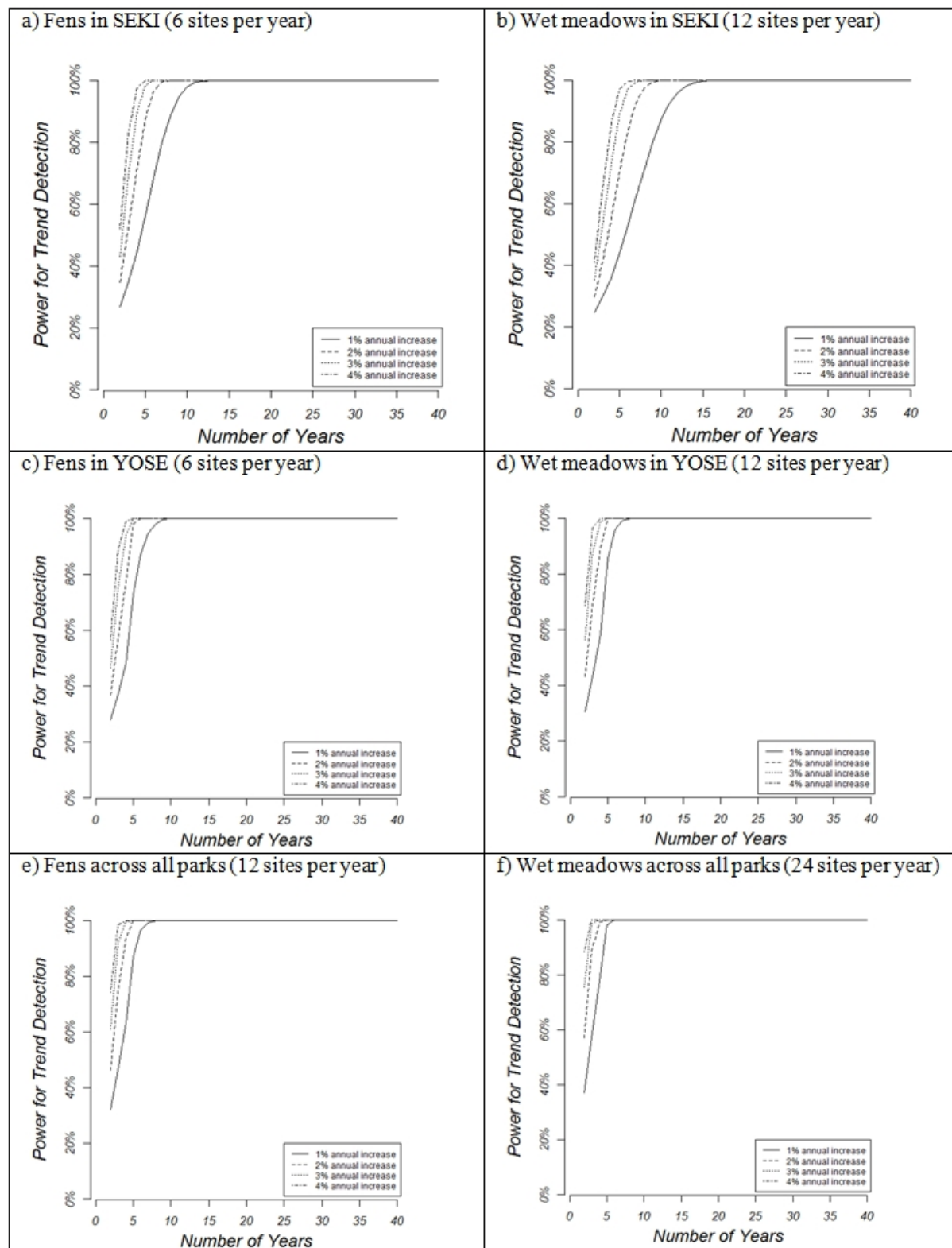


Figure 3.22. Power to detect population increases in the NWI prevalence index in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

Overall, the highest power to detect trend is obtained from monitoring the NWI prevalence index and percent cover of perennial, herbaceous dicots and non-graminoid monocots. For almost all levels of estimation, monitoring these indicators should provide at least 80% power to detect increasing trends of at least 1% annually within 15 years. The remaining indicators all attain 80% power for larger annual trends of 2% or more within 20 to 30 years with the exception of the percent bare ground indicator. This indicator exhibits higher variability than the rest of the vegetation indices and 80% power is attained only for the larger trends after nearly 30 consecutive survey years.

4. Power Analysis of Hydrologic Indicators

4.1 Pilot data

Two pilot data sets contain measurements of depth to water table for monitoring trends in hydrology (Table 4.1). One data set comes from three years of work in Tuolumne Meadows (Figure 4.1) and the other data set is from four years of surveys conducted in six meadows within SEKI. The SEKI data will be useful for measuring variance components related to both time and space, and the YOSE data will be used to estimate variance components over time. The set of wells unrelated to restoration projects were identified and used for variance component estimation.

Table 4.1. Summary of hydrology pilot data.

Metric	YOSE meadows	SEKI meadows
Years	2006-2008	2005-2008
Number of meadows	1 (Tuolumne)	6 (Cabin, Crescent, Dorst, Halstead, Log, Round)
Total number of wells	47	45

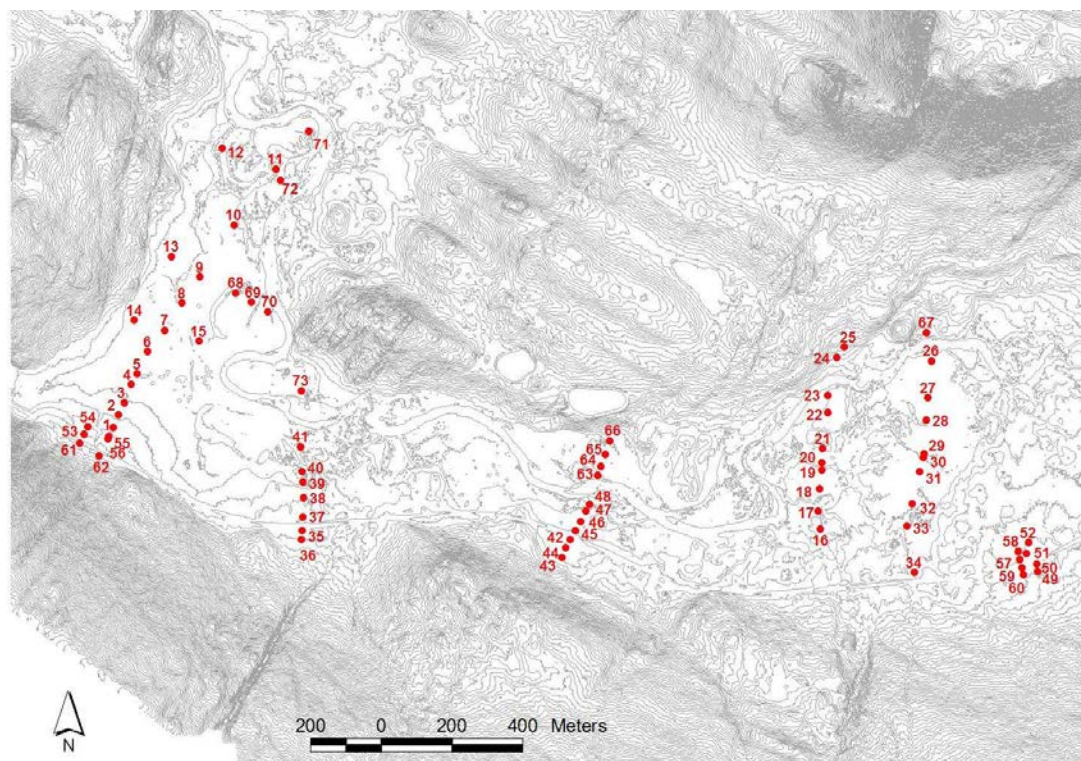


Figure 4.1. Tuolumne Meadows well locations.

Well depth data from Tuolumne Meadow in YOSE display interannual variability with highest levels in the spring and well depth decreasing over the course of the summer (Figure 4.2). The well data

from SEKI do not show substantial variability among visits within a year (Figure 4.3). Furthermore, plots of well depth for each SEKI meadow indicated that well depth did not vary greatly among meadows, among years, or within years. Note that month-level means from SEKI are derived from multiple within-month visits at each of six meadows, whereas the YOSE means by month only represent one meadow with multiple within-month visits. The lack of replication in the YOSE survey prevents determining if the variation is specific to Tuolumne Meadows or if the decreasing trend within a year is consistent across YOSE.

