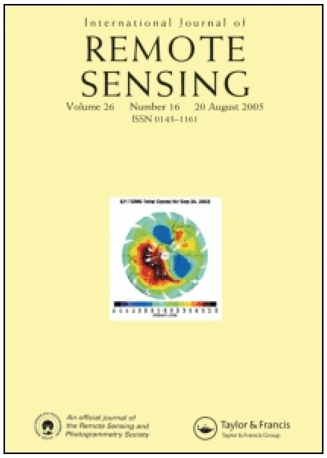

International Journal of Remote Sensing
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713722504

Close-range remote sensing of aquatic macrophyte vegetation cover

M. Jakubauskas; K. Kindscher; A. Fraser; D. Debinski; K. P. Price

Online Publication Date: 15 December 2000
To cite this Article: Jakubauskas, M., Kindscher, K., Fraser, A., Debinski, D. and Price, K. P. (2000) 'Close-range remote sensing of aquatic macrophyte vegetation cover', International Journal of Remote Sensing, 21:18, 3533 - 3538
To link to this article: DOI: 10.1080/014311600750037543
URL: http://dx.doi.org/10.1080/014311600750037543

INT. J. REMOTE SENSING, 2000, VOL. 21, NO. 18, 3533–3538

Close-range remote sensing of aquatic macrophyte vegetation cover

M. JAKUBAUSKAS†*, K. KINDSCHER‡, A. FRASER‡, D. DEBINSKI§ and K. P. PRICE†

†Kansas Applied Remote Sensing (KARS) Program, 2291 Irving Hill Road, University of Kansas, Lawrence, Kansas 66045-2969, USA
‡Kansas Biological Survey, 2401 Constant Ave, University of Kansas, Lawrence, Kansas 66045-2969, USA
§Department of Animal Ecology, 124 Science II, Iowa State University, Ames, Iowa 50011, USA

(*Received 30 September 1998; in final form 27 March 2000*)

Abstract. This study used ground-based hyperspectral radiometry to examine variations in visible and near-infrared spectral reflectance of spatterdock (*Nuphar polysepalum* Engelm.) as a function of vegetation cover. Sites were sampled in Swan Lake in Grand Teton National Park, Wyoming, using a 512-band spectroradiometer to measure reflectance over the range 326.5–1055.3 nm (visible-near-infrared) and simultaneous estimates of spatterdock cover. Linear correlations between spatterdock cover and spectral reflectance were statistically significant at the 0.05 significance level in two specific ranges of the spectrum: 518–607 nm; and 697–900 nm. Predictability of spatterdock cover using spectral variables was best using an NDVI transformation of the data in a non-linear equation ($r^2 = 0.95$).

1. Introduction

Spatterdock (*Nuphar polysepalum* Engelm.), also known as yellow pond lily or cow lily, is the only species of waterlily native to the western United States. The plant is an emergent aquatic macrophyte, occurring in water depths of up to three meters in ponds, lakes, and oxbows. Spatterdock is characterized by large (10–40 cm) ovate, waxy leaves that float on the water surface, and large distinctive yellow to red-tinged blossoms. Emergent aquatic macrophytes such as spatterdock are important components of pond ecosystems, providing shade cover and maintaining cooler water temperatures for fish and other aquatic organisms. As spatterdock requires high water quality, poor or declining spatterdock cover may therefore provide an indicator of water quality status and change. *In situ* sampling of emergent wetland vegetation such as spatterdock presents numerous challenges, including access to and accurate location of sampling plots. While aerial photography and satellite remotely sensed imagery have been used to monitor seasonal and yearly changes in the extent of aquatic macrophytes (Jensen *et al.* 1993, Jensen 1992, Nohara 1991, Welch *et al.* 1988), few studies have attempted to address quantitative estimation of cover based on spectral reflectance. Our intent is to quantify relationships between

*e-mail: mjakub@eagle.cc.ukans.edu

International Journal of Remote Sensing
ISSN 0143-1161 print/ISSN 1366-5901 online
http://www.tandf.co.uk/journals

spectral reflectance and spatterdock cover, with the eventual goal of developing a methodology for indirect estimation of spatterdock cover using multispectral remotely sensed imagery.

