Section 6 Report Review

Attachment to a letter dated September 16, 1998

Project: Aerial Videography of Black-capped Vireo Habitat in Central Texas

Final or interim report? Final

Job Number: 57

Report: _X_ is acceptable as is

____ is acceptable as is for an interim report, but the following comments are made for future reference

____ needs revision (listed below)

Comments: (Note to commenter: If you make comments directly on a copy of the report, write legibly and dark so comments will reproduce well when photocopied.)

A valiant effort and well-written report!

FINAL REPORT

As Required By

THE ENDANGERED SPECIES PROGRAM

TEXAS

GRANT NUMBER: E-1

Project 57: Aerial Videography of Black-capped Vireo Habitat in Central Texas

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July 31, 1998

FINAL REPORT

STATE: Texas **GRANT NO:** E - 1 - 9

PROGRAM TITLE: Endangered and Threatened Species Conservation

PERIOD COVERED: September 1, 1994 - August 31, 1997

PROJECT NUMBER: 57

PROJECT TITLE: Aerial Videography of Black-capped Vireo Habitat in Central Texas

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Date

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Summary

The black-capped vireo, *Vireo atricapillus*, is federally-listed as endangered. Due to the vireo's rarity, identification of the bird's habitat is urgently needed. The objectives of this study were: (1) to acquire airborne videography at state parks and wildlife management areas (WMA's) in the central Texas region where black-capped vireos are known to occur; (2) to classify potential habitat of black-capped vireos on the state properties using Landsat TM imagery; (3) to interpret videographic images of vegetation for potential black-capped vireo habitat; (4) to complete an assessment of agreement between satellite image classifications and interpreted videography; (5) to determine the suitability of aerial videography as an accuracy assessment tool for satellite-based mapping of rare species habitat. Integration of field surveys, satellite image interpretations and videography were accomplished as follows: Six state properties were ground-surveyed to identify black-capped vireo breeding habitat in central and southwest Texas (Connally, Lockwood and Stuart, unpublished data, Connally, 1997). Survey data were digitized into a geographic information system and combined with aerial photography to serve as base-line information for a land-cover classification of black-capped vireo habitat. Spectral reflectance signatures were collected from TM imagery of mapped habitat areas and used to develop unsupervised/supervised hybrid classifications. The resulting classified images contain three habitat classes (representing low, medium and high amount of vegetation canopy) and one non-habitat class. Total area of land-cover classified as "habitat" versus "non-habitat" was determined for each Landsat TM subscene. Aerial videography was flown as near as possible over previously surveyed locations for the purpose of verifying Landsat classifications using the methods of Wunneburger (1992). Individual video frames were sampled from videography of

each park and interpretated as either "habitat or "non-habitat" An analysis of agreement between satellite classifications and aerial videography interpretations was determined using the coefficient of agreement (Kappa statistic).

Statement of Need

The black-capped vireo, *Vireo atricapillus*, is federally listed as endangered. The historic breeding range of the black-capped vireo (BCV) included south-central Kansas, central Oklahoma, central and southwest Texas, and north and central Coahuila, Mexico (Graber, 1961). BCV's no longer occur in Kansas and are extremely rare in Oklahoma. The main threats to BCV populations include cowbird parasitism, destruction and modification of nesting habitat, and possible destruction of wintering habitat (Campbell, 1995; U.S. Fish and Wildlife Service, 1996). Loss of historic breeding habitat has elevated the need to identify and locate the current breeding range of this species.

In this study, we address the application of aerial videography and Landsat TM image interpretation as techniques to identify and map breeding habitat of the black-capped vireo in central Texas. The status of many rare species can be determined, to a large degree, by the quality and amount of remaining available habitat Black-capped vireos currently are found in 40 counties in central and southwest Texas (U.S. Fish and Wildlife Service, 1996). The quality and abundance of breeding habitat for black-capped vireos in these counties is not known. Continuous coverage imagery provided by satellite imagery may provide a way to estimate how much breeding habitat remains for black-capped vireos.

Landsat TM images and other satellite images provide spectral coverage of relatively large spatial extent (e.g., 12,000 sq. mile per TM scene). Inventory costs become substantial when one attempts to ground-verify the thematic accuracy of habitat classifications for rare species across multiple satellite scenes. In our example, black-capped vireo breeding populations are scattered over a 57,000 sq. mile area. Our objective, therefore, was to assess aerial videography, in its current state, as an alternative inventory and monitoring tool at the landscape scale. Ways in which aerial videography might be modified to make it serve as a more effective tool for habitat monitoring are also discussed.

As part of this process, we created land-cover classifications of 6 state parks and WMA's with regards to 'habitat' and 'non-habitat'. Each of these properties is known to contain active black-capped vireo breeding populations or has had black-capped vireo sitings in the very recent past (< 10 yrs ago). The parks are small to medium in size (ranging from ca. 500 - 20,000 acres) with public access and well-documented vegetative characteristics. The sites include Possum Kingdom State Natural Area (Palo Pinto Co.), Dinosaur Valley State Park (Somervell Co.), Meridian State Park (Bosque Co.), Colorado Bend State Park (San Saba Co.), Kerr Wildlife Management Area (Kerr Co.) and Devil's River State Natural Area (Val Verde Co.).

Background

Because black-capped vireos occur over a wide ranged of physiographic and edaphic conditions, the composition of plant species associated with their habitat vary across the breeding range. In general, breeding habitat tends to consist of scrub-type vegetative communities that include oak (*Quercus* spp.) and have extensive low-level (< 3 m) brush (Campbell, 1995; Farquhar and Maresh, 1996; Grzybowski, 1986). Other woody plant species that have been associated with black-capped vireo breeding habitat in Texas include guajillo

(*Acacia berlandieri*), whitebrush (*Aloysia ligustrina*), agarito (*Berberis trifoliata*), hackberry (*Celtis spp.*), elbowbush (*Forestiera pubescens*), Texas ash (*Fraxinus texensis*), Ashe juniper (*Juniperus ashei*), cenizo (*Leucophyllum fructescens*), sumac (*Rhus spp.*), honey mesquite (*Prosopis glandulosa*), Texas mountain-laurel (*Sophora secundiflora*), and cedar elm (*Ulmus crassifolia*) (Campbell, 1995; Connally, 1993, 1997; Wolfe et al., 1996). Woody vegetation coverage ranges from 35-85% (Wolfe *et al.*, 1996). In much of the black-capped vireo breeding range, habitat appears to be in "early" or "middle" seral stages as a result of major disturbances such as fire or brush-clearing management practices (Graber, 1961; Grzybowski, 1986, O'Neal, 1996). Vireo habitat is thought to disappear as "late-succession" closed-canopy woodlands block out the growth of the requisite understory vegetation (Connally, 1993). Farquhar and Maresh (1996) indicate that these succession dynamics probably do not apply in the southwest portion of the breeding range where thin soils and low rainfall preclude the growth of closed-canopy woodlands.

Satellite image classification methods have recently been used as an inventory tool to identify potential habitat of rare bird species (Breininger et al. 1991; Herr and Queen, 1993; Miller and Conroy, 1990; Shaw, 1989) and to identify previously unknown native grassland areas (Lauver and Whistler, 1993). Shaw (1989) applied Landsat TM to study black-capped vireo breeding habitat on military lands in Texas. Specifically, Shaw applied a hybrid unsupervised/supervised classification method to identify BCV potential breeding habitat at Camp Bullis, San Antonio, Texas. The resulting classification consisted of 11 land-cover types. The overall accuracy of the classification was high (89%), however potential breeding habitat could not be separated out as a discrete class. In this study, we attempt to classify black-capped vireo breeding habitat by (1) using ground data from multiple-year field surveys on state properties, (2) using aerial photography to assist in developing and selection of TM spectral training sets, (3) masking satellite imagery within mapped polygons that represent all known habitat areas at each property. Image masking was used in order to analyze *only* the spectral variation associated with known BCV breeding habitat.

Aerial videography techniques have been used to inventory vegetation conditions associated with grasslands, forests, and agricultural crop production (reviewed by Graham, 1993). Most recently, aerial videography has been used to verify satellite image classifications as part of the national GAP Analysis Program (Scott et al., 1993; Graham, 1993; Slaymaker and Stenberg, 1996; Wunneburger et al., 1996). The application of videography to verify image classifications of rare species habitat is an extension of the GAP Analysis procedure. The videography techniques used here are described in Wunneburger (1992).

The objectives of this study were: (1) to acquire airborne videography at six state properties in the central Texas region where black-capped vireos are known to occur; (2) to classify the potential habitat of black-capped vireos in the six parks using Landsat TM imagery; (3) to interpret videographic images of vegetation containing known and potential black-capped vireo habitat; (4) to complete an accuracy assessment including Kappa coefficient of agreement between image classifications and interpreted videography; (5) to determine the suitability of aerial videography as an accuracy assessment tool for satellite-based mapping of rare species habitat.

Approach

Ground Surveys

As part of the Endangered Species Act recovery effort, state parks and other public lands were previously surveyed for the presence of breeding populations of black-capped vireo (Connally, Lockwood and Stuart, unpublished data; Connally, 1993; O'Neal, 1996). BCV survey areas are divided into four U.S. Fish and Wildlife Service-designated recovery regions: (1) north-central Texas; (2) Edwards Plateau; (3) Concho Valley; and (4) the Stockton Plateau and Trans-Pecos (USFWS, 1996; TPWD 1997). Three of the four regions are represented in this study: Possum Kingdom State Park, Dinosaur Valley State Park and Meridian State Park are located in north-central Texas; Colorado Bend State Park and Kerr Wildlife Management Area are located on the Edwards Plateau and Devils River State Natural Area is located on the Stockton Plateau. Locations containing BCV territories were mapped onto USGS 7 1/2 min quad maps and entered into the Texas Biological Conservation Database (Nature Conservancy, 1993) of the Texas Parks and Wildlife Department. Each of the six properties in this study had either (a) active populations of black-capped vireo (Devils River State Natural Area, Dinosaur Valley State Park, Colorado Bend State Park, and Kerr Wildlife Management Area) or (b) BCV sitings within the last ten years (Meridian State Park, Possum Kingdom State Park). The use of study sites without active black-capped vireo populations, (b) above, led to complications in our image interpretation procedures as will be discussed in the results/discussion section below. However, since classifications were conducted independently for each park, such complications were confined to the analysis within each property.

Image Processing and Interpretation

Image classifications for each of the six properties were derived from Landsat 5 TM scenes obtained from March 1990 to March 1992. Subscenes of TM imagery showing each of the properties are given in Figure 1. Black and white aerial photography was also acquired for each property from the 1989 - 1990 USGS 1:40,000 NAPP series. Image processing and GIS analyses were completed using a SPARC Ultra computer (Sun Microsystems, Inc.) with Imagine software (ERDAS Inc.) and Arc/Info software (Environmental Systems Research Institute, Inc.). Landsat TM image processing and interpretative methods are given in Table 1. Satellite imagery for each property was clipped from full TM scenes in the following Park boundary polygons were digitized from USGS 7.5 min. quads. The full TM scene was then clipped to a small rectangle containing the boundary polygon. Black & white NAPP photography was scanned at 400 dpi and georeferenced using 7 to 22 ground control points (the number of ground control points varied with park size). Ground control coordinate data were gathered using Trimble GPS Pathfinders and differentially corrected using post-processing methods. The mapped breeding habitat areas, derived from ground surveys, were converted into digital GIS polygon layers. Each breeding habitat polygon represents a cluster of black-capped vireo territories within a contiguous vegetative area. Breeding habitat polygons were overlaid against scanned NAPP aerial photography to assist with classifying satellite imagery. A hybrid unsupervised/supervised classification approach was used (Table 1). A preliminary step for each property was to run an unsupervised classification to yield 50 classes. A second analysis was initiated which focused only on the TM imagery associated with breeding habitat. Each habitat polygon was individually processed through an unsupervised classification. Each unsupervised classification, in turn, provided signatures to be merged with signatures from other habitat polygons. Pixels

Table 1-- Procedures for hybrid supervised/unsupervised image classification of black-capped vireo breeding habitat on each study site.