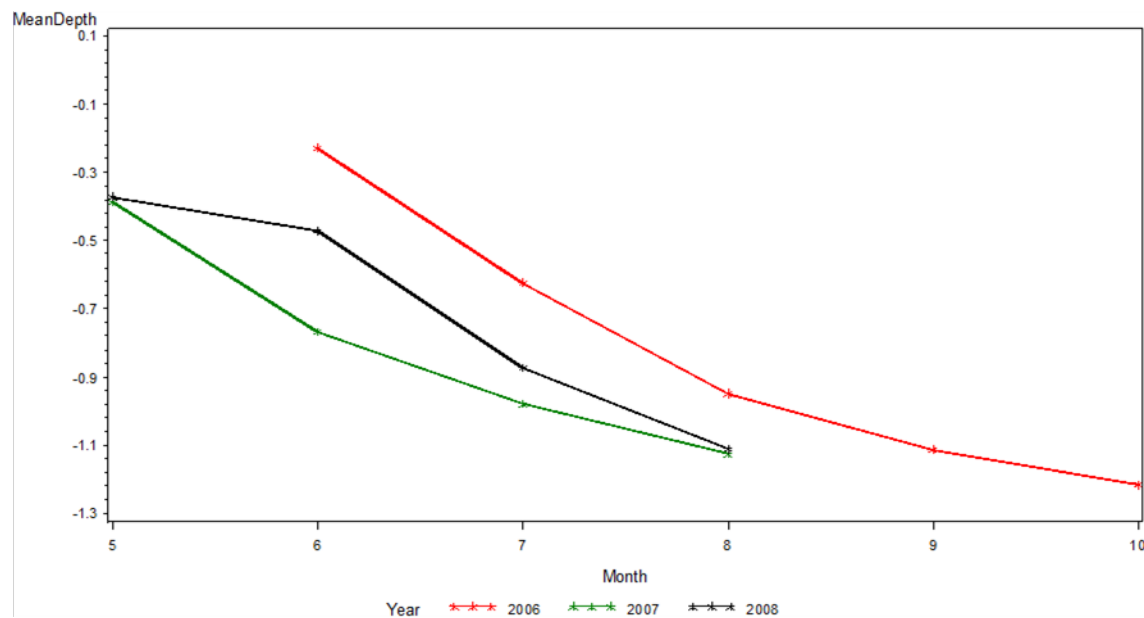


Figure 4.2. YOSE well depth means (cm) by month and year.

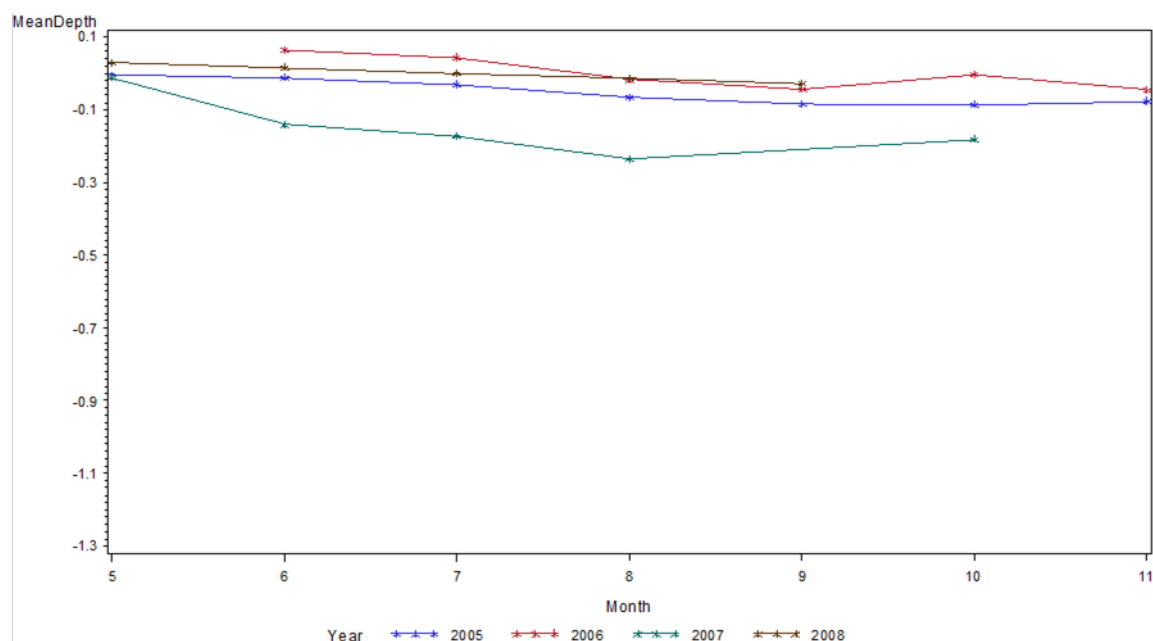


Figure 4.3. SEKI well depth means (cm) by month and year.

4.2 Results

The variance component estimates for the well depth data are given in Table 4.2. Because data from YOSE were collected from only Tuolumne Meadow, no wetland-level variance component could be estimated. The estimate of site-to-site variation measured in SEKI wet meadows is used to estimate this missing variance component. Because there was no replication within YOSE, the estimation of network-level variance components was not feasible.

Table 4.2. Estimated variance components for water depth (cm).

Park	Wet Type	site-to-site variation (σ_a^2)	variation among site- level slopes (σ_t^2)	year-to-year variation (σ_b^2)	residual variation (σ_e^2)
ALL	F	—	—	—	—
ALL	WM	—	—	—	—
YOSE	F	—	—	—	—
YOSE	WM	0.000145*	—	0.018210	0.045170
SEKI	F	0.000014	—	0.000616	0.000874
SEKI	WM	0.000145	0.000115	0.002710	0.001649

* This site-to-site variance component for wet meadows in Yosemite was estimated from the pilot data collected in Sequoia & Kings Canyon wet meadows

The results of the power analysis for increasing trends in well depth are provided in Figure 4.4. Approximated power is excellent, with power to detect even an annual change of 1% within 15 years with 80% power. The pilot data include many within-year revisits that allow variation components to be estimated. The depth data from YOSE indicate that year-to-year variation may be smallest if depth measurements are taken in May or August (Figure 4.2). However, the SEKI data suggest that well depth measurements may not change much within and across years. These results indicate that wells should be visited each year as closely together in time as possible to reduce within-year variation that would be unexplainable without within-year replication.

