Delineation of Pacific Northwest SAVs from Aerial Photography: Natural Color or Color Infrared Film?

David R. Young[1], David T. Specht[1], Bradley D. Robbins[1], and Patrick J. Clinton[2]
[1]U.S. Environmental Protection Agency and [2]OAO Corporation
2111 S.E. Marine Science Dr., Newport, OR 97365-5260

ABSTRACT

Our study was conducted within a PNW estuary to determine the utility of false-color infrared film versus natural (true) color-negative film for recognizing and quantifying submersed aquatic vegetation (SAV) growing on an intertidal flat. During the summer of 1997 aerial photographs were obtained of Yaquina Bay, OR during a negative tidal event using both infrared and true color film (scale 1:7200). SAV distributions were delineated from digital orthorectified images derived from both film types, using a digital classification approach as well as a traditional photointerpretation approach. A field survey of 160 sites was conducted within one week of the aerial flights. The detection of SAV and bare substrate was compared among all methods using an accuracy assessment technique based on the ground survey data. Resultant accuracy assessment values were similar for both film types. However, the digital classification obtained for Yaquina Bay, Oregon, using the color infrared film was judged to be preferable to that obtained from the natural color film.

Introduction

Submersed aquatic vegetation (SAV) has been recognized as an important habitat for both recreational and commercially important organisms, such as salmonids and crustaceans. Subsequently, a program to monitor the temporal dynamics of SAV distributions within coastal estuaries has been initiated by NOAA (Coastal Change Analysis Program; C-CAP). The C-CAP protocol, based on a North Carolina study, stipulates that color-negative, color-reversal, or black-and-white film be used to delineate SAV (Dobson *et al.* 1995). The use of false-color infrared film was found to be much less effective in the detection of SAV because infrared light (recorded by false-color film) is absorbed to a much greater degree than is photovisible light as it passes through water.

However, a major difference exists between southeastern estuaries, where C-CAP protocols were developed, and Pacific Northwest (PNW) estuaries. Specifically, many eastern estuaries have large expanses of subtidal SAV flats with small (typically < 1m) diurnal tides. In contrast, PNW estuaries are characterized by large expanses of intertidal SAV flats which are exposed by tidal shifts often greater than 2 m. Because color infrared film provides good contrast between vegetated and unvegetated terrestrial areas, it's use has been extended successfully to intertidal SAV flats in the PNW (J. Civille and T. Mumford, WA Dept. Natural Resources, pers. comm.). Thus, we conducted a comparative study to determine the utility of false-color infrared film (CIR) versus natural or true color-negative (TC) film for delineating intertidal SAV in a PNW estuary.

Methods

Study Site

Yaquina Bay and its associated estuary can be characterized as a drowned river valley with a total area of 1730 ha and 1000 ha of intertidal mudflat (Figure 1). SAV taxa in Yaquina Bay are composed of two seagrass species (*Zostera marina* L. and *Z. japonica*), and two green macroalgae genera (*Ulva* spp. and *Enteromorpha* spp.) dominating. In contrast to the ephemeral blooms of green macroalgae which occur between late spring and early fall in this estuary, both seagrass species occur as annual and perennial forms. Our study was initiated in summer 1997 to maximizes our ability to detect the major SAV taxa within the intertidal zone of Yaquina Bay during daylight hours.

Aerial and Ground Surveys

On the morning of July 23, 1997, during an extreme low tide, two remote sensing surveys of the study area were conducted. The first survey occurred between 9:25 and 9:40 a.m., using Kodak Aerocolor HS SO-358 high speed color-negative film (TC) in 23 cm x 23 cm (9 in. x 9 in.) format. The second survey was conducted between 10:09 and 10:28 a.m., using Kodak Aerochrome Infrared 2443 film (CIR) in 23 cm x 23 cm (9 in. x 9 in.) format. The nominal tide level rose from -1.67 ft to -1.63 ft during the first survey, and from -1.34 ft to -1.01 ft during the second survey. The flight plan was controlled using an airborne Geographical Positioning System (GPS) in conjunction with a surveyed ground station and post-processed differential correction (DGPS). Additional photo-visible ground control points also were surveyed for subsequent geopositioning. Stereophotographs with 60 percent frontlap and 30 percent sidelap were obtained, and used to produce digital orthorectified aerial photographs from both film types with a nominal ground pixel resolution of 0.20 m. The data collected aerially also were compared to ground survey data obtained during the summer of 1997 within one week of the aerial survey. We selected 160 reference stations within one of two habitat classes: vegetated and bare substrate, situated below the level of the supra-intertidal salt marsh. At each station a 1 m^2 area was surveyed for the presence/absence of each SAV taxa. A detailed description of the ground survey procedure is presented elsewhere (Young *et al.*, 1998).