Preparation of Landsat TM image.
- Load satellite image into computer image processing system.
- Clip out subscene of raw image containing state property.
- Use bands 1-5, & 7 for classification procedures.

Unsupervised classification using ISODATA clustering method.
- Number of unsupervised classes set to 50.
- ISODATA function set to 20 interations.
- Convergence threshold set to 95%.

Integration of mapped habitat polygons into supervised classification.
- Create GIS layer of breeding habitat.
- Create layer for each individual habitat polygon.
- Convert polygons into raster format.
- Load rasterized habitat data into image processing system.
- Mask out individual black-capped vireo polygon from subscene of raw TM imagery.
- Run unsupervised classification on each habitat subscene (12 classes, 20 interations).
- Using 1:40,000 NAPP aerial photos (enlarged 2X), gather signatures associated with vegetation located inside mapped habitat polygons.
- Repeat for each habitat polygon.
- Merge signature sets.
- Using the resulting signature file to run supervised classification on park subscene.

Run matrix operation to integrate results from unsupervised and supervised classifications

Assign classes:
- non-habitat = 0
- very dense canopy = 1
- moderately dense canopy = 2
- less dense canopy = 3

Figure 1 -- Landsat TM satellite image subscenes for the following localities: (a) Devil's River State Natural Area; (b) Kerr Wildlife Management Area; (c) Colorado Bend State Park; (d) Meridian State Park; (e) Dinosaur Valley State Park; (f) Possum Kingdom State Park. Landsat image color assignment is blue (Band 1), green (Band 5), and red (Band 7). Dates of Landsat imagery are from March 1990 to March 1992. Blue lines indicate state property boundary; yellow polygons contain black-capped vireo breeding habitat.

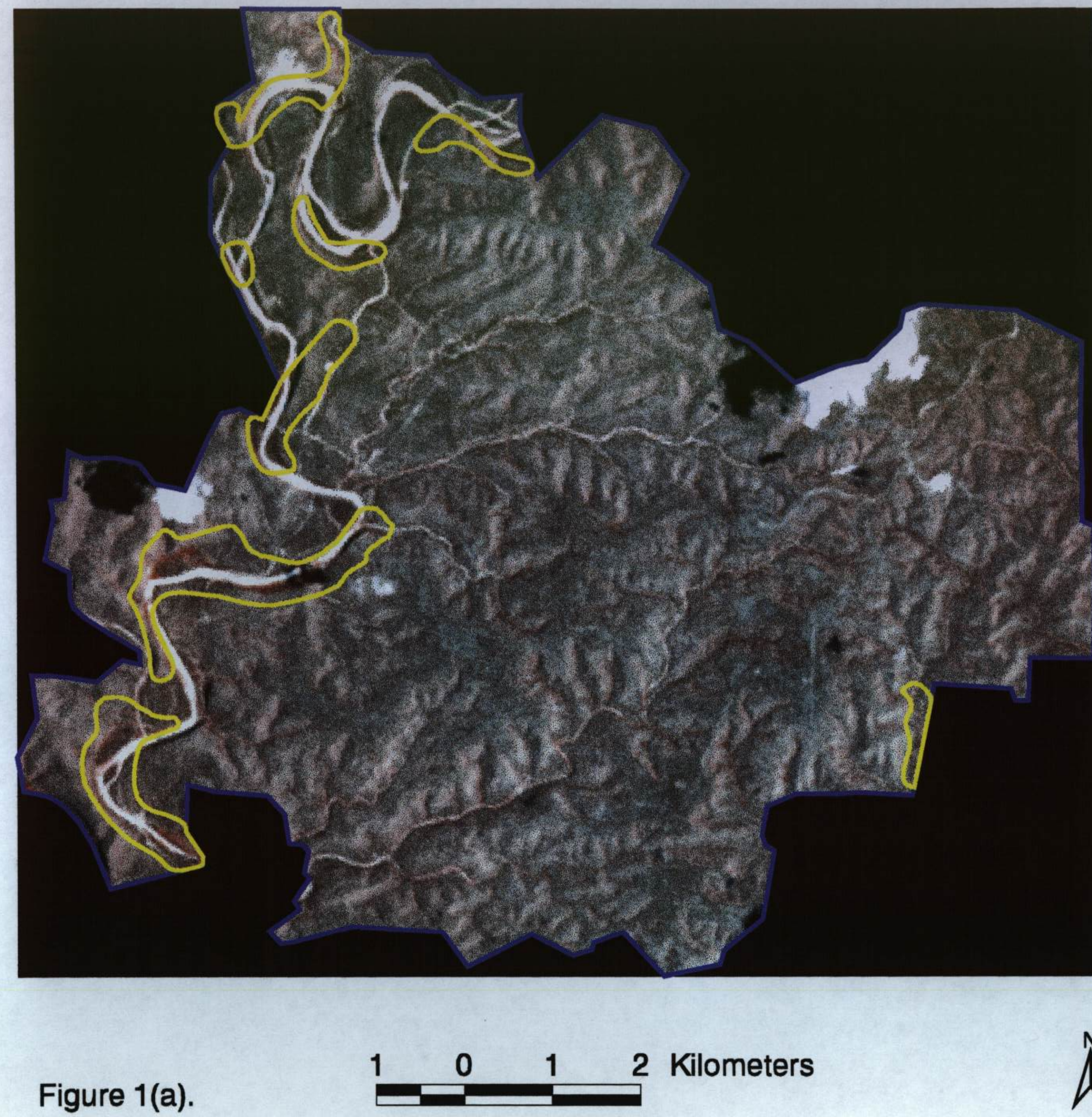


Figure 1(a).

Figure 1(b).

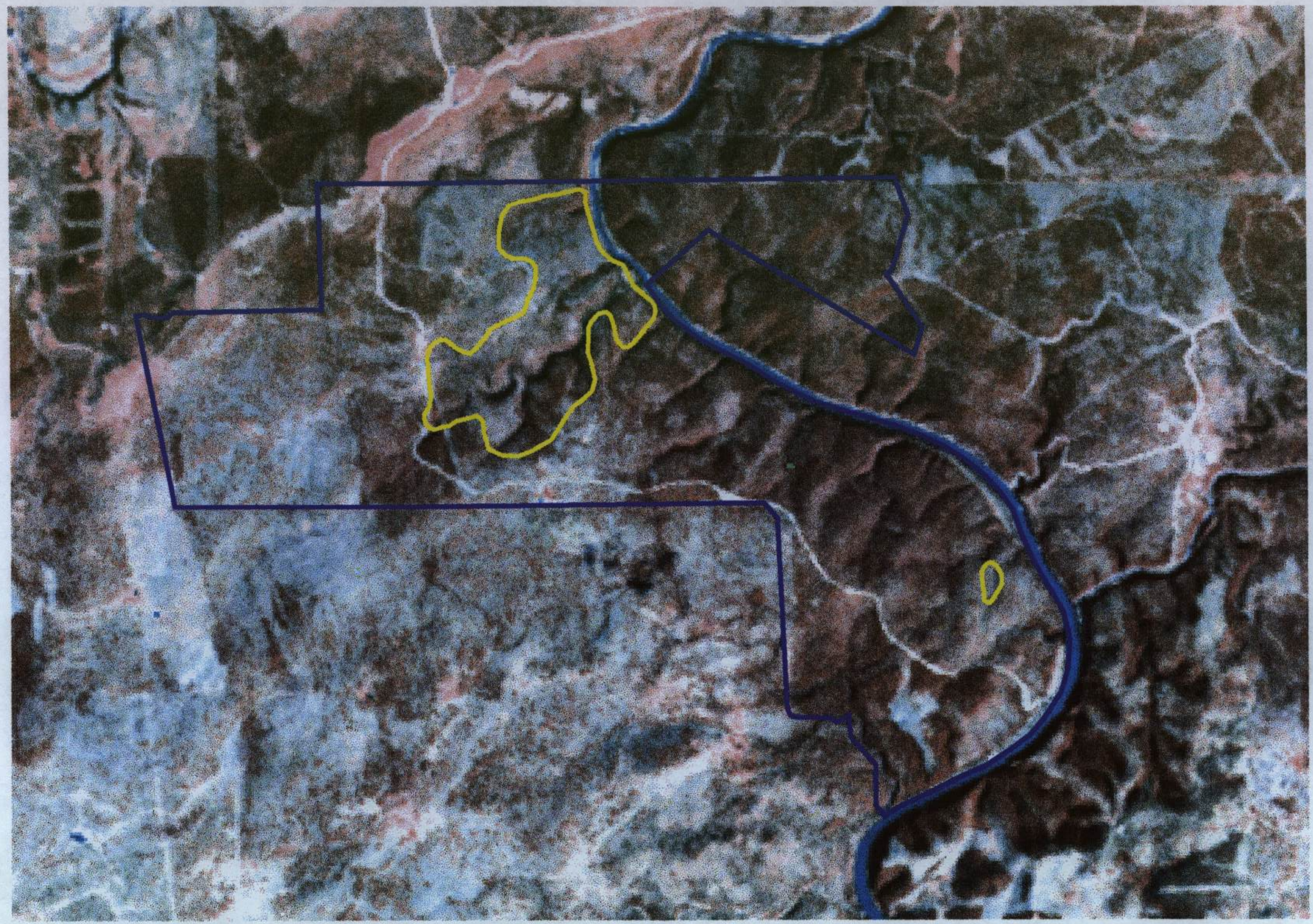


Figure 1(c).

