



Forested Vernal Wetland Vegetation Monitoring Protocol, Cape Cod National Seashore

Natural Resource Report NPS/NERO/NRR—2015/1001



ON THE COVER

Forested vernal wetland in CACO

Forested Vernal Wetland Vegetation Monitoring Protocol, Cape Cod National Seashore

Natural Resource Report NPS/NERO/NRR—2015/1001

Stephen M. Smith (Plant Ecologist)

National Park Service
Cape Cod National Seashore
99 Marconi Site Road
Wellfleet, MA 02667

August 2015

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Northeast Coastal and Barrier Network website (<http://science.nature.nps.gov/im/units/ncbn/>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/NRPM>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Smith, S. M. 2015. Forested vernal ponds wetland vegetation monitoring protocol, Cape Cod National Seashore. Natural Resource Report NPS/NERO/NRR—2015/1001. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	vii
Previous studies	1
Potential threats	2
Rationale for monitoring forested vernal wetland vegetation at CACO	3
Management objectives	3
Monitoring objectives.....	3
Sampling Design	3
Abiotic variables.....	4
Number and Location of Sampling Units.....	5
Frequency and timing of Sampling	6
Power Analysis of Plant Communities	7
Power analysis on IS sites based on transect data	8
Power analysis on non-IS sites based on transect data.....	8
Power analysis on IS sites based on whole wetland survey data.....	10
Summary of power analyses.....	11
Field Methods	13
Field Season Preparations and Equipment Setup	13
Sampling Procedures	13
End-of-day Procedures	13
End-of-season Procedures	13
Data Management, Analysis, and Reporting	15
Recommendations for Data Summaries and Statistical Analyses	15
Reporting Schedule	15
Personnel Requirements and Training	17
Roles and Responsibilities.....	17
Qualifications and Training.....	17
Operational Requirements	19

Contents (continued)

	Page
Annual Workload and Field Schedule.....	19
Facility and Equipment Needs.....	19
Startup Costs and Budget Considerations	19
References.....	21
Standard Operating Procedure (SOP) #1. Preparations and equipment setup prior to field season.....	25
Standard Operating Procedure (SOP) #2. Training observers	27
Standard Operating Procedure (SOP) #3. Using the global positioning system.....	29
Standard Operating Procedure (SOP) #5. Conducting the monitoring.....	33
Standard Operating Procedure (SOP) #6. Reporting	41
Standard Operating Procedure (SOP) #7. Data Management.....	45
Standard Operating Procedure (SOP) #8. Preparations and Equipment Storage at the Conclusion of the Field Season.....	47
Standard Operating Procedure (SOP) #9. FVW monitoring safety	49
Standard Operating Procedure (SOP) #10. General safety	51
Appendix I. Transect metadata	AI-1
Appendix II. List of species recorded in IS wetlands to date.....	AII-1

Figures

	Page
Figure 1. Physiognomy of two different forested vernal wetlands across CACO.	2
Figure 2. Map of the 15 Forested Vernal Wetland monitoring sites at Cape Cod National Seashore.	5
Figure 3. Original three wetlands surveyed by Roman and Barrett (2004) and subsequently by Smith et al. (2006, 2011) with transect orientations	31
Figure 4. Diagram showing scheme for establishing transects in additional IS wetlands.	32
Figure 5. Map of 15 intensively-monitored sites.	34
Figure 6. Layout of transect for vegetation monitoring.	35
Figure 7. Conceptual diagram of vegetation with a FVW (left) and the process by which the cover of each species is estimated visually (mental consolidation of each species and comparison to overall wetland area).	36
Figure 8. PVC poles with markings on sides to help delineated areas for cover class category designation.	36
Figure 9. Diagram showing the zig-zag path the field crew should take through each wetland for whole-site surveying.	37
Figure 10. Example of vegetation layering resulting in total cover of > 100% across the surveyed area (right).	37

Tables

	Page
Table 1. Power values for detecting species composition changes in individual wetlands.	8
Table 2. Power probability values to detect a change in species composition of all non-IS wetlands.....	8
Table 3. Power probability values for the detection of a 20%, 50%, and 80% change in species richness in the IS subset from the original mean.....	9
Table 4. Power values for the detection of a 20%, 50%, and 80% change in the frequency of species belonging to various growth form.....	9
Table 5. Power values for the detection of a 20%, 50%, and 80% change in species richness in the IS subset from the original mean.	10
Table 6. Power values for change in the frequency of species belonging to specific wetland indicator categories (whole wetland surveys).	10
Table 7. Power values for change in the frequency of species belonging to growth form categories (whole wetlands surveys).....	10

Background and Objectives

Scattered across the glacial outwash plain of outer Cape Cod are discrete, variable-sized depressions in the ground surface. These depressions were originally formed by the weight of ice blocks left behind by the retreating glacier almost 18,000 years ago. Sea level rise since that time forced a concurrent rise in the fresh groundwater lens, which floats atop the denser seawater below. This resulted in the permanent flooding of deep depressions (i.e., lakes or “kettle ponds”) and seasonal flooding of shallow ones. The latter are vernal wetlands, also known as vernal pools or ponds. Vernal wetlands on the glacial outwash plain are referred to in this document as “forested vernal wetlands” or FVWs. This terminology is based on the surrounding landscape of pine woodland or mixed pine-oak forest, something that distinguishes them from dune slack wetlands, which are surrounded by dunes (also vernal). They are further distinguished from the latter by their geologic origin. While FVWs are glacially-derived, dune slack wetlands occur in a region that formed by post-glacial erosion and re-deposition of sediments from Atlantic-side beaches (the northern tip of Cape Cod). Kettle Ponds are also present in Maine and in mountainous areas such as Colorado.

The flooding and drying cycle within FVWs fosters the development of distinctive assemblages of plants (Figure 1) and animals. Annual variability in flood duration (hydroperiod) of FVWs can be substantial depending on wetland bathymetry, precipitation and antecedent groundwater levels, but there is generally standing water from early spring to mid-summer with little to none by the end of August (Colburn 2005). Wetland plant communities have developed within these basins in response to these conditions. Aside from the floodplains of major river systems such as the Herring River (Wellfleet) and the Pamet River (Truro) and kettle pond shorelines, vernal wetlands constitute the principal habitat for many freshwater wetland taxa. From a wildlife perspective, FVWs are critical habitat. For example, the State Endangered *Papaipema cataphracta* (water-willow stem borer) depends upon *Decodon verticillatus* (water-willow), which is a common species in many vernal wetlands. For a wide variety of insects and amphibians such as wood frogs (*Lithobates sylvatica*) and spotted salamanders (*Ambystoma maculatum*) FVWs provide critical breeding habitat.

Previous studies

Prior to Smith et al. (2007), the focus of study within FVWs in CACO was on water chemistry, hydrology, and fauna (Portnoy 1990, 1998, 2004), with very little quantitative data had been collected on plant communities. Dr. John Portnoy and Robert Cook (NPS staff) mapped and provided general descriptions of 66 FVWs within the boundaries of Cape Cod National Seashore (CACO). In addition, a detailed study of vegetation three vernal wetlands in Eastham (within CACO) was conducted during a wet (1997) vs. dry (1999) year to examine physico-chemical and floristic responses to hydrology (Roman and Barrett 2004). Sobczak (1999), Sobczak and Cambeiri (2001) and Sobczak et al. (2003) characterized basin profiles, peat depths, and hydrologic functioning of these same wetlands. Colburn et al. (2005) documented fauna and followed hydrology in nine FVWs (including the three mentioned above) in Eastham from 1999 through 2002. Tupper (2006) collected quantitative data along transects in 29 vernal wetlands (both FVWs and dune slack wetlands) in an effort to describe breeding habitat for Fowler’s toads.

In 2006, Smith et al. (2007) mapped 82 wetlands and re-surveyed permanent transects within the three wetlands selected and studied by Roman and Barrett (2004) in 1997 and 1999. During that year, 6 more sites were selected randomly from the entire group of known wetlands, and transects were established within them, after which the vegetation was assessed in the same way. Sites with transects were termed intensively monitored sites or “IS sites”. In 2011, transects at all nine IS sites were surveyed and six additional randomly-selected IS sites were included in the surveys to bring the total to 15 (Smith et al. 2013). These IS sites provide the basic methods for the FVW monitoring protocol proposed here.

Potential threats

Although there are no immediate direct threats to FVWs such as destruction from development, there may be various anthropogenic factors that influence FVWs in a more indirect way. One of the biggest concerns is the growth of adjacent towns, which is accompanied by increasing groundwater withdrawal for urban consumption. Depletion of groundwater can impact the hydrologic regime of nearby wetlands (Sobczak and Cambareri 2002). Furthermore, nutrient loading of groundwater could influence species composition and/or succession. More broadly, various aspects of climate change such as altered precipitation quantity and chemistry, temperature, evaporation, and the effects of sea level rise on the groundwater table may have significant effects on these wetlands (Brooks 2009). For example, drought events are likely to increase in frequency throughout the northeastern US as a result of climate change (Hayhoe et al. 2007). If this does occur, it is expected that the abundance of obligate wetland plant species will decrease (Bauder 2000). In addition, rising temperatures may promote wetland succession through changes in hydrology as has been observed in Alaska (Klein et al 2005).

Biological threats to vernal wetlands also exist. For example, exotic and/or invasive plant species such as common reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*) are already significant problem in other wetland systems within CACO. Invasive species such as these can greatly alter the structure and functioning of ecosystems, including the extirpation of native species.



Figure 1. Physiognomy of two different forested vernal wetlands across CACO.

Rationale for monitoring forested vernal wetland vegetation at CACO

Management objectives

Vegetation constitutes the physical configuration of vernal wetlands and governs the biogeochemical cycling of this ecosystem. The principal rationale for long-term (i.e., continuous) monitoring vegetation in FVWs is to better understand their structure and function, and to assess spatial and temporal variability in the plant communities, especially as they respond to various external pressures. This knowledge can then be used to guide any management activities needed to help protect and preserve this natural resource. To date, CACO has not developed specific management objectives for FVWs. However, the maintenance of natural hydrology, natural rates of plant succession, control of invasive taxa, and maintenance of natural processes are some of the more important issues. Additionally, CACO wishes to preserve this habitat for wildlife such as the Eastern spadefoot toad (*Scaphiopus holbrookii*) (state threatened). Thus, changes in vegetation could indicate change in the ability of these wetlands to serve as habitat for the uncommon fauna. Finally, vernal wetlands are afforded protection under the Massachusetts Wetland Act and even more stringent protection under various town bylaws.