SAV Classification

Traditional Photo Interpretation

A traditional photo interpretation procedure was utilized to detect SAV presence in both CIR and TC aerial photographs. Specifically, each of the 160 reference stations were viewed electronically at a scale of 1:500 using ArcView (Version 3.0a) by three of the authors (Young, Specht, and Robbins) who independently determined the presence or absence of SAV from the remote images.

Algorithm Development and Image Analysis

The digital SAV classification of both the CIR and TC orthorectified aerial photographs was conducted using a mosaic of 12 digital images within ERMapper (Version 5.5). The development of an algorithm to classify SAV from CIR utilized a large (~100 ha) intertidal area with known distributions of SAV. Our algorithm, which proved to be highly accurate, had minimal edge effects among the mosaic's orthophotographic boundaries, and is similar to a combination of an Infrared Percentage Vegetation Index (IPVI) and an Atmospherically Resistant Vegetation Index (ARVI) (see a description of these indices in Ray, 1994). The resulting classified image was exported into ArcInfo (Version 7.1.2) Geographic Information System (GIS) and converted into a raster grid at the original scale of 0.2 m pixel size. The grid then was converted into a vector polygon coverage and, using an overlay technique in ArcInfo, was compared to a point coverage of ground survey data. In the overlay process, a polygon classified as SAV was considered to be classified correctly if it included, or was within 1.28 m of, a ground station location representing SAV. The 1.28 m distance function represents the combined spatial accuracy of the point and polygon coverages (RMSE of 0.78 m) plus the nominal distance from the center to the edge of a 1 m^2 ground station area (0.5 m).

The application of our algorithm to TC digital orthophotography was less successful, as were our attempts to develop a new algorithm. We didn't succeed because the spectral characteristics of macroalgae in the visual range are shared with those of open water, and because the spectral characteristics of seagrasses in the visual range are shared with those of bare substrate, particularly sandy sediment.

Data Analysis

To compare the results of our several classifications of SAV versus bare substrate in the study area (Figure 1), we used the error matrix approach described by Congalton (1991). In this approach, the percentage of stations with a given classification obtained via the remote sensing approach that agree with the reference (ground survey) results is termed Users Accuracy. Alternatively, the percentage of stations with a given classification obtained from the ground survey that are correctly classified by the remote sensing is termed Producers Accuracy. A third commonly used category, termed Overall Accuracy, also is included.

Results and Discussion

Our results did not yield a significant difference ($p > 0.05$; two-tail Student's t-test) between the CIR and TC Overall Accuracy values (Table 1). Thus the use of either CIR or TC for the detection and quantification of SAV and bare substrate can be recommended. However, equally clear is the qualitative indication that the CIR approach is more useful when distributions of exposed SAV within intertidal flats are digitally classified. Specifically, a visual comparison of orthorectified aerial photographs of the study area using both CIR and TC film suggests that the digital classification of the TC film over-represents SAV distributions (Figure 2). Thus, it appears that the algorithm we developed for the classification of the CIR images was inadequate when applied to the TC images. We therefore conclude that our digital classification obtained for Yaquina Bay using the CIR film is preferable to that obtained from the TC film.

Acknowledgments

The ground reference survey was conducted by employees of DynCorp/TAI, Inc. stationed at Newport, OR and EPA scientists and staff of the Western Ecology Division's Coastal Ecology Branch. The aerial photography was conducted by Bergman Photographic, Inc. (Portland, OR); the orthorectified digital photographs were produced by Photogrammetric Digital Services, Inc. (Eugene, OR). Mention of trade names or commercial products does not constitute endorsement or recommendation for use. This paper has been subjected to EPA's peer review and administrative review process and has been approved for publication as an EPA document.

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Table 1: Accuracy assessment error matrices (%) of SAV versus bare substrate classification by traditional photointerpretation and digital classification (Congalton, 1991).