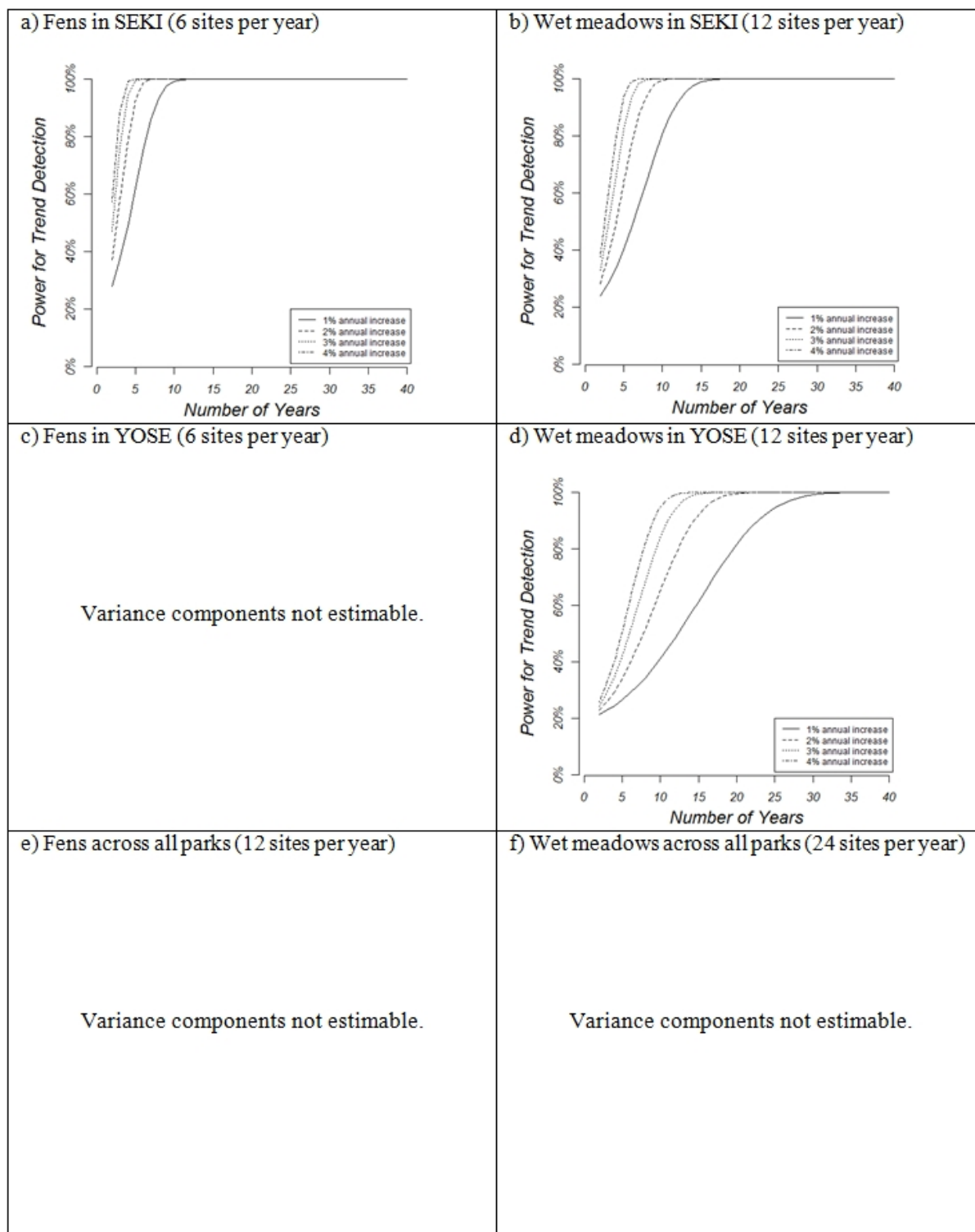


Figure 4.4. Power to detect population increases in **well depth (cm)** in tests of trend computed at the $\alpha=0.20$ significance level for a [(1-0),(1-3)] revisit design.

5. Conclusions

A comparison of serially-alternating augmented revisit designs indicated that all designs incorporating an annual panel of sufficient size will attain nearly optimal power for trend detection. Optimizing annual resources, the primary goal of trend detection, and the secondary goal of status estimation, the WEI workgroup decided on the [(1-0),(1-3)] revisit design.

Several indicators demonstrated exceptional power for trend detection. These indicators include well depth; the NWI prevalence index; and percent cover of perennial, herbaceous dicots and non-graminoid monocots. Power to detect trends as low as 1% annually may reach 80% in less than 15 years for these indicators. Indicators that appear highly variable for long-term monitoring include percent predators for terrestrial invertebrates and percent bare ground for vegetation surveys. Power of 80% or more is achieved for the remaining indicators by sampling consecutive years over a 20 to 30 year period.

This power analysis underscores the need for consistent sampling over a long time period for powerful trend detection. The most effective approach for achieving high power to detect trends over time is to ensure that at least the annual panel is surveyed each year using methods that are consistent over time.

6. Literature Cited

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Appendix 5: Database Documentation

March 2017

Prepared by Leslie Chow, Alex Eddy, and Jonathan Nesmith

Change History

Revision Date	Rev. No.	Author	Changes Made	Reason for Change
None	–	–	–	–

Add more rows as needed.

Introduction

Data management can be divided into two phases, an initial design phase and an implementation phase. Initial design consists of defining the data model, its entities and their relationships. Implementation involves defining and executing standardized procedures to populate and maintain the database. Those procedures are described in this document.

Overview of Database Design

The Sierra Nevada Network Wetland Ecological Integrity (WEI) monitoring project database is a Microsoft Access 2010 application. Its design is based on the NPS I&M Natural Resource Database Template (NRDT) version 3.2 (National Park Service. 2007) and is consistent with database standards described in the SIEN Data Management Plan (Cook and Lineback 2008).

Two tables, tblSites and tblSiteVisits form the core of the WEI database. They correspond, respectively, to tblLocations and tblEvents in the NRDT. TblSites stores the location information for each sampling unit while tblSiteVisits stores data associated with individual sampling events at those sampling units. The remaining data tables within the database characterize wetland vegetation, hydrology, invertebrates, and measures of disturbance and wetland condition at the sampling unit for each sampling event (Tables A5.1 – A5.58). These data tables are hierarchically ordered in a parent-child arrangement using a combination of natural and/or globally unique artificial identifiers (GUIDs) as primary and foreign keys to normalize the data and avoid redundancy that might otherwise be required in the nested-plot sampling design described in the Narrative. Figure A5.1 illustrates the data model and relationships between data tables in the WEI database. Note that Figure A5.1 only includes key tables to provide a conceptual model of the database. Also present in the database, but not shown, are additional look-up tables used to define categorical variables in fields within other tables.

The SIEN strategy for maintaining the integrity of the WEI database uses the “working copy/master copy” model adopted by other I&M networks. The data models for the “working copy” and the “master” (archive version) are identical. The “working copy” is used to store the current season’s data while the “master copy” serves as a data archive suitable for multi-year analyses. The working copy of the database includes a graphical user interface in the form of a switchboard that provides access to various database functions. Controls on the switchboard are used to access data entry forms, tools for managing lookup-tables and contact information as well as queries for performing QA/QC operations and data summaries. The master copy of the database incorporates a front-end user interface with additional tools for generating summary information, reports and formatted export files. The front and back-end databases are linked using the MS-Access table linking utility.

In general, project staff have read/write access to the working copy of the database to perform data entry and data verification procedures. Read/write access to the master copy of the database is limited to the Database Manager and Project Lead. Access rights to both copies of the database are controlled by network level directory and file permissions.

The transition from paper data sheets to electronic data entry on handheld computers in the field introduces new challenges for verifying that data have been entered correctly. Although electronic data entry saves time and reduces the likelihood of transcription errors during the conversion from analog to digital format, it introduces the possibility of data entry errors in the field that may be more difficult to identify and correct later. For this reason, the database makes extensive use of validation rules, range limits, and lookup fields. While these safeguards reduce the potential for data entry errors, not all errors can be programmatically prevented. For example, four and five character plant species codes in a lookup field may only differ by a character or two. This could easily lead to the wrong species being selected. To prevent this, the electronic data entry forms will require the user to select a scientific name rather than a species code from the lookup list even though the species code is what will be stored in the data record. Additional tools in the database like queries that generate a species list in the field will also assist in identifying errors at the sampling site where discrepancies can more easily be resolved.

Finally, it is imperative that field personnel be adequately trained and cognizant of the importance of ensuring that data are correctly recorded and checked before leaving the field site. This will be an important component of field crew training (SOP 21) and should be stressed throughout the field season. Back-up paper datasheets will also always be carried in the field should there be a malfunction in the electronic data recording device or database.