Monitoring objectives

In accordance with the National Park Service's Inventory & Monitoring program to develop inventories and implement monitoring protocols for all ecosystem types within Park units. The main objective of this specific protocol is to document spatial and temporal change within Forested Vernal Wetland plant communities, water quality, and soil properties. With respect to the vegetation, more specifically the protocol seeks to determine the status and trends in forested vernal wetland vegetation communities by species, growth form, and wetland indicator category.

Sampling Design

The primary focus of vegetation monitoring is to understand the distribution of species in FVWs across CACO and to document short and long-term temporal trends in cover and composition over time. For this protocol, vegetation sampling is conducted in the subset of 15 wetlands (IS sites) in July-August for which there are permanent transects established, as well as in 40 additional sites with no transects where a different method of assessment was used. The vegetation is assessed in two ways. One method is based on recording vegetation along the transects and the other involves a more general "meander" type survey through the entire wetland. The transect method is based on the original surveys conducted by Roman and Barrett (2004) and continued by Smith et al. (2007, 2013). Three transects have been established at each IS site. The transects extend from the middle of the wetland to dry land into upland vegetation (all transect bearings and locations are contained in Appendix I).

Vegetation cover by species (trees, shrubs, herbaceous) is recorded within 1-m² contiguous plots that run along each transect. The plots are designated by meter intervals on a field tape along the entire length of the transect. Cover in each plot is estimated visually based on a modified Braun-Blanquet cover class values (SOPs#4 and 5 contain all the specific details on this monitoring). For each survey, the Project manager should calculate species frequencies (the number of times a plant species occurs divided by the total number of plots), % cover (using the mid-points of cover class categories derived from the Braun-Blanquet scale), and species richness.

The whole wetland meander survey is based upon methods developed by Smith (2013) and is also used in CACO's kettle pond and dune slack vegetation monitoring protocols. This is used for both the IS sites as well as the additional 40 sites that were randomly selected to provide a broader sampling of wetlands. The field crew walks through the wetland in a zigzag fashion (this is done after the transect surveys) and estimates the cover (based on the modified Braun-Blanquet scale discussed above) of each species encountered. The purpose of this type of survey is to document vegetation outside the very thin slices of wetland represented by the transects. By doing this, species that are within the wetland, but may not have been encountered along the transects, can be assessed (SOP#5 contains all the specific details on this type of monitoring). For the meander survey, species richness and % cover should be calculated.

Abiotic variables

Several abiotic variables that are important for describing the structure and functioning of FVWs were added in 2011 in order to document long-term changes, and are discussed in this protocol. These are water quality, soil properties, and hydrology. Surface water pH and conductivity is measured every 3-meters along each transect using a hand-held multiparameter unit. Conductivity is an indication of salt spray and groundwater (high conductivity) vs. rainwater (low conductivity) influence, which can affect plant communities (Griffiths and Orians 2003) and organic matter decomposition (Duckworth and Kresser 1991, Sival and Grootjans 1996). Acidity (pH) is an indicator of successional stage (Sival 1996, Sival and Grootjans 1996, Adema et al. 2002) and groundwater (less acidic) vs. rainwater (more acidic) contributions to hydrology. Decreasing groundwater influence, which could occur as a consequence of groundwater extraction or drought, would theoretically result in more rapid acidification of FVWs. This, in turn, may result in increasing abundance of more acid-tolerant vegetation.

Soil samples are collected at the transect start points near the middle of each wetland and every 5 m thereafter along each transect. The samples are analyzed for percent soil organic matter. Organic matter content is indicative of both successional stage and hydroperiod in that there tends to be more organic matter accumulation in older, wetter sites (Richardson and Vepraskas 2000) and the accumulation of organic matter facilitates the establishment of later successional species (Berendse et al. 1998). Soil organic matter also influences the hydrology of wetlands. Organic matter is much less permeable than inorganic sand of the surrounding basin. Thus, more rainwater would be trapped and retained by wetlands with thicker organic layers that do not allow percolation to the groundwater. Similarly, groundwater has more difficulty penetrating wetlands through the subsurface peat. Thus the water surface of wetlands with thicker peat layers can be lower than the surrounding groundwater at times (and vice versa). Where organic matter layers are thin and not well developed, there is greater connectivity between groundwater and wetland hydrology. All these factors have the potential to influence the structure of FVW communities.

Water depth (wetland bottom to water surface) at the middle point of each 1-m segment (corresponding to each vegetation plot) along the transects is recorded with a meter stick at the time of vegetation sampling. Hydrology is of critical importance to the structure and functioning of FVWs, as it is in all wetland ecosystems. Although water depths will vary in virtually all years,

especially in years of extreme drought or flooding, long term trends reflecting changes in climatological parameters that regulate precipitation evaporation should ultimately be revealed, given that water level measurements are conducted on roughly the same dates each year.

The main objective for monitoring abiotic variables is to provide some perspective on vegetation changes. For example, if water level, chemistry, or soil organic matter changes significantly over time, the vegetation communities may be influenced by these changes. Vice versa, major changes in vegetation can result in significant changes in these abiotic variables.

Number and Location of Sampling Units

Currently, there are 15 sites in which vegetation monitoring occurs. Three of these sites were selected (based on a hydrologic gradient) and surveyed by Roman and Barrett (2004). The rest were selected randomly (using ARCGIS randomization tools) from the entire group of known FVWs that were mapped and surveyed in Smith et al. (2006) and Smith et al. (2011). Figure 2 shows the extent of sites that currently form the backbone of this monitoring protocol.



Figure 2. Map of the 15 Forested Vernal Wetland monitoring sites at Cape Cod National Seashore.

Frequency and timing of Sampling

It is proposed that wetlands be monitored every 5 years based on previous analyses of temporal change (Roman and Barrett 2004, Smith et al. 2013). The monitoring is done in July-August when the vegetation is at the peak of the growing season.

Power Analysis of Plant Communities

Power analysis for the multivariate species data on the IS sites was done indirectly using Bray-Curtis similarity values that compared each plot with every other plot, which is based largely on the power analysis developed by James-Pirri et al. (2007) for salt marsh vegetation communities. Bray-Curtis values, calculated using PRIMER software, indicate species composition similarities among samples (the samples being individual plots or entire sites). For example, a Bray-Curtis value of 60 indicates a higher similarity between two samples than a value of 40. From these data, the following were calculated for each site based on the 2011 data: 1) the mean Bray-Curtis value, 2) the standard deviation of those values, and 3) a hypothetical new mean Bray-Curtis value representing a negative change of 5%, 10%, 20%, and 50% (i.e., decreasing similarity). Negative changes were chosen here because it is considered more important to document shifts in species composition away from the original condition. Subsequently, the power to detect these deviations was calculated using a t-test (Power and Sample Size ver. 3.0) (Dupont and Plummer 1990) ($\alpha=0.05$). The same process was undertaken for species composition for all non-IS sites, where the samples were not plots within a site but the site itself.

For univariate data (e.g., species richness or frequencies of species belonging to specific wetland indicator or growth form categories), power analysis was conducted on the nine sites common to the 2006 and 2011 surveys. For reference, the wetland indicator categories used in the analyses are defined as follows (USACOE 1987 and USACOE 2012):

- Obligate wetland (OBL). Almost always occurs in wetlands (estimated probability > 99%) under natural conditions
- 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 (estimated probability 34% – 66%) or non-wetlands

*designation for each species based on USDA PLANTS database (plants.usda.gov).

To conduct power analyses on univariate data, the following were calculated: 1) the difference between values for each site in 2006 vs. 2011) the standard deviation of those differences, and 3) a change in the original mean value for all sites (i.e., mean of the 2006 data) of 20%, 50%, or 80%. Using the number of samples (sites), the standard deviation of the differences between each site by year, the change in means we wish to detect (20%, 50%, or 80%), and statistical confidence level ($\alpha=0.05$) the power was calculated using Power and Sample Size (Version 3.0) (Dupont and Plummer 1990). Data from the nine sites common to the 2006 vs. 2011 surveyed was used since only three wetlands were assessed in 1997. The remaining 6 of the 15 IS sites have only one set of data from 2011 and, as such, could not be included in the analysis

Power analysis on IS sites based on transect data

The power to detect changes in species composition within the individual IS wetlands was generally very high (Table 1) for relatively low (i.e., 10% and above) levels of change.

Table 1. Power values for detecting species composition changes in individual wetlands.

	P (5%)	P (10%)	P (20%)	P (50%)
VP2	0.31	0.84	1.00	1.00
VP3	0.92	1.00	1.00	1.00
VP12	0.93	1.00	1.00	1.00
VP20	0.44	0.95	1.00	1.00
VP33	0.31	0.81	1.00	1.00
VP35	0.20	0.57	0.99	1.00
VP39	0.93	1.00	1.00	1.00
VP41	0.77	1.00	1.00	1.00
VP59	0.55	0.99	1.00	1.00
VP63	1.00	1.00	1.00	1.00
VP73	0.16	0.48	0.97	1.00
VP81	0.28	0.79	1.00	1.00
VP97	1.00	1.00	1.00	1.00
VP120	0.76	1.00	1.00	1.00
VP139	1.00	1.00	1.00	1.00

Power analysis on non-IS sites based on transect data

For non-IS sites (i.e., the more general survey of entire wetlands), the power to detect species composition changes for all wetlands as a group was fairly high in that a change of 20% in similarity from one time to the next had a statistical power of 1.00. In addition, a change of only 10% was very close to the power threshold of 0.80 (Table 2).

Table 2. Power probability values to detect a change in species composition of all non-IS wetlands.

P (5%)	P (10%)	P (20%)	P (50%)
0.251	0.73	1	1

The power to detect a change in species richness in the IS wetlands as a group (all sites combined) was 0.73 for a 20% change and 1.0 for a 50-80% change (Table 3).

Table 3. Power probability values for the detection of a 20%, 50%, and 80% change in species richness in the IS subset from the original mean (2006) (highlighted data are those power values equal to or exceeding the 0.80 threshold).

Change level	Probability
20%	0.73
50%	1.00
80%	1.00

For the IS wetlands as a group, the power to detect changes in the frequency of species that fell into various growth form and wetland indicator categories (i.e., the number of species divided by the total number of species recorded) was low for many categories (Table 4). However, power was high (~0.80 or above) for shrub and tree frequencies at a change of 50% and 80%. Ferns, grasses, and vines also had high power values but only for a change of 80%. The power to detect a 50% and 80% change in OBL species was as high as it was for FAC at an 80% level of change. It is noteworthy that if all non-woody (i.e., herbaceous species) are combined, the power to detect change improves substantially. In this regard, the power to detect 20%, 50%, and 80% changes in this growth form is 0.60, 0.99, and 1.00, respectively (this data not in table).

