NBS/NPS Vegetation Mapping Program

An Environmentally-Driven Approach to Vegetation Sampling and Mapping at Yosemite National Park

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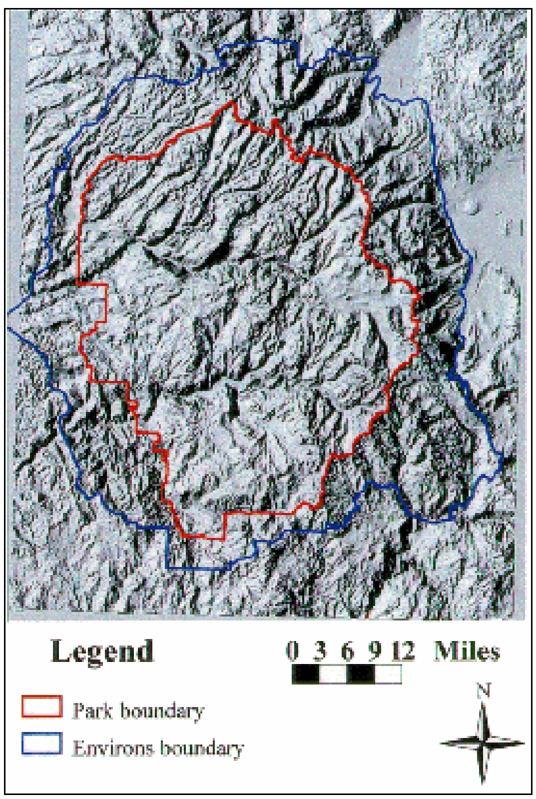
Background

The vegetation of Yosemite National Park, along with a large area of the surrounding landscape, will be classified and mapped through the application of standards that have been developed for the BRD/NPS Vegetation Mapping Program. The park and its environs is a large and environmentally complex area, encompassing over 1.39 million acres across the east and west slopes of the Sierra Nevada (see Figure 1). The diversity of vegetation types across this range of habitats is exceedingly complex. Past efforts to characterize and map the greater Yosemite region have resulted in the delineation of the broad scale vegetation patterns. The present mapping effort will present both a finer spatial delineation of vegetation polygons and the application of a consistent detailed vegetation classification system to characterize these polygons. This classification and mapping exercise will require a significant new sampling and analysis effort. An environmentally driven sampling approach is being developed to maximize the sampling efficiency for vegetation classification and mapping. This report describes the process that is being used to develop this sampling strategy, presents the preliminary map of Yosemite bio-environments, and a preliminary assessment of the sampling strategy that was completed using an existing vegetation map of the area.

Sampling Approaches

Many traditional ecological sampling techniques emphasize random plot and transect placement. However, the distribution of plant communities is not randomly distributed across the landscape, but is strongly influenced by environmental factors such as hydrology, insolation, temperature, and nutrient availability. Traditional randomized approaches have been shown to be sub-optimal for the study of non-random patterns (Gillison and Brewer 1985). Gillison and Brewer's study demonstrated that the same amount of information gathered by a random transect approach could be captured in a 27% shorter transect that was based on environmental stratification. In addition, this stratified approach was shown to capture 21% more patch richness than traditional random sampling techniques.

Figure 1. Yosemite National Park and Environs



In stratified random approaches, knowledge of the driving environmental factors and their relationship to the vegetation is used to develop a strategy for efficiently sampling the full range of biotic diversity. One of these approaches is the gradient-directed transect (gradsect) method, in which transects are placed along each of the major environmental gradients affecting vegetation pattern. Similar, but non-linear (transect) approaches also restrict sampling to sections of the larger area that demonstrate a high concentration of steep environmental gradients. Access points are taken into consideration when choosing these transects or other concentrated sampling areas, further increasing the efficiency of the data collection strategy.

Encompassing approximately 1.39 million acres of high-relief terrain, Yosemite and its environs contain an estimated 130 vegetation alliances and associations. The size of the region, combined with the unusually rugged terrain, makes the use of traditional sampling methods difficult. Yosemite staff have used the best available technology to increase the efficiency and accuracy of their vegetation sampling and mapping efforts. During the 1980's, Yosemite was one of the first National Parks to apply satellite imagery to vegetation sampling and mapping. Yosemite was also one of the first National Parks to make a long-term commitment to manage spatial information in Geographic Information Systems (GIS). The use of these technologies has resulted in good vegetation maps that have successfully captured the vegetation at a relatively coarse level of classification and spatial resolution.

The overall objective of the sampling and mapping effort is to produce a more detailed vegetation map for the greater Yosemite area. This detail will be evidenced in the classification resolution of the vegetation units as well as in the spatial resolution of the map units. The specific goal of the sampling strategy development effort described in this report is to identify a set of sample points that represent the range of environmental diversity across the greater Yosemite area. Fine scale biophysical patterns have been identified and mapped across the landscape and these will be used to direct vegetation sampling. Data collected using an environmentally stratified and replicated sampling scheme will provide the basis for developing a finer level, robust vegetation classification and map. The resulting information will help to elucidate the functional relationships between landscape features and vegetation types that are critical to resource conservation and resource management.