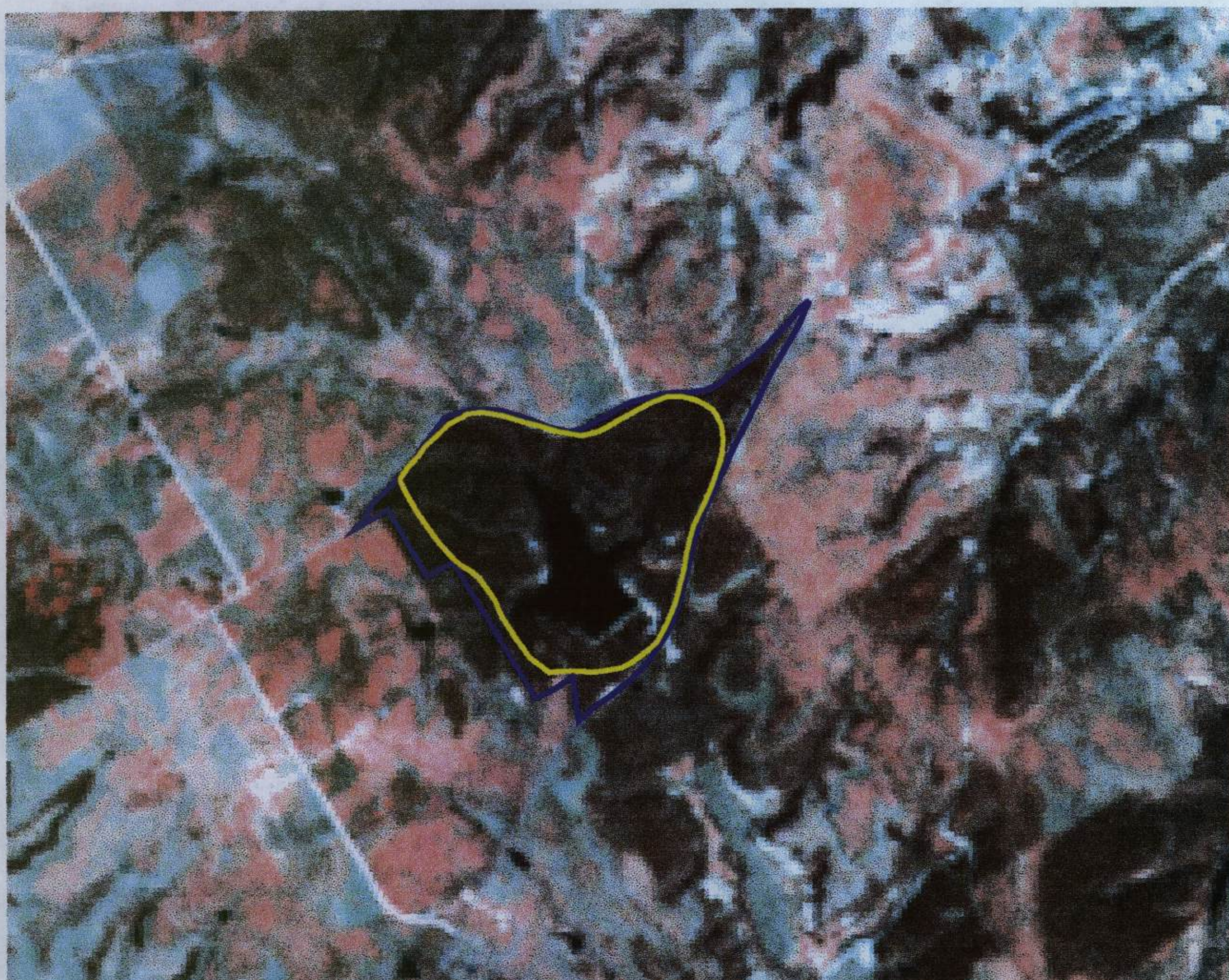
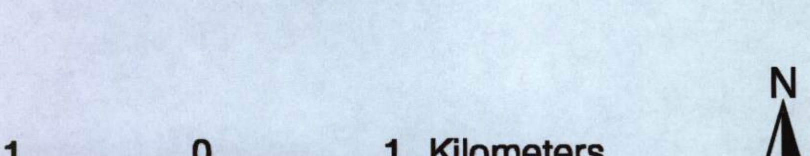


Figure 1(d).



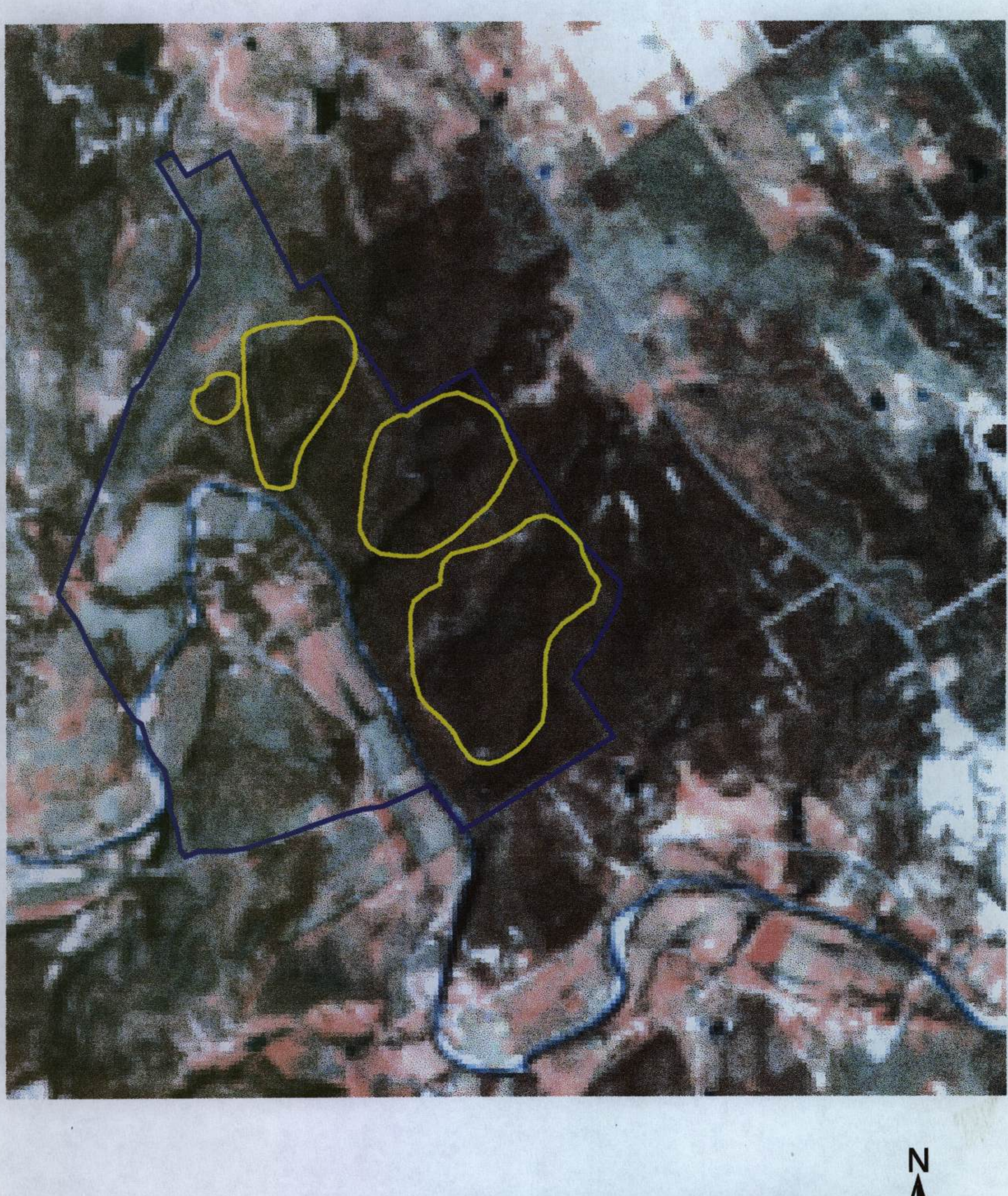


Figure 1(e).

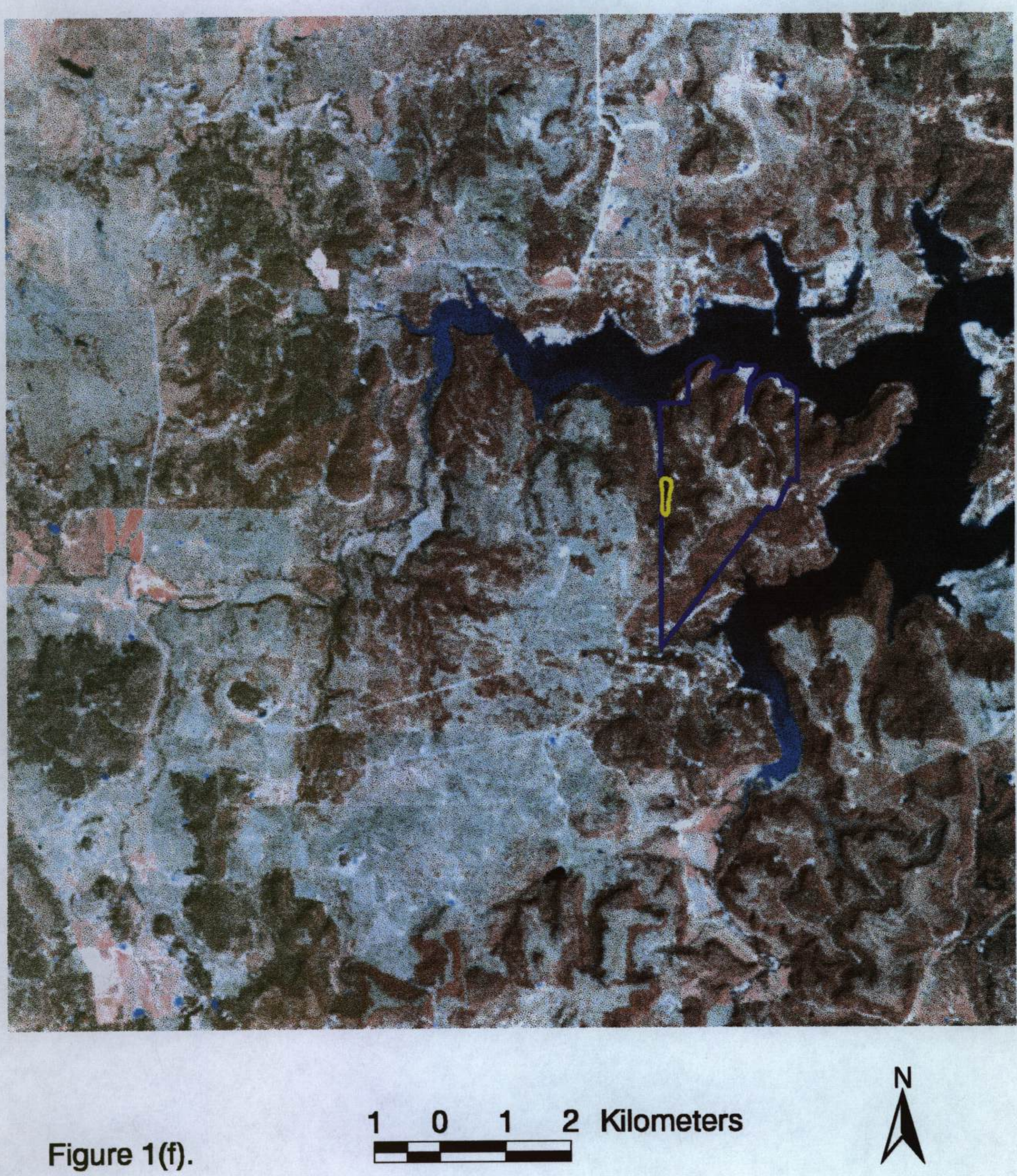


Figure 1(f).

representing habitat classes were selected from each habitat polygon with the aid of NAPP black and white aerial photography. Signature sets from all polygons were then merged for the final supervised classification on the park. A matrix was used to combine the results of the two analyses (see Table 1). Those pixels that were identified as habitat in both procedures were classified as habitat in the final TM classification. All other pixels were lumped into a cover-type called "non-habitat". Habitat classes were further divided into "very dense habitat", "moderately dense habitat", and "less dense habitat" (based on appearance in aerial photography). Accuracy assessment analysis (discussed below) addresses only the two general classes: "habitat" and "non-habitat". The accuracy of vegetation density subclasses was not determined.

Use of Videography

Each of the six parks was flown using a Cessna 182 equipped with an airborne videographic system (Wunneburger, 1992). Figure 2 gives schematic details of the videographic data capture and data formatting system. Flight lines were targeted at study site locations containing known BCV breeding habitat Orientation of flight lines consisted of east-west across each property to capture video images of 1 or more BCV breeding areas. Each individual video frame contains an area of ca. 200 x 300 m. A comparison of the level of image detail between videographic and Landsat imagery is shown in Figure 3. Videography was used to assess the accuracy of Landsat TM image classifications, that is, the level of agreement between videographic interpretations and TM image classifications. Video frames were sampled systematically from the total set of video imagery taken at each park. Frames were sampled at 3 second intervals using a Targa-16 frame grabbing card and stored on CD-ROM and 8 mm tape. Video frames for the agreement analysis were selected without knowledge of image content, that is, without a priori knowledge of whether or not they contained black-capped vireo breeding habitat.