Within the Greater Yellowstone Ecosystem, spatterdock is generally found in small (usually <20 ha), relatively shallow ponds formed in glacial moraine deposits at the end of the Pleistocene glaciation. Of the wetland vegetation communities that occur in the park, spatterdock occurs in the deepest water, before open water begins, and is commonly ringed by shallow-water wetland vegetation communities, including bulrush (*Scirpus acutus* Muhl.), common spikerush (*Eleocharis palustris* {L.} R.&S.), or beaked sedge (*Carex rostrata* Stokes). Other wetland vegetation communities within the Yellowstone region include willow (*Salix wolfii*, *Salix boothii*, *Salix planifolia*), sedge meadows (dominated by *Carex rostrata*), bulrushes (*Scirpus acutus*) and common spikerush (*Eleocharis palustris*) (Kindscher *et al.* 1998).

2. Methods

Field sampling was performed in Grand Teton National Park, Wyoming, at multiple sites on Swan Lake, a shallow pond with an approximate area of 20 ha. Fifteen plots, representing a range of spatterdock cover from 0–100% were sampled on 30 July 1998 between 1145 and 1215 hrs MDT. Readings were taken using an Analytical Spectral Devices (ASD) Personal Spectroradiometer II, recording 512 discrete spectral bands over the range 326.5–1055.3 nm (visible to near-infrared), with an instantaneous-field-of-view (IFOV) of 0.47 radian. Nadir view measurements for each $1\,\mathrm{m}\times 1\,\mathrm{m}$ quadrat were made with the sensor head at 2 m above the water surface. Ten spectroradiometer scans per quadrat were acquired and internally averaged by the ASD system. Spectral measurements were converted to reflectance by dividing them by white reference scans of a Spectralon standard white reference panel immediately prior to taking spectral measurements. Cloud cover was variable during sampling, necessitating calibration before each spectral reading for each quadrat. Visual estimates of percentage spatterdock cover were made at the time of each spectral measurement. A Normalized Difference Vegetation Index (NDVI) was calculated using spectral reflectance values at 660 nm (red reflectance) and 830 nm (near-infrared reflectance) and the equation $(\mathrm{NIR}-\mathrm{Red})/(\mathrm{NIR}+\mathrm{Red})$. For this study, data from wavelengths shorter than 400.33 nm and longer than 900.56 nm were not used due to noise in the reflectance signal. Correlations between spatterdock percent cover and spectral reflectance data were calculated using a significance level of $\alpha=0.05$.

3. Results and discussion

Spectral reflectance curves for high (78%, 88%, and 100%) cover values by spatterdock form a classic vegetation spectral response curve, with high reflectance in wavelengths greater than 750 nm and strong absorption in 400–500 nm (blue reflectance) and 600–700 nm (red reflectance) (figure 1). As the percentage cover by spatterdock decreases, exposing progressively more water area to the sensor, reflectance rapidly decreases in the 700–900 nm range, eventually producing a nearly flat reflectance curve for 0% plant cover (100% water area). The reflectance curve for 100% water cover does not fall to zero reflectance in any band, however, due to residual bottom and volume reflectance (Goodin *et al.* 1993, Han and Rundquist 1994). Decreases in spectral reflectance of lesser magnitude occur in the 525–575 nm range of the spectrum with decreasing plant cover.

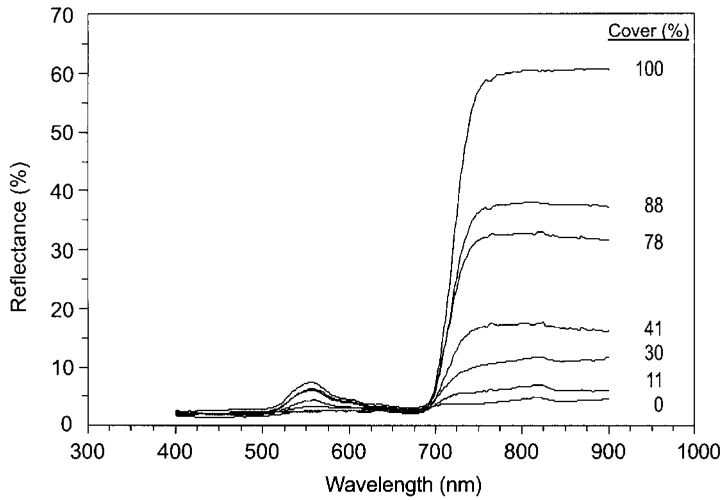

Figure 1. Spectral reflectance curves over the range of 400–900 nm for spatterdock cover ranging from 0–100%.

