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LIGHT REFLECTANCE CHARACTERISTICS AND FILM IMAGE RELATIONS AMONG THREE AQUATIC PLANT SPECIES

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Abstract.—Radiometric canopy light reflectance measurements were made on three aquatic plant species in Lake Texana near Edna in southeast Texas. Plant species studied included waterhyacinth (*Eichhornia crassipes*), American lotus (*Nelumbo lutea*) and hydrilla (*Hydrilla verticillata*). Reflectance measurements were made at the visible green (0.52-0.60 μm), visible red (0.63-0.69 μm), and near-infrared (NIR) (0.76-0.90 μm) wavelengths. Reflectance values differed significantly (P=0.05) among the three species at all three wavelengths. Differences in reflectance were primarily attributed to variable foliage coloration and vegetative density; however, the NIR reflectance of hydrilla was also contributed to by a large percentage of the plant being below the water surface. Color-infrared (CIR) aerial photographs of the three species showed that they could be readily differentiated. Reflectance measurements were related to the image tonal responses of the plant species on CIR film.

The inaccessibility and often large expanses of many wetlands make ground inventory and assessment difficult, time consuming, expensive and often inaccurate (Scarpace et al. 1981). Consequently, remote sensing techniques employing aerial photography have been used extensively to inventory and assess wetlands (Carter 1982; Tiner 1997). The high resolution of aerial photography makes it particularly useful for dis-tinguishing among individual aquatic plant species (Seher & Tueller 1973; Carter 1982; Martyn 1985).

Light reflectance measurements have been used to differentiate between stressed and nonstressed crop plants (Gausman 1985) and to distinguish among individual crop, weed and wetland plant species (Gausman & Allen 1973; Gausman et al. 1981; Best et al. 1981). Reflectance measurements have also been used to distinguish between woody plant species (Gausman et al. 1977) and coastal zone plant species (Everitt et al. 1999) and related to their tonal responses on CIR aerial photographs.

Little information is available on the light reflectance characteristics of aquatic plant species. The objectives of this study were to: (1)

characterize the visible and NIR reflectance of three common aquatic plant species in a Texas lake and (2) evaluate large scale CIR aerial photography for remotely distinguishing among these plant species.

STUDY SITE

This study was conducted at Lake Texana near Edna in Jackson County, Texas. Edna is located approximately 35 km northeast of Victoria, Texas. Lake Texana was chosen as a study site because it supports large populations of aquatic plant species. Plant canopy reflectance measurements, aerial photographs and ground truth observations were conducted for this study.

METHODS AND MATERIALS

Radiometric plant canopy reflectance measurements were made on three common aquatic plant species: waterhyacinth (*Eichhornia crassipes*), American lotus (*Nelumbo lutea*) and hydrilla (*Hydrilla verticillata*). Waterhyacinth is a floating species, American lotus is an emersed species, and hydrilla is a submersed species. These species are abundant in Lake Texana and occur in lakes and streams throughout the southeastern United States. Reflectance measurements were made on 10 randomly selected plant canopies of each species with a Barnes modular multispectral radiometer (Robinson et al. 1979). Measurements were made in the visible green (0.52-0.60 μm), visible red (0.63-0.69 μm) and NIR (0.76-0.90 μm) spectral bands with a sensor that had a 15-degree field-of-view placed approximately 1.0 to 1.5 m above each plant canopy. Measurements were made using a small boat. Field radiometric measurements were corrected to reflectance using a barium sulfate standard. All reflectance measurements were made between 1130 and 1400 h under sunny conditions on 30 September 1998. Overhead photographs were taken of plant canopies measured with the radiometer to help interpret reflectance data.

Kodak Aerochrome CIR (0.50-0.90 μm) type 2443 film was used for aerial photographs. Color-infrared film is sensitive in the visible green (0.50-0.60 μm), visible red (0.60-0.70 μm), and NIR (0.70-0.90 μm) spectral regions. Photographs were taken with a Hasselblad 70-mm camera equipped with a 80-mm lens and an orange (minus blue) filter. The camera had an aperture setting of f11 at 1/500 sec. Photographs were taken on 11 August 1998 at an altitude above ground level of 460 m and a scale of approximately 1:6000. All photographs (nadir) were obtained under sunny conditions using a Cessna 404 fixed-wing aircraft. The camera was mounted vertically in a camera port in the floor of the

Table 1. Canopy light reflectance of three aquatic plant species at the green, red, and near-infrared wavelengths. Reflectance measurements were made with a Barnes modular multispectral radiometer at Lake Texana near Edna, Texas.

