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Digitized Small Format Aerial Photography as a Tool for Measuring Food Consumption by Trumpeter Swans

A novel approach combining microdensitometry and computer digital analysis of small format color IR aerial photographs is employed to quantify the vegetative changes in an estuary caused by overwintering trumpeter swans.

Introduction

Trumpeter swans (*Cygnus cygnus buccinator*) wintering at Comox Harbour, British Columbia (Figures 1 and 2) feed on the roots and rhizomes of the dominant emergent vegetation, Bulrush (*Scirpus americanus*) (McKelvey, 1981). Their feeding results in a hole or crater in the otherwise continuous mat of vegetation, which regenerates very slowly.

where the root mat was not completely destroyed, can subsequently be identified by a very sparse growth of the vegetation. It seemed probable that the rate of food consumption by the swans could be estimated by measuring changes in the areal extent of the vegetation. We report here the successful use of microdensitometry and digital analyses of aerial photographs to objectively measure those changes.

Abstract: *A new approach, combining microdensitometry and computer digital analysis of small format color IR aerial photographs, was used to detect changes in estuarine vegetation caused by overwintering trumpeter swans. The technique was found to be useful because changes would be difficult to delineate using conventional airphoto interpretation techniques and also because field survey methods are laborious. Two levels of vegetation changes, which corresponded to heavy and light feeding by the swans, were detected. These changes could be used to measure food consumption rates of trumpeter swans.*

Small format (70-mm) aerial photographs were used at Comox Harbour to record the areal extent of the emergent vegetation before and after its use by wintering swans. The aerial photographs clearly recorded changes in the vegetation but, due to the very fine nature of the pattern caused by the feeding swans, direct measurement of those changes was difficult.

Areas of heavy feeding can be identified during the following growing season by the complete absence of any vegetation. Areas of light feeding,

The objectives of the study were to

- Produce digital color images of similar quality to the original color IR airphotos by scanning microdensitometry.
- Detect changes in the vegetation caused by the feeding of the swans by overlaying digitized two-dated color images.
- Detect areas of heavy and light feeding that would correspond to McKelvey's (1981) partly and totally devegetated areas.
- Identify potential problems with the technique.

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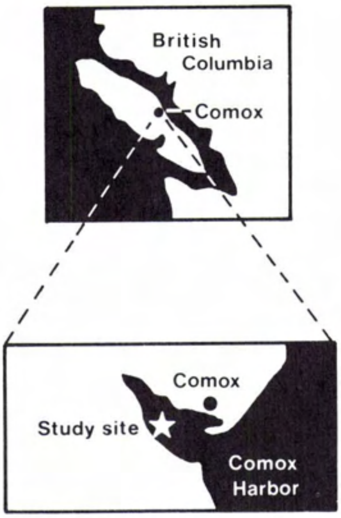

FIG. 1. Study site location.

METHODS

COLOR IR AERIAL PHOTOS

Aerial photographs were obtained by McKelvey in August 1978 and again in May 1980 (Plate 1a) using a De Havilland Beaver equipped with a Hasselblad 500 EL and a Zeiss Distigon 50-mm *f*5.7 lens using Kodak 2443 Aerochrome IR film (McKelvey 1981). Flight levels were approximately 610-m above ground level, resulting in a scale of 1:12 000.

THE MICRODENSITOMETER

The Canada Centre for Remote Sensing Image Analysis System 11/40 PDS microdensitometer was used to produce digital data for the study. That microdensitometer is capable of scanning both translucent and opaque materials. Thus, black-and-white or color transparencies or prints may be scanned (M. D. Watt, unpublished report, 1979)[1]. The digital data were recorded on 1600 bpi, nine track odd parity tape, and image densities were based on 0 to 255 gray scale levels. The sensing aperture size was 50 micrometres. The transparencies of the study areas were scanned using blue, green, and red filters. Two sets of data were obtained, corresponding to the 1978 and 1980 photos.

DIGITAL ANALYSIS

The image digital data for the 1978 photo were superimposed on the image digital data from the 1980 photographs (Plate 1b).

Supervised classification (Lee *et al.*, 1977) was used for the digital analysis. This procedure consisted of establishing training areas representing heavy and light feeding and then using statistics from these two training areas in a maximum likelihood supervised classification (Anon., 1981).