Methods

In May of 1997, a group of ecologists, spatial analysts and resource managers gathered at the Yosemite Research Station to develop the spatial data needed to support the completion of a efficient vegetation sampling strategy. Land management history and previous ecological surveys across the region had been reviewed in preparation for this meeting. The following tasks were completed for the study area:

(1) The preliminary list of vegetation types expected to occur in the study area was reviewed and refined.
(2) Existing plot data were assessed for their contribution to the refinement of the classification and required sampling effort.
(3) The most significant environmental variables that determine the distribution of vegetation types were identified, as were the appropriate classes for these variables.
(4) The appropriateness of available spatial datasets that could directly or indirectly map the driving environmental variables was determined.
(5) The most important spatial data sets were aggregated to develop a map of bio-environments across the study area.
(6) The map of bio-environments, along with road and trail maps was used to develop a preliminary vegetation sampling strategy across the study area.
(7) The efficiency of this preliminary sampling strategy was evaluated against an existing coarse-scale vegetation map of Yosemite (Weislander 1935, Moore 1993).

Determining the Magnitude of the Sampling Effort

The first step in identifying an efficient sampling approach was the development of a preliminary list of vegetation types for the study area at the classification level that is required for the mapping effort. The preliminary vegetation list was completed by a thorough literature review, a review of the California Natural Diversity Database's ecology files, and a review of earlier vegetation classifications and maps from Yosemite Park along with plot data from the surrounding National Forests. Approximately 130 vegetation alliances and related vegetation associations were identified as having a high probability of occurring within the study area.

This preliminary identification of vegetation types had two purposes. The first was to determine the number of sampling points that would be necessary across the study area to refine and document the vegetation types at a consistent level of classification. Past sampling and classification efforts were reviewed in relationship to the list of classification types to determine the additional number of plots per type that will be needed to meet the standards and objectives of this project. Over 350 plots that had been collected in previous research efforts in the park were reviewed for completeness and assigned to specific vegetation types for this purpose. Assuming a minimum of approximately 5 plots per vegetation type, 300 additional plots would be needed to fully characterize the vegetation.

The Delineation of Bio-Environments across the Study Region

The second use of the preliminary vegetation list was to provide the framework for the identification of the key environmental variables that determine the distribution patterns of the vegetation across this area. This was evaluated by experts of the local ecology. The driving variables for the vegetation at Yosemite and environs were determined to be nutrient availability, temperature, soil moisture, and solar insolation. None of these variables could be directly portrayed using existing spatial datasets for the study area. Slope, aspect, elevation, hydrology and geology maps were selected to be used to indirectly portray the direct variables that drive the distribution and patterning of the vegetation. Slope, aspect and elevation are closely correlated with temperature, soil moisture and insolation. Geology and hydrology are directly correlated with the resource gradients of nutrient and moisture availability.

Ecological experts subdivided these surrogate environmental variables into a restricted number of suitable classes that portray a meaningful, but manageable, number of vegetation bio-environments.

> The environmental differences and discontinuity between the ***East*** and ***West Slopes*** of the Sierra warranted treating them as two distinct ecological entities. An available digital

map delineating the Yosemite Park boundaries was used to create these divisions. See Figure 2.

Nine ***Elevation*** classes were identified based on well documented shifts in vegetation structure and composition. Different classes were selected for the east and the west slopes of the Sierras. The Digital Elevation Model (DEM) maps were used to delineate these classes. See Figure 2.

The ***Hydrology*** information was simplified into two classes, hydric and non-hydric. These were determined by merging a digital surface water map with a digital elevation model (DEM) to represent the intersection of surface waters with the landscape. The environs hydrology/DEM coverage was then converted to a 1,000,000-cell grid that allowed the aggregation of all cells containing water or within the horizontal plane of a water-bearing cell. This selection represented the hydric class that was used in the final map of bio-environments. All areas excluded from this selection were labeled non-hydric. The USGS River Reach files were used to create these maps in conjunction with the DEM. See Figure 3.

Five ***Aspect*** classes were recognized: southwest-facing, northwest-facing, northeast-facing, southeast-facing and flat areas with no aspect. The Digital Elevation Model (DEM) maps were used to delineate these classes. See Figure 4.

Three ***Slope*** classes were identified, characterizing level ground, moderate slope and steep slopes. The Digital Elevation Model (DEM) maps were used to delineate these classes. See Figure 5.

Geology was divided into five classes based on major substrate types that had an observed general influence on vegetation. State of California geologic substrate maps were used to represent these geologic classes. See Figure 6.

An additional variable that was introduced into this analysis was that of disturbance history. Maps were available that portrayed the locations of fires between 1930 and 1997. As the composition of vegetation will be determined by this natural disturbance phenomenon, two ***Fire History*** classes were also used to represent the bio-environments across the study area. The maps of fire disturbance which were combined to create this coverage had been developed and maintained by the Yosemite GIS lab. See Figure 7.

The environmental variables and their associated classes are presented in Table 1.

Table 1. Environmental variables and classes established for the study area.