	Young		Specht		Robbins		Digital	
Accuracy	**SAV**	**Bare**	**SAV**	**Bare**	**SAV**	**Bare**	**SAV**	**Bare**
Users – CIR	89.7	68.2	85.2	68.8	87.5	72.7	92.4	64.0
Producers – CIR	78.9	83.3	82.0	73.6	84.2	77.8	72.9	88.9
Overall – CIR	80.5		79.0		81.9		78.5	
Users – TC	82.8	76.8	84.1	73.0	78.3	63.8	77.2	51.3
Producers – TC	90.2	63.2	87.2	67.7	84.2	54.4	71.4	58.8
Overall – TC	81.1		80.6		74.1		67.2	
Mean Overall – CIR	80.5							
Mean Overall – TC	78.6							

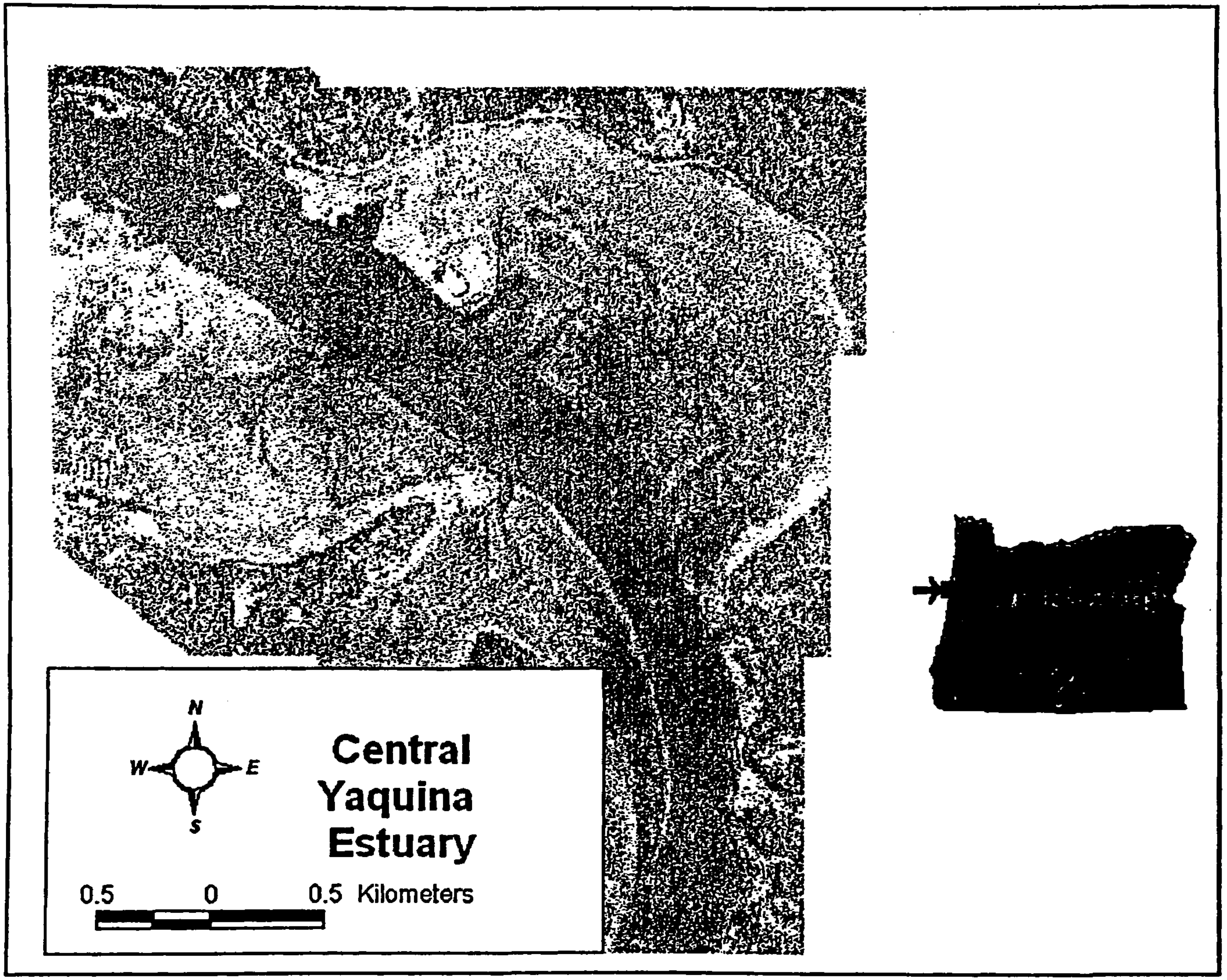

Figure 1: Site map showing location of Yaquina Bay on the west coast of Oregon.