The training process involved the following three steps:

(1) Defined Training Areas: Twenty-five training sites (Plate 1c) for heavy and 13 for light feeding are delineated by means of locating those feeding areas on the TV monitor.

(2) Defined Semi-Supervised Training (SST) Areas: The SST subroutine takes advantage of the user's understanding of the underlying structure of the image data and allows the user to
- (a) select and display any two image data channels (e.g., 1978 and 1980 channel 2 Green filter);
- (b) have a scatterplot of a sample of that image's data displayed on an image plane, indicating the gray scale level;
- (c) draw an ellipse (or a rectangle or any arbitrary shape) superimposed over the scatterplot to "define a class" (e.g., heavy feeding, Plate 1d, yellow)
- (d) refine the class in (C) by adjusting the shape of the ellipse if desired;
- (e) use (d) as training and a parallelepiped classifier to define a "single class" (e.g., heavy feeding) in a graphic plane superimposed over the original image, to indicate all image pixels whose grey scale values fall inside the ellipse area (Plate 1d); and
- (f) point to an image pixel with the cursor to see where that pixel appeared in the scatterplot. Called "feature space exploration," it allowed the user to determine
  - (i) where in the scatterplot his data were located,
  - (ii) how those data were distributed, and
  - (iii) how discrete the data were when compared with other classes of data.

(3) Purified Training Areas: purified training areas (Plate 1e, orange) are obtained by eliminating those pixels that do not fall within the classes identified in (1) defined training areas and (2) defined SST areas.

The final stage in the digital image supervised classification process was the use of the full maximum likelihood classifier. This classifier was optimized for time, by the use of the parallelepiped pre-

FIG. 2. An overview of the study site within Comox Harbour, British Columbia.

[1] Canada Centre for Remote Sensing, 2464 Sheffield Road, Ottawa, Ontario, K1A 0Y7.