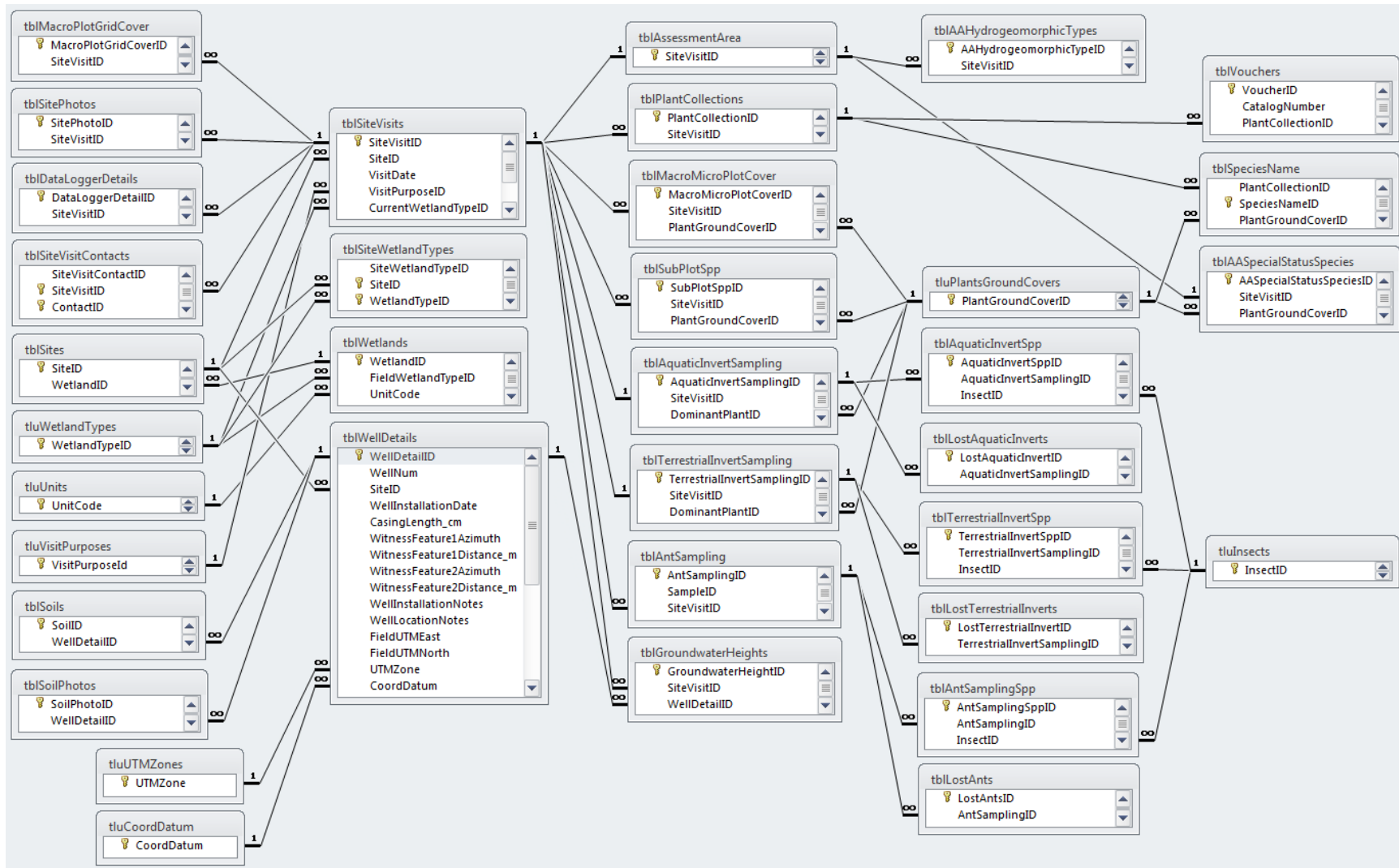


Figure A5.1. Relationships diagram for Wetlands Ecological Integrity Monitoring project database. Not all fields in every table are shown and are instead listed in the Data Dictionary.

Data Dictionary

This data dictionary (Tables A5.1 – A5.58) lists key tables in the Wetlands Ecological Integrity Monitoring database. Each table consists of the table name, field name, data type, field size, and a brief description of the field contents or data domain.

Table A5.1. tblAAHydrogeomorphicTypes

FIELD NAME	Data Type	DESCRIPTION
AAHydrogeomorphicTypeID	AutoNumber	Unique ID identifying each hydrogeomorphic type record
SiteVisitID	Number	Field linking assessment area data to sitevisit data
HydrogeomorphicTypeID	Number	Hydrogeomorphic type within the assessment area from look-up table
Percent	Number	Estimated percentage of assessment area within each identified hydrogeomorphic type
Notes	Memo	Notes related to the hydrogeomorphic types found within the assessment area
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.2. tblAASpecialStatusSpecies

FIELD NAME	Data Type	DESCRIPTION
AASpecialStatusSpeciesID	AutoNumber	Unique ID identifying each special status plant record
SiteVisitID	Number	Field linking special status plants to assessment area data via sitevisitID
PlantGroundCoverID	Number	Species ID of special status plant species found in assessment area
Area_m2	Number	Estimated total area of special status species (m2)
NumberOf Patches	Text	Estimated number of patches of special status species
LargestPatchUTMEast	Number	Easting UTM location of largest patch of special status species
LargestPatchUTMNorth	Number	Northing UTM location of largest patch of special status species
Notes	Text	Notes on special status plants within assessment area
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.3. tblAntSampling

FIELD NAME	Data Type	DESCRIPTION
AntSamplingID	AutoNumber	Unique ID for the ant sampling event
SampleID	Text	Sample ID assigned in the field "Ant [number]-[bait]"
SiteVisitID	Number	Field linking ant data to sitevisit data
SamplingMethod	Text	From tluSamplingMethod
StartTime	Date/Time	Time the sampling starts
EndTime	Date/Time	Time the sampling ends
BaitType	Text	Bait Used in ant sample collection from look-up table
VialID	Text	Vial ID assigned to the sample "Unit_SiteNum_WetlandType_WellNum-SampleID"
CompassDirectionID	Number	Macroplot corner where sampling occurred from tluCompasDirections
NumberInverts	Number	An estimated count of the number of individuals at the bait taken prior to sample collection
Notes	Memo	Notes relating to the ant sampling event
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.4. tblAntSamplingSpp

FIELD NAME	Data Type	DESCRIPTION
AntSamplingSppID	AutoNumber	Unique identifier for each ant species record per sample
AntSamplingID	Number	Link to tblAntSampling
InsectID	Number	Species code for individuals found during ant sampling from look-up table
Number	Number	Count of individuals
Notes	Memo	Notes relating to the ant sampling event
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.5. tblAquaticInvertSampling

FIELD NAME	Data Type	DESCRIPTION
AquaticInvertSamplingID	AutoNumber	Unique identifier for each aquatic invertebrate collection record
SiteVisitID	Number	Field linking aquatic invert data to sitevisit data
SampleID	Text	Sample ID assigned in the field "aquatic [number]"
VialID	Text	Vial ID assigned to the sorted sample "Unit_SiteNum_WetlandType_WellNum-SampleID"
SamplingMethod	Text	Lookup field from InvertebrateSamplingMethod group in tluSamplingMethod
LocationNotes	Memo	Notes on the location where aquatic sample was collected
StartTime	Date/Time	Time the sampling began
EntryPointUTMEast	Number	Easting UTM location where Aquatic macroinvertebrate sampling is initiated
EntryPointUTMNorth	Number	Northing UTM location where Aquatic macroinvertebrate sampling is initiated
SamplingDirection	Number	Azimuth of the direction that aquatic macroinvertebrate sampling proceeds from entry point
DominantPlantID	Number	Plant species with the highest cover in the aquatic macroinvertebrate sampling area
NearestTallVegDistanceID	Number	Estimated distance (m) to nearest tall (>3 m) vegetation from look-up table
CanopyHeight1	Number	Estimated canopy height (cm) at sample origin
CanopyHeight2	Number	Estimated canopy height (cm) at 2nd point along transect
CanopyHeight3	Number	Estimated canopy height (cm) at 3rd point along transect
CanopyHeight4	Number	Estimated canopy height (cm) at end of transect
WaterDepth1	Number	Estimated water depth (cm) at sample origin
WaterDepth2	Number	Estimated water depth (cm) at 2nd point along transect
WaterDepth3	Number	Estimated water depth (cm) at 3rd point along transect
WaterDepth4	Number	Estimated water depth (cm) at end of transect
WaterFlow_cm_sec	Number	Rate of water flow (cm/sec) at sample origin
Notes	Memo	Notes relating to the aquatic macroinvertebrate sampling event
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.6. tblAquaticInvertSpp

FIELD NAME	Data Type	DESCRIPTION
AquaticInvertSppID	AutoNumber	Unique identifier for each aquatic species record per sample
AquaticInvertSamplingID	Number	Link to tblAquaticInvertSampling
InsectID	Number	Species code for individuals found during aquatic macroinvertebrate sampling from look-up table
Adult	Number	Count of individuals of this species in the adult live stage
Larva	Number	Count of individuals of this species in the larva live stage
Pupa	Number	Count of individuals of this species in the pupa live stage
PositiveID	Yes/No	Logical field indicating confirmed IDs
Notes	Memo	Notes related to individuals within the sample
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.7. tblAssessmentArea

FIELD NAME	Data Type	DESCRIPTION
SiteVisitID	Number	Field linking assessment area data to sitevisit data
AssessmentAreaNotes	Memo	General comments on the assessment area
Natural	Yes/No	Logical indicator of whether undisturbed "natural" habitat is present in the assessment area
DispersedRecreation	Yes/No	Logical indicator of whether signs of dispersed recreation are present in the assessment area
DevelopedRecreation	Yes/No	Logical indicator of whether signs of developed recreation are present in the assessment area
UrbanSuburbanDevelopement	Yes/No	Logical indicator of whether signs of urban/suburban developement are present in the assessment area
LandUseNotes	Memo	Notes on the land use types encountered in the assessment area
HummocksStrings	Yes/No	Logical indicator of whether hummocks/strings are present in the assessment area
PoolsFlarksWaterTracks	Yes/No	Logical indicator of whether Pools/flarks/water tracks are present in the assessment area
FloatingMats	Yes/No	Logical indicator of whether floating mats are present in the assessment area
CobblesBoulders	Yes/No	Logical indicator of whether cobbles/boulders are present in the assessment area
UnvegetatedFlats	Yes/No	Logical indicator of whether unvegetated flats are present in the assessment area
AnimalMoundBurrows	Yes/No	Logical indicator of whether animal mounds/burrows are present in the assessment area
StandingSnags	Yes/No	Logical indicator of whether standing snags are present in the assessment area

