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RADAR MONITORING OF WETLANDS FOR MALARIA CONTROL

Interim Report II

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INTRODUCTION

Malaria is the most important vector-borne tropical disease (Collins and Paskewitz, 1995) and there is no simple and universally applicable form of vector control. While new methods such as malaria vaccine or genetic manipulation of mosquitoes are being explored in the laboratories, the need for more field research on malaria transmission remains very strong. For the foreseeable future many malaria programs must focus on controlling the vector, the anopheline mosquito, often under the specter of shrinking budgets. Therefore information on which human populations are at the greatest risk is especially valuable when allocating scarce resources.

The goal of the Radar Monitoring of Wetlands for Malaria Control Project is to demonstrate the feasibility of using Radarsat or other comparable satellite radar imaging systems to determine where and when human populations are at greatest risk for contracting malaria. The study area is northern Belize, a region with abundant wetlands and a potentially serious malaria problem. A key aspect of this study is the analysis of multi-temporal satellite imagery to track seasonal flooding of anopheline mosquito breeding sites. Radarsat images of the test site in Belize have been acquired one to three times a month over the last year, however, to date only one processed image has been received from the Alaska SAR Facility for analysis. Therefore analysis at this stage is focussed on determining the radar backscatter characteristics of known anopheline breeding sites, with future work to be dedicated toward seasonal changes.

APPROACH

The approach used is the same as described in the First Interim Report. The four major anopheline mosquitos responsible for malaria transmission in Belize are: <u>Anopheles albimanus</u>, <u>A. darlingi</u>, <u>A. psuedopuntipennis</u>, and <u>A. vestitipennis</u>. Each has a specific habitat type where it prefers to lay its eggs. In the northern Belize region the primary mosquito vectors are <u>A. albimanus</u> and <u>A. vestitipennis</u>. <u>A. albimanus</u> breeds in marshes with low sparse cover of macrophytes and abundant floating algal mats (Rejmankova et al., 1996). <u>A. vestitipennis</u> breeds in either marshes with tall, dense macrophytes, or in flooded forests (Rejmankova et al., in prep.). Therefore the focus on the Radarsat research is to monitor conditions in these two marsh types, and if possible in the forests as well.

Prior experience has shown that it is very difficult to identify specific wetland types with single channel radars such as Radarsat. Hence we use the approach first advanced by Pope et al. (1992): spaceborne optical sensors (in this case SPOT multi-spectral) are used to identify and map mosquito breeding habitats with dry season imagery and then radar is used to monitor conditions within these habitats.

OPTICAL IMAGE ANALYSIS

Four SPOT multi-spectral satellite images covering the northeastern quarter of Belize were acquired on February 6, 1992. The SPOT images were first georeferenced using GPS measurements made in the field and location information in 1:50,000 topographic maps. Registration errors were less than one pixel (20 m). A portion of each SPOT image was extracted that covered the region with field data. Each image segment was analyzed separately (designated NW, NE, SW, and SE). This analysis focusses on the SE segment (referred to as the SE test site).

An unsupervised isoclass clustering technique was used to convert each three-band multi-spectral image segment into individual classified images with 45 classes. These classes were then grouped interactively into 7 land cover types using field observations (with GPS coordinates) and color infrared photographs acquired in February 1993. The multi-spectral SPOT data were extracted from the tall marsh and forest classes produced in the first classification run and subjected to a second iteration of the isoclass clustering to refine the classification.

Field studies of larval habitats have identified dense, tall macrophytes as one of favored habitat types for A. vestitipennis.

In an attempt to use the SPOT imagery to isolate and map this larval habitat we separated the initial tall marsh class into a low biomass tall sparse marsh class, and a high biomass tall dense marsh class. We used a near infrared/red ratio (SPOT band 3/2) ≥ 1.8 to define the tall dense marsh class (tall sparse marsh <1.8). This ratio is a good proxy for biomass and although the 1.8 is somewhat arbitrary, the cluster dendrograms did indicate a natural break between classes at about this ratio.

The final SPOT classification contains 10 land cover types (Table 1): The low sparse marsh (9) and water (10) classes correspond almost exactly with the published (Rejmankova et al., 1995) distribution of low sparse macrophyte and freshwater classes, respectively, which were produced with the same SPOT imagery and similar classification techniques (although of a smaller area). Our field data are consistent with those of Rejmankova et al. (1995) in indicating that the low sparse marsh is composed primarily of monospecific or mixed communities of <u>Eleocharis</u> spp. or low sparse <u>Cladium jamaicense</u>. These communities often contain mats of cyanobacteria and are confirmed larval habitats for <u>Anopheles albimanus</u>. Rejmankova et al.'s (1995) second marsh class "tall, dense macrophyte" represents a broad group of <u>Cladium jamaicense</u>, <u>Typha domingensis</u>, and <u>Phragmites australis</u> communities and contains our two tall marsh classes 7 and 8. Rejmankova et al.'s "tall, dense macrophyte" class does not correlate directly with any known anopheline breeding habitat. Our division of this unit into high and low biomass types is an attempt to separate out the denser marshes (A. vestitipennis larval habitat).