VARIABLES:	**East/West Slopes and Elevation (ft) with corresponding major vegetation zone)**	**Hydrology**	**Aspect**	**Slope**	**Geology**	**Fire History**
CLASSES:	W < 3000 (foothill woodland)	Hydric	SW	0-3 degrees	Granitic	Burned since 1930
	W 3000-5000 (black oak-ponderosa pine)	Non-hydric	NW	3-35 degrees	Volcanic	Not burned since 1930
	W 5000-7000 (mixed conifer-white fir)		NE	>35 degrees	Moraine	
	W 7000-9000 (red fir)		SE		Alluvium	
	W 9000-11000 (mountain hemlock-whitebark pine)		FLAT		Metamorphic	
	W > 11000 (alpine)					
	E < 8000 (pinyon-juniper)					
	E 8000-10000 (lodgepole pine-whitebark pine)					
	E > 10000 (alpine)					
NUMBER	9	2	5	3	5	2

Figure 2. Elevation Classes

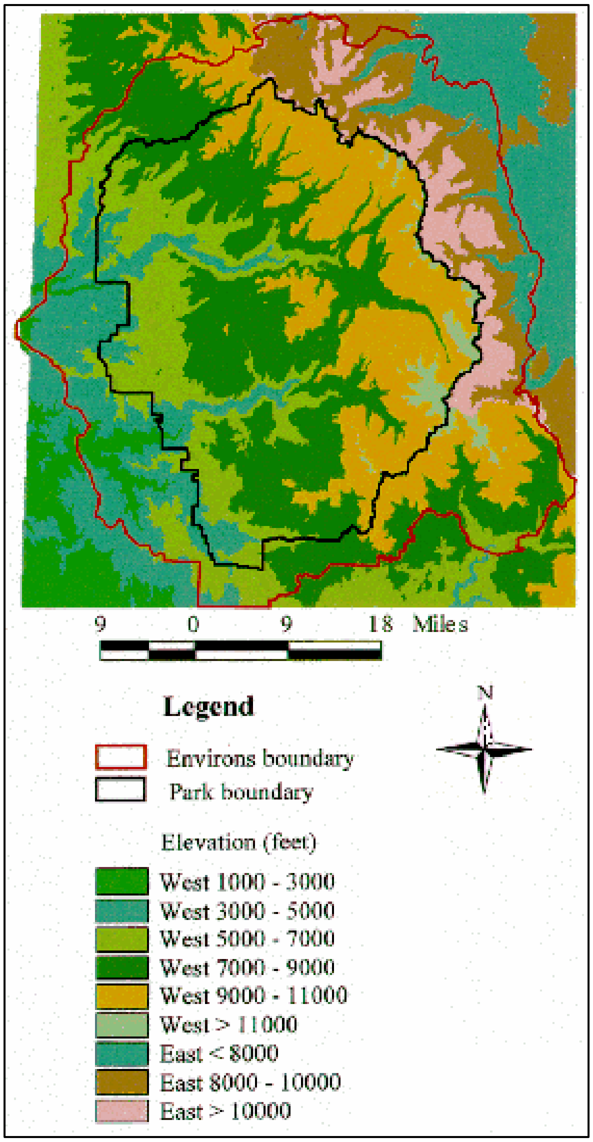


Figure 3. Hydrologic Classes

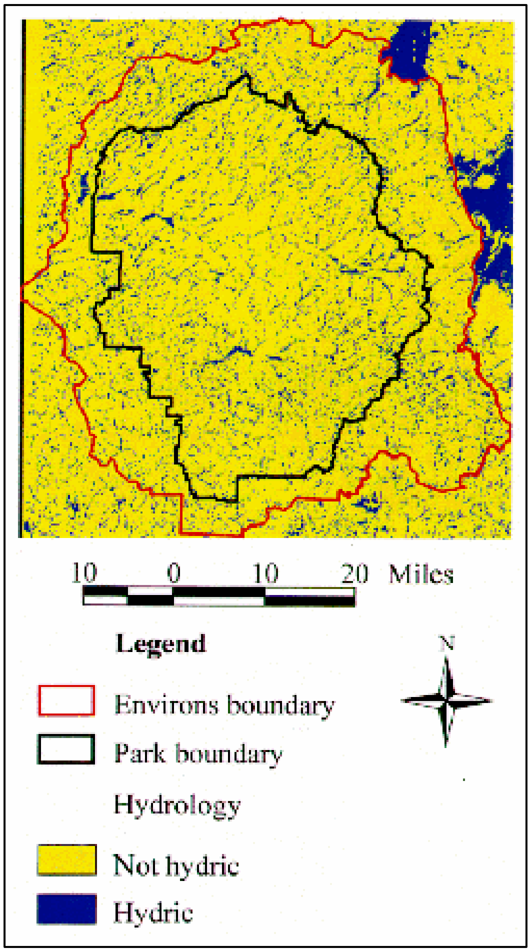


Figure 4. Aspect Classes

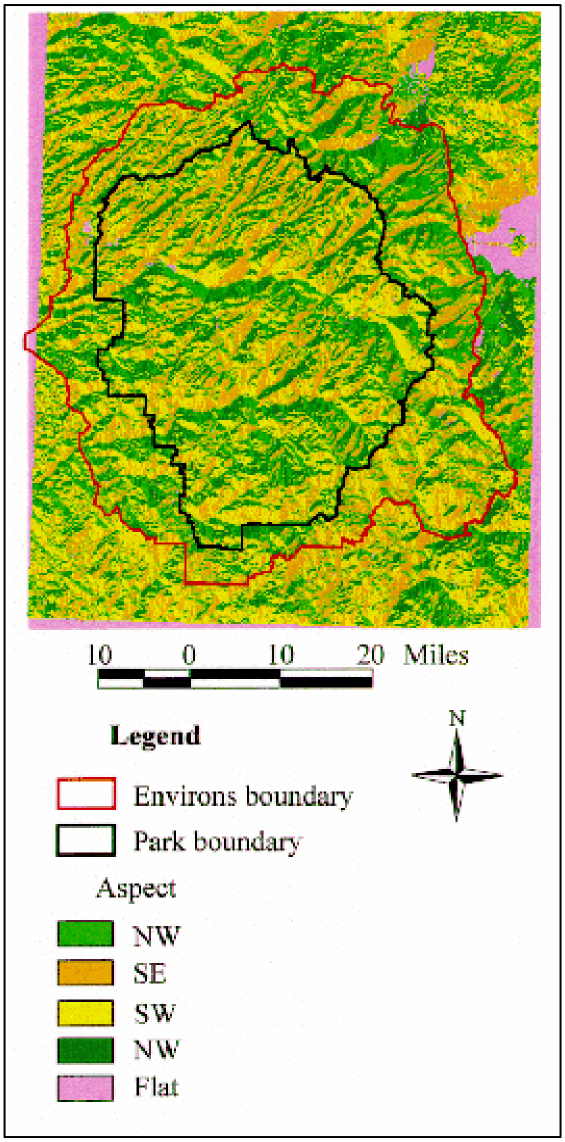


Figure 5. Slope Classes

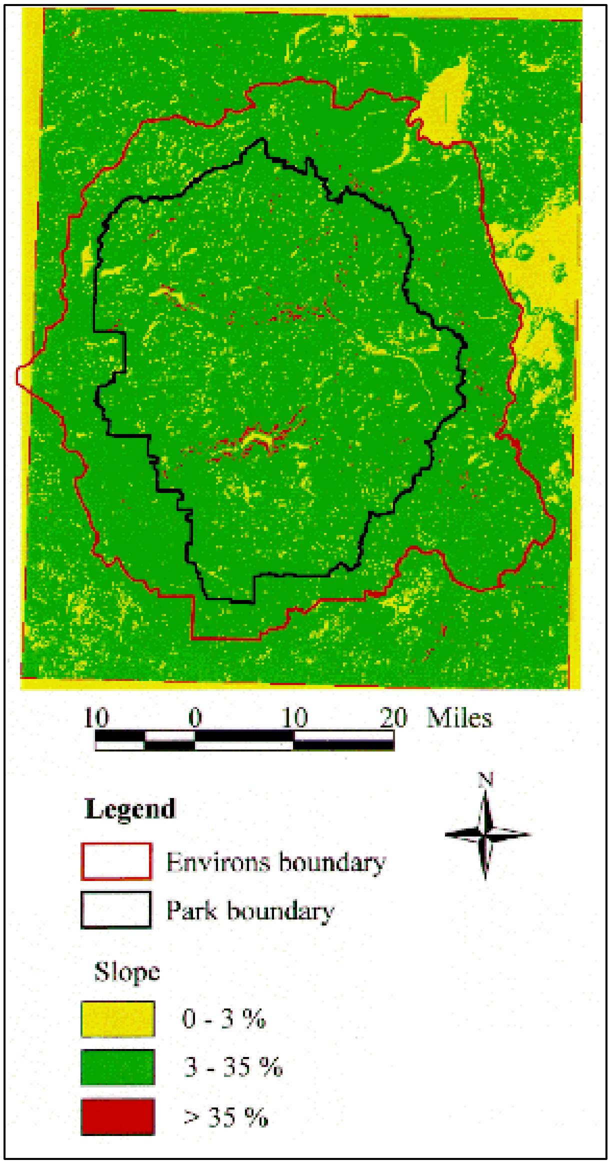


Figure 6. Geologic Classes

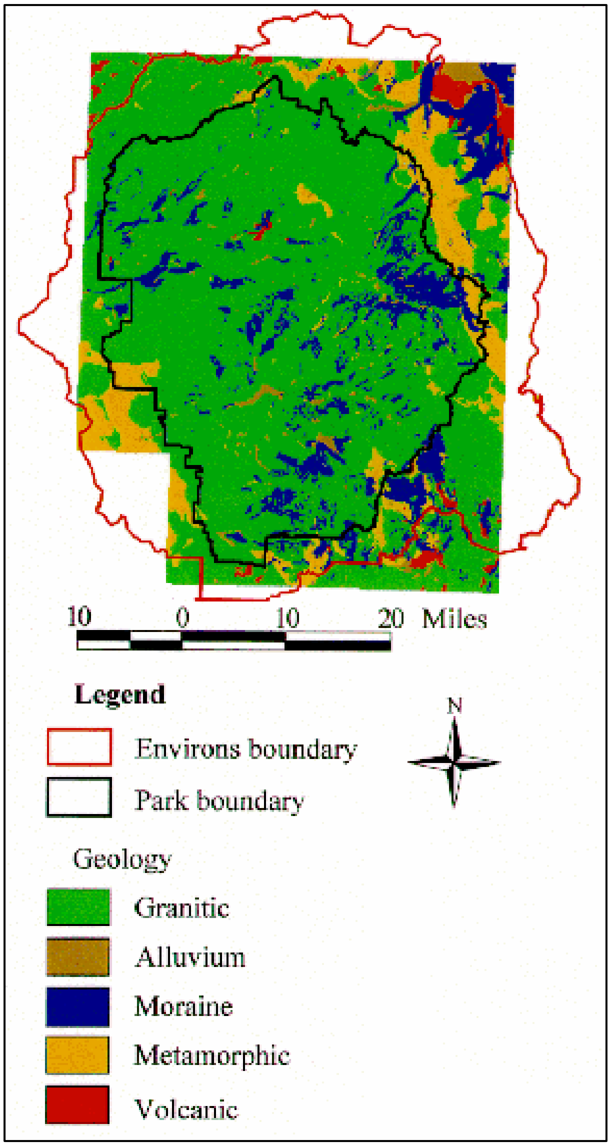
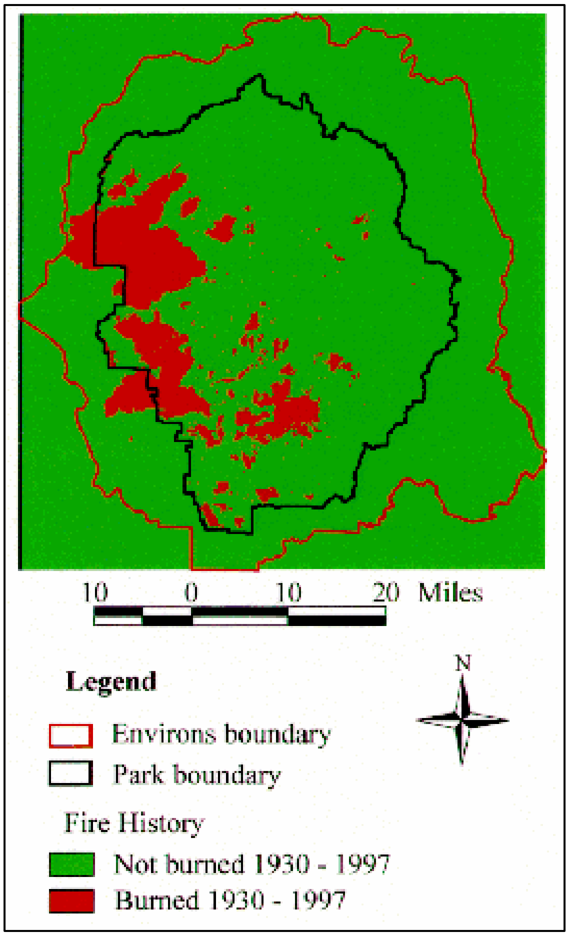


Figure 7. Fire History Classes