Videography was georeferenced using autonomous GPS with an initial accuracy of +- 100m. The decision to use autonomous GPS arose from (a) the need to have a pilot operating alone with the videographic system as part of a larger state-wide videographic survey; and (b) the availability of georeferenced NAPP 1:40,000 bw aerial photography which was already being used to assist with the Landsat image classification procedure. Videography was then rubbersheeted with georeferenced NAPP photography using image processing software (ERDAS, Inc.). RMS error associated with georeferenced NAPP aerial photography was +-20 m.. All videographic images were interpretated as "presence" or "absence" of breeding habitat. Interpretations were made by a single observer/interpreter (JPM). Interpretation of videography depends on two critical areas of knowledge: familiarity with the individual land-cover classes; and interpretive experience with the land-cover classes both on the ground and as they appear in the aerial image. Video image interpretation can be facilitated by the use of the video tape (the video motion provides a 3-dimensional aspect to the view of the vegetation) and also by site visits to compare vertical and horizontal views of representative plant species (Slaymaker and Stenberg, 1996). Standard accuracy assessment methods were applied to the classified images including calculation of error matrices, omission and commission errors, percent overall accuracy, and Kappa coefficient of agreement (Congalton, 1991). The Kappa coefficient of agreement (KHAT statistic) is a measure of whether the classification and verification data agree more than would be expected than by chance alone. The Kappa coefficient ranges from 0 (agreement solely due to chance) to 1 (total agreement)(Rosenfield and Fitzpatrick-Lins, 1986).

Results and Discussion

Videographic Image Interpretation of BCV Habitat

Examples of individual video frames, interpretated as BCV "habitat" or "non-habitat", are given in Figure 4 (a) - (f). The ease with which video frames could be interpretated varied considerably among study sites. Video frames representing sites that would be considered "typical" BCV habitat showed vegetation with moderate canopy (30-70%) intermixed with areas of open grass. Examples of habitat considered "typical" can be seen in Fig.s 4(b)(i), 4(c)(i) and 4(e)(i) (taken from Kerr Wildlife Management Area, Colorado Bend State Park and Dinosaur Valley State Park). Conversely, video frames interpretated as "non-habitat" at those same state properties showed woody vegetation cover of less than 30% or had significant amounts of bare ground suggesting insufficient shrub cover at less than 3 m level (see Fig.s 4(b)(ii), 4(c)(ii) and 4(e)(ii), labeled "non-habitat"). At the southwest property, Devil's River State Natural Area, BCV habitat is mostly restricted to the edges of the dry river drainages, especially along canyon walls. Figure 4(a)(i) shows BCV habitat along the dry streambed of Dolan Creek. A canyon wall of ca. 75 m height runs along the lower third of the video image. A video frame interpretated as "non-habitat" at Devil's River SNA is given in Fig. 4(a)(ii). Much of the "non-habitat" land cover at Devil's River consisted of large expanses of mostly bare ground (< 30% canopy) interspersed with several xeric plant species (see Connally, 1993). Interpretations of video frames were most problematic at two northern study sites, Meridian State Park and Possum Kingdom State Park. At Meridian State Park, much of the property consisted of vegetation cover with greater than 70%

Figure 2 -- Schematic diagrams of aerial videography system (Wunneburger, 1992); (a) airborne data capture; (b) post-flight data formating; (arrows indicate direction of data flow); A ~ analog; D ~ digital.

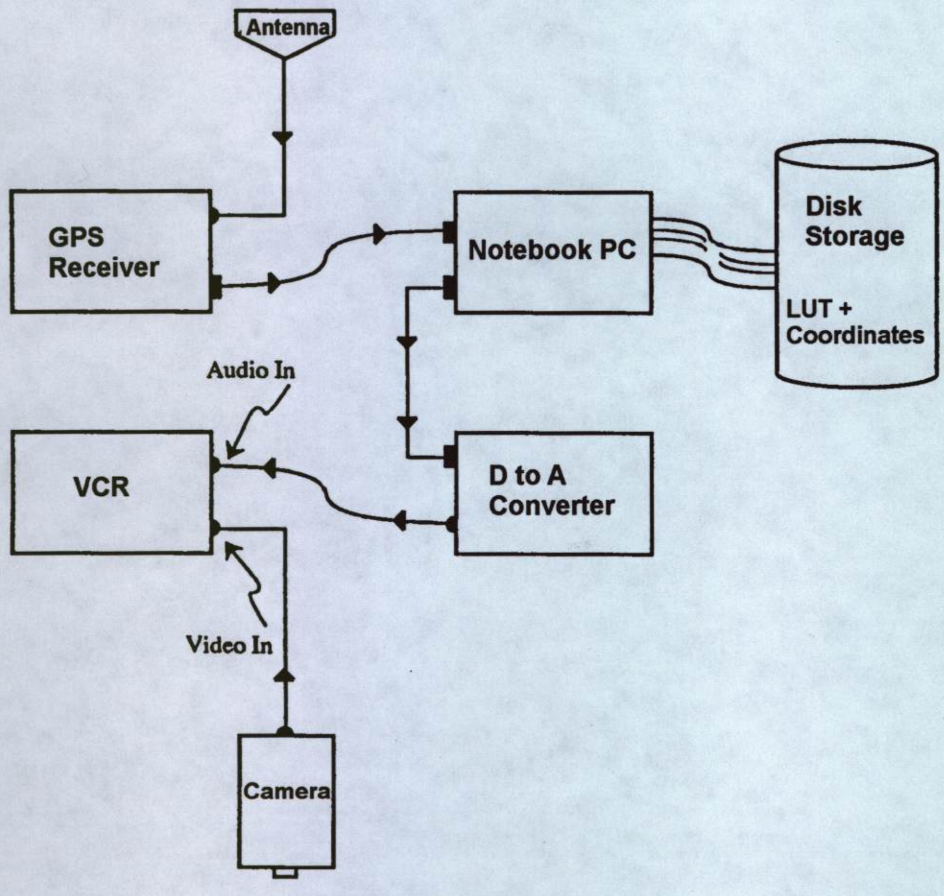


Figure 2(a): Data capture

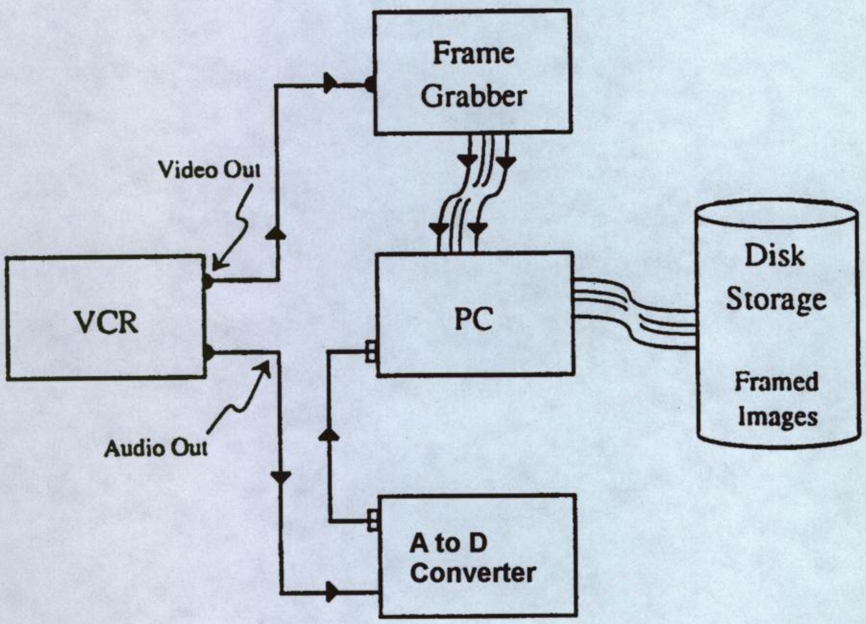


Figure 2(b): Data formatting

Figure 3 -- Overlay of videography frame on Landsat TM pixels. View shows Devil's River at southwest boundary of Devil's River State Natural Area (Val Verde Co., TX). Arrow indicates geographic North direction.

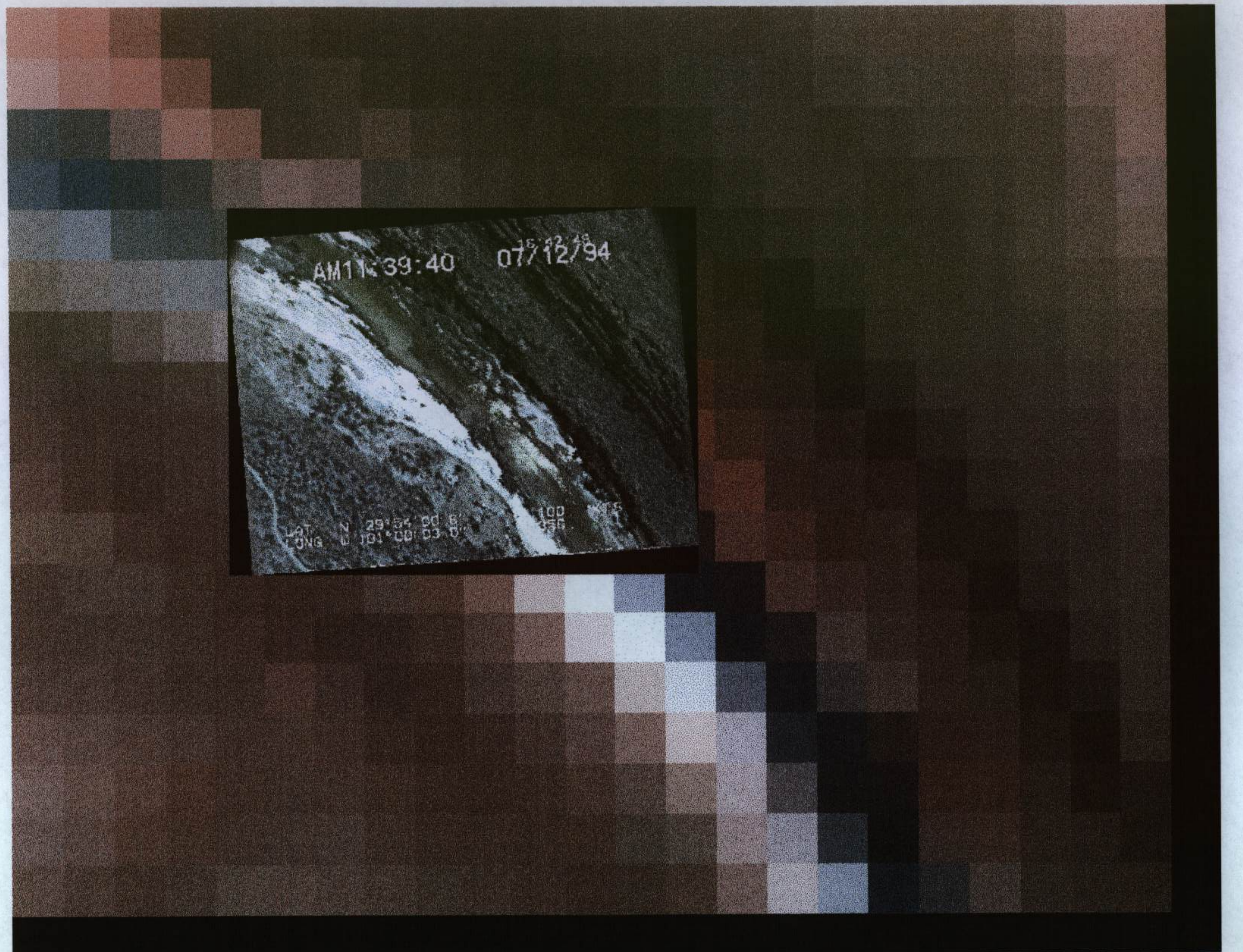


Figure 3. Devils River State Natural Area
Videography Overlay on Landsat TM Imagery

canopy (as shown in Fig.(d)(i)). According to various BCV habitat descriptions, (for example, Campbell, 1995), this would be sub-optimal habitat. BCV sitings at Meridian have been sporadic (one in 1988; one in 1997) and no active populations have been observed at the site since the early 1980's (M. Lockwood, pers. comm.) "Non-habitat" at Meridian State Park was limited to either open bodies of water or open ground with < 30% canopy (for example, see Fig (d)(ii)). Video interpretation at Possum Kingdom State Park was also problematic. While BCVs are known to occur in Palo Pinto County, occurrence of BCV at Possum Kingdom is based on a siting of two individuals in 1991 (Connally, 1993, 1997). Like Meridian SP, video frames interpreted as "habitat" at Possum Kingdom tended to have vegetation canopy amounts exceeding 70% and would therefore be considered suboptimal (as seen in Fig. 4(f)(i)). As with our other study areas, video frames from Possum Kingdom containing less than 30% canopy or with extensive bare ground were interpreted as "non-habitat" (Fig. 4(f)(ii)).