FIELD NAME	Data Type	DESCRIPTION
TreedPatch	Yes/No	Logical indicator of whether area within the assessment area is dominated by trees
WillowShrub	Yes/No	Logical indicator of whether area within the assessment area is dominated by willows or shrubs
SpringMound	Yes/No	Logical indicator of whether assessment area contains spring mounds
DefinedChannel	Yes/No	Logical indicator of whether a defined natural water channel is present within the assessment area
WrackOrganicDebris	Yes/No	Logical indicator of whether abundant wrack or organic debris is present within the assessment area
BankSlumpUndercut	Yes/No	Logical indicator of whether bank slumps or undercuts are present in the channel within the assessment area
HighWaterMarks	Yes/No	Logical indicator of whether repeated concentric or parallel high water marks are present within the assessment area
LargeWoodyDebris	Yes/No	Logical indicator of whether large woody debris is present within the assessment area
OpenWater	Yes/No	Logical indicator of whether areas of deeper water >10 m wide are present within the assessment area
SoilCracks	Yes/No	Logical indicator of whether soil cracks >1 inch deep are present within assessment area
StructuralPatchNotes	Memo	Notes on the structural patch types encountered in the assessment area
PointSourceDischarge	Yes/No	Logical indicator of whether a point source discharge is present in the assessment area
NonPointSourceDischarge	Yes/No	Logical indicator of whether a non-point source discharge is present in the assessment area
DitchesDiversion	Yes/No	Logical indicator of whether ditches/diversion are present in the assessment area
UpstreamDitchesDiversion	Yes/No	Logical indicator of whether ditches/diversion are present upstream of the assessment area
HistoricLivestockGrazing	Yes/No	Logical indicator of whether signs of historic livestock grazing are present in the assessment area
CurrentPackstockGrazing	Yes/No	Logical indicator of whether signs of current packstock grazing are present in the assessment area
GroundwaterExtraction	Yes/No	Logical indicator of whether groundwater extraction is occurring in the assessment area
FillPlacedInWetland	Yes/No	Logical indicator of whether fill has been placed in the assessment area
GradingCompaction	Yes/No	Logical indicator of whether there are signs of grading/compaction in the assessment area
HeavyMetalImpaired	Yes/No	Logical indicator of whether there are signs of heavy metal impairment in the assessment area
HeadcutErosionGully	Yes/No	Logical indicator of whether there are headcuts or erosion gullies present in the assessment area
TrashOrRefuse	Yes/No	Logical indicator of whether there is trash present in the assessment area
Mowing	Yes/No	Logical indicator of whether there are signs of mowing in the assessment area
SocialTrails	Yes/No	Logical indicator of whether there are social trails in the assessment area
DevelopedTrails	Yes/No	Logical indicator of whether there are developed trails in the assessment area
RoadsGravelDirt	Yes/No	Logical indicator of whether there are gravel/dirt roads in the assessment area

FIELD NAME	Data Type	DESCRIPTION
RoadsPaved	Yes/No	Logical indicator of whether there are paved roads in the assessment area
TreeCuttingSaplingRemoval	Yes/No	Logical indicator of whether there are signs of tree cutting/sapling removal in the assessment area
EvidenceOfFire	Yes/No	Logical indicator of whether there is evidence of fire in the assessment area
EvidenceOfFlood	Yes/No	Logical indicator of whether there is evidence of floods in the assessment area
CheckDamsRiprap	Yes/No	Logical indicator of whether there are check dams or riprap in the assessment area
StressorNotes	Memo	Field notes on the observed stressors found in or around the assessment area
NEBufferDistanceID	Number	ID of distance category to nearest disturbance NE of assessment area (from tluBufferDistances)
NWBufferDistanceID	Number	ID of distance category to nearest disturbance NW of assessment area (from tluBufferDistances)
SEBufferDistanceID	Number	ID of distance category to nearest disturbance SE of assessment area (from tluBufferDistances)
SWBufferDistanceID	Number	ID of distance category to nearest disturbance SW of assessment area (from tluBufferDistances)
NEBufferChangeInElevation	Number	Binary indicator of whether the nearest disturbance to the NE is uphill (+) or downhill (-)
NWBufferChangeInElevation	Number	Binary indicator of whether the nearest disturbance to the NW is uphill (+) or downhill (-)
SEBufferChangeInElevation	Number	Binary indicator of whether the nearest disturbance to the SE is uphill (+) or downhill (-)
SWBufferChangeInElevation	Number	Binary indicator of whether the nearest disturbance to the SW is uphill (+) or downhill (-)
BufferNotes	Memo	Notes on buffers
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.8. tblDataLoggerDetails

FIELD NAME	Data Type	DESCRIPTION
DataLoggerDetailID	AutoNumber	Unique identifier for each datalogger record
SiteVisitID	Number	Field linking datalogger data to sitevisit data
LoggerID	Number	ID for each individual data logger
LoggerLocation	Text	Location of datalogger. If not a well number, should be a description with UTM coordinates
StartDate	Date/Time	Date and time that the logger was installed in the field
EndDate	Date/Time	Date and time that the logger was downloaded or removed from the field
FileDownloadDate	Date/Time	Date and time that datalogger file is downloaded (either in the field or the office)
FileName	Text	Logger data file name formatted as yyyyymmdd-site name.file extension
DoucmentPath	Hyperlink	File path where the datalogger file was downloaded

FIELD NAME	Data Type	DESCRIPTION
UploadToNPSWQDate	Date/Time	Date datalogger data were uploaded to NPSWQ database
LoggerNotes	Memo	Notes on the datalogger records
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.9. tblGroundwaterHeights

FIELD NAME	Data Type	DESCRIPTION
GroundwaterHeightID	AutoNumber	Unique identifier for each groundwater height record
SiteVisitID	Number	Site visit ID
WellDetailID	Number	WellDetail ID
MeasurementTime	Date/Time	Time that well reading is taken (hour and minute in 24-hour clock)
DistanceToGroundSurface_cm	Number	Distance (cm) from the top of the well casing to the ground surface
DistanceToGroundwater_cm	Number	Distance (cm) from the top of the well casing to groundwater
GroundwaterDepth_cm	Calculated	Calculated field of groundwater depth (cm) = [DistanceToGroundwater_cm]-[DistanceToGroundSurface_cm]
Notes	Memo	Notes about the groundwater depth measurement
CreatedDate	Date/Time	Date record was created or modified

Table A5.10. tblLostAnts

FIELD NAME	Data Type	DESCRIPTION
LostAntsID	AutoNumber	Unique identifier for each lost ant record per sample
AntSamplingID	Number	Link to tblAntSampling
Count	Number	Note the number and taxa of any ants that escaped the sample
Notes	Memo	Notes about the lost record (species or family if known)
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.11. tblLostAquaticInverts

FIELD NAME	Data Type	DESCRIPTION
LostAquaticInvertID	AutoNumber	Unique identifier for each lost aquatic record per sample
AquaticInvertSamplingID	Number	Link to tblAquaticInvertSampling
Count	Number	Number of lost individuals
Notes	Memo	Notes about the lost record (species or family if known)
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.12. tblLostTerrestrialInverts

FIELD NAME	Data Type	DESCRIPTION
LostTerrestrialInvertID	AutoNumber	Unique identifier for each lost terrestrial record per sample
TerrestrialInvertSamplingID	Number	Link to tblTerrestrialInvertSampling
Count	Number	Number of lost individuals
Notes	Memo	Notes about the lost record (species or family if known)
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.13. tblMacroMicroPlotCover

FIELD NAME	Data Type	DESCRIPTION
MacroMicroPlotCoverID	AutoNumber	UniqueID identifier for macro and micro plot cover of plot and visit
SiteVisitID	Number	Field linking plant collection data to sitevisit data
PlantGroundCoverID	Number	Link to PlantGroundCoverID lookup table
NorthPercentCover	Number	Percent cover (est. to 1%)of the individual species within the North microplot
EastPercentCover	Number	Percent cover (est. to 1%)of the individual species within the East microplot
SouthPercentCover	Number	Percent cover (est. to 1%)of the individual species within the South microplot
WestPercentCover	Number	Percent cover (est. to 1%)of the individual species within the West microplot
TreeCount	Number	Count of tree species >1.37 m found growing in the macroplot
CoverClassID	Number	Coverclass of vascular plant species growing in the macroplot