Table 4. Power values for the detection of a 20%, 50%, and 80% change in the frequency of species belonging to various growth form (A) and wetland indicator (B) categories in the IS subset from the original mean (2006) (highlighted data are those power values equal to or exceeding the 0.80 threshold; SAV=submerged aquatic vegetation).

A. Growth form										
Change level	Fern	Floating	Forb	Grass	Rush	SAV	Sedge	Shrub	Tree	Vine
20%	0.22	0.07	0.05	0.11	0.06	0.06	0.06	0.19	0.52	0.14
50%	0.75	0.22	0.06	0.47	0.08	0.13	0.09	0.84	1.00	0.61
80%	1.00	0.54	0.07	0.88	0.13	0.28	0.17	0.99	1.00	0.95

B. wetland indicator category			
Change level	OBL	FACW	FAC
20%	0.75	0.06	0.14
50%	0.99	0.15	0.62
80%	1.00	0.33	0.97

OBL=obligate species, FACW=facultative wetland species, FAC=facultative species

Power analysis on IS sites based on whole wetland survey data

The power to detect changes in species richness from meander surveys was very high for all levels of change, ranging between 0.95 and 1.0 (Table 5). For changes in the frequency of species belonging to various wetland indicator categories power was high for OBL species but only for 50% and 80% changes (Table 6). Power was low for all FACW or FAC categories with the exception of an 80% change in FACW, which had a value of 0.85. Power values were low (well below 0.80) in virtually all growth form categories for all levels of change (Table 7). The exceptions were shrub frequencies at a 50% and 80% change and rush frequencies at an 80% change.

Table 5. Power values for the detection of a 20%, 50%, and 80% change in species richness in the IS subset from the original mean (2006) (highlighted data are those power values equal to or exceeding the 0.80 threshold).

Change level	Probability
20%	0.95
50%	0.99
80%	1.00

Table 6. Power values for change in the frequency of species belonging to specific wetland indicator categories (whole wetland surveys).

Change level	Probability		
	OBL	FACW	FAC
20%	0.56	0.09	0.07
50%	0.99	0.38	0.22
80%	1.00	0.85	0.54

Table 7. Power values for change in the frequency of species belonging to growth form categories (whole wetlands surveys).

Change level	Probability									
	Fern	Floating	Forb	Grass	Rush	SAV	Sedge	Shrub	Tree	Vine
20%	0.07	0.07	0.07	0.09	0.10	N/A	0.08	0.34	0.06	0.09
50%	0.21	0.18	0.20	0.33	0.46	N/A	0.28	0.98	0.14	0.33
80%	0.51	0.43	0.45	0.73	0.86	N/A	0.67	1.00	0.30	0.73

Similar to the transect data, if all non-woody (i.e., herbaceous species) are combined, the power to detect change greatly improves. The power to detect 20%, 50%, and 80% changes in this growth form is 0.75, 1.00, and 1.00.

Summary of power analyses

For multivariate species data, the power to detect change was very high for minor changes in composition, indicating that the protocol is adequate for monitoring this important parameter of the vegetation

Univariate data generally did not show high statistical power for change detection in many cases. However, there were some exceptions. There is a relatively high probability of detecting changes in species richness based on transect data for a 20% change and very high levels for larger changes. The power to detect changes in species richness based on whole wetland surveys was very high for all levels of change. In addition, there is a high probability (0.80 or above) of detecting change in shrub cover in both types of surveys. If all herbaceous species are combined, the power to detect change is also quite high, especially for 50% and 80% levels of change. This is important given that it is these growth form categories that represent the species responsible for plant succession (i.e., increases in woody vegetation, decreases in herbaceous vegetation). In addition, the power values for detecting a 50% change in OBL species were high. The loss or gain of OBL species may indicate significant changes in hydrology, which can occur over both short and long time scales, although detecting a 50% change only documents major, rather than minor, changes.

Despite the mixed results of power analysis for many univariate measures of vegetation change, one of the most important components of this protocol is changes in species composition, which cannot be tested. In addition, it is important to note the findings from the 2011 vernal wetland monitoring report (Smith et al. 2013), where an Analysis of Similarities (ANOSIM; Clarke and Warwick 2001), which examined multivariate species data from every transect, showed that all individual sites changed significantly between 2006 and 2011 (Smith et al. 2013). Adding more transects within each site may improve statistical power to detect change in univariate data such as species richness or frequencies of various growth forms, although this may also reduce power if variability among transects increases. The addition of 6 new sites in 2011 may have already improved the power to detect changes in the wetlands as a group. However, there is a limit to the addition of new sites and transects since all monitoring must be accomplished within a relatively short time frame during July-August. Notwithstanding, increasing the number of IS sites from 15 to 20 should be considered as a next step to improve the spatial coverage of monitoring. Whether all monitoring can be completed after the addition of more sites will remain to be seen during the next round of surveys in 2016.

In terms of general statistical analyses, if the original three sites selected by Roman and Barrett (2004) are included, the results can only be interpreted in the context of the 15 wetlands. If these sites are omitted from the analyses, the results can be interpreted from the perspective of all wetlands within CACO as all other sites were selected randomly.

Field Methods

The following sections provide a basic overview of field operations and safety. Note that these procedures are described in more detail in the SOP section of this document.

Field Season Preparations and Equipment Setup

Prior to the field season, it is important that the lead biotech set aside some time to become familiar with the vegetation he/she is likely to encounter and the process of identifying unknown specimens. Historic data, field guides (see SOP#2), and electronic documents summarizing key morphological attributes for identifying species are available in CACO's North Atlantic Coastal Laboratory (NACL) library and on the NACL server within Y:\I&M_Projects\Forested_Vernal_Pools.

The entire crew, including the Project Manager, also must make sure that all equipment is available (see Equipment list in SOP#1) and in working order before use. Before conducting the actual sampling, vegetation data from the last (most recent) survey should be extracted from the database so that it can be used as a reference. Finally, both members of the field crew should review the entire protocol and make sure that they understand all the components of sampling, quality assurance, and data management.

Sampling Procedures

A discussion of all sampling procedures can be found in the SOPs further below.

End-of-day Procedures

Upon returning from the field, any voucher specimens collected as unknown specimens should be identified (see SOP#5). Field notes/datasheets should immediately be checked for completeness and accuracy and then photocopied. The backup copies should be stored in a separate folder in a fireproof cabinet. If there is time, it is advisable to enter data the same day that it is collected. Alternatively, one day a week can be set aside for this purpose. As a general rule, the time between data collection and entry should be minimized to the greatest extent possible and in no case should be longer than one week.

Throughout the day, and especially at the end of the day, each crew member should check themselves and each other for attached ticks. If any are discovered, they should be carefully removed in a manner prescribed in the "tick safety" presentation – a PowerPoint file located on the NACL server. Anyone who finds an attached tick must then fill out a safety documentation form and submit it to the Project Manager, who will then forward all information to the CACO Safety Officer.

End-of-season Procedures

At the completion of the field season, the lead biotech is responsible for writing an end-of-season report. The report should outline the activities undertaken, summarize key findings, and discuss any problems or issues that arose and suggestions for revisions/improvements. The crew must thoroughly inspect all the equipment to ensure that each item is in working order and a list of items that need replacing or repair is compiled. The vehicle assigned to the FVW monitoring crew for the season should be thoroughly cleaned.

All field workbooks, datasheets, and notes should be organized and given to the Project Manager for safe keeping. It is imperative that the all the data be entered into the electronic database and a preliminary QA/QC of the data be conducted before the field crew leaves at the end of the season.

Data Management, Analysis, and Reporting

Recommendations for Data Summaries and Statistical Analyses

After following SOP#7 for data handling and quality assurance/ quality control, there are many different ways in which to analyze vegetation data (Kent and Coker 1996 can be consulted for a comprehensive view of vegetation description and analysis). In general, analyses should be based upon the kinds of research or management questions driving the monitoring. Changes in floristic composition will almost always be the most important management consideration. Changes in environmental variables are also important for understanding these systems. For cover class data, ordination techniques are an excellent way to describe spatial and temporal variability. Changes in species composition over time and space can be illustrated using non-metric multidimensional scaling (NMSD), and clustering (Clarke and Warwick 2001). Analysis of Similarities (ANOSIM), and Similarity Percentages (SIMPER) provide statistical tests for analyzing species composition differences.

For univariate data, such as growth form frequency values, the means and standard errors of the mean (standard deviation divided by the square root of the number of samples) should be calculated and plotted. To examine temporal shifts, mean values calculated from different survey years can be compared. Statistical validation of such changes can be conducted using paired or independent T-tests or repeated measures ANOVA. Regression analysis can also be used to assess longer temporal trends – for example, change in shrub percentages over the last three sampling periods (note: regressions must be based on at least three datasets, since a line cannot be defined by only two points).

Reporting Schedule

Reporting should be done after every season of fieldwork (once every five years) to assess temporal trends. The report should include background information about the project, a summary of what was accomplished during the season, and some basic analyses of the data (see previous section).

Personnel Requirements and Training

Roles and Responsibilities

General oversight and implementation of the protocol is provided by the Project Manager, which, ideally, will be a Plant Ecologist or Botanist. The Project Manager's specific duties include: staff selection, training, and supervision, data analysis, reporting and interpreting results, and protocol evaluation. The data collection portion of the protocol can be carried out with a biological technician accompanied by a student intern/volunteer. The biotech will supervise all aspects of data collection and processing, including several aspects of QA/QC, such as data entry and proofing. The Project Manager is responsible for ensuring that information is collected in a way that will be compatible with the existing database structure. The Inventory and Monitoring (I&M) Coordinator provides supervision and oversight of the Cape Cod Ecosystem Monitoring (CCEM) program and is responsible for ensuring that all project, program, NPS, and scientific standards are met.

Qualifications and Training

The ability to make rapid, accurate IDs in the field is critical to completing fieldwork in a timely manner. Minimally, the lead biotech should be very familiar with the majority of plant taxa likely to be encountered. Where deficiencies occur, the Project Manager should assist the technician in developing the knowledge and skills required for identification (including the use of field guides, etc.). For unknown species that cannot be identified in the field, the crew must be able to use taxonomic keys and other relevant materials to attempt confirmation. It is extremely helpful to allot some time prior to sampling to become familiar with the plant communities of the monitoring network and to develop skills in estimating percent cover (see SOP#5).