Landsat TM Image Interpretation of BCV Habitat

Classified Landsat TM subscenes for each study site are shown in Figure 5. Total and relative amounts of "BCV habitat" and "BCV habitat" sub-classes based on vegetation cover density are given in Table 2. Landsat subscenes with the greatest relative amount of "BCV habitat" were: Kerr Wildlife Management Area, Colorado Bend State Park, Meridian State Park, and Dinosaur Valley State Park (Figure 5 (b) - (e) . Each of these subscenes had greater than 30% of the total area classified as "BCV habitat". Landsat subscenes with the least relative amount of "BCV habitat" were: Devil's River State Natural Area and Possum Kingdom State Park (Figure 5 (a) and (f)). Each of these two subscenes had less than 15% total area classified as "BCV habitat". An outcome of these results is that the relative amount of "BCV habitat" is <u>not</u> a direct predictor

Figure 4 -- Examples of videography interpretated as (i) black-capped vireo "habitat" and (ii) non-habitat" for each study site. Interpretations are based on features viewed in the center of each video frame. Videography frames are taken from the following localities: (a) Devil's River State Natural Area; (b) Kerr Wildlife Management Area; (c) Colorado Bend State Park; (d) Meridian State Park; (e) Dinosaur Valley State Park; (f) Possum Kingdom State Park. Arrow symbol at lower right indicates North.

Figure 4(a)(i).

Devils River State Natural Area
"habitat"

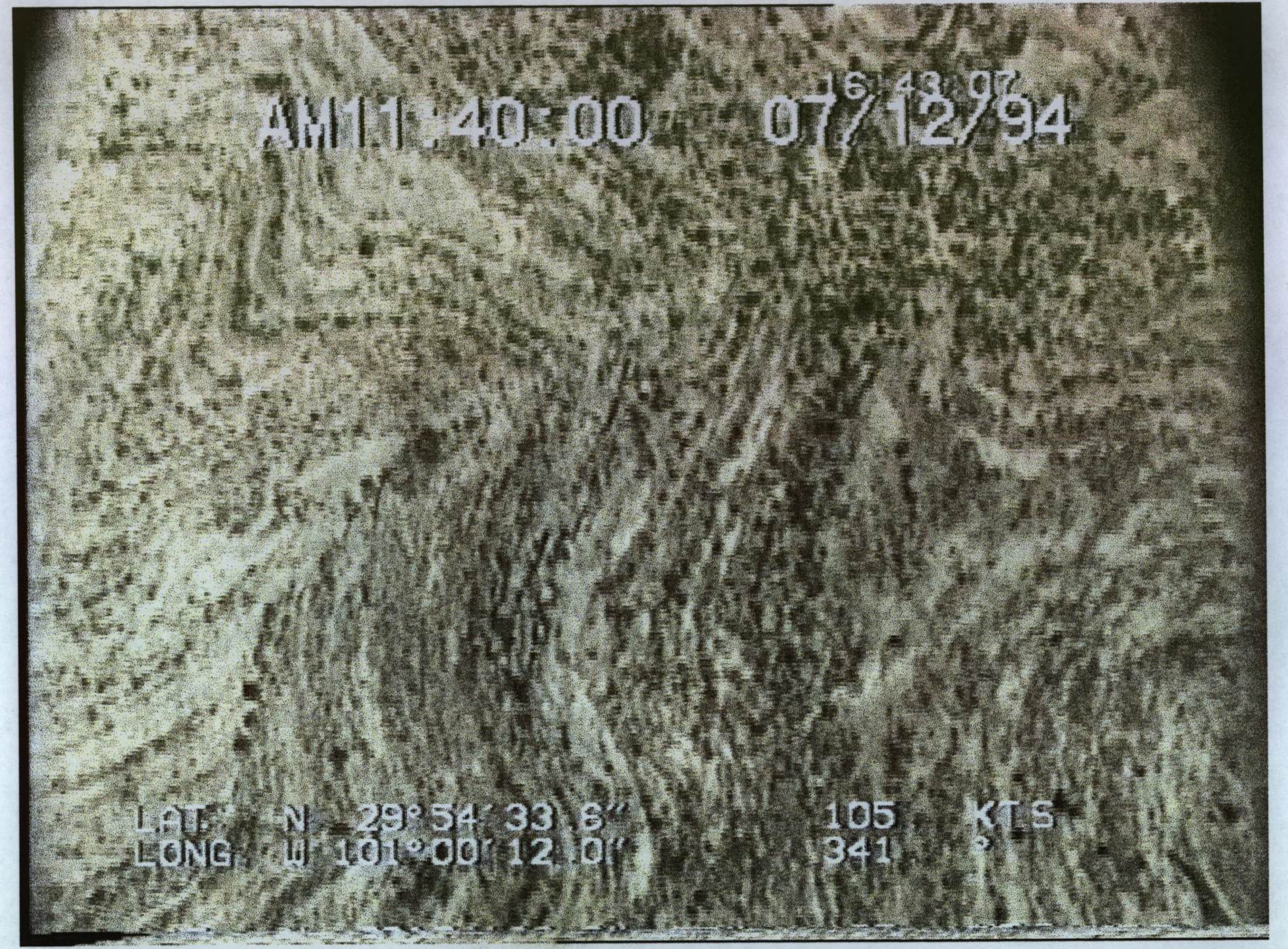


Figure 4(a)(ii). Devils River State Natural Area
"non-habitat"

Figure 4(b)(i). Kerr Wildlife Management Area "habitat"

Figure 4(b)(ii).

Kerr Wildlife Management Area
"non-habitat"

Figure 4(c)(i).

Colorado Bend State Natural Area
"habitat"

Figure 4(c)(ii). Colorado Bend State Natural Area
"non-habitat"

Figure 4(d)(i).

Meridian State Park
"habitat"

Figure 4(d)(ii). Meridian State Park
"non-habitat"

Figure 4(e)(i).

Dinosaur Valley State Park
"habitat"

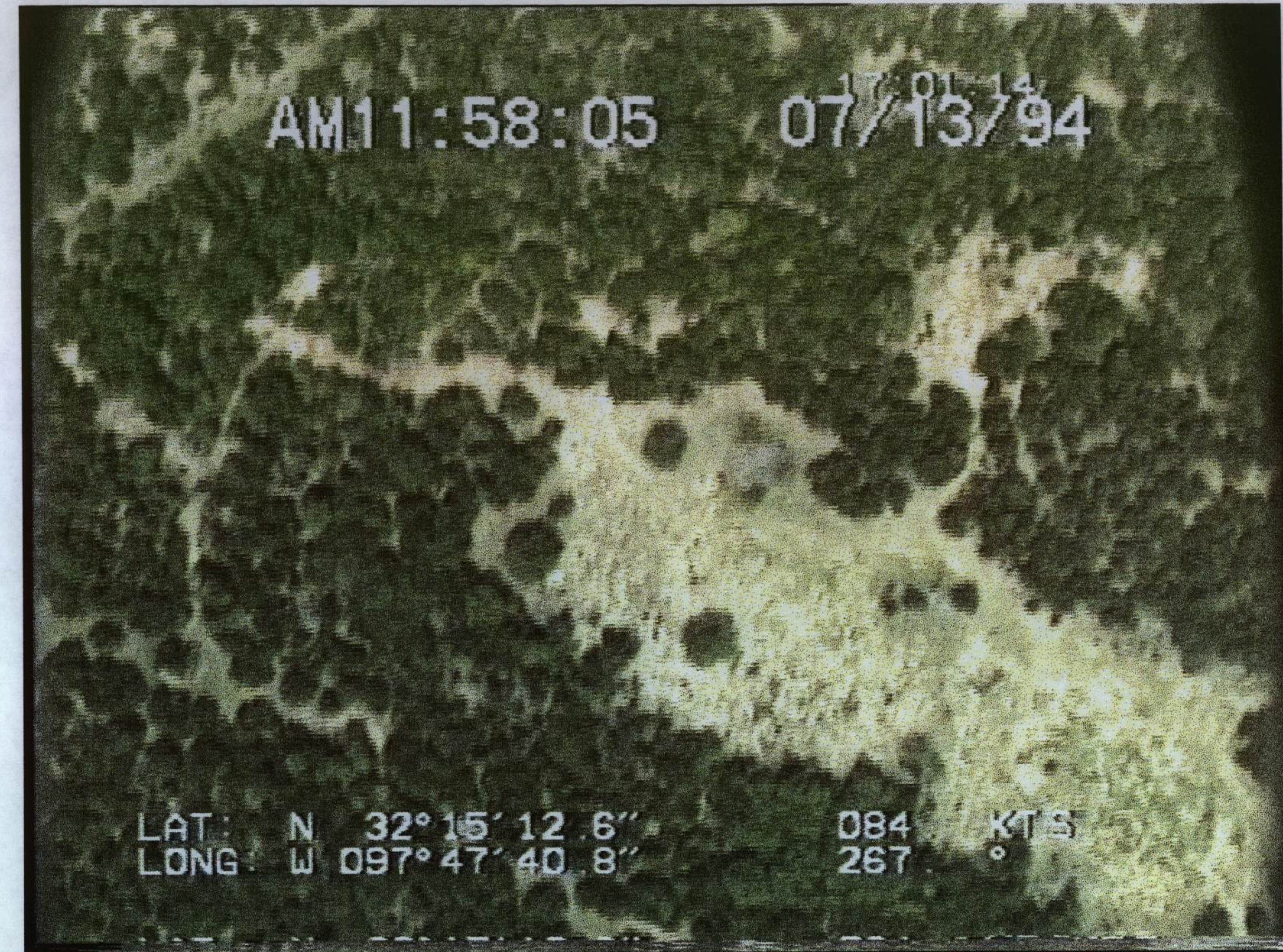


Figure 4(e)(ii).

Dinosaur Valley State Park
"non-habitat"

Figure 4(f)(i).

Possum Kingdom State Park
"habitat"

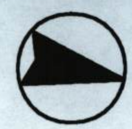


Figure 4(f)(ii). Possum Kingdom State Park "non-habitat"

of active BCV populations. In particular, the classified Meridian SP subscene had large amounts of "BCV habitat" while Devils River SNA had relatively little. As mentioned above, Meridian SP does not have active BCV populations while multiple sitings of BCVs have been recently recorded at Devils River SNA and adjacent Dolan Falls (within the past five years).