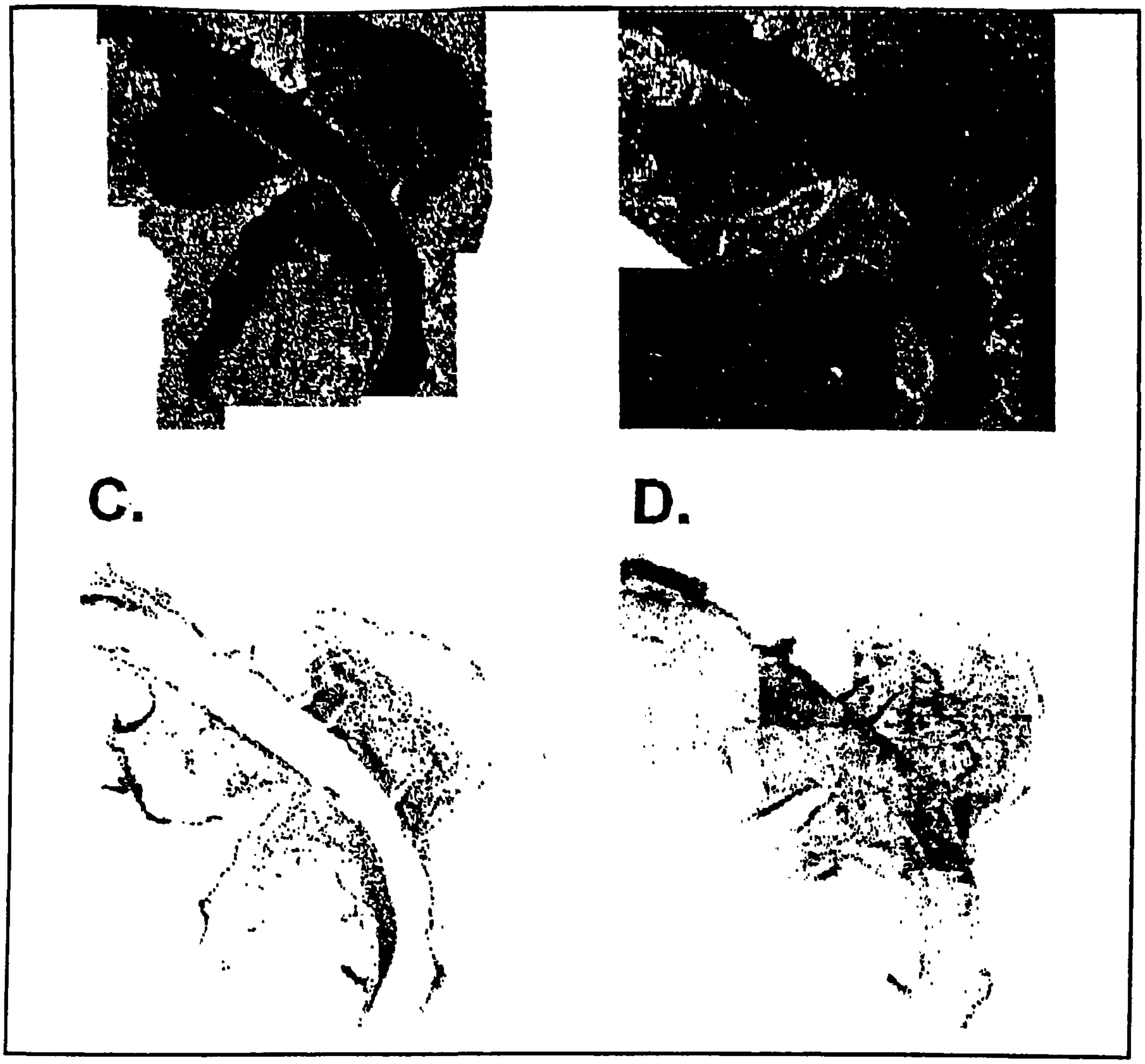

Figure 2: A comparison of orthorectified aerial photographs using CIR (A) and TC (B) and their associated digital classifications (C and D).

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