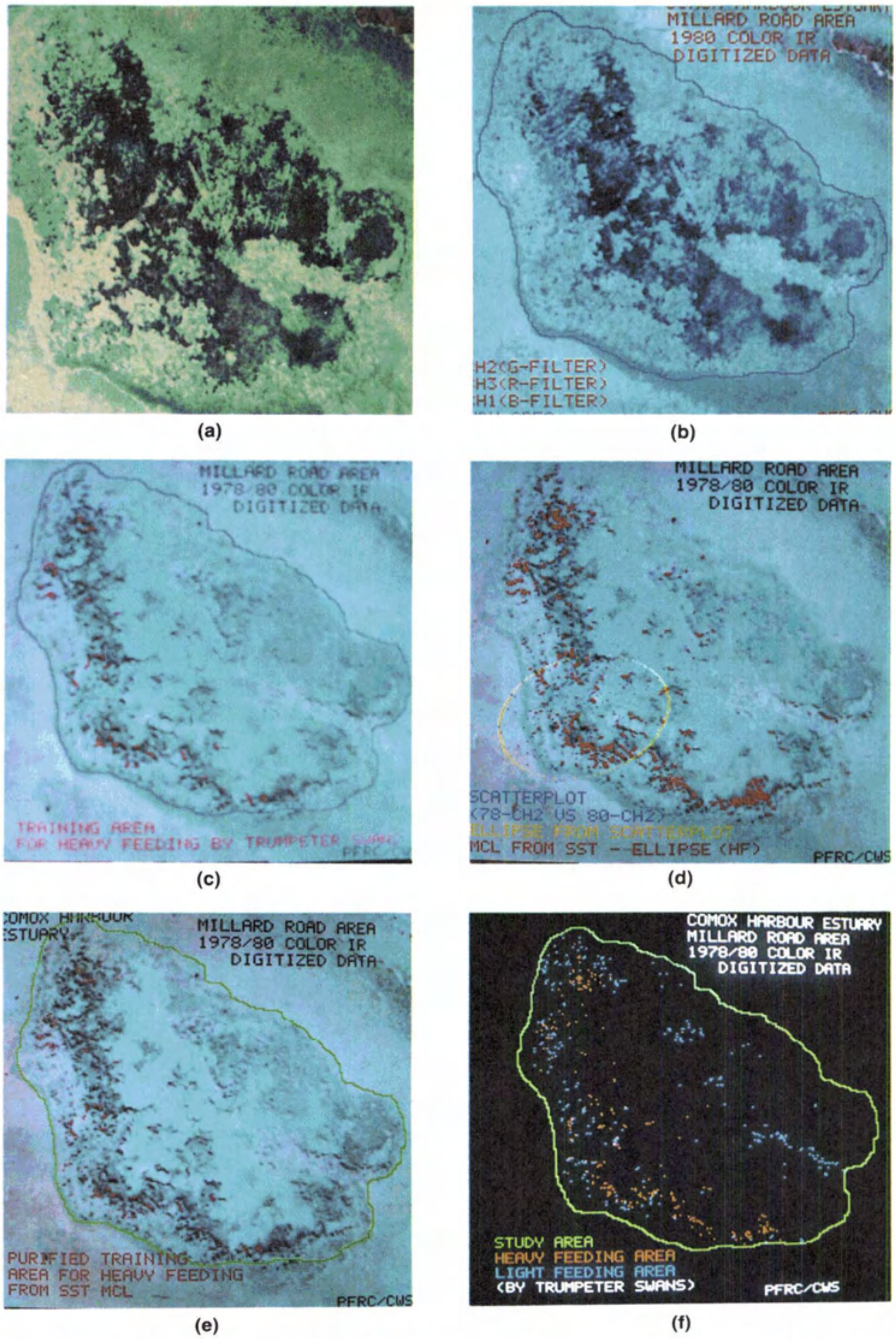

PLATE 1. (a) 1980 small format (70-mm) aerial photo showing the study area. (b) Digitized color image for 1980, produced from computer data and displayed on the GEMS 300 color monitor. (c) Training areas for heavy feeding (orange). (d) Semi-supervised training areas (orange) for heavy feeding (blue dots indicated scatter plot on X(78-CH2) and Y(80-CH2) coordinates with gray scale levels 0 at left lower corner and with a maximum of 255 along the X and Y coordinates; yellow indicated the User defined ellipse; and orange dots indicated the single class (HF) classification results from a parallelepiped classifier with ellipse as training area). (e) Purified training areas (orange) for heavy feeding. (f) Results of supervised classification, heavy feeding in orange and light feeding in blue.

classifier, to truncate the maximum likelihood distance calculation wherever appropriate. As a result, two classes, which corresponded to heavy and light feeding, were defined and are shown in plate 1f (heavy feeding in orange and light feeding in blue) and in Figure 3 (GEMS 300 computer output).

GROUND ASSESSMENT

A topographic survey (Figure 4) was carried out in 1981 to determine the size of the estuary study area. This information was used to determine the pixel size (Figure 3). Field observations were also made in 1981 to compare locations of areas identified on 70-mm aerial photographs and on microdensitometric color image as areas of heavy and light feeding with locations on the ground. Quantitative assessments were not undertaken, because establishing permanent plots on the estuary and making ground based measurements of changes in those plots were beyond our means.

RESULTS

DIGITIZED COLOR IMAGE

The digitized color image (Plate 1b) for 1980, produced from the computer data and displayed on the GEMS 300 color TV monitor, compared well with the aerial photo image (Plate 1a).

DETECTION OF VEGETATIVE CHANGES OVER THE 1978/80 PERIOD

When the 1978 digital data were superimposed on the 1980 data, the areas where feeding had occurred were easily determined (Plate 1c). The successful delineation was due to the fact that vegetation existed in the feeding areas in the August 1978 digital data but, as a result of the swans feeding, the vegetation disappeared in the May 1980 digital data. Therefore, the fed areas form a unique gray scale level that did not exist elsewhere. Ground assessments led to the conclusion that areas delineated by the supervised classification (Plate 1f) represented very closely the actual swan feeding activity within the study site between August 1978 and May 1980.