Correlation coefficients were plotted as a function of wavelength (figure 2). Linear correlations between spatterdock cover and spectral reflectance were statistically significant in two specific ranges of the spectrum: 518–607 nm; and 697–900 nm. Highest correlations occurred at 546–559 nm ($r = 0.88$) and 718–725 nm ($r = 0.94$). The linear correlation between spatterdock cover and NDVI was significant ($r = 0.94$). While the relationship between green reflectance (560 nm) and cover can be captured in a linear function (figure 3), scatterplots of near-infrared reflectance (830 nm) indicate that the relationship is best represented as an exponential function ($r^2 = 0.91$) (figure 4). Similarly, the relationship between NDVI and cover is best

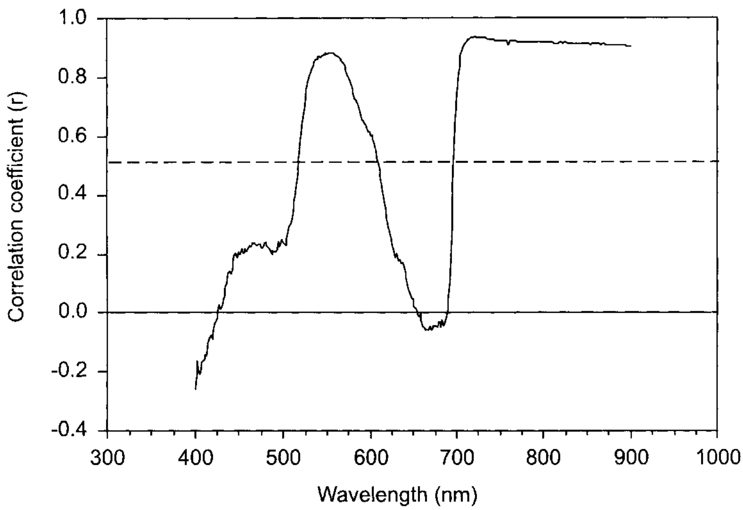

Figure 2. Correlation coefficients ($\alpha = 0.05$) between spectral reflectance and percent cover, plotted as a function of wavelength. Critical value for r (0.514) is indicated by the dashed line.

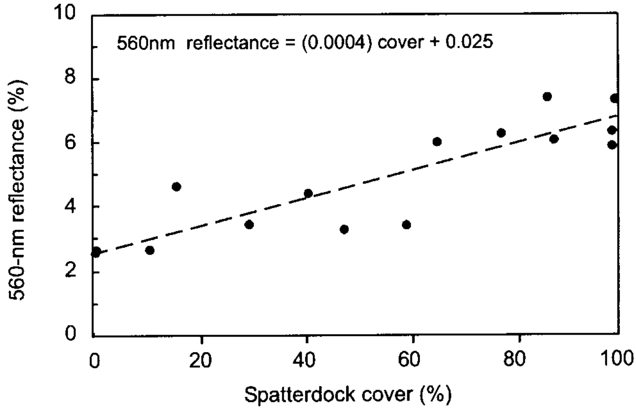

Figure 3. Linear relationship between green reflectance (560 nm) and spatterdock cover ($r^2 = 0.87$).

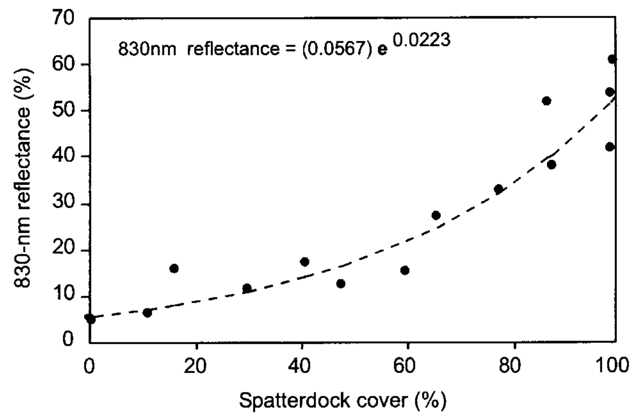

Figure 4. Exponential relationship between near-infrared reflectance (830 nm) and spatterdock cover ($r^2 = 0.91$).

represented by a quadratic function, indicating increasing NDVI values with increasing cover by spatterdock ($r^2 = 0.95$) (figure 5). Results from the close range hyperspectral radiometry suggest that the percentage cover by spatterdock can be predicted using a single narrow band of spectral reflectance in the green or near-infrared ranges of the spectrum. Predictability increases slightly using an NDVI transformation of the data in a nonlinear equation.