A better indicator of BCV presence would have to address some aspect of habitat quality. From additional Landsat TM analysis, we classified density of vegetation cover associated with BCV habitat. This was achieved by breaking the "BCV habitat" class into "high", "medium" and "low" vegetation cover density. Total amounts of each vegetation density class are given in Table 2. Relative amounts of each vegetation density class are given in Table 2 (with respect to total subscene area) and in Table 3 (with respect to total "BCV habitat area"). Among the four study sites with active BCV populations, each had substantial representation (> 15%) of the "low" vegetation cover density class (Table 3, column (c), Devil's River, Kerr WMA, Colorado Bend, and Dinosaur Valley SP). In contrast, both of the two study sites with sporadic BCV sitings had 15% or less "low" vegetation cover density class (Table 3, column (c), Meridian SP, Possum Kingdom SP). Regarding one of these sites, Meridian SP, Connally (1993) hypothesized that habitat for BCV was no longer available due the invasion of Ashe juniper throughout most of the shinnery areas. This would imply that vegetation closure as a result of juniper woodland succession would, at some point, exceed a maximum threshold that BCV's could tolerate. In Table 3, we attempted to measure landscape-level trends in BCV habitat vegetation density. Both Meridian State park and Possum Kingdom state Park have the highest levels of vegetation closure based on the analysis in Table 3. As indicated above, neither site has active BCV populations although both are in counties where BCVs were historically known to occur. This pattern could be incorporated into a grid-cell model of "BCV habitat" that eliminates large

Table 2 -- Extent of black-capped vireo habitat based on Landsat TM image interpretations. Class 'A' to class 'C' represent cover types of decreasing vegetation cover.

Devils River SNA Subscene

Total pixels: 216480 (13530ha)
Total habitat: 26997 (1687.31ha) (12.47%)
(Class 'A'): 3791 (236.94ha) (1.75%)
(Class 'B'): 11440 (715.00ha) (5.28%)
(Class 'C'): 11766 (735.38ha) (5.44%)

Kerr WMA Subscene

Total pixels: 109368 (6835.50ha)
Total habitat: 70987 (4436.69ha) (64.91%)
(Class 'A'): 29308 (1831.75ha) (26.80%)
(Class 'B'): 16974 (1060.88ha) (15.52%)
(Class 'C'): 24705 (1544.06ha) (22.59%)

Colorado Bend SP Subscene

Total pixels: 153176 (9573.50ha)
Total habitat: 67591 (4224.44ha) (44.13%)
(Class 'A'): 14233 (889.56ha) (9.29%)
(Class 'B'): 32551 (2034.44ha) (21.25%)
(Class 'C'): 20807 (1300.44ha) (13.58%)

Meridian SP Subscene

Total pixels: 64728 (4045.50ha)
Total habitat: 20266 (1266.63ha) (31.31%)
(Class 'A'): 5853 (365.81ha) (9.04%)
(Class 'B'): 11431 (714.44ha) (17.66%)
(Class 'C'): 2982 (186.38ha) (4.61%)

Dinosaur Valley SP Subscene

Total pixels: 49880 (3117.50ha)
Total habitat: 18340 (1146.25ha) (36.77%)
(Class 'A'): 9527 (595.44ha) (19.10%)
(Class 'B'): 5457 (341.06ha) (10.94%)
(Class 'C'): 3356 (209.75ha) (6.73%)

Possum Kingdom SP Subscene

Total pixels: 95700 (5981.25ha)
Total habitat: 12755 (797.19ha) (13.33%)
(Class 'A'): 10076 (629.75ha) (10.53%)
(Class 'B'): 2679 (167.44ha) (2.80%)
(Class 'C'): 0

Table 3 -- Percent high, medium, and low density vegetation cover based on Class A, Class B, and Class C, each divided by (Class A + Class B + Class C) within each subscene in Table 2.

Site	Vegetation Cover Density			Vegetation Closure Index
	(a)	(b)	(c)	100 - (c)
	high	medium	low	
Devil's River	14	42	44	56
Kerr WMA	41	24	35	65
Colorado Bend	21	48	31	69
Meridian	29	56	15	85 [a]
Dinosaur Valley	52	30	18	82
Possum Kingdom	79	21	0	100[a]

[a] site does not support active BCV populations (occasional BCV sitings only).

Figure 5 -- Hybrid supervised/unsupervised classification of black-capped vireo habitat based on Landsat TM imagery. Methods of classification are given in Table 1. Line features include: State properties boundaries (blue) and survey of black-capped vireo breeding areas (yellow). Pixel colors represent the following classes: Red = "BCV habitat -- very dense vegetative cover"; Green = "BCV habitat -- medium dense vegetative cover"; Blue = "BCV habitat -- less dense vegetative canopy"; White = undetermined cover; Black = non-habitat.

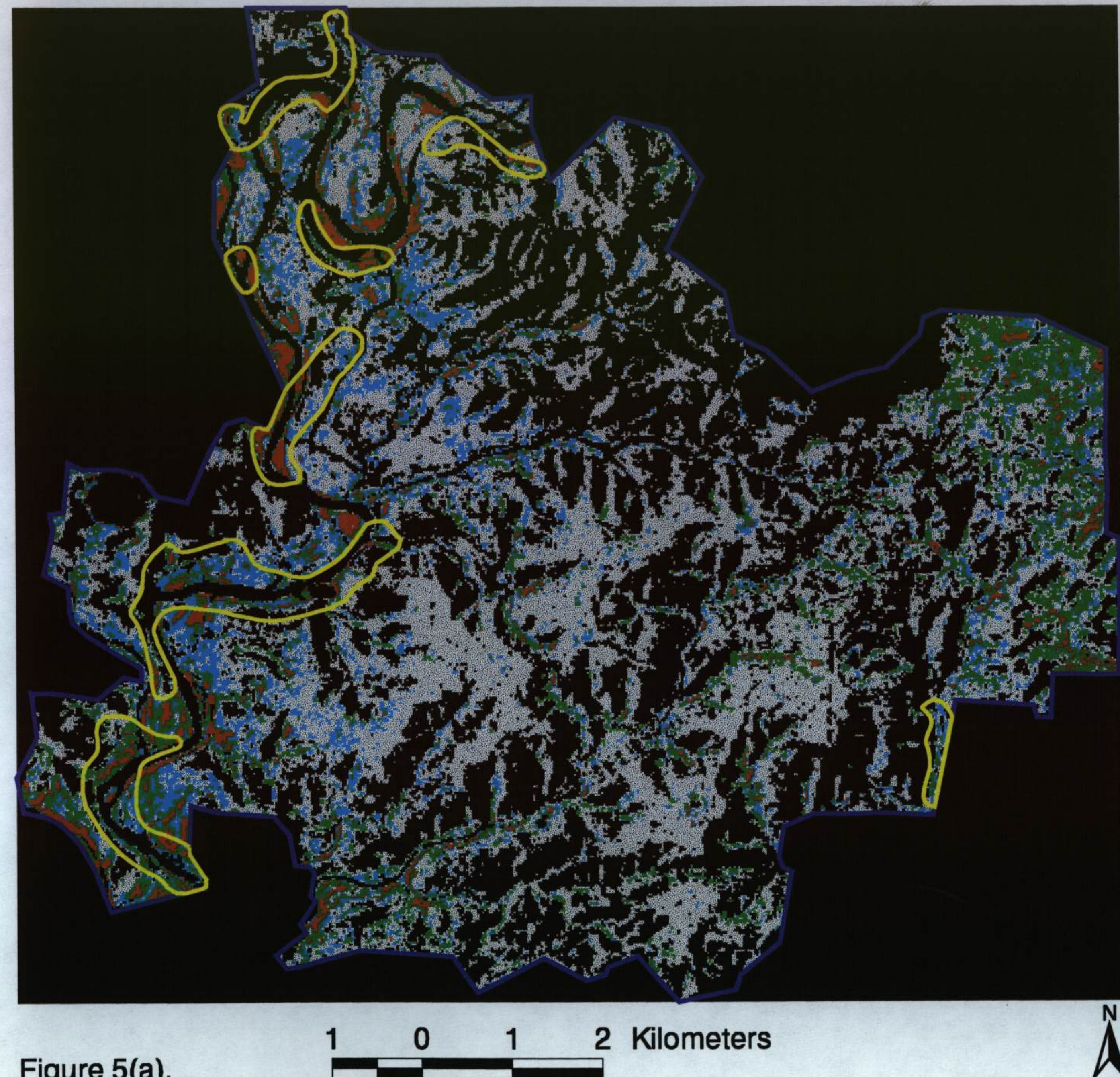


Figure 5(a).

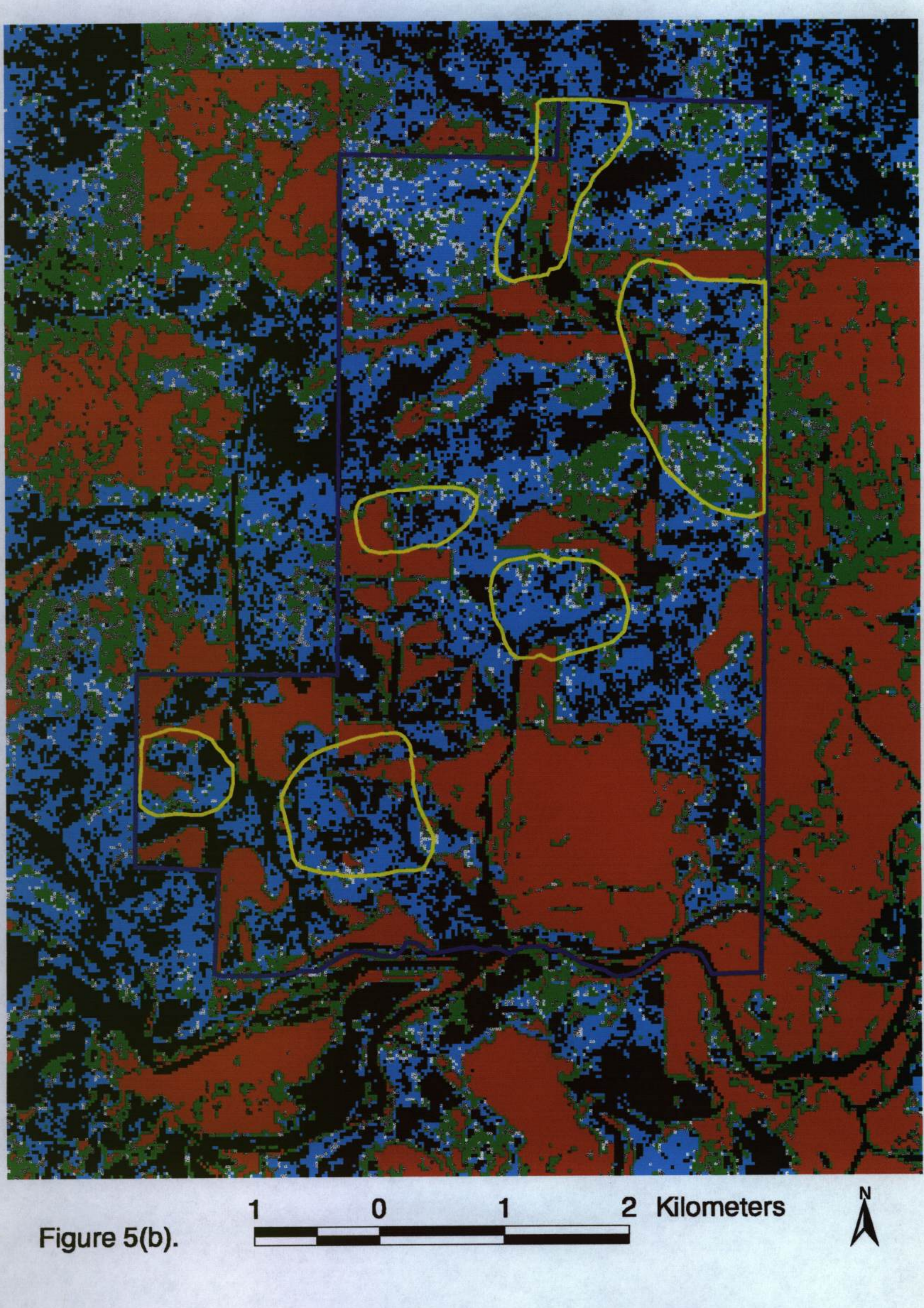


Figure 5(b).