FIELD NAME	Data Type	DESCRIPTION
IsPresent	Yes/No	Presence/absence indicator for bryophyte species found within the macroplot
Voucher	Number	Voucher number assigned to the plant collection in the field
Notes	Memo	Notes related to the individual species within the micro or macroplot
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.14. tblMacroPlotGridCover

FIELD NAME	Data Type	DESCRIPTION
MacroPlotGridCoverID	AutoNumber	Unique identifier for each macro plot grid point record
SiteVisitID	Number	Field linking macroplot grid data to sitevisit data
PointNumber	Number	Value between 1 and 100. All points should be used
CoverTypeID	Number	Cover type of the 100 points sampled within the macroplot
SelectedForPeatDepth	Yes/No	Logical indicator of whether the point was one of the five randomly selected numbers between 1 and 100 for peat depth sampling
PeatDepth_cm	Number	Depth of pet (cm) measured using a soil probe at 5 locations in the macroplot
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.15. tblPlantCollections

FIELD NAME	Data Type	DESCRIPTION
PlantCollectionID	AutoNumber	Unique ID identifying each plant collection record collected in the field
SiteVisitID	Number	Field linking plant collection data to sitevisit data
VoucherNumber	Number	Voucher number assigned to the plant collection in the field
SountOutForID	Yes/No	Logical indicator of whether the plant collection was sent out for ID or not
Mounted	Yes/No	Logical indicator of whether the plant collection was mounted or not
PlantCollection#	Text	Unique identifier composed of "Park"-"SiteNum"-"WetlandType"-"WellNum"-"VoucherNum"
CollectorID	Number	Unique ID of the person who made the collection
Notes	Memo	Notes about the plant collection

FIELD NAME	Data Type	DESCRIPTION
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.16. tblSitePhotos

FIELD NAME	Data Type	DESCRIPTION
SitePhotoID	AutoNumber	Unique identifier of each photo record
SiteVisitID	Number	Field linking site photo data to sitevisit data
PhotoCodeID	Number	ID assigned to type of photo that was taken (from tluPhotoCodes)
PhotoNum	Number	Photo number assigned by the camera
FileName	Text	File name assigned to the photo
FilePath	Text	File path where the original photo was downloaded
Azimuth	Number	Azimuth (degrees) in which the photo was taken
CameraID	Text	Unique ID of camera used to take photo. Can also be a description of photo was taken on a non-SIEN camera
CameraImageID	Text	Image ID assigned by the camera
PhotographerID	Number	Unique ID of the person who took the photo
PhotoDesc	Memo	Description of the photo that is being taken
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.17. tblSites

FIELD NAME	Data Type	DESCRIPTION
SiteID	AutoNumber	AutoNumber for the specific site within a wetlands selected by the GRTS draw or Index site selection
WetlandID	Number	AutoNumber for the specific wetland polygon selected by the GRTS draw and Index sites
Site_Name	Text	Unique site name for the target wetland including GRTS #
GRTSOrder	Number	GRTS order number assigned to each of thirty locations selected within each wetland
UTMEast	Number	GRTS generated Easting UTM coordinate for specific Site location. All coordinates are recorded in NAD83, UTM Zone 11N

FIELD NAME	Data Type	DESCRIPTION
UTMNorth	Number	GRTS generated Northing UTM coordinate for specific Site location. All coordinates are recorded in NAD83, UTM Zone 11N
HydrogeomorphicTypeID	Number	Hydrogeomorphic type of the site from tluHydrogeomorphicTypes
SiteNotes	Memo	Notes about the site or plot setup.
SiteGRTSPointNotes	Memo	Notes on the hydrogeomorphic types assigned to each site.
Active	Yes/No	Yes/No indicator of whether the site location was selected for sampling
CreatedDate	Date/Time	Date the record was created or modified

Table A5.18. tblSiteVisitContacts

FIELD NAME	Data Type	DESCRIPTION
SiteVisitContactID	AutoNumber	Unique identifier for each site visit contact record
SiteVisitID	Number	Link to SiteVisitID
ContactID	Number	Link to Contact ID
ContactRole	Text	Role that the contact served during the visit from tluContactRole
CreatedDate	Date/Time	Date record was created or modified

Table A5.19. tblSiteVisits

FIELD NAME	Data Type	DESCRIPTION
SiteVisitID	AutoNumber	Unique identifier for each site visit
SiteID	Number	Link to SiteID
VisitDate	Date/Time	Date site was visited
VisitPurposeID	Number	From tluVisitPurpose describing the purpose of the visit
CurrentWetlandTypeID	Number	From tluWetlandTypes giving wetland type assigned during visit
ProtocolVersion	Text	Version of the protocol being used for sampling during visit
SiteVisitNotes	Memo	Notes about the wetland/site as a whole (route, conditions, weather, etc.) related to the visit.
CreatedDate	Date/Time	Date record was created or modified

Table A5.20. tblSiteWetlandTypes

FIELD NAME	Data Type	DESCRIPTION
SiteWetlandTypeID	AutoNumber	Unique identifier of each site wetland type record
SiteID	Number	Link to tblSite
WetlandTypeID	Number	Link to tluWetlandType
Percent	Number	Percent of the assigned wetland type in the site (percentages of all listed sites within a site should add up to 100%)
CreatedDate	Date/Time	Date the record was created or modified

Table A5.21. tblSoilPhotos

FIELD NAME	Data Type	DESCRIPTION
SoilPhotoID	AutoNumber	Unique identifier of photo of each soil section
WellDetailID	Number	Link to WellDetailID
CoreDepthSection	Number	Core depth section in the photo 1 = 0-50 cm, 2 = 51-100 cm, 3 = 101-150 cm, 4 = 151-200 cm
PhotoNum	Text	PhotoNumber assigned to the photo as unique identifier
SoilPhotoNotes	Memo	Notes on the soil photos
CreatedDate	Date/Time	Date record was created or modified

Table A5.22. tblSoils

FIELD NAME	Data Type	DESCRIPTION
SoilID	AutoNumber	Unique identifier of the soil record
WellDetailID	Number	Link to WellDetailID
StartDepth	Number	Starting depth (cm) of soil section
EndDepth	Number	Ending depth (cm) of soil section
SoilColor	Text	Munsell soil color
SoilTexture	Text	Qualitative description of soil texture
SoilNotes	Memo	Additional notes about specific soil section

FIELD NAME	Data Type	DESCRIPTION
CreatedDate	Date/Time	Date record was created or modified

Table A5.23. tblSpeciesName

FIELD NAME	Data Type	DESCRIPTION
PlantCollectionID	Number	Link to PlantCollections table
SpeciesNameID	AutoNumber	Unique identifier for each species name record
PlantGroundCoverID	Number	Link to PlantGroundCoverID lookup table
IdentifiedBy	Text	Unique ID for the person who identified the collection
IdentifiedDate	Date/Time	Date identification was made or changed
CurrentName	Yes/No	Logical indicator of whether the given name is the current scientific name recognized in the Jepson Manual
SpecieNameNotes	Memo	Notes on the species name record
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.24. tblSubPlotSpp

FIELD NAME	Data Type	DESCRIPTION
SubPlotSppID	AutoNumber	Unique identifier for each subplot record per site visit
SiteVisitID	Number	Field linking subplot data to sitevisit data
PlantGroundCoverID	Number	Link to PlantGroundCoverID lookup table
SeedlingHeightClassID	Number	ID of the seedling height class for each subplot record
SeedlingCount	Number	Count of seedlings in each subplot record
Notes	Memo	Notes about the subplot record
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.25. tblTerrestrialInvertSampling

FIELD NAME	Data Type	DESCRIPTION
TerrestrialInvertSamplingID	AutoNumber	Unique identifier for each terrestrial invertebrate collection record
SiteVisitID	Number	Field linking terrestrial invertebrate data to sitevisit data
StartTime	Date/Time	Time the sampling began
SamplingMethod	Text	Lookup field from InvertebrateSamplingMethod group in tluSamplingMethod
SampleID	Text	Sample ID assigned in the field "terrestrial [number]"
VialID	Text	Vial ID assigned to the sorted sample "Unit_SiteNum_WetlandType_WellNum-SampleID"
NearestTallVegDistanceID	Number	Estimated distance (m) to nearest tall (>3 m) vegetation from look-up table
SoilMoistureLevel	Text	Soil moisture category from look-up table
DonimantPlantID	Number	Plant species with the highest cover in the macroplot from tluPlantGroundCovers
CanopyHeightNorth_cm	Number	Average height (cm) of herbaceous vegetation at the North subplot corner
CanopyHeightSouth_cm	Number	Average height (cm) of herbaceous vegetation at the South subplot corner
CanopyHeightEast_cm	Number	Average height (cm) of herbaceous vegetation at the East subplot corner
CanopyHeightWest_cm	Number	Average height (cm) of herbaceous vegetation at the West subplot corner
ComplexityHitsNorth	Number	Number of complexity hits at the North subplot corner
ComplexityHitsSouth	Number	Number of complexity hits at the South subplot corner
ComplexityHitsEast	Number	Number of complexity hits at the East subplot corner
ComplexityHitsWest	Number	Number of complexity hits at the West subplot corner
SkyCondition	Text	Sky condition category from look-up table
ShadingByTreesPercent	Number	Percent of plot that is shaded by trees at time of sampling
WindSpeedClassID	Number	Wind speed category from look-up table
Notes	Memo	Notes relating to the terrestrial macroinvertebrate sampling event
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.26. tblTerrestrialInvertSpp