AREAS OF HEAVY AND LIGHT FEEDING

Vegetation changes, corresponding to heavy and light feeding by the swans, were detected at two levels. Pixel counts of heavy and light feeding areas for the study site were obtained from computer output (Figure 3). The study area occupied 30 874 pixels (13 430 m^2,) of which 239 pixels or 0.77 percent (104 m^2) were areas of heavy feeding and 291 pixels or 0.94% (127 m^2) were areas of light feeding, between August 1978 and May 1980.

DISCUSSION

Although multitemporal airborne or satellite sensing data have been successfully used for the detection of changes in the urban-rural boundary (Jensen and Toll, 1982; Christensen and Lachowski, 1982), environmental disturbance (Aronaff and Ross, 1982), water and vegetational wetlands (Wickware and Howarth, 1981), and land use (Adeniyi, 1980), this was the first time that microdensitometry has been used to study estuarine vegetation changes over time. No serious problems were encountered. Because the dominant vegetation seldom grows taller than 50 cm (McKelvey, 1981), lens distortions and shadows would not affect the delineation of heavy or light feeding areas. A minor discrepancy may have been introduced by drawing the survey area free hand on the TV monitor, to coincide with the survey map (Figure 4). However, because each pixel represented only about 0.435 m^2, that error is thought to have been small.

The heavy and light feeding areas could only be surveyed with great effort in the field. It is impossible to delineate those changes using conventional photo interpretation techniques at 1:12 000 scale, even with enlarged photos. The digital analytical technique appeared well suited for this work.

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                    >> GRAPHIC PLANE AREA SUMMARY <<

ENTER AREA OF A PIXEL (IN HECTARES)->0.43495 X 10^-2
GIVE CHANNELS TO SUMMARIZE ->1,2,3,4,5
                                 *** AREA ***
                                    THMARA

                      ALARM= 21768.=    94.680 KM2 ( 33.22%)
               UNCLASSIFIED= 34662.=   150.762 KM2 ( 52.89%)
HEAVY FEEDING AREA/THEME(1)=   239.=    1.040KM2 (  0.36%) X 10^-4
LIGHT FEEDING AREA/THEME(2)=   291.=    1.266KM2 (  0.44%) X 10^-4
STUDY BOUNDARY    /THEME(3)=   859.=    3.730KM2 (  1.31%) X 10^-4
STUDY AREA        /THEME(4)= 30874.=  134.280KM2 ( 47.11%) X 10^-4
SURVEY AREA       /THEME(5)= 20655.=   89.839KM2 ( 31.52%) X 10^-4
                   THEME(6)=     0.=    0.000KM2 (  0.00%)
                   THEME(7)=     0.=    0.000KM2 (  0.00%)
TT11  --  STOP     THEME(8)=     0.=    0.000KM2 (  0.00%)
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FIG. 3. GEMS 300 computer output.

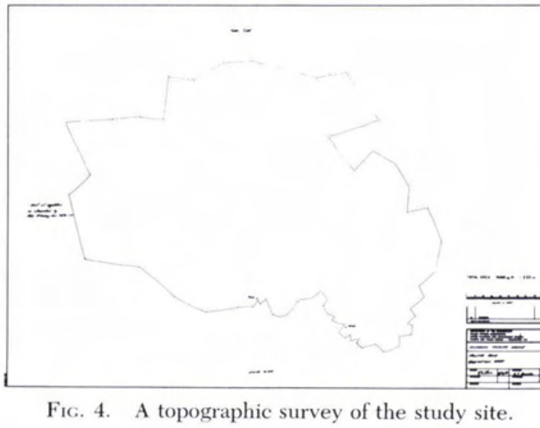

FIG. 4. A topographic survey of the study site.

Conclusions

The usefulness of a technique combining digitized data from inexpensive small format (70-mm) aerial photographs and microdensitometry has been demonstrated. A minor advantage of digital data was that one could assign a different color for each channel in order to obtain the best combination of colors for the image. This could not be done on aerial photographs. The major advantage of digital data was that one could superimpose multi-data for the detection of changes. Again, this could not be done on aerial photographs. The technique is well suited for detecting changes in trumpeter swan feeding estuaries in British Columbia, and can classify areas into those of heavy and light feeding. Knowing how many swan-use days the study area received over the study period, and the regeneration time of the plants, an estimate of the carrying capacity of the study area could be obtained. This matter is being investigated and will be the subject of a later report.

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