Ideally, both members of the field crew will have a good working knowledge of plant mensuration techniques and plant community ecology. Additionally, both members of the field crew will be trained in the following areas:

- Implementation of the specific field procedures and methods in this protocol
- GPS navigation and compass use
- Tick bite prevention and treatment
- General field safety (e.g., prevention of poison ivy, heat exhaustion, etc.)
- Vehicle safety and driving etiquette
- Equipment maintenance and storage
- Use of two-way radios
- Computer use guidelines
- Data entry and basic principles of data QA/QC, database functionality
- Data storage guidelines

Operational Requirements

Annual Workload and Field Schedule

To complete data collection in a timely manner for the 15 sites, the field crew should plan to visit at least one site per 2 days for the IS surveys. This totals 30 days or 6 work weeks. This provides an adequate buffer for cancellations or delays due to inclement weather during the 8-week period of July-August and ensures enough time for gathering data on environmental variables, which is done concurrently.

Facility and Equipment Needs

The field crew will require use of normal office space and a computer linked to the NACL server. Internet connectivity is necessary as plant identification and general research can be aided by referencing various websites, such as the U.S. Department of Agriculture PLANTS and other databases (see SOP#2). A small amount of additional space will be necessary for storage of unidentified plant specimens. The crew will also require a vehicle (preferably a pick-up truck) with four-wheel drive capability. All other equipment needs are listed in SOP#1.

Startup Costs and Budget Considerations

Project-specific costs are primarily limited to personnel, which includes a plant ecologist/botanist and either two biological technicians or a biological technician and a student intern/volunteer. The I&M Coordinator and Project Manager will also contribute to overall staffing costs for the project. Other costs will generally be related to equipment repair and replacement, vehicle maintenance, etc.

References

- Adema, E. B., A. P. Grootjans, J. Petersen, and J. Grijpstra. 2002. Alternative stable states in a wet calcareous dune slack in The Netherlands. *Journal of Vegetation Science* 13:107-114
- Bauder, E.T. 2000. Inundation effects on small-scale plant distributions in San Diego, California vernal pools. *Aquatic Ecology* 34:43-61.
- Berendse, F., E.J. Lammerts, and H. Olff. 1998. Soil organic matter accumulation and its implications for nitrogen mineralization and plant species composition during succession in coastal dune slack wetlands. *Plant Ecology* 137:71-78.
- Brooks, R.T. 2009. Potential impacts of global climate change on the hydrology and ecology of ephemeral freshwater systems of the forests of the northeastern United States. *Climatic Change*, 95:469-483.
- Clarke, K.R. and R.M. Warwick. 2001. Change in marine communities: an approach to statistical analysis and interpretation. 2nd edition. Plymouth Marine Laboratory, Plymouth, UK.
- Colburn, E. 2005. Assessment of relationships between hydrology and the freshwater fauna of kettle ponds and vernal Pools. Final report to the US National Park Service, Water Resources Division and Cape Cod National Seashore. Cape Cod National Seashore, Wellfleet, MA.
- Dupont, W. D., and W. D. Plummer. 1990. Power and Sample Size Calculations: A Review and Computer Program Controlled Clinical Trials 11:116–128.
- Griffiths, M. E., and C. M. Orians. 2003. Salt spray differentially affects water status, necrosis, and growth in coastal sandplain heathland species and their successors. *American Journal of Botany* 90(8):1188-1196
- Hayhoe, K., C.P. Wake, T.G. Huntington, L. Luo, M.D. Schwartz, J. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. DeGaetano, T.J. Troy, D. Wolfe. 2007. Past and future changes in climate and hydrological indicators in the US Northeast. *Climate Dynamics* 28:381-407.
- James-Pirri, M. J., C.T. Roman, and J.F. Heltshe. 2007 . Power analysis to determine sample size for monitoring vegetation change in salt marsh habitats. *Wetlands Ecology and Management* 15:335-345.
- Kent, M., and P. Coker. 1996. *Vegetation Description and Analysis: A Practical Approach*. John Wiley and Sons: New York, NY.
- Klein, E., E.E. Berg, and R. Dial. 2005. Wetland drying and succession across the Kenai Peninsula Lowlands, south-central Alaska. *Canadian Journal of Forest Research* 35:1931-1941.
- Portnoy, J.W. 1990. Breeding biology of the spotted salamander *Ambystoma maculum* (Shaw) in acidic temporary ponds at Cape Cod (USA). *Biological Conservation* 53:61-75.

- Portnoy, J.W. 1998. Vernal ponds of Cape Cod National Seashore: location, water chemistry, and *Ambystoma* breeding biology. NPS Internal technical report. QX-88-04.
- Portnoy, J.W. 2004. Ecological response of vernal wetlands and kettle ponds to hydrologic alteration: soil and sediment characteristics along monitored transects. NPS report. Cape Cod National Seashore, Wellfleet, MA.
- Richardson, J. L., and M. J. Vepraskas. 2000. Wetland soils: genesis, hydrology, landscapes, and classification . Lewis Publishers, Boca Raton, FL.
- Duckworth, C.M.S., and M.S. Cresser. 1991. Factors influencing nitrogen retention in forest soils. *Environmental Pollution* 72:1-21
- Roman, C.T. and N.E. Barrett. 2004. Vegetation along upland-to-wetland gradients of vernal wetlands and kettle ponds: predicting vegetation response to hydrologic alteration. NPS report. Cape Cod National Seashore, Wellfleet, MA.
- Sival, F. P. 1996. Mesotrophic basiphilous communities affected by changes in soil properties in two dune slack chronosequences. *Acta Botanica Neerlandica* 45:119-131
- Sival, F. P., and A.P. Grootjans. 1996. Dynamics of seasonal bicarbonate supply in a dune slack: effects on organic matter, nitrogen pool, and vegetation succession. *Vegetatio* 126: 39–50.
- Smith, S.M. J. Allen, and H. Ruggiero. 2007. Assessment of vegetation in forested vernal wetlands of Cape Cod National Seashore, 2006. NPS Technical Report. Cape Cod National Seashore, Wellfleet, MA.
- Smith, S. M., M. Esposito, and M. Cox. 2013. Forested vernal pond vegetation monitoring in Cape Cod National Seashore: summary of 2011 field work and comparisons to 1997 and 2006 data. Natural Resource Technical Report NPS/CACO/NRTR—2013/786. National Park Service, Fort Collins, Colorado.
- Smith, S. M. 2013. Dune slack wetland vegetation monitoring protocol, Cape Cod National Seashore. Natural Resource Report NPS/NER/NRR—2013/388. National Park Service, Fort Collins, Colorado.
- Sobczak, R.V. 1999. Preliminary hydrologic report submitted to the National Park Service, Cape Cod National Seashore. Cape Cod Commission, Barnstable, MA.
- Sobczak, R.V., and T.C. Cambareri. 2002. Optimizing well placement in a coastal aquifer: Outer Cape Cod, Massachusetts. *Journal of the American Water Resources Association* 38:747-757.
- Sobczak, R.V., T.C. Cambareri, and J.W. Portnoy. 2003. Physical hydrology of selected vernal pools and kettle hole ponds in the Cape Cod National Seashore, Massachusetts. Final Report to the National Park Service Water Resources Division. Cape Cod Commission, Barnstable, MA, and Cape Cod National Seashore, Wellfleet, MA.

Tupper, T.A. 2006. Variables influencing vocalization and breeding effort in the Fowler's toad, *Bufo fowleri*, in southern New England, USA. Ph.D. dissertation. George Mason University, VA.

U.S. Army Corps of Engineers. 1987. US Army Corps of Engineers Wetland Delineation Manual. Technical Report Y-87-1. Environmental Laboratory, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi 39180-0631.

U.S. Army Corps of Engineers. 2012. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region (version 2.0), ERDC/EL TR-12-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Standard Operating Procedure (SOP) #1. Preparations and equipment setup prior to field season

Cape Cod National Seashore

FVW Vegetation Monitoring Protocol

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

Preparation

To prepare for the field season, the field crew must complete the following activities:

1. Review the entire protocol and discuss with the Project Manager
2. Review species lists (Appendix II) and plant characteristics for species identification (see SOP#2)
3. Retrieve and review prior data for reference, which can be found on the NACL server.
4. Visit actual sites or similar habitats to become familiar with vegetation, practice identification skills, and rehearse setting up plots
5. Consult maps of site locations
6. Inspect equipment and compile the items listed below

Equipment List

- Field tape (100 m)
- Vials for storage of porewater samples
- Ziploc bags (1 gallon) for storage of soil samples
- Water quality meter (pH, conductivity)
- Compass

- Datasheets/field notebooks (example data sheets can be found on the NACL server)
- GPS unit (and extra AA batteries for the unit) with site coordinates
- Hardcopy map of site locations with plot layout diagrams
- List of species previously found in plots (legacy data)
- Plant identification materials (field guides, digital images, etc.) (see SOP #2)
- Chest waders
- Insect repellent
- Pre-contact solution for prevention of poison ivy and poison sumac
- 1 m² PVC plot
- Cell phone and two-way radio with Park contact numbers, including Dispatch (508-957-0732), which are available on the NACL server

Standard Operating Procedure (SOP) #2. Training observers

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

Identification of Plant Taxa

At the beginning of the season, the Project Manager (botanist, plant ecologist) will take the field crew out to actual sites or similar habitats and review as many different taxa as possible. The field crews are to review a list of species (from historic data) they are likely to encounter and study characteristics, images, or actual samples from CACO herbaria at the North Atlantic Coastal Laboratory or Salt Pond Visitor Center. Extra emphasis should be placed on taxa that are difficult to identify.

In addition, the following guidebooks are recommended for plant identification:

- Garrett E. Crow and C. Barre Hellquist. 2000. Aquatic and Wetland Plants of Northeastern North America, Volume I, Pteridophytes, Gymnosperms, and Angiosperms: Dicotyledons. University of Wisconsin Press, WI.
- Garrett E. Crow and C. Barre Hellquist. 2000. Aquatic and Wetland Plants of Northeastern North America, Volume II, Angiosperms: Monocotyledons. University of Wisconsin Press, WI.
- Dwellley, M. J. 2000. Trees and shrubs of New England. Down East Books: Camden, ME.
- Gleason, H. A., and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. New York Botanical Garden: Bronx, NY.
- Holmgren, N. H. 1998. Illustrated Companion to Gleason and Cronquist's Manual: Illustrations of the Vascular Plants of Northeastern United States and Adjacent Canada. The New York Botanical Garden: Bronx, NY.
- Magee, D. W., and H. E. Ahles. 1999. Flora of the Northeast: A manual of the vascular flora of New England and adjacent New York. University of Massachusetts Press: Amherst, MA.
- Newcomb, L. 1977. Newcomb's wildflower guide. Little, Brown and Company: Boston, MA.
- Stuckey, I. H., and L. L. Gould. 2000. Coastal Plants from Cape Cod to Cape Canaveral. University of North Carolina Press: Chapel Hill, NC.