The remaining classes of interest are the palm savanna and swamp forest, both of which are seasonally flooded and are therefore potential breeding sites. Mosquito larval sampling to date has not identified palm savannas as an important anopheline breeding habitat and therefore will not be considered further in this analysis. Swamp forests are known to contain larval habitats of A. vestitipennis and A. punctimacula. Only one swamp forest type (5) could be reliably separated in the SPOT analysis.

RADARSAT IMAGE ANALYSIS

This analysis is based upon the Radarsat image acquired on January 28th, 1997. The Radarsat image was converted to an 8-bit raster and resampled to the 20 m SPOT image resolution. The Radarsat image was then coregistered to the SPOT images using prominent geographic features easily recognizable in both images. A 3 pixel by 3 pixel median filter was used to reduce speckle noise. Next a radar image segment (Figures 2) was cut out corresponding to the SE test site (Figure 1) in the SPOT image analysis. A density slice Radarsat image was produced (Figure 3) to accentuate the major backscatter differences present in the image. Radar backscatter statistics were extracted for each of the 7 natural land cover types (excluding urban/bare ground, pasture/fallow, and cropland). The results are presented in Table 2, along with a comparison with the analysis of the NW test site (Rio Hondo) from Interim Report I.

DISCUSSION

Many of the same radar backscatter patterns discussed for the NW test site in Interim Report I are present the SE test site. For example backscatter from the marsh types is highly variable, as indicated by comparing Figure 1 with Figures 2 and 3. Note that the tall dense marsh (pink), tall sparse marsh (purple), and short sparse marsh (red) areas in the SPOT image often (but not always) contain radar bright (red in Figure 3) patches. Major differences between the NW and SE test site are that in the SE site bright returns are much more common from tall dense marsh and much more rare from the tall sparse marsh. This is quantitatively shown by comparing the backscatter values in Table 2, where the tall dense marsh is 4 DN higher and the tall sparse marsh 4 DN lower in the SE compared to NW test sites. This pattern suggests that water levels were higher in the SE compared to NW on January 28, 1997 when the image was acquired. Pope et al. (1997) has demonstrated that for tall marshes with >50% cover exhibit large increases backscatter when flooded, whereas all marshes with <30% exhibit decreases in backscatter when flooded. The increase is due to double bounce reflections off the water and plant stems, while the decreases are due to forward scattering off the open water. The data in Table 2 are consistent with high water levels in the SE and lower levels (but still flooded) in the NW.

Interestingly, the low sparse marsh has the highest mean backscatter in both test sites. Flooding typically does increase backscatter in this type of marsh, however the backscatter magnitude is usually lower than in the tall marshes (Pope et al., 1997). This may indicate that this marsh is completely flooded, whereas the tall marshes are only partly flooded resulting in a mixed signal and a lower mean backscatter. Some indication of this is found in comparisons of Figures 1 and 3, where the very high backscatter zones (red in Figure 3 = DN >80) correlate best with the tall dense marsh (pink) class.

Another difference between the SE and NW test sites is that the water has much higher (>5 DN) values in the SE compared to NW sites. Comparison of the SPOT classified image (Figure 1) and the density slice Radarsat image (Figure 3) clearly show that many of the water areas in the SE give bright returns (especially note the lagoon in the southwest [lower left] portion of the SE site). Examination of the histograms for the water class in the SE site reveals that they are bimodal, suggesting there are two distinct conditions present. These are probably open water and water with either emergent or floating vegetation, possible algal mats. These algal mats are important anopheline mosquito breeding sites and this finding will be examined in more detail in future work.

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Table 1. SPOT classification of land cover types for the SE test site, northern Belize.

Land Cover Type		Map Color	Percent Cover (Total Area = 2069 km2)
1.	Urban/Bare Ground	White	2.8
2.	Pasture/Fallow	Yellow	19.4
3.	Cropland	Brown	10.1
4.	Forest	Dark green	36.5
5.	Swamp Forest	Light green	8.1
6.	Palm Savanna	Orange	8.5
7.	Tall Dense Marsh	Pink	2.5
8.	Tall Sparse Marsh	Purple	5.6
9.	Low Sparse Marsh	Red	3.1
10.	Water	Blue	3.5

Table 2. Radarsat backscatter from natural land cover types. SE and NW (Interim Report I) test site, northern Belize.