Plant species	Reflectance (%) for three wavelengths		
	Green	Red	Near-infrared
Nelumbo lutea (Willd.) Pers (American lotus)	9.3 a[1]	3.4 a	47.5 a
Eichhornia crassipes (Mart.) Solms (Waterhyacinth)	4.3 b	1.7 b	42.3 a
Hydrilla verticillata (L. F.) Royle (Hydrilla)	3.0 c	1.6 b	15.3 b

[1] Means within a column followed by the same letter do not differ significantly at the 5% probability level, according to Duncan's multiple range test.

aircraft. Field surveys were conducted at sites where aerial photographs were obtained. Aerial photographic prints were used to verify plant species and ecological parameters.

Visible green and red, and NIR reflectance data were analyzed using *ANOVA* techniques. Duncan's multiple range test was used to test statistical significance at the 0.05 probability level among means (Steel & Torrie 1980). Trade names are included for the benefit of the reader and do not imply an endorsement of or a preference for the product listed by the United States Department of Agriculture.

Results and Discussion

Mean canopy light reflectance measurements for the three plant species at three wavelengths are given in Table 1. Reflectance values differed significantly (P=0.05) among the three species at the visible green wavelength, with American lotus having the highest reflectance and hydrilla the lowest. At the visible red wavelength, American lotus had higher reflectance than waterhyacinth and hydrilla. Differences in visible reflectance among the plant species was primarily attributed to differences in foliage color and subsequent plant pigments (Myers et al. 1983; Gausman 1985). American lotus had light green leaves, whereas waterhyacinth and hydrilla had dark green and deep dark green leaves, respectively. The darker green foliage (higher chlorophyll concentration) of waterhyacinth and hydrilla reflected less of the green light and absorbed more of the red light than the light green foliage (lower chlorophyll concentration) of American lotus (Gausman 1985).

American lotus and waterhyacinth had significantly higher (P=0.05) reflectance at the NIR wavelength than hydrilla (Table 1). Near-infrared reflectance in vegetation is highly correlated with plant density (Myers et al. 1983; Everitt et al. 1986). A qualitative analysis of the overhead photographs of the three species showed that American lotus and water-hyacinth had greater leaf density and less gaps in their canopies than hydrilla. American lotus and waterhyacinth also had large leaves as opposed to the very small leaves of hydrilla. Both American lotus and waterhyacinth had > 90% cover with very little water showing in the background. Conversely, hydrilla had 50-60% cover with only the upper portion of the plants exposed at the surface; a large percentage of the plant biomass was approximately 1-2 cm below the surface of the water. The low NIR reflectance of hydrilla was attributed to both its more open canopy and to the water integrated with its canopy which absorbed a large percentage of the NIR light (Myers et al. 1983; Everitt et al. 1989).

American lotus, waterhyacinth and hydrilla could be distinguished in CIR aerial photographs (not shown) obtained on 11 August 1998 at Lake Texana. American lotus had a distinct pink image response, whereas waterhyacinth had a bright red image tone. Hydrilla had a dark brown color that could be easily differentiated. Mixed populations of American lotus and waterhyacinth had a orange-red color. All three species had similar CIR image responses at eight scattered locations in Lake Texana and could be readily separated at each location.

The pink image of American lotus was primarily attributed to its high visible green and moderately high visible red reflectance values, whereas the bright red image tone of waterhyacinth was attributed to both its low green and red reflectance values. The high NIR reflectance of both American lotus and waterhyacinth also contributed to their image responses. The dark brown color of hydrilla was primarily attributed to its very low NIR reflectance; however, its low visible green and red reflectance also influenced its image response. Martyn (1985) reported that surfaced hydrilla plants had a cinnamon-brown image tone in CIR aerial photos. The darker brown CIR image of hydrilla in this study was probably due to a large percentage of the plants being slightly below (1-2 cm) the water surface.

CONCLUSIONS

Results from this study showed that radiometric plant canopy light reflectance measurements at two visible wavelengths and one NIR wavelength varied greatly for American lotus, waterhyacinth and hydrilla. Differences in reflectance among the three plant species was related to variable foliage colors and plant canopy densities. The low NIR reflectance of hydrilla was also contributed to a large percentage of the plant being below the water surface. Color-infrared aerial photographs obtained of the three species showed that they could be readily distinguished. Reflectance measurements could be related to the CIR film tonal responses of the three species. Although the phenology of these species was not studied, the optimum time to acquire aerial photographs is probably from mid to late summer when the plants have reached peak foliage development (Everitt et al. 1980). The reflectance measurements assisted in the interpretation and understanding the association among the plant species reflectivity and color tonal responses on the CIR film. The ability to remotely distinguish among American lotus, waterhyacinth and hydrilla should enhance future remote sensing inventories of lakes and other waterways where these species occur.

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