- Svenson, H. K., and R. W. Pyle. 1979. The Flora of Cape Cod. Cape Cod Museum of Natural History: Brewster, MA.
- New England Wildflower Society's Go Botany website (<https://gobotany.newenglandwild.org/>)

*A very good personal reference for difficult to identify species is Arthur Haines, the author of *Flora Novae Angliae*. Delta Institute of Natural History, 167 Thorne Mountain Road, Canton, ME 04221; 207-837-4920

The following web sites are also recommended:

- <http://plants.usda.gov/>
- <http://www.ct-botanical-society.org/docs/fernchart.html>
- <http://www.ct-botanical-society.org/>
- <http://hua.huh.harvard.edu/FNA/>
- http://rsgisias.crrel.usace.army.mil/nwpl_static/data/DOC/lists_2014/Regions/pdf/reg_NCNE_2014v1.pdf

Note: Appendix II lists all species and genera that have been encountered in the wetlands to date.

Standard Operating Procedure (SOP) #3. Using the global positioning system

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

General Use

GPS units are used to navigate to and record waypoints. These instructions are for the use of Garmin GPSmap 76S units. For all other GPS models, consult with CACO's GIS Specialist and the manuals with operating instructions. Keep the GPS unit dry at all times. In wet conditions the unit should be placed inside a clear plastic bag. This will not interfere with its ability to function properly. Do not leave the unit on for long periods of time between uses as the batteries will drain quickly. When working in waterbodies the unit should be kept in a waterproof container or pouch. If the unit is accidentally dropped into water, do not attempt to turn it on. Return to the office and immediately consult with the Project Manager for the proper course of action.

Satellite reception may vary substantially depending upon interference from trees, topography, structures, weather, and satellite configurations. The unit should be held face up (i.e., the display screen facing upward). Also make sure that the antenna is pointing skyward.

Recording Points

The datum for all coordinate values is NAD-83 and the coordinate system is Universal Transverse Mercator (UTM) (Zone 19T).

To record new points on Garmin GPSmap 76S units (the most current technology at CACO), follow this procedure:

- Press the "menu" button (starting from any screen) twice.
- Highlight the "Waypoints" option and hit "Enter".
- Press "menu" again and select "New Waypoint".
- Hit the "menu" button one more time, select "Average position" and press "Enter".
- Wait until the unit has achieved an accuracy level (shown onscreen under "estimated accuracy") of < 5m (this usually requires measurement > 100 position counts)

Navigating

All waypoints will be upload into GPS units by the Project manager prior to the field season. However, thick canopy cover presents a problem in navigating with GPS units in that satellite reception is significantly hindered. In such cases, it is advisable to move into any open areas in the nearby vicinity. If satellite reception is still poor, it will be necessary to use hardcopy maps of the sites. For more information on the use of GPS technology, refer to the technical manuals for the specific GPS unit being used.

Standard Operating Procedure (SOP) #4. Establishing and Marking Transects

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

Transects in the original three wetlands (VP33, 39, and 41) first surveyed by Roman and Barrett (2004) are spaced and oriented in different ways, the reasons for which are not known. Diagrams of these transects are presented below in Figure 3.

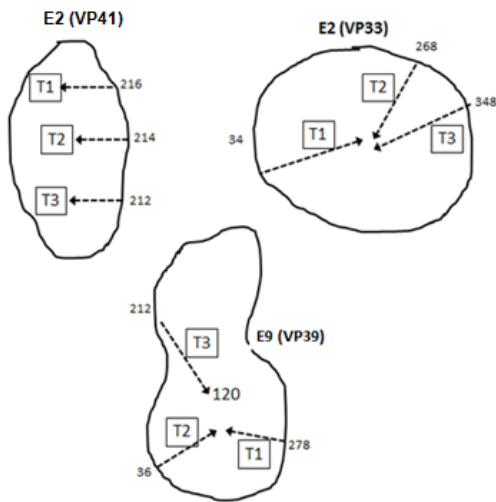


Figure 3. Original three wetlands surveyed by Roman and Barrett (2004) and subsequently by Smith et al. (2006, 2011) with transect orientations (bearings shown are pondward from shoreline; E2, E8, and E9 are the original names given to these wetlands by Dr. Robert Cook (CACO Wildlife biologist)).

To establish transects in the other IS wetlands, and to standardize the way in which transects in any additional wetlands might be placed, the field crew walks to the estimated “center” of the wetland where a 1.25-inch diameter PVC stake serves as the permanent marker for all 3 transect start points. From this interior center point, one crew member should walk with a field tape along the following pre-determined (randomly-chosen) bearings to delineate the 3 transects (1st transect = 5° from center point, 2nd transect = 160 ° from center point, 3rd transect = 240 ° from center point) (Figure 4).

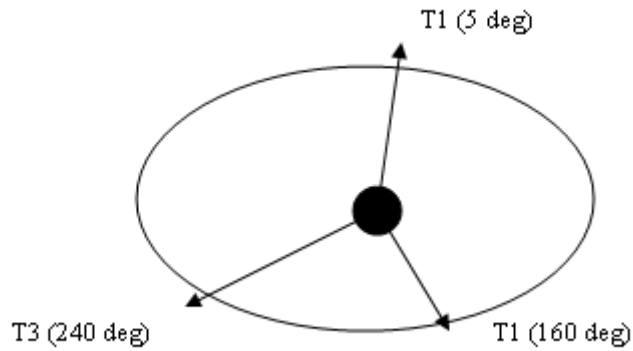


Figure 4. Diagram showing scheme for establishing transects in additional IS wetlands.

Each transect was extended onto dry land several meters upslope of where hydrophytic vegetation ended. The total length of each transect was recorded and the wetland center points and upland end points were all marked with PVC posts. The nearest tree to the upland marker was tagged with an aluminum tree tag to help with relocation. At times, the crew could only approximate the pre-determined bearings due to the difficulties of navigating through virtually impenetrable vegetation in certain locations. Where such conditions were encountered, the crew placed the field tape as close as possible to the specified bearing, but in an area that was navigable. All specific transect bearings are listed in Appendix I and are contained in a metadata file that is provided to the field crew.

Standard Operating Procedure (SOP) #5. Conducting the monitoring

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

Conducting the vegetation sampling

Monitoring of the intensive subset (IS)

All site metadata (coordinates, transect lengths, transect center-point locations) are saved on the NACL server in: Y:\I&M_Projects\Forested_Vernal_Wetlands\Metadata. All transect origins (center point of wetlands) have GPS coordinates and are listed in Appendix I and in the metadata file.

The vegetation monitoring should be conducted in July-August during the peak growing season. Currently there are 15 IS sites in which vegetation is surveyed (Figure 5). In conducting the monitoring the field crew must first navigate to the wetland that is to be assessed. Within the wetland, they then must navigate to the start point of the transects (marked by a PVC stake). The start points are the end of the transects that lie within the pond, not the upland end. Once there, a field tape should be stretched out across the wetland from the marker in the direction (bearing) specified for the particular transect they are working on. Care should be taken not to walk along the exact bearing where subsequent plant data will be collected. The length of each transect is given in the metadata (and in Appendix I) and the field tape should therefore be extended to these distances, ending up at the PVC stake that was hammered in along the upland edge to demarcate the transect finish point. Make sure that the tape is taught.

Once the transect tape has been set up, plant cover by species is recorded within 1-m² contiguous plots that are demarcated with a 1m x 1m PVC frame (Figure 6). The plots are defined by the meter intervals along the field tape. Each transect is surveyed from the pondward start point toward the upland. Plot placement always to the right (and immediately adjacent to) of the transect looking upslope toward the upland. Cover by species in each plot is estimated visually based on a Braun-Blanquet cover class values (0=0%, 1=<1%, 2=1-5%, 3=6-25%, 4=26-50%, 5=51-75%, 6=76-100%). To do this, it is necessary to mentally group together the plants of each species so that they occupy a single, contiguous area within the plot (Figure 7). A cover class is then decided upon depending on the visualized area that the species occupies relative to the entire plot. Markings defining percent cover within the 1m² PVC quadrat are helpful in this regard (Figure 8). While this method has an obvious element of subjectivity, it is a commonly accepted technique for assessing

vegetation. Furthermore, it is not as time consuming as other methods such as point intercept, which allows for many more sampling sites (plots, transects, wetlands) to be assessed.



Figure 5. Map of 15 intensively-monitored sites.

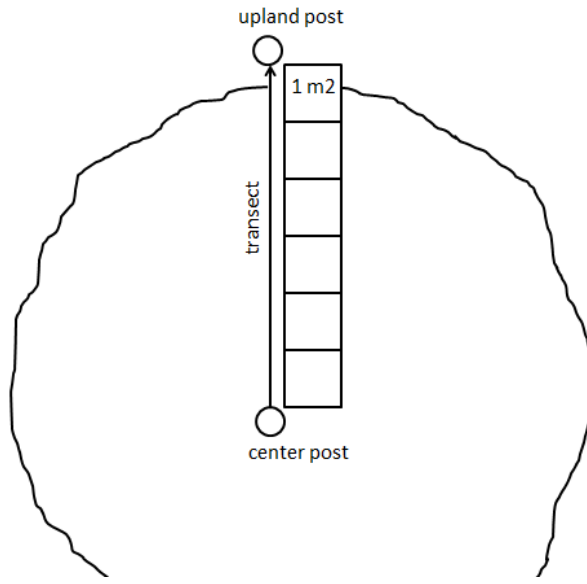


Figure 6. Layout of transect for vegetation monitoring.

Conducting the meander (whole wetland, non-transect based) vegetation surveys

The vegetation of the 15 IS sites is also characterized by visual assessments of cover by species but throughout the entire extent of the wetland. The upslope limit of hydrophytic vegetation (i.e., the limit of OBL, FACW, and FAC species) delineates the assessed area in the same way that the boundary of a plot does. Cover (horizontal area occupied) by species is estimated visually based on a Braun-Blanquet cover class values (1=<1%, 2=1-5%, 3=6-25%, 4=26-50%, 5=51-75%, 6=76-100%). Estimating plant cover in this way can be very challenging when working in large, complex wetlands. The crew should meander through the entire wetland in a zigzag fashion and then make a decision on an appropriate cover category for each species encountered (Figure 9). The best way to do this is to first record every species encountered, and then assign cover class values to them on a second walk-through. Note that the cover for all species within a defined area can add up to >100% since there are different layers of vegetation at different heights (Figure 10).