The map of each environmental variable was modified to represent specific classes that were determined as ecologically important to the response of the vegetation. Each map was transformed into 30 meter grids cells across the study area, with each grid cell representing the specific class attribute. All of the maps were then merged (overlaid) to create a secondary map. Each grid cell in the secondary map contained the class attributes of each environmental variable. Each unique combination of environmental classes represented an approximation of a distinct bio-environment.

Of the 2700 possible unique factorial combinations of all the environmental variable classes, about 1275 combinations actually occurred in the study area. This number, though large, was considered to be realistic given the size, topography, and overall environmental complexity of the study area. Additional filters that could reduce the number of bioenvironments that would need to be sampled were considered. The glaciated and granitic nature of the park has left large areas either unvegetated (bare rock) or covered by water. The spatial analysts identified and refined the aquatic areas using the hydrology and DEM grids to select the cells within, but not touching, the lake shores. A LandSat Thematic Mapper (TM) satellite image of the study area was the basis for the identification of unvegetated grid cells through the application of a minimum greenness threshold (NDVI). Masking out the grid cells that were fully covered by open water or were unvegetated rock removed approximately 300 bio-environments from the analysis. The final number of bio-environment types that needed to be sampled across this study area was 1074.

Results: The Development of a Sampling Strategy

The sampling goal is to obtain adequate vegetation data from every unique bio-environment. It is recognized that there may be more than one vegetation type found in each bio-environment. Similarly, one vegetation type could be found in multiple bio-environments. To develop the most efficient sampling strategy, areas with the steepest environmental gradients (places with multiple bio-environments in close proximity to each other), were identified and a subset of these were selected based on accessibility criteria.