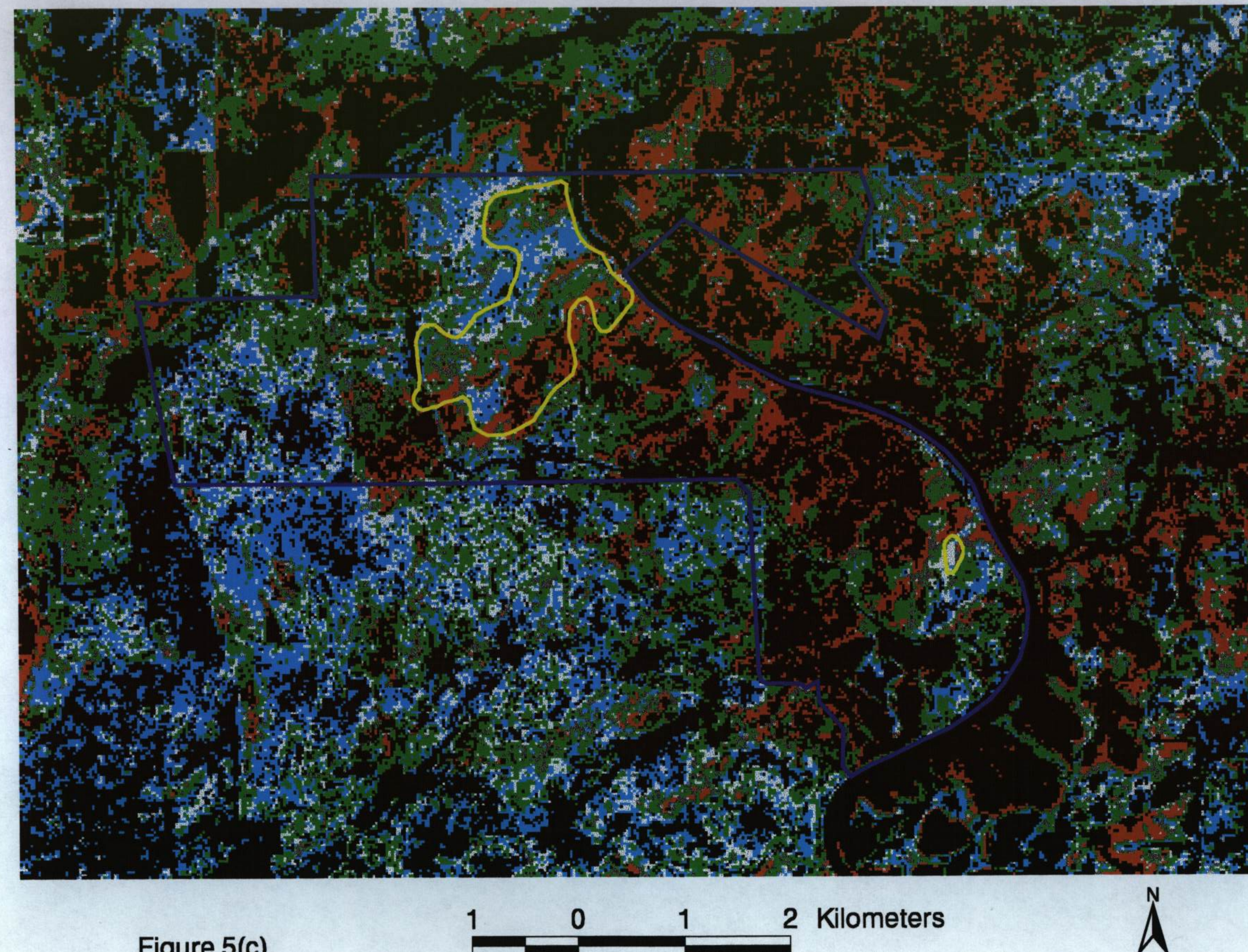


Figure 5(c).

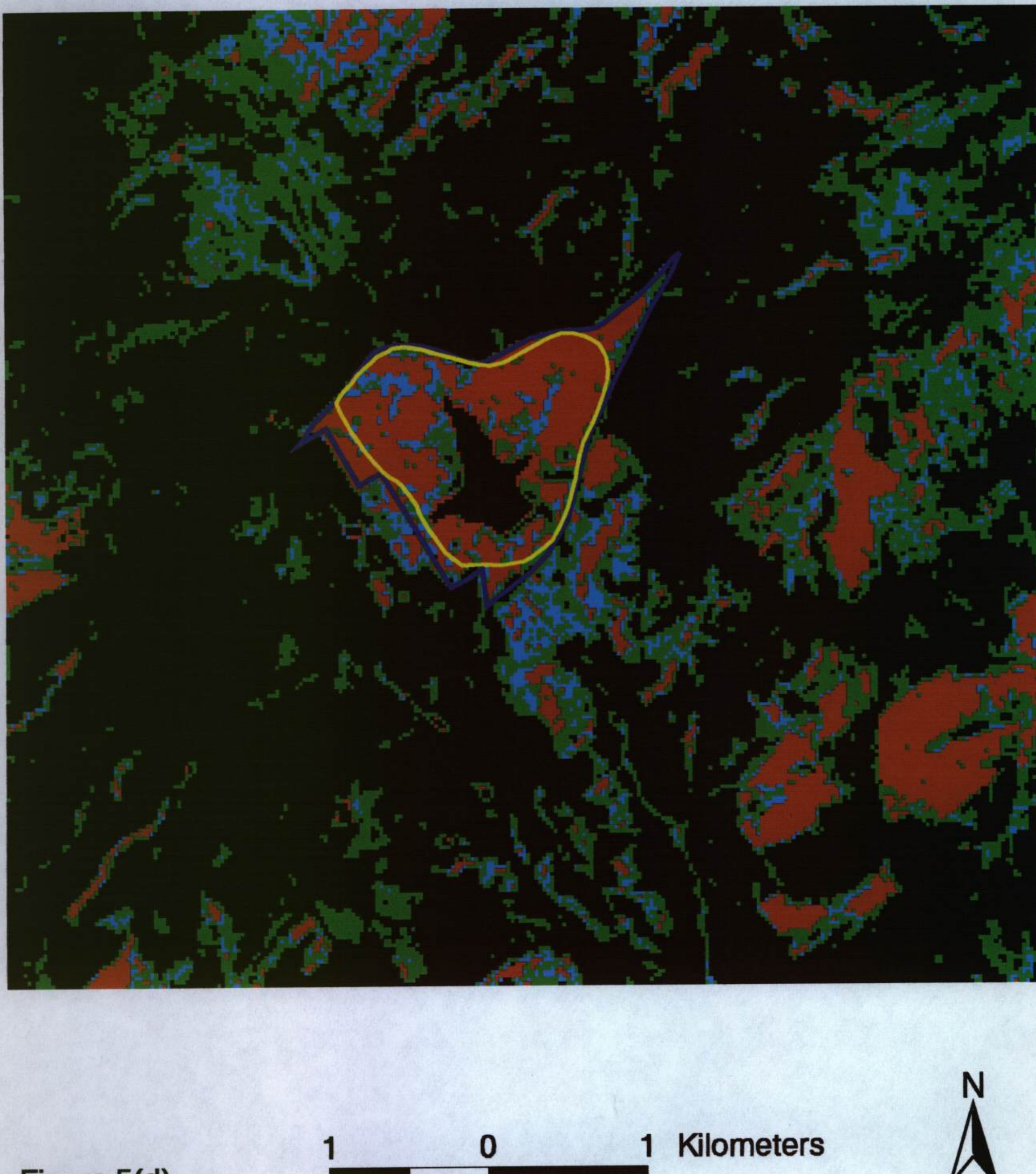


Figure 5(d).

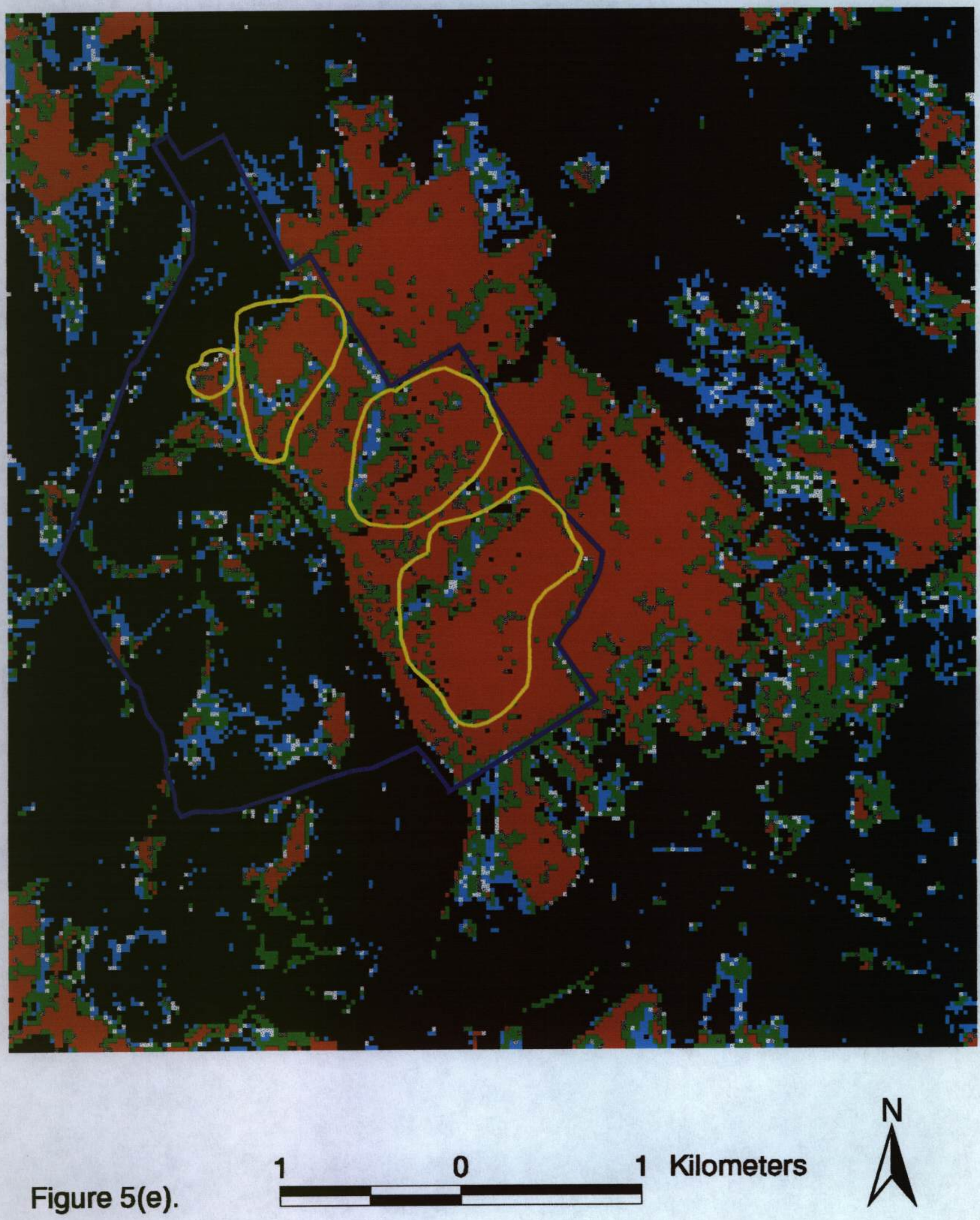


Figure 5(e).