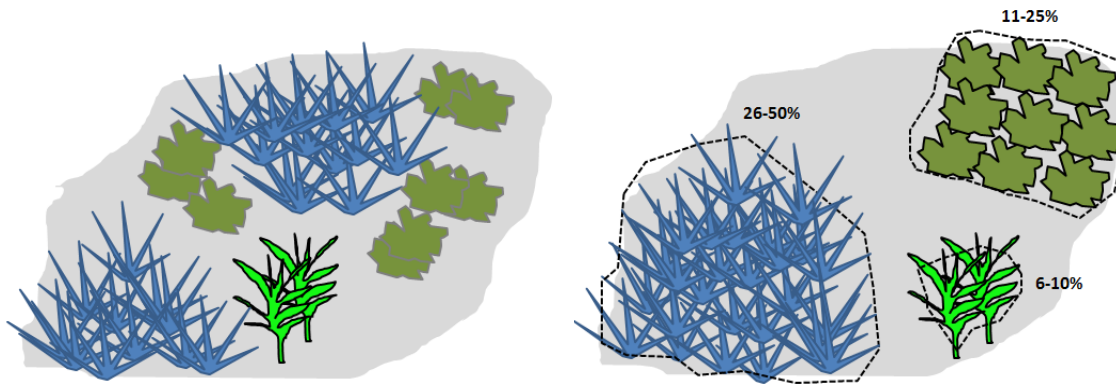


Figure 7. Conceptual diagram of vegetation with a FVW (left) and the process by which the cover of each species is estimated visually (mental consolidation of each species and comparison to overall wetland area).

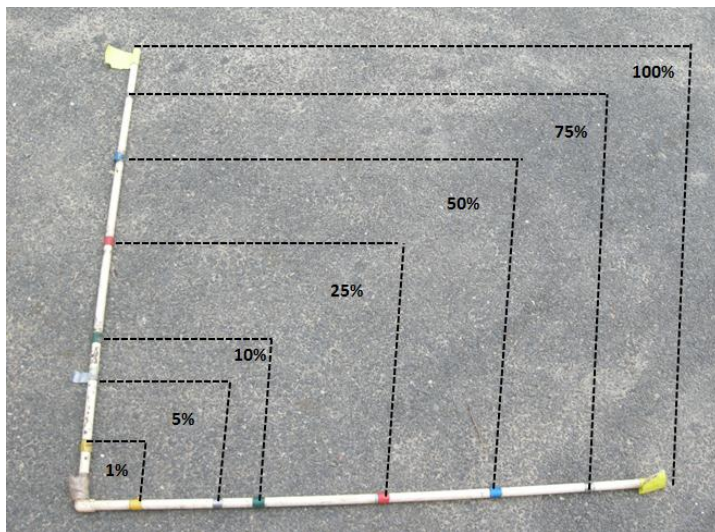


Figure 8. PVC poles with markings on sides to help delineated areas for cover class category designation.

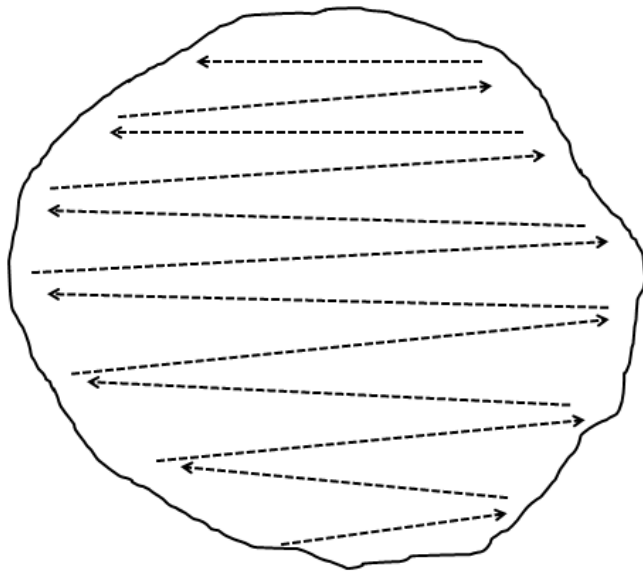


Figure 9. Diagram showing the zig-zag path the field crew should take through each wetland for whole-site surveying.

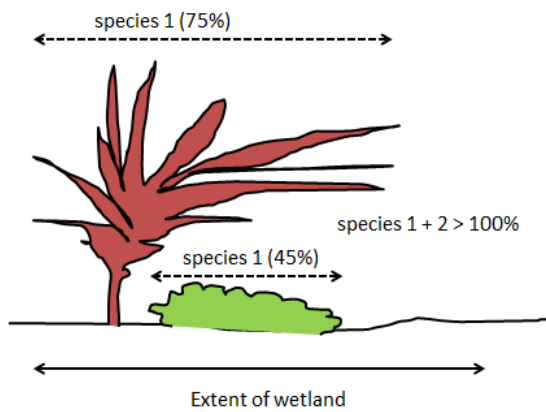


Figure 10. Example of vegetation layering resulting in total cover of > 100% across the surveyed area (right).

Conducting the environmental monitoring

Within the 15 IS FVWs, several abiotic variables are characterized. These include hydrology (water level fluctuation), basic porewater chemistry (pH, conductivity), and soil organic matter content.

Hydrology

Water depth (wetland bottom to water surface) at the middle point of each 1-m segment of tape (corresponding to each vegetation plot) is recorded with a meter stick placed on the bottom and held vertically. This should be done at the time of vegetation sampling along the transects.

Surface water pH and conductivity

Surface water (i.e., within the top 10 cm) from each pond is tested for pH and conductivity in the field using a portable water quality meter (Oakton Multi-Parameter PCSTestrTM35).

Beginning at the start points, the sampling is conducted every three meters along each transect until dry land is encountered. The probe is immersed in the water column so that the sensor lies within the top 10 cm of water. A reading for pH and conductivity is then collected and recorded. The sampling should be done before any other work is conducted on that day to avoid disturbing the water column and soils to the extent possible. In other words, the sampling should be done as the crew first walks out to the center stake. Calibration, use, and maintenance of the water quality meter can be found at <http://www.4oakton.com/SellSheets/35425-00,-05,-10.pdf>.

Soil organic matter

Three soil cores (20-cm depth) are extracted from randomly selected locations around the common start point (center pole) of the three transects (n=3), or from the start point of each individual transect where the transects do not originate from a common point (e.g., VP41), using a 4-cm diameter butyrate coring tube. Thereafter, one core should be collected at every 5 meters along each transect. To conduct the sampling, the coring tube is inserted into the sediment to a depth of at least 20 cm. The sample is then pushed out of the corer using a plunger (PVC pole with a cap on the end). This sediment is then pushed out into a sample bag and transported back to the laboratory for processing. Samples are thoroughly dried in a convection oven for 3 days at 80°C and homogenized. Soil organic matter (SOM) is determined from a subsample of the homogenized material (~10 g) by weight loss after combustion of the organic matter in a subsample using a muffle furnace set to 550°C for 5 hours.

Identifying and Recording Unknown Species

In the event that a species cannot be identified in the field, a voucher sample should be collected from outside the transects. Flowers or fruit, even if they are last year's growth, are very helpful in identification. In general, the specimens should appear "typical" and healthy, based on leaf shape, color, etc. In the case of small plants, roots or underground stems can also be used in identifying specimens. If no specimens can be found outside the transects, a small amount of material (i.e., a branch, or portion of the stem with a few leaves) should be harvested in a way that will not compromise the survival of the plant. If this is not possible or there is reason to suspect that the species may be rare with State or Federal status, a digital photograph can be taken instead. Samples

can be stored in a refrigerator on a short-term basis (i.e. ~1 week) or air-dried and pressed flat between 2 pieces of cardboard for long-term storage.

There are several different tools available for identification. The simplest way is to use the expertise of the Project Manager. Color photography, identification guides, taxonomic keys, and the NACL and Salt Pond Visitor's Center herbaria are other sources of information. As a last resort, if the specimen still cannot be identified, the plant should be listed as "unidentified <growthform>" in the database (i.e., unidentified tree/shrub/graminoid/fern etc.).

Standard Operating Procedure (SOP) #6. Reporting

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

Reporting

A comprehensive report should be generated after each field season consisting of:

- The results and documentation of work accomplished, analyses of trends and comprehensive assessments of resource condition and ecosystem integrity; and assessments of the efficacy of monitoring methods, the validity of design assumptions, and the overall utility of the protocol for answering the monitoring questions.

The manner in which these reporting objectives are met will be determined by the Project Manager and the I&M Coordinator.

Standard Operating Procedure (SOP) #7. Data Management

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

File Management

Any image files for the current season will be stored in a separate images folder (Y://images) to facilitate cataloguing of all image files at the Park. The I&M Project directory is intended to hold all current and frequently accessed files. An archive directory was established to house information for each monitoring program more permanently at the end of each year.

The data must be stored in at least two local locations. The first storage location will be in the designated project archive on the NACL server (which is backed up daily). Files in the archive will be stored in read only file format. The second location will be on a DVD that will be stored in a fireproof cabinet. Paper worksheets and notes will be filed and stored.

Database files that are moved to an archive folder are considered permanent. Changes should not be made to these databases once archived. Copies of database files that are modified after archiving must include detailed revision notes stored in its internal database revision history table for reference. Any changes to data stored in an archived file must also be documented in a text document stored in the same folder as the database. Whenever practical, data should not be changed via direct entry into a table.

Data Entry

Data entry into an excel file (where the formatting is determined by the project manager) should be completed as soon as possible after the field data is collected, generally within one week. If possible, the data entry should be done by one of the technicians who performed the field work so that the technician's memory will aid in the transcription process. Data entry should ideally be done by two people. The goal of data entry is to achieve 100% correct transcription entries. To minimize transcription errors, CACO policy is to verify a minimum of 10% of records to their original source. If possible, however, the original technician should check 100% of the data entry on the following day. Once the computerized data are verified as accurately reflecting the original field data, the paper forms are archived and the electronic version is used for all subsequent calculations.

Data Availability

This protocol, reports, data, and all other products will be available directly from CACO or the IRMA website. Data can also be transferred using e-mail or ftp where available. Requests for data and reports before they are published on a CACO I&M website should be directed to:

Stephen Smith, Ph.D., Plant Ecologist, Cape Cod National Seashore, 99 Marconi Site Road, Wellfleet, MA 02667; stephen_m_smith@nps.gov.