A GIS analysis identified the tightest spatial clusters of multiple, unique bio-environments. A map was produced (see Figure 8) that represented these areas of steep environmental gradients. Approximately 80 percent of the bio-environments were contained within these clustered, high gradient areas. Representative examples of the residual 20 percent of bio-environments that did not occur in these high gradient areas were selected for sampling on the basis of their proximity to access points, such as roads and trails.

Accessibility to both the clustered and unclustered bio-environments was determined by an additional GIS analysis that located areas within a specified distance from access points off roads and trails. Figure 9 shows the distribution of all roads and major trails in the Park and environs. Figure 10 shows the distribution of all 1074 sampling sites that

Figure 8. Areas of High Concentration of Unique Bioenvironments

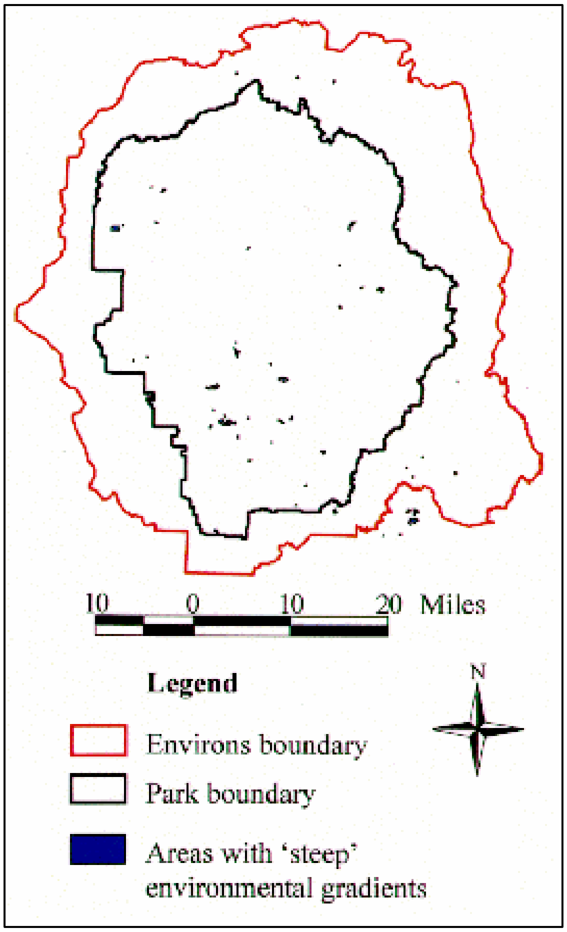


Figure 9. Roads and Trails

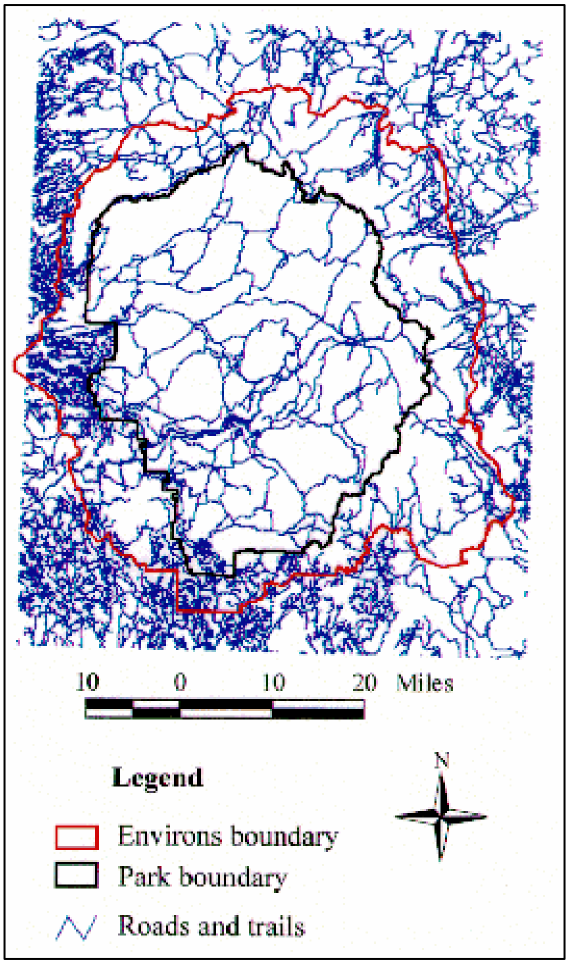
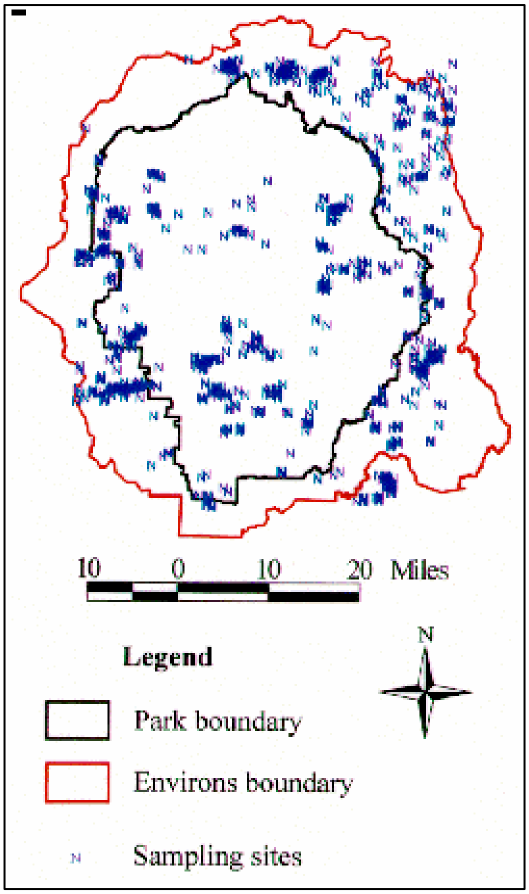