FIELD NAME	Data Type	DESCRIPTION
TerrestrialInvertSppID	AutoNumber	Unique identifier for each terrestrial species record per sample
TerrestrialInvertSamplingID	Number	Link to tblTerrestrialInvertSampling
InsectID	Number	Species code for individuals found during terrestrial macroinvertebrate sampling from tblInsects
Abundance	Number	Count of individuals of this species or morphospecies
Morphospecies	Number	Morphospecies of terrestrial invertebrate species
PositiveID	Yes/No	Logical field indicating confirmed IDs
Notes	Memo	Notes related to individuals within the sample
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.27. tblVouchers

FIELD NAME	Data Type	DESCRIPTION
VoucherID	AutoNumber	Unique identifier for each voucher entry
CatalogNumber	Text	Unique number assigned by herbarium curator
PlantCollectionID	Number	Link to PlantCollections table
AccessionNumber	Text	Assigned by herbarium curator; one number applies to batches of collections
Park	Text	KICA=Kings Canyon; SEQU=Sequoia; DEPO=Devils Postpile; YOSE=Yosemite
Locality	Memo	Description of local area where plot is located (e.g., Silliman Creek Drainage, Slopes above Deadman Canyon)
Site description(User1)	Memo	Short description of the environmental conditions of the location where the voucher was collected
Description(Study Name)	Memo	Study name that voucher was collected for
Elevation (ft)	Number	Elevation at which the voucher was collected
Location	Memo	Location where the voucher is archived
Datum	Text	Datum of listed coordinates
UTM Z/E/N	Text	UTM zone/Easting/Northing
Item Count	Number	Count of collections on the voucher
County	Text	County where the voucher was collected
State	Text	State where the voucher was collected

FIELD NAME	Data Type	DESCRIPTION
Catalog Date	Date/Time	Date that the voucher was accessioned into the herbarium
Cataloger	Text	Name of individual that accessioned the voucher into the herbarium
VoucherNotes	Memo	Notes on specific voucher record
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.28. tblWellDetails

FIELD NAME	Data Type	DESCRIPTION
WellDetailID	AutoNumber	Unique ID of the well
WellNum	Number	Unique number assigned to each well and recorded on tag affixed to the well casing
SiteID	Number	AutoNumber for the specific site within a wetlands selected by the GRTS draw or Index site selection
WellInstallationDate	Date/Time	Date that the well was installed in the field
CasingLength_cm	Number	Length of the well casing
WitnessFeature1Azimuth	Number	Azimuth to witness feature 1 from well
WitnessFeature1Distance_m	Number	Distance (m) to witness feature 1 from well
WitnessFeature2Azimuth	Number	Azimuth to witness feature 2 from well
WitnessFeature2Distance_m	Number	Distance (m) to witness feature 2 from well
WellInstallationNotes	Memo	Notes related to well installation
WellLocationNotes	Memo	Notes related to well location such as instructions for navigating to well
FieldUTMEast	Number	Easting UTM measured in field for well location
FieldUTMNorth	Number	Northing UTM measured in field for well location
UTMZone	Text	UTM zone of listed coordinates
CoordDatum	Text	Datum of listed coordinates
EstHError	Number	Estimated accuracy of UTMs from the GPS recorded in the field
AccuracyNotes	Text	Notes on GPS accuracy measurement
FieldElevation	Number	Elevation recorded in the field (m) by the GPS at the well
GPSUnitID	Text	Unique identifier of the GPS unit used to record location and elevation information
Gleyed	Yes/No	Yes/No indicator of whether any portion of the soil core contains gleyed soil features

FIELD NAME	Data Type	DESCRIPTION
Mottled	Yes/No	Yes/No indicator of whether any portion of the soil core contains mottled soil features
OrganicHorizon	Yes/No	Yes/No indicator of whether any portion of the soil core contains an organic horizon
OrganicHorizonDepth_cm	Number	Depth of organic horizon (cm)
SulfuricOdor	Yes/No	Yes/No indicator of whether any portion of the soil core has a sulfuric odor
Other	Text	Yes/No indicator of whether any portion of the soil core displays other characteristics of wetland soils
HumificationRate	Number	Humification (decomposition) rate using the von Post method (scale from 1-10)
CreatedDate	Date/Time	Date record was created or modified

Table A5.29. tblWetlands

FIELD NAME	Data Type	DESCRIPTION
WetlandID	AutoNumber	AutoNumber for the specific wetland polygon selected by the GRTS draw and Index sites
GRTSName	Text	Name assigned by GRTS Draw. Includes GRTS ORDER
GRTSOrder	Number	GRTS order number assigned to each wetland in SEKI and YOSE
UnitCode	Text	Four letter Park Unit code (YOSE, SEKI, or DEPO)
Panel	Text	Panel that the wetland is assigned to based on GRTS order
Mdcaty	Text	Grouping variable used in GRTS draw (Meadow, Fen_Meadow)
Wgt	Number	Weighting value used in GRTS draw for each mdcaty group
EvalStatus	Text	Year the wetland was last sampled. If a wetland has not been sampled it is listed as not evaluated. If a wetland was rejected, it is listed as rejected.
EvalReason	Text	If a site was rejected, a reason for rejection is given.
GRTSNotes	Memo	Any comments specific to that wetland relating to the GRTS draw
WatershedID	Text	Unique identifier for each watershed made up of park code, CDFPWSNAME, and WALW221_ID from the Calwater database v 2.2.1
MeadowName	Text	Name of meadow (from watershed or tributary name)
MeadowComplexType	Text	WetMaP meadow complex type (Fen, Fen_Meadow, Meadow)
PolygonID	Text	Unique identifier used to identify each wetland polygon from the Wetland mapping project
MeadowArea_sm	Number	Estimated meadow area in square meters derived from GIS polygon

FIELD NAME	Data Type	DESCRIPTION
MeadowPerimeter_m	Number	Estimated length of polygon perimeter derived from GIS (m)
MeadowNotes	Text	Notes on each specific meadow polygon from the wetland mapping project
MeadowUTMEast	Number	East UTM coordinate for MeadowPolygon centroid. All coordinates are recorded in NAD83, UTM Zone 11N
MeadowUTMNorth	Number	North UTM coordinate for MeadowPolygon centroid. All coordinates are recorded in NAD83, UTM Zone 11N
FieldWetlandTypeID	Number	From tluWetlandTypes listing assigned wetland type of polygon in field
WetlandNotes	Memo	Notes about the wetland
CreatedDate	Date/Time	Date the record was created or modified

Table A5.30. tluAddressTypes

FIELD NAME	Data Type	DESCRIPTION
AddressType	Text	List of address types used in tluContacts AddressType field

Table A5.31. tluBaitTypes

FIELD NAME	Data Type	DESCRIPTION
BaitType	Text	List of bait types used in BaitType field in tblAntSampling

Table A5.32. tluBufferDistances

FIELD NAME	Data Type	DESCRIPTION
BufferDistanceID	AutoNumber	Unique id for the buffer distance category
BufferDistance	Text	Text field listing buffer distance range
SortOrder	Number	Sort order of BufferDistance

Table A5.33. tluCompassDirections

FIELD NAME	Data Type	DESCRIPTION
CompassDirectionID	AutoNumber	Unique ID for each compass direction
CompassDirection	Text	List of compass directions used in protocol
Degrees	Number	Degrees of listed compass directions

Table A5.34. tluContactRoles

FIELD NAME	Data Type	DESCRIPTION
ContactRole	Text	List of roles that each participant can be assigned to on the project

Table A5.35. tluContacts

FIELD NAME	Data Type	DESCRIPTION
ContactID	AutoNumber	Unique ID for each contact
LastName	Text	Last name of contact
FirstName	Text	First name of contact
MiddleInit	Text	Middle initial of contact
Organization	Text	Organization contact is affiliated with
PositionTitle	Text	Position of the contact within the organization
AddressType	Text	Type of address that is listed from tluaddress type
Address	Text	First line in address
Address2	Text	Second line in address
City	Text	City
StateCode	Text	Two letter state code
ZipCode	Text	Zip code
Country	Text	Country
EmailAddress	Text	Email address
WorkPhone	Text	Work phone format: xxx-xxx-xxxx