Standard Operating Procedure (SOP) #8. Preparations and Equipment Storage at the Conclusion of the Field Season

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

At the end of the field season, it is imperative that all equipment be inventoried, repaired (or replaced) if necessary, and stored in its proper location. The data and resulting products (e.g., reports) should also be organized and archived. To accomplish this, the field crew should follow these steps:

1. Compile, clean, and return all equipment to its proper storage place
2. Clean the assigned vehicle and make sure it is left with a full tank of gas and sufficient oil.
3. Organize and photocopy all field datasheets and notes. Give all data to Project Manager for safekeeping
4. Make sure all data has been entered into the electronic database and saved in the proper folder on the NACL server
5. Complete end-of-season report

Standard Operating Procedure (SOP) #9. FVW monitoring safety

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

In addition to the basic requirements of the programmatic SOP (#10), the following safety measures will be implemented as part of the FVW Monitoring Protocol:

- the Project Manager will encourage field staff to use insect repellent on their clothes;
- the Project Manager will provide light-colored coveralls if desired by field staff;
- field crews are encouraged to perform periodic tick checks while in the field;
- the Project Manager will ensure adequate poison ivy pre-contact solution (such as Ivy Block™) and post-contact wash (such as Technu™) is available for the duration of the field season.

In addition, all project personnel are encouraged to recommend changes or additions to the programmatic safety SOP (SOP#10 in this protocol).

Standard Operating Procedure (SOP) #10. General safety

Revision History Log:

Revision #	Date	Author	Changes Made	Reason for Change

Purpose and Applicability

This programmatic SOP identifies required safety training and establishes procedures for all staff, volunteers, and visiting scientists implementing CACO's long-term monitoring protocols.

Procedures and General Requirements

Required Safety Training and Procedures

All project managers, seasonal staff, volunteers, and visiting scientists working on long-term monitoring protocols will receive the safety training and implement the procedures in Table

1. All project managers and year-round staff will refresh themselves on these safety topics at least annually. It is recommended that this occur at the beginning of each data collection cycle in conjunction with seasonal staff training. Table 1 summarizes the minimum content to be covered during training, provides a list of resources where available, and establishes mandatory safety procedures. The I&M Coordinator and the Division's Safety Committee representatives will review this SOP and Table 1 periodically to ensure the referenced resources and requirements are up to date.

Project-specific Safety Training and Procedures

Each protocol will include a safety SOP which will incorporate this programmatic SOP by

reference. The protocol-specific safety SOP will also specify any additional safety topics, training, and procedures needed to conduct the monitoring project in manner consistent with CACO's Safety Policy. For example, any protocol that will involve laboratory analysis should require the laboratory safety orientation. Also, during revision of monitoring protocols and immediately following any accident or near-miss, project managers will evaluate the monitoring procedures and materials involved to determine if additional safety training or procedures are appropriate. The CACO Safety SOP on Job Hazard Analysis (CACO SOP # S002) is a useful tool to help project managers identify safety concerns associated with specific monitoring activities. Project managers can review Tables 1&2 for recommended training content, resources, and procedures likely to pertain to several long- term monitoring protocols. In addition, any protocol involving use of the

analytical lab, chemicals, or hazardous materials should be reviewed by the Lab Manager to ensure appropriate safety and environmental management procedures are included.

Reporting and Documenting Safety Training

Table 1 will also be used as a checklist to document that appropriate safety training has

occurred and that project staff agree to implement safety procedures. Additional project- specific safety training or procedures can be extracted from the safety SOP of the relevant protocol and appended to Table 1. Upon completion of safety training, Table 1 will be signed by the project staff member, volunteer, or visiting scientist. Some of the required training will be accomplished through CACO Safety Training Modules. Each module includes a completion certificate that should be printed and signed by the person completing the training and by their supervisor. The signed completion certificate should be attached to the signed checklist. The project manager will forward copies of the signed checklist and module completion certificates along with a completed Safety Documentation Form to the CACO Safety Officer to document that the training has been completed.

Although Table 1 is organized differently than the CACO Safety Orientation Checklist, there is complete overlap of topics pertinent to monitoring operations. Therefore, the procedures established by this programmatic SOP will also enable the project manager and new staff member to complete the CACO Checklist at the same time.

Project Supervision

Project managers will check in with project staff at regular intervals (at least once a month)

to evaluate the efficacy of safety procedures and to maintain a general awareness of safe practices. More frequent check-in is recommended for new staff and during the summer field season. All staff and supervisors are encouraged to use the CACO employee award program to reward diligence, innovation, or other demonstrations of staff commitment to safety. Project managers should also refresh themselves at least annually on the procedures and documentation requirements associated with worker's compensation.

Revision log for P2: Safety Standards and Procedures for Monitoring Projects

Summary of Revisions	New Version	Effective
Original version finalized	Version 1	8/2005
Revised Table 1 – updated resources section to include PowerPoint presentations and new references where applicable; updated some procedures sections to include completing the referenced Safety Training Modules	Version 2	04/2009
Page 3 Table 1: modified NACL General Safety to include “no open footwear in bays or shop” and under training; minimum content added “and footwear” after proper attire Page 6 Table 2: Motor Boat Operation – added reference to SOP#P106	Version 3	09/2010
Table 2: Dangerous Marine Life and Snorkeling/Freediving SOPs added, edits made to reflect current staffing	Version 4	05/2013

Table 1 - Required Safety Training and Procedures for All CCEM Projects

Topic	Training: Minimum Content	Resources	Procedures
1. CACO Safety Rules and Policies	-location and general contents of CACO Safety Manual -overview of Park Safety Policy and related rules -role of Safety Committee and identification of Division representatives	-Park Safety Policy (Memo dated May 18, 1999) -CACO SOP # S001 and # S017	- project staff will review the Park Safety Policy and SOPs S001 (general safety rules and disciplinary policy) and 0017 (Safety committee role and functions) at least once a year -new project staff will read these materials during their initial safety training and orientation, and before engaging in any work in the field or analytical lab
2. Safety Reporting and Documentation	-how to report an accident -how to report a safety hazard -use and location of Safety Documentation Forms (SDF)	-CACO SOP # S021 (incident reporting and investigation)	- incidents or hazards will be reported and documented appropriately -the project manager will review SDFs and will evaluate whether monitoring procedures should be modified to eliminate or reduce risk
3. NACL - General Safety	-laboratory information for non-users -fire extinguisher and first aid kit locations -what to do in case of accident or emergency -evacuation route -float plan procedures -proper attire and footwear	-NACL Health and Safety Program Manual -Lab Manager -Emergency instruction sheet (pg 9 in NACL Health and Safety Program Manual)	-project staff will comply with analytical lab safety rules at all times -the float plan table will be filled out by each person or team prior to heading out to the field -in the event that they may need to unexpectedly go into the field, all staff should insure they have close toed shoes (not sandals) on hand at work; no open footwear in lab bays or shop
4. Working Alone	-radio training and/or cell phone use -locking procedures at end of day	-list of radio call numbers and important phone numbers (e.g. 911, dispatch, District Rangers' offices, etc)	-project staff working alone in the field will carry either a radio or cell phone -Current cell phone numbers should be on the NACL contact list and posted near the float plan -staff planning to work alone in the analytical lab after hours or on weekends must obtain prior approval from their supervisor and from the Lab Manager or Lab Tech -staff planning to work alone with shop equipment after hours or on weekends must obtain prior approval from their supervisor

Table 1 - Required Safety Training and Procedures for All LTEM Projects - continued

Topic	Training: Minimum Content	Resources	Procedures
5. Vehicle Safety	-use and limitations of 4WD vehicles -vehicle safety equipment use -defensive driving -what to do in case of an accident - not allowed to use cellular telephones, including hands free devices and voice-activated features, while operating government motor vehicles (including rented or privately owned vehicles used while on official NPS business or travel).	-NACL Vehicle Coordinator -CACO Government Vehicle Safety Checklist -PowerPoint presentation on vehicle safety (Motor_Vehicle_Safety_Final)	-project staff will wear seatbelts, drive with headlights on at all times, and obey all traffic regulations -staff will use cones and reflective vests as instructed -staff will demonstrate extraordinary driving etiquette, particularly in the summer on Rte 6 -staff will maintain vehicles clean and free of safety hazards -all vehicle problems will be reported immediately - new project staff will complete the referenced Safety Training Module
6. Common Hazards	-stinging insect nests on structures, cable posts, sheds, etc -proper lifting and carrying technique -slip/trip/fall/eye hazards	-PowerPoint presentation on Cape_Cod_Environment -daily Env/Safety Minutes	-project managers will share and review with project staff the Env/Safety Minutes that are related to common hazards topics - new project staff will complete the referenced Safety Training Module
7. Heat Stress	-heat stress prevention -symptoms of heat stress	- PowerPoint presentation on Cape_Cod_Environment -CACO SOP # S003 (Heat Stress Procedures) -local forecast info: http://www.srh.noaa.gov/data/forecasts/MAZ022.php?warncounty=MAC001&city=Truro	-new or summer seasonal project staff will read the referenced CACO Safety SOP during their initial safety training and orientation, and before engaging in any field work -project staff will wear appropriate clothing and carry ample water and sunscreen when working in the field -new project staff will complete the referenced Safety Training Module
8. Hypothermia	-hypothermia prevention -symptoms of hypothermia	- PowerPoint presentation on Cape_Cod_Environment -local forecast info: http://www.srh.noaa.gov/data/forecasts/MAZ022.php?warncounty=MAC001&city=Truro	- when working in the field fall through spring, project staff will wear appropriate clothing, will carry ample fluids, and will carry or store in the vehicle an extra, dry layer of clothing -staff will maintain waders or other waterproof PPE in proper, leak-free condition -new project staff will complete the referenced Safety Training Module

Table 1 - Required Safety Training and Procedures for All LTEM Projects - continued

Topic	Training: Minimum Content	Resources	Procedures
9. Lyme and Tick-Bourne Disease	-preventing tick bites (clothing – it is our policy to tuck pants into socks, repellant – especially if wearing shorts in the field) -MUST do tick checks daily; even if not in field (ticks can be transferred in vehicles and office areas) -treating field clothes -tick identification -Lyme disease symptoms	-CACO SOP # S S004 (Lyme and Tick Borne Diseases) -CACO Safety Training Module: Lyme Disease and Tick Protection Program ppt (Tick_and_Lyme_Prevention)	- new project staff will read the SOP during their initial safety training and orientation, and before engaging in any field work -new project staff will complete the referenced Safety Training Module -staff will perform a tick check at the conclusion of each field day -use of insect repellant is recommended -project managers will ensure that staff know the location of MSDSs for insect repellant
10. Poison Ivy	-identifying poison ivy -preventing exposure -post-contact prevention -symptoms and treatment	- - PowerPoint presentation on Cape_Cod_Environment	-use of pre-contact solution (such as Ivy Block) and post-contact washes (such as Tecnu) are recommended if working in areas with poison ivy -project managers will ensure that staff know the location of MSDSs for pre- and post-contact solutions -new project staff will complete the referenced Safety Training Module
11. Brown-tail moth	-identifying brown-tail moth tents and caterpillars -preventing exposure -symptoms and treatment	-USDA info: www.fs.fed.us/na/durham/ima/pubs_maps/pdf/browntail_moth2.pdf - PowerPoint presentation on Cape_Cod_Environment	-field staff will be alert for brown-tail clusters when entering potential habitat - use of protective lotion (such as Ivy Block) is recommended when entering into potential brown-tail habitat - new project staff will complete the referenced Safety Training Module
12. Hunting Season	-Cape Cod hunting seasons -rules regulating hunting in the park	-Mass Wildlife hunting info: http://www.mass.gov/dfwel/dfw/dfwrec.htm http://www.nps.gov/caco/parkmgmt/hunting-information.htm	- for field work conducted during hunting season: -staff will wear hunter orange vests or coats when working in hunting areas with poor visibility (woods, shrubs) -project managers will ensure staff are aware of hunting season dates and which field sites are in hunting areas -extra caution will be exercised during shotgun deer season; field work in wooded hunting areas will be avoided during this time if possible

I acknowledge that these safety topics above have been reviewed, and I agree to implement the safety procedures described above.