Extending these results to satellite data may result in weaker statistical relationships, given the broader bandwidths of multi-spectral sensors carried on current earth-observing satellites (SPOT, Landsat, and Indian IRS). Statistical relationships between spatterdock cover and green reflectance measured by satellite sensors will be affected to a greater degree than relationships with the near-infrared bands. The wide green reflectance bandwidths of the three satellite-based systems capable of resolving spatterdock occurence (SPOT XS, 500–590 nm, Landsat Thematic Mapper, 520–600 nm, and Indian IRS LISS-III, 520–590 nm) incorporate ranges of the green spectrum in which correlations between spectral reflectance and cover were low to nonsignificant (figure 2). In the near-infrared, however, given the high correlations

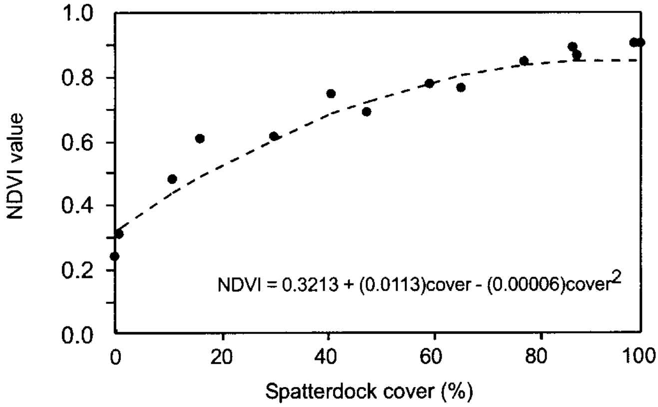

Figure 5. Quadratic relationship between the Normalized Difference Vegetation Index (NDVI) computed using reflectance values at 660 nm and 830 nm and spatterdock cover ($r^2 = 0.95$).

between cover and all near-infrared bands (figure 2), this should not present a problem for the three satellite sensors cited (SPOT XS, 790–890 nm; Landsat Thematic Mapper, 760–900 nm; and the Indian IRS LISS-III, 770–860 nm). Spatial resolution differences between systems, however, should pose less of a problem, as the relationship between spatterdock leaves and spatial resolution in this study fits the definition of the L-resolution scene model (Strahler *et al.* 1986), where the scene elements (the spatterdock leaves) are smaller than the area over which spectral reflectance is recorded by the spectroradiometer. Therefore, statistical relationships between spatterdock cover and spectral reflectance recorded by lower spatial resolution sensors (e.g. satellite imagery) and also fitting the definition of an L-resolution model, should be similar to values measured in this study.

Acknowledgments

Funding for this research was provided in part by the United States Environmental Protection Agency, National Center for Environmental Research and Quality Assurance (NCERQA). Although the research described in this article has been funded in part by the EPA, it has not been subjected to the Agency's peer review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred. Hillary Loring assisted with field sampling of spatterdock cover. Permission to conduct research in Grand Teton National Park was provided by Dr Robert Schiller. This is Journal Paper No. J-18076 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, Project 3377, and supported by Hatch and State of Iowa funds.

References

Goodin, D., Han, L., Fraser, R. N., Rundquist, D. C., and Stebbins, W. A., 1993, Analysis of suspended solids in water using remotely sensed high resolution derivative spectra. *Photogrammetric Engineering and Remote Sensing*, **59**, 505–510.

Han, L., and Rundquist, D. C., 1994, The response of both surface reflectance and the underwater light field to various levels of suspended sediments: Preliminary results. *Photogrammetric Engineering and Remote Sensing*, **60**, 1463–1471.

Jensen, J. R., Narumalani, S., Weatherbee, O., and Mackay, H. E., 1993, Measurement of seasonal and yearly cattail and waterlily changes using multidate SPOT panchromatic data. *Photogrammetric Engineering and Remote Sensing*, **59**, 519–525.

Jensen, J. R., 1992, Measurement of seasonal and yearly aquatic macrophyte changes in a reservoir using multidate SPOT panchromatic data. *Technical Papers, American Society for Photogrammetry and Remote Sensing* (Bethesda, MD: American Society for Photogrammetry and Remote Sensing), **1**, 167–176.

Kindscher, K., Fraser, A., Jakubauskas, M., and Debinski, D., 1998, Identifying wetland meadows in Grand Teton National Park using remote sensing and average wetland values. *Wetlands Ecology and Management*, **5**, 265–273.

Nohara, S., 1991, A study on annual changes in surface cover of floating-leaved plants in a lake using aerial photography. *Vegetatio*, **97**, 125–136.

Strahler, A. H., Woodcock, C. E., and Smith, J. A., 1986, On the nature of models in remote sensing. *Remote Sensing of Environment*, **20**, 121–139.

Welch, R., Remilliard, R. R., and Slack, R. B., 1988, Remote sensing and geographic information system techniques for aquatic resource evaluation. *Photogrammetric Engineering and Remote Sensing*, **54**, 177–185.