FIELD NAME	Data Type	DESCRIPTION
WorkExtension	Text	Phone number extension if applicable
ContactNotes	Memo	Notes about the contact
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.36. tluCoordDatum

FIELD NAME	Data Type	DESCRIPTION
CoordDatum	Text	Datum that the GPS coordinates were recorded in

Table A5.37. tluCoordUnits

FIELD NAME	Data Type	DESCRIPTION
CoordUnit	Text	Units that the value was recorded in

Table A5.38. tluCoreDepths

FIELD NAME	Data Type	DESCRIPTION
CoreDepthID	AutoNumber	Unique id for each core depth category
CoreDepth	Text	Text description of core depth range (cm)
SortOrder	Number	Sort order of core depth categories

Table A5.39. tluCoverClasses

FIELD NAME	Data Type	DESCRIPTION
CoverClassID	AutoNumber	Unique id for each cover class category
CoverClass	Text	Text description of cover class range
SortOrder	Number	Sort order of cover class categories

Table A5.40. tluCoverTypes

FIELD NAME	Data Type	DESCRIPTION
CoverTypeID	AutoNumber	Unique id for each cover type category
CoverTypeCode	Text	Code of the cover type used in the point count cover survey
CoverType	Text	Description of the cover type identified in the point count cover survey
SortOrder	Number	Sort order of the cover type categories

Table A5.41. tluDataLoggers

FIELD NAME	Data Type	DESCRIPTION
LoggerID	AutoNumber	Unique ID assigned to each logger record
LoggerCode	Text	Unique code assigned to each logger unit
LoggerType	Text	Data logger type/brand
LoggerSN	Text	Data logger serial number
LastCalibratedDate	Date/Time	Date unite was last calibrated
OperatingSystem	Text	Data logger operating system software
DatePurchased	Date/Time	Date data logger was purchased
Notes	Memo	Comments on datalogger units
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.42. tluHydrogeomorphicTypes

FIELD NAME	Data Type	DESCRIPTION
HydrogeomorphicTypeID	AutoNumber	Unique id for each hydrogeomorphic type record
HydrogeomorphicType	Text	Hydrogeomorphic types taken from Weixelman et al. 2011
SortOrder	Number	Sort order of the hydrogeomorphic types

Table A5.43. tlulnsects

FIELD NAME	Data Type	DESCRIPTION
InsectID	AutoNumber	Unique id for each record
SpeciesCode	Text	Species code assigned to each record usually derived from first 2 letters of Genus and species
IT IS	Text	ITIS ID assigned to record scientific name and authority
InvertebrateTaxonID	Number	ID that identifies the taxon category of each record from tlulnvertebrateTaxonTypes
ScientificName	Text	Genus and species of record
CommonName	Text	Common name of record
Order	Text	Order of record
Family	Text	Family of record
Genus	Text	Genus of record
Species	Text	Species of record
Subspecies	Text	Subspecies of record
Variety	Text	Variety of record
Authority	Text	Authority of record
Synonyms	Text	Synonyms of record. If multiple, separate with semicolon
Invasive	Yes/No	Yes/No indicator of whether the species is invasive
Notes	Memo	Notes
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.44. tlulnvertebrateTaxonTypes

FIELD NAME	Data Type	DESCRIPTION
InvertebrateTaxonTypeID	AutoNumber	Unique ID for each invertebrate taxon type record
InvertebrateTaxonType	Text	Description of the taxon group of each record, usually Common Name (Order)

Table A5.45. tluOrganizations

FIELD NAME	Data Type	DESCRIPTION
Organization	Text	List of the organization type used in tluContacts

Table A5.46. tluPanelForms

FIELD NAME	Data Type	DESCRIPTION
MaintenanceID	AutoNumber	Unique ID of each maintenance record
FormName	Text	The name of the form that the record is associated with
Label	Text	The field name of the record
AppliesTo	Text	Task the record performs (ListMaint, DataEntry)
SortOrder	Number	Sort order of the form categories by FormName

Table A5.47. tluPhotoCodes

FIELD NAME	Data Type	DESCRIPTION
PhotoCodeID	AutoNumber	Unique ID for each photo code
PhotoCode	Text	Code used in Picklist to identify plot photos
PhotoCodeDescription	Text	Description of each photo code
SortOrder	Number	Sort order of the photo codes

Table A5.48. tluPlantGroundCovers

FIELD NAME	Data Type	DESCRIPTION
PlantGroundCoverID	AutoNumber	Unique ID for each record
Code	Text	Species code assigned to each record usually derived from first 2 letters of Genus and Species
IsGroundCover	Yes/No	Yes/No indicator of whether the record is a ground cover category
NRCS	Text	NRCS ID assigned to record scientific name and authority
IT IS	Number	ITIS ID assigned to record scientific name and authority

FIELD NAME	Data Type	DESCRIPTION
SEKIPlantID	Text	SEKI ID assigned to record scientific name and authority
YOSEPlantID	Text	YOSE ID assigned to record scientific name and authority
PlantTaxonTypeID	Number	ID that identifies the taxon category of each record from tluPlantTaxonTypes
ScientificName	Text	Genus and species of record
CommonName	Text	Common name of record
Family	Text	Family of record
Genus	Text	Genus of record
Species	Text	Species of record
Subspecies	Text	Subspecies of record
Variety	Text	Variety of record
Authority	Text	Authority of record
Synonyms	Text	Synonyms of record. If multiple, separate with semicolon
IsInvasive	Yes/No	Yes/No indicator of whether the species is invasive
TandE	Yes/No	Yes/No indicator of whether the species is Listed as threatened or endangered
NonNative	Yes/No	Yes/No indicator of whether the species is NonNative
Notes	Memo	Notes
CreatedDate	Date/Time	Date/time record was created or modified

Table A5.49. tluPlantTaxonTypes

FIELD NAME	Data Type	DESCRIPTION
PlantTaxonTypeID	AutoNumber	Unique ID assigned to each PlantTaxonType record
PlantTaxonType	Text	Plant taxon type categories

Table A5.50. tluSamplingMethods

FIELD NAME	Data Type	DESCRIPTION
SamplingMethod	Text	Insect Sampling Method categories

Table A5.51. tluSeedlingHeightClasses

FIELD NAME	Data Type	DESCRIPTION
SeedlingHeightClassID	AutoNumber	Unique ID assigned to each SeedlingHeightClass record
SeedlingHeightClass	Text	Seedling height class categories
SortOrder	Number	Sort order in which to display the seedling height class categories

Table A5.52. tluSkyConditions

FIELD NAME	Data Type	DESCRIPTION
SkyCondition	Text	Categories of sky conditions using in tblTerrestrialInvertSampling.SkyCondition

Table A5.53. tluSoilMoistureLevels

FIELD NAME	Data Type	DESCRIPTION
SoilMoistureLevel	Text	Categories of soil moisture conditions using in tblTerrestrialInvertSampling.SoilMoistureLevel

Table A5.54. tluUnits

FIELD NAME	Data Type	DESCRIPTION
UnitCode	Text	Four letter park code
UnitName	Text	Full park name

Table A5.55. tluUTMZones

FIELD NAME	Data Type	DESCRIPTION
UTMZone	Text	UTM Zone

Table A5.56. tluVisitPurposes

FIELD NAME	Data Type	DESCRIPTION
VisitPurposeID	AutoNumber	Unique ID assigned to each visit purpose record
VisitPurposeCode	Text	Descriptive code of the visit purpose
VisitPurpose	Text	Short description of the task performed during the site visit

Table A5.57. tluWetlandTypes

FIELD NAME	Data Type	DESCRIPTION
WetlandTypeID	AutoNumber	Unique ID assigned to each wetland type record
WetlandType	Text	Wetland Type category
SortOrder	Number	Sort order in which to display the wetland type categories

Table A5.58. tluWindSpeedClasses

FIELD NAME	Data Type	DESCRIPTION
WindSpeedClassID	AutoNumber	Unique ID assigned to each wind speed class record
WindSpeedClass	Text	Wind speed class category
SortOrder	Number	Sort order in which to display the wind speed class categories

Literature Cited

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- National Park Service. 2007. Natural Resource Database Template Version 3.2 documentation. Natural Resource Program Center, Office of Inventory, Monitoring, and Evaluation, Fort Collins, CO. 30 p.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
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