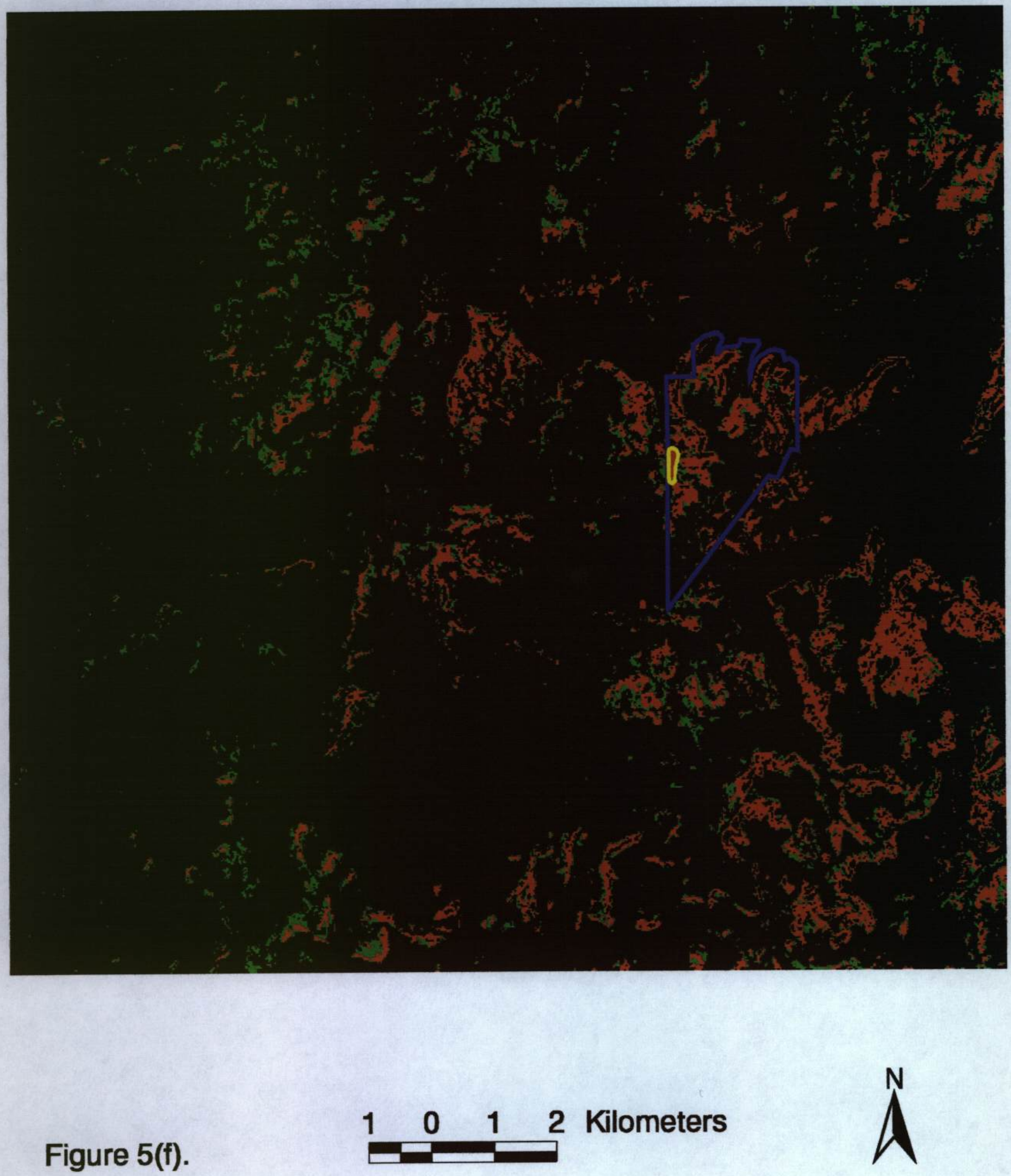


Figure 5(f).

expanses of uniformly-high density vegetation. In other words, high density vegetation with low variability in canopy over a large area would not selected out of the "BCV habitat" class.

Accuracy Assessment and Measure of Agreement between Landsat Classifications and Aerial Videography

Error matrices comparing Landsat TM image classifications and interpretations of aerial videography are given in Table 4 and are based on the methods of Congalton (1991). Accuracy assessment, in this study, is a measure the Landsat image classification quality using the videography as reference data. For discussion, overall accuracy is defined as: the number of Landsat TM pixels correctly classified in reference to the videography at that location divided by the total number of video frames interpretated for that study site. Overall accuracy percentages for each study site and Kappa coefficient of agreement are given in Table 5 (with source data in Table 4). Overall accuracy percentage values were disappointingly low, with only one of six parks exceeding 80% overall accuracy. As was expected, Kappa coefficient of agreement values were lower than overall accuracy percentages in all cases (Rosenfield and Fitzpatrick-Lins, 1986). For two parks (Devil's River State Natural Area and Colorado State Park), the Kappa coefficient was actually less than 0%, suggesting that agreement between satellite image classifications and videography was solely due to chance. The low range in overall accuracy levels (43% to 83%) and Kappa values (-12% to 67%) may be explained in part, by known sources of error (which we will discuss below).

Producer's accuracy is a measure of the error of omission within each Landsat image class (i.e., "habitat" and "non-habitat"). Producer's accuracy is defined as: the number of Landsat pixels in a given class correctly classified with reference to the videography divided by the total

Table 4 -- Error matrices for six primary sample areas (parks) comparing image interpretation based on Landsat TM image classification and aerial videography.

(a) Devil's River State Natural Area

		Videography		
		Habitat	Non-habitat	Totals
Landsat TM	Habitat	4	8	12
	Non-habitat	13	22	35
	Totals	17	30	47

(b) Kerr Wildlife Management Area

		Videography		
		Habitat	Non-habitat	Totals
Landsat TM	Habitat	26	25	51
	Non-habitat	5	11	16
	Totals	31	36	67

(c) Colorado Bend State Natural Area

		Videography		
		Habitat	Non-habitat	Totals
Landsat TM	Habitat	14	28	42
	Non-habitat	16	19	35
	Totals	30	47	77

(d) Meridian State Park

		Videography		
		Habitat	Non-habitat	Totals
Landsat TM	Habitat	22	0	22
	Non-habitat	8	18	26
	Totals	30	18	48

(e) Dinosaur Valley State Park

		Videography		
		Habitat	Non-habitat	Totals
Landsat TM	Habitat	27	1	28
	Non-habitat	14	18	32
	Totals	41	19	60

(f) Possum Kingdom State Park

		Videography		
		Habitat	Non-habitat	Totals
Landsat TM	Habitat	11	0	11
	Non-habitat	26	15	41
	Totals	37	15	52

Table 5 -- Accuracy assessment and measure of agreement based on frequency data given in Table 4.

Site	Producer's Accuracy "Habitat"	Producer's Accuracy "Non-habitat"	User's Accuracy "Habitat"	User's Accuracy "Non-habitat"	Overall Accuracy	Agreement K-HAT
Devil's River State Natural Area	24%	73%	33%	63%	55%	-3%
Kerr Wildlife Management Area	84%	31%	51%	69%	55%	14%
Colorado Bend State Park	46%	40%	33%	54%	43%	-12%
Meridian State Park	73%	100%	100%	69%	83%	67%
Dinosaur Valley State Park	66%	95%	96%	56%	75%	51%
Possum Kingdom State Park	30%	100%	100%	63%	50%	20%

number of video frames sampled for that class. Producer's accuracy for the "habitat" class ranged from 24% to 84% among study sites; producer's accuracy for the "non-habitat" class ranged from 40% to 100%. User's accuracy is indicative of the error of commision or inclusion within each Landsat image class. User's accuracy is defined as: the number of Landsat pixels in a given class correctly classified with reference to the videography divided by the total number of Landsat pixels sampled for that class. Users's accuracy for habitat ranged from 33% to 100%; user's accuracy for the non-habitat class ranged from 54% to 69%. User's and producer's accuracy values were generally low, but highly variable, across all study sites. Interestingly, the study site with the highest overall accuracy turned out to be Meridian State Park, where no active populations of BCV are known, and where definitions of what constitutes habitat were most problematic owing to canopy closure (see Section: Landsat TM Image Interpretation of BCV Habitat, above).

Why were levels of agreement so low between videography and Landsat TM image classifications? To answer this, we need to consider possible sources of error which might have contributed to low thematic accuracy. Spatial error can contribute directly to thematic error in remote sensing classifications (Dodson et al., 1993). In this instance, smaller BCV habitat features (< 20 m) brought into play the spatial precision constraints both of TM imagery and videography (which was not differentially corrected). In particular, black-capped vireos maintain territories along dry river and stream drainages on habitat patches were so narrow so as to render TM imagery and uncorrected videography useless. Spatial error near the edges of habitat patches is most critical as it leads to thematic mismatch between the videography and TM imagery. The other main source of error in our study was the positive identification of BCV habitat in the two separate analyses. Important components of BCV habitat, especially the low level vegetation which is critical for nesting, were difficult to separate apart from other vegetation types. Classification of vegetation based on age and height has been problematic in other recent remote sensing studies (e.g., "tree size" in Gonzales, 1994). It is a painfully simple fact that tree height is best seen from the ground rather than from above.

Our original intention was to develop remote sensing methods which would lead to distribution-wide maps of BCV breeding populations in Texas. While it still remains possible to achieve that goal, results presented in this report indicate that Landsat imagery and aerial videography interpretations alone are not sufficient to map breeding habitat at the standard minimum level of thematic classification accuracy, i.e., at the 80% level (Congalton, 1991). Extensive GPS-based ground data of vegetation and vireo occurrence sitings are necessary (in combination with videography and/or satellite imagery) to create accurate breeding distribution maps. We are currently gathering GPS-based roadside data on BCV habitat and occurrence sitings throughout the Texas BCV breeding distribution for this purpose.

Management Conclusions of Study

Aerial videography is a relatively inexpensive tool for gathering large quantities of remotely sensed information. While image quality is not as good as aerial photography of equal scale, it is sufficient to be quite useful in most applications. A major advantage of videography over aerial photography is that the initial analog data can be very rapidly turned onto electronic digital data by way of frame grabbers and computer modems. Lack of availability of GPS differential correction, in this study, represented a major logistical drawback, requiring us to rubbersheet individual video frames to georeferenced aerial photography, in order to complete the analysis. In particular, lack of differentially corrected data introduced the possiblity of spatial errors of > 20 m which made it almost impossible to map many BCV habitat features. Needless-to-say, future studies would require incorporating GPS differential correction into the videographic process.

Problems associated with interpreting videography as BCV habitat included (1) inability to identify low-level vegetation conditions beneath dense canopy; (2) inability to rigorously define what constitutes BCV habitat from the view above; (3) insufficient numbers of mapped occurrence localities on some of our study sites. Numbers of BCV sitings may become less of a problem as more occurrence data on TPWD park lands is converted into GIS format. Additional ground data may enable other remote sensing methods (e.g., CIR digital ortho-photography) to be used more effectively to create maps of vegetation associated with BCV breeding habitat.

Acknowledgements

Shannon Breslin and Susan Perry provided major field support during the first half of this project. James Hinson and Amy Hays provided valuable assistance with the development of image processing and GIS methods. Funding for this project was provided through ESA Section 6 Grant Texas E-1.

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