Figure 10. BPU Sampling Sites



were selected using the strategy of identifying high gradient clusters with a supplemental accessibility analysis.

For some bio-environments, adequate plot data exist and will obviate the need for further sampling, but the specific bio-environments with adequate existing data have not yet been determined. Existing vegetation plots that meet minimal standards for vegetation data and geographic referencing are presently being evaluated for use in this project. All acceptable plots are being attributed with preliminary vegetation classes based using the developing list of US National Vegetation Classification types. The locations of these plots are being mapped across the Park so that those bio-environments that have already been sampled will be factored into the sampling strategy for this project.

Testing the Effectiveness of the Bio-Environmental Sampling Strategy

The effectiveness of this sampling strategy was tested against an existing vegetation map for Yosemite National Park. This map was created from Wieslander's (1935) vegetation survey of the Park, which listed all tree species with greater than 20 percent cover for each delineated polygon. Based on these lists, Moore (1993) assigned vegetation types to each of these polygons (see Table 2). The map representing this work, and the basis for testing the environmentally based sampling strategy, is presented in Figure 11.

The Weislander map only covers Yosemite National Park. However, the sampling strategy described here would sample vegetation over a significantly larger area. Of the 1074 sampling sites that were identified in the larger environs, only 486 are located within the actual Park boundary. The 588 sites located outside of the Park would undoubtedly sample many of the vegetation types that were found also in the Park. Taking this into consideration, a partial test of the comprehensiveness of the sampling scheme was conducted by comparing the distribution of sampling sites within the Park to the existing Park map of major vegetation types. The robustness of the bio-environment sampling approach was then evaluated by determining the proportion of the vegetation types identified on the map that would have been sampled at least once under this environmentally driven sampling approach.

Table 2 lists the Moore (1993) vegetation types, the total area occupied by each type, the number of sampling sites located within each, and the proportion of the 486 within-Park sampling sites that this represents.

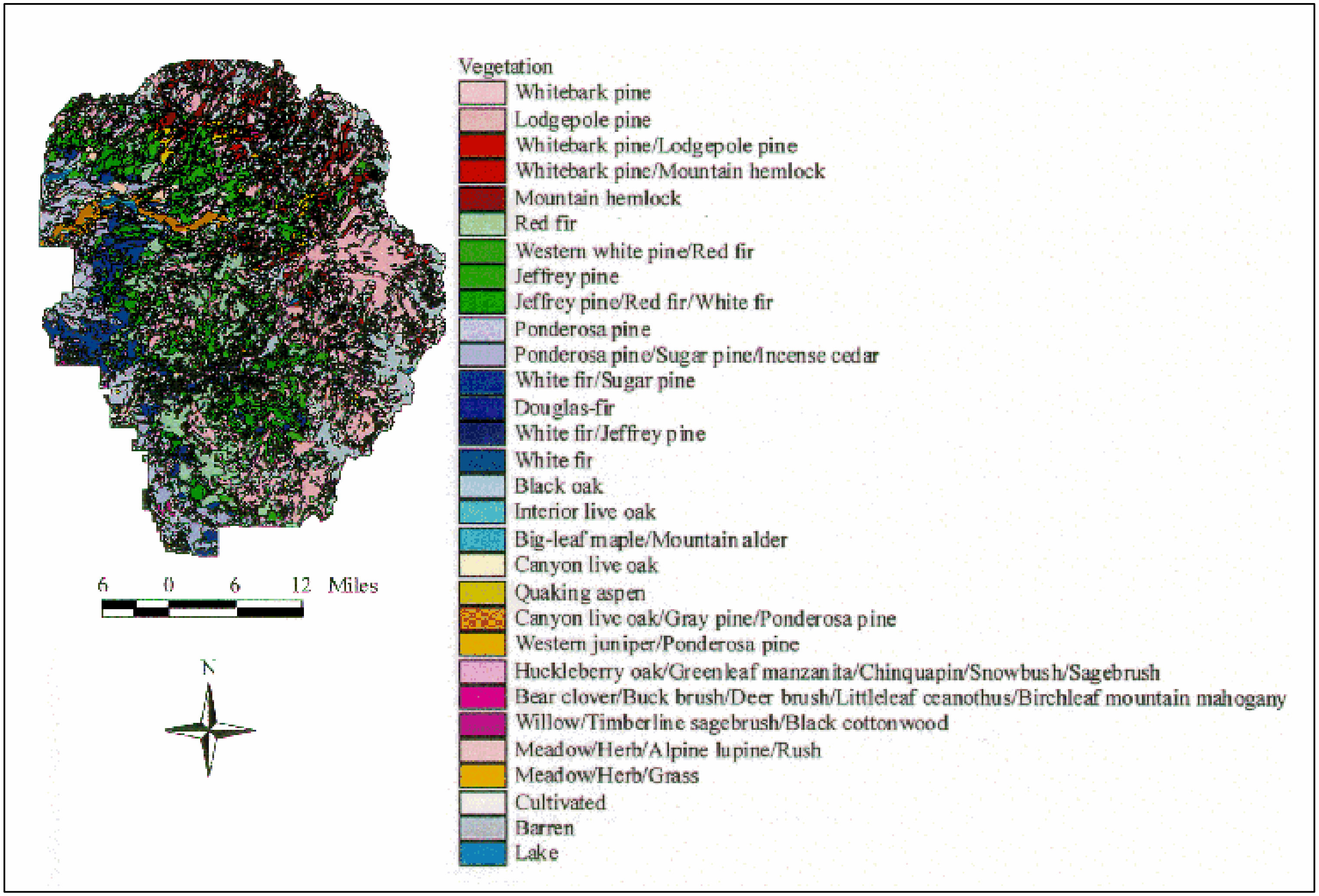
Table 2. Moore's (1993) Vegetation Types and Bio-Environmental Sample Sites