Name

Signature

Date

Table 2 - Training and Implementation Standards That May Apply to One or More Protocols

Topic	Training: Minimum Content	Resources	Procedures
Safety for Analytical Lab Users	-to be determined by the Lab Manager and/or Lab Tech depending on the type of chemical and equipment use planned	-NACL Health and Safety Program Manual	-implementation standards recommended by the Lab Manager and/or Lab Tech will be incorporated into the Safety SOP for each protocol that requires use of the analytical lab
Canoe/Kayak Use	-lifting, lowering, and carrying techniques -required equipment -canoe/kayak entry, exit, and paddling -hazardous conditions -what to do in the event of capsize	-CACO SOP # S0014 (this SOP is geared toward canoe use in interpretive programs but has useful information)	-when in use, a canoe or kayak must be equipped with a PFD for each person and a 5-10 ft length of rope tied to the bow or stern -anyone using a canoe or kayak alone, or at least one person in each team of two or more, must demonstrate they have the ability and experience to control and safely paddle a canoe or kayak
Motor Boat Operation	-DOI Motor Boat Operators' Safety Course	-Course Coordinator for CACO CACO SOP#P106 Boat Ops & Maint.doc	-only certified (through the referenced course) operators may use motorized vessels -crew and passengers will comply with any directives from the certified operator of the vessel - complete list of safety equipment for non-LE boats from Boating SOP must be on board each vessel prior to departure
Dangerous marine life	-JSA.Water-Based Activities in Areas Where Jellyfish May Occur	G:\EVERYONE\SAFETY\CACO JSA'sJSA.Water-Based Activities in Areas Where Jellyfish May Occur	-Currently, threat from severe reactions to Lion's Mane or Man O War is low. Particularly dangerous jelly's (<i>Gonionemus</i>) don't occur in CACO waterbodies, but they do occur on Cape Cod (Sage Lot Harbor, Waquoit)
Snorkeling/Freediving	-JSA_SOP_Freediving_final	G:\EVERYONE\SAFETY\CACO JSA'sJSA_SOP_Freediving_final	-various certifications and check-out dive required before snorkeling can be used as part of a monitoring protocol, refer to SOP for details.

Appendix I. Transect metadata

Site	Transect	Bearing from center point	Transect length	Center point cords (UTM)
VP2	T1	18°	15	418749 4640383
VP3	T1	5°	21	416603 4644349
VP12	T1	5°	19	414261 4646618
VP20	T1	10°	33	412536 4648538
VP33	T1	64°	20	420076 4633638
VP35	T1	5°	15	419911 4633597
VP39	T1	82°	38	420538 4634087
VP59	T1	5°	14	416232 4644532
VP63	T1	5°	20	416009 4647313
VP73	T1	335°	15	414158 4648574
VP81	T1	12°	21	410405 4655987
VP97	T1	0°	31	411548 4641243
VP120	T1	80°	23	414629 4649115
VP139	T1	5°	15	414691 4646187
VP41	T1	45°	39	multiple center points, no coordinates
VP2	T2	160°	12	
VP3	T2	180°	15	
VP12	T2	160°	21	
VP20	T2	160°	22	
VP33	T2	212°	37	
VP35	T2	168°	21	
VP39	T2	324°	29	
VP59	T2	160°	14	

Site	Transect	Bearing from center point	Transect length	Center point cords (UTM)
VP63	T2	160°	24	
VP73	T2	160°	11	
VP81	T2	160°	10	
VP97	T2	160°	14	
VP120	T2	170°	20	
VP139	T2	160°	14	
VP41	T2	45°	29	
VP2	T3	240°	9	
VP3	T3	240	26	
VP12	T3	270	17	
VP20	T3	240	35	
VP33	T3	248	41	
VP35	T3	240	16	

Site	Transect	Bearing from center point	Transect length	Center point cords (UTM)
VP59	T3	265	20	
VP63	T3	240	20	
VP73	T3	293	13	
VP81	T3	240	13	
VP97	T3	250	53	
VP120	T3	310	14	
VP139	T3	240	22	
VP41	T3	45	49	

Appendix II. List of species recorded in IS wetlands to date.

Wetland Species	Common name
<i>Acer rubrum</i>	Red maple
<i>Acorus americanus</i>	American sweet flag
<i>Amelanchier</i> sp	shadbush
<i>Betula papyrifera</i>	shite birch
<i>Betula populifolia</i>	gray birch
<i>Bidens connata</i>	beggartick
<i>Brasenia schreberi</i>	water sheild
<i>Calamagrostis canadensis</i>	bluejoint
<i>Carex comosa</i>	bristly sedge
<i>Carex longii</i>	Long's sedge
<i>Carex lurida</i>	Shallow sedge
<i>Carex scoparia</i>	broom sedge
<i>Carex</i> spp.	Carex sedges
<i>Cephalanthus occidentalis</i>	buttonbush
<i>Ceratophyllum demersum</i>	hornwort
<i>Chamaecyparis thyoides</i>	Atlantic white cedar
<i>Chamaedaphne calyculata</i>	leatherleaf
<i>Clethra alnifolia</i>	pepperbush
<i>Decodon verticillatus</i>	water willow
<i>Drosera intermedia</i>	oblong-leaved sundew
<i>Dulichium arundinaceum</i>	three-way sedge
<i>Eleocharis palustris</i>	common spikesedge
<i>Eleocharis</i> spp.	Spikesedge species
<i>Eriophorum angustifolium</i>	cottongrass
<i>Eupatorium dubium</i>	joe pyeweed
<i>Euthamia tenuifolia</i>	slender goldentop
<i>Galium boreale</i>	northern bedstraw
<i>Galium tinctorium</i>	stiff marsh bedstraw

Wetland Species**Common name**

<i>Glyceria canadensis</i>	rattlesnake mannagrass
<i>Hypericum boreale</i>	northern stjohnswort
<i>Hypericum canadense</i>	Canada stjohnswort
<i>Ilex verticillatum</i>	winterberry
<i>Juncus acuminatus</i>	tapertip rush
<i>Juncus canadensis</i>	Canada rush
<i>Juncus effusus</i>	common rush
<i>Kalmia angustifolia</i>	sheep laurel
<i>Leersia oryzoides</i>	rice cutgrass
<i>Lemna minor</i>	duckweed
<i>Ludwigia palustris</i>	marsh seedbox
<i>Lycopus virginicus</i>	<u>Virginia water horehound</u>
<i>Lyonia ligustrina</i>	maleberry
<i>Lysimachia terrestris</i>	swamp candles
<i>Myrica gale</i>	sweetgale
<i>Morella pennsylvanica</i>	northern bayberry
<i>Najas spp.</i>	water nymph
<i>Nuphar lutea ssp. variegata</i>	yellow water lily
<i>Nymphaea odorata</i>	white water lily
<i>Nyssa sylvatica</i>	black gum
<i>Onoclea sensibilis</i>	sensitive fern
<i>Osmunda cinnamomea</i>	cinnamon fern
<i>Osmunda regalis</i>	royal fern
<i>Photinia floribunda</i>	purple chokeberry
<i>Phragmites australis</i>	common reed
<i>Poa palustris</i>	fowl bluegrass
<i>Polygonum hydropiper</i>	marshpepper knotweed
<i>Pontederia cordata</i>	pickerelweed
<i>Potamogeton spp.</i>	pondweed
<i>Proserpinaca palustris</i>	mermaidweed

Wetland Species**Common name***Rhododendron viscosum*

swamp azalea

Rosa palustris

swamp rose

Rubus flagellaris

northern dewberry

Rynchospora alba

white beak-sedge

Sagittaria latifolia

broadleaf arrowhead

Salix cinerea

gray willow

Salix nigra

black willow

Schoenoplectus pongens

common threesquare

Scirpus cyperinus

woolgrass

Scutellaria galericulata

common skullcap

Sium suave

water parsnip

Smilax rotundifolia

roundleaf catbriar

Solanum dulcamara

bittersweet nightshade

Solidago rugosa

wrinkle leaved goldenrod

Sparganium americanum

Americal bur-reed

Spiraea alba

white meadowsweet

Spiraea tomentosa

steeplebush

Thelypteris palustris

marsh fern

Triadenum virginicum

Virginia marsh stjohnswort

Typha angustifolia

narrowleaf cattail

Utricularia spp

bladderwort

Vaccinium corymbosum

highbush blueberry

Vaccinium macrocarpon

cranberry

Viburnum dentatum

arrowwood

Viburnum nudum

witherod

Woodwardia virginica

Virginia chain fern

Upland species**Common name***Deschampsia flexuosa*

hairgrass

Gaylussacia baccata

black huckleberry

Ilex glabra

inkberry

Morella pennsylvanica

Northern bayberry

Parthenocissus quinquefolia

Virginia creeper

Pinus rigida

pitch pine

Prunus serotina

black cherry

Quercus alba

white oak

Quercus ilifolia

scrub oak

Quercus velutina

black oak

Toxicodendron radicans

poison ivy

Vitis labrusca

Fox grape

Rosa multiflora

mutiflora rose

Verbascum thapsus

common mullein

Sassafras albidum

sassafras

Robinia pseudoacacia

black locust

Rhus copallina

winged sumac

Agrostis hyemalis

winter bentgrass

Corylus cornuta

beaked hazel

Solidago rugosa

wrinkleleaf goldenrod

Populus grandidentata

big-toother aspen

Ailanthis alissima

tree of heaven

Fagus grandifolia

beech

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.

NPS 609/129419, August 2015

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™