SPECTRAL REFLECTANCE CHARACTERISTICS OF CALIFORNIA SUBALPINE MARSH PLANT COMMUNITIES

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Abstract: Reflectance spectra (414–948 nm) were recorded at ground level from leaves and canopies of subalpine marsh macrophytes near Lake Tahoe, California in 1994. Canopy architecture of the dominant species suggested that canopy reflectance should differ from one another: yellow pond-lily (Nuphar polysepalum) has a horizontal canopy; hardstem bulrush (Scirpus acutus) has a vertical canopy; beaked sedge (Carex rostrata) has a spherical (randomly distributed) canopy. Data were used to 1) analyze effects of canopy architecture on reflectance properties, 2) examine effects of canopy architecture on use of spectral vegetation indices as predictors of biomass, and 3) develop methods for detecting species distributions. Leaf reflectance spectra were different in shape and magnitude across the spectrum, with canopy architecture and cover having marked effects on albedo and wavelength-dependent variance among samples. Nuphar polysepalum (horizontal canopy) showed the least difference between canopy and leaf reflectance, S. acutus (vertical canopy) reflectance was most affected by canopy architecture, and C. rostrata (spherical canopy) was intermediate. Reflectance in the near infrared (NIR) region was strongly reduced, while reflectance in the visible region was minimally affected, producing small red/NIR differences and low vegetation indices. Seven vegetation indices were tested for correlation with plant biomass. Fresh and dry green biomass of C. rostrata were significantly correlated with all indices (p<0.002), while no correlation was found between any index and fresh or dry green biomass of N. polysepalum (p>0.13) or S. acutus (p>0.21), suggesting that spectral indices as estimators of biomass assume a spherical vegetation canopy. Differences between Thematic Mapper (TM) bands 3 (red) and 2 (green) normalized by the sum of reflectance ((TM3 - TM2)/(TM3 + TM2)), was significantly different among species (p<0.05) and was used as the basis of a supervised classification of a large Lake Tahoe marsh. The classification agrees with the data on distributions of species and expected distributions in relation to water depth.

Key Words: subalpine marshes, freshwater wetland, remote sensing of wetlands, canopy architecture, vegetation indices, wetland monitoring, spectral reflectance

INTRODUCTION

Monitoring the effects of multiple, interacting stresses on ecosystems dominated by long-lived organisms such as trees is difficult due to the long temporal scales at which ecological processes operate. Effective monitoring of these ecosystems requires indicators that respond in a rapid and measurable way to anthropogenic and natural stresses. Previous work on ecological indicators has concentrated on using one or a few species (Landres et al. 1988, Adamus and Brandt 1990, Hunsacker and Carpenter 1990). This narrow focus is based on an assumption that the selected species respond to all potential stresses or to the most significant ones facing the ecosystem (Kimball and Levin 1985, Cairns 1986). Entire species assemblages, as opposed to a specific species, may be more sensitive indicators of ecological stress. For example, shifts in relative abundances of taxa or of functional groups, or changes in species distributions along environmental gradients can be monitored using remote sensing.

Subalpine marshes that are found scattered throughout the forested ecosystems of the western United States have a combination of botanical and hydrologic properties that may make them suitable as ecological indicators of short-term changes in the surrounding landscape. These properties include 1) processes in the larger landscape being strong determinants of marsh ecosystem characteristics; 2) marshes responding rapidly to environmental change; and 3) marshes being more easily monitored than the larger forested communities because of their small size and distinct boundaries. We investigated the use of remote sensing to detect within-marsh distributions of dominant marsh plant species.
Marshes in the Sierra Nevada depend on water sources that have been in close contact with plants and soils of the surrounding watershed. Precipitation in the Sierra Nevada range has a distinct winter maximum due to winter storms moving inland from the Pacific Ocean that produce large annual snowfalls (up to 22.5 m). During the summer growing season, almost no precipitation occurs (less than 5% of annual total) except for an occasional convectional thunderstorm (Storer and Usinger 1963, Reuter 1995). Consequently, marshes in the region depend on runoff and groundwater discharge derived from snowfall. This situation closely ties marsh hydrology to upland communities and ties the marsh ecology to upland conditions.

Herbaceous plant species, which can respond rapidly to local changes in environmental conditions, dominate these plant communities and are typically found in monospecific zones that are distributed along the water-depth gradient. The positions of these zones are determined by local environmental gradients that can change from year to year (Windell et al. 1986). Variations in the positions of these zones and in standing biomass may correlate with changing ecosystem conditions over the recent past (one to several years) and provide a means of quantitatively assessing these changes.

An important basis for expecting that Sierra Nevada subalpine marsh communities would be useful ecological indicators, and the main focus of this paper, is the potential that remote sensing can be used to monitor species distributions and biomass. The dominant species, which grow in adjacent, distinct zones have very different canopy architectures. Yellow pond-lily, *Nuphar polysepalum* Englemann (= *N. luteum* (L.) Sibth. and Sm. ssp. *polysepalum* (Englemann) Beal), typically occupies the deepest, semipermanently flooded parts of the marsh and has a horizontal canopy with leaf surfaces oriented nearly horizontally (i.e., leaf angles near 90°). Hardstem bulrush, *Scirpus acutus* Bigelow var. *occidentalis* (Watson) Beetle, occupies areas of intermediate water depth where the soil generally remains permanently moist and has an extremely vertical canopy with leaf surfaces oriented near vertical (i.e., near 0°). Beaked sedge, *Carex rostrata* Stokes (= *C. utriculata* Boott), occupies the seasonally flooded shallower portions of the marsh that often dry out by midsummer. This species has a spherical canopy with a quasi-normally distributed surface orientation and a mix of horizontally and vertically oriented elements (Figure 1) (Windell 1986, Hickman 1993).

Canopy architecture is a major determinant of canopy reflection properties. It affects reflectance through...