[Highlighted rows identify the vegetation types that would not have been sampled using the environmentally driven sampling approach.]

Vegetation Type (Dominant Species)	Total Area Occupied in Park (ha)	Percent of Total Park Area	Number of Bio-EnvironmentSample Sites	Percent of Bio-Environment Sample Sites
Whitebark pine	10438	3.5	0	0.0
lodgepole pine	65671	21.7	111	22.8
whitebark pine/lodgepole pine	1392	0.5	0	0.0
whitebark pine/mountain hemlock	3927	1.3	0	0.0
mountain hemlock	12801	4.2	7	1.4
red fir	27295	9.0	31	6.4
western white pine/red fir	11647	3.9	9	1.9
Jeffrey pine	24052	8.0	28	5.8
Jeffrey pine/red fir/white fir	16051	5.3	30	6.2
ponderosa pine	13569	4.5	54	11.1
ponderosa pine/sugar pine/incense cedar	13764	4.6	23	4.7
white fir/sugar pine	11844	3.9	36	7.4
Douglas-fir	1900	0.6	25	5.1
white fir/Jeffrey pine	5165	1.7	5	1.0
white fir	88	0.0	3	0.6
black oak	1286	0.4	1	0.2
interior live oak	95	0.0	0	0.0
big-leaf maple/mountain alder	28	0.0	0	0.0
canyon live oak/Jeffrey pine	6571	2.2	9	1.9
quaking aspen	802	0.3	2	0.4
canyon live oak/gray pine/ponderosa pine	4779	1.6	14	2.9
western juniper/ponderosa pine	3686	1.2	1	0.2
huckleberry oak/greenleaf manzanita/chinquapin/snow bush/sagebrush	5891	1.9	6	1.2
bear clover/buck brush/deer brush/littleleaf ceanothus/birchleaf mountain mahogany	718	0.2	0	0.0
willow/timberline sagebrush/black cottonwood	1364	0.5	0	0.0
meadow/herb/alpine lupine/rush	9368	3.1	31	6.4
meadow/herb/grass	620	0.2	6	1.2
cultivated	81	0.0	1	0.2
barren	44535	14.7	48	9.9
lake	2894	1.0	5	1.0
TOTAL	**302321**	**100**	**486**	**100.0**

Figure 11. Yosemite National Park Vegetation

(Wieslander 1935, Moore 1993)



Twenty-three of the 30 vegetation types, or 76 percent, would have been sampled at least once using the bio-environment sampling strategy. These types represent 94 percent of the area of the Park. Of the 7 types that would not have been sampled, only 2 occupy more than 0.5 percent of the total area of the Park. These 2 types - whitebark pine and whitebark pine/mountain hemlock - typically occur at elevations above 10,000 feet on west to northeast facing slopes (T. Keeler-Wolf, *personal communication*). They are common at high elevations within the park and also occur outside of the Park boundary, but within the study area. It is possible that at least two of the 588 sampling sites (54.7 percent of the total) located outside of the Park would capture these two whitebark pine vegetation types. However, because these are very sparsely vegetated types, it is also possible that the NDVI greenness index needs to be recalibrated to ensure that whitebark pine areas are not being "masked out" as high elevation bare rock.

The sampling approach appears to be robust in providing comprehensive sampling of most major vegetation types while maximizing efficiency. However, the usefulness of this method for capturing the finer-scale association or alliance level classification to be used for the map of the area will only be known after sampling has been completed.

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