Land Cover	Backscatter (DN)	
	SE Test Site	NW Test Site
Forest	57.7 ±0.01	58.5 ±0.02
Swamp Forest	58.1 ±0.02	61.2 ±0.07
Palm Savanna	59.4 ±0.02	59.3 ±0.06
Tall Dense Marsh	62.0 ±0.04	57.9 ±0.07
Tall Sparse Marsh	58.1 ±0.04	62.2 ±0.03
Low Sparse Marsh	64.1 ±0.05	63.4 ±0.07
water	45.7 ±0.05	40.0 ±0.13
Full test site	56.7 ±0.01	57.4 +0.03

Figure 1. Land cover classification of SPOT multi-spectral image, SE test site, northern Belize (image height 52 km, north at top). Key: White - urban/bare ground; yellow - pasture/fallow; brown - cropland; dark green - forest; light green - swamp forest; orange - savanna; pink - tall dense marsh; purple - tall sparse marsh; red - low sparse marsh; and blue - water.

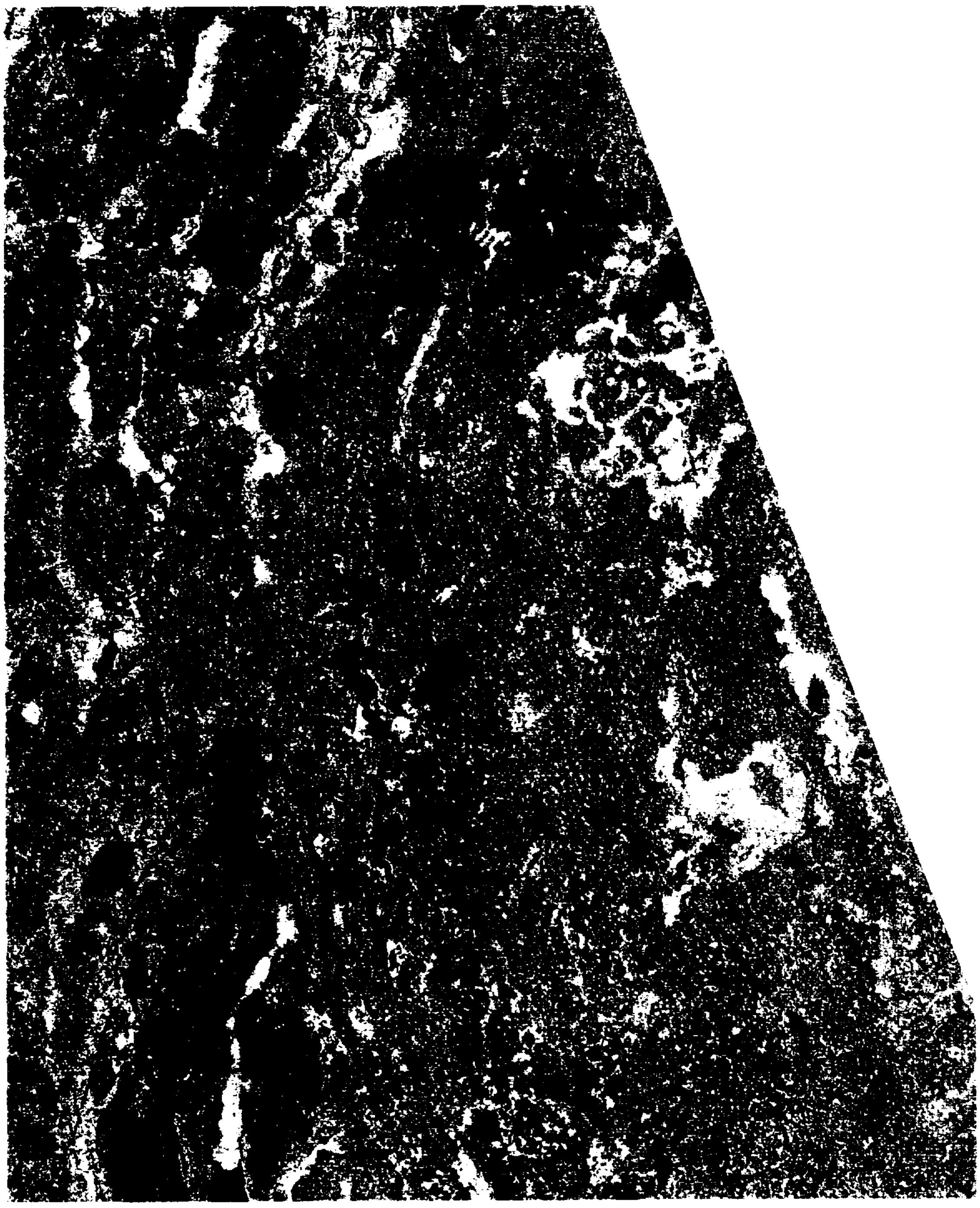

Figure 2. Radarsat image of the SE test site, northern Belize (3x3 median filter, normalized contrast stretch; image height 52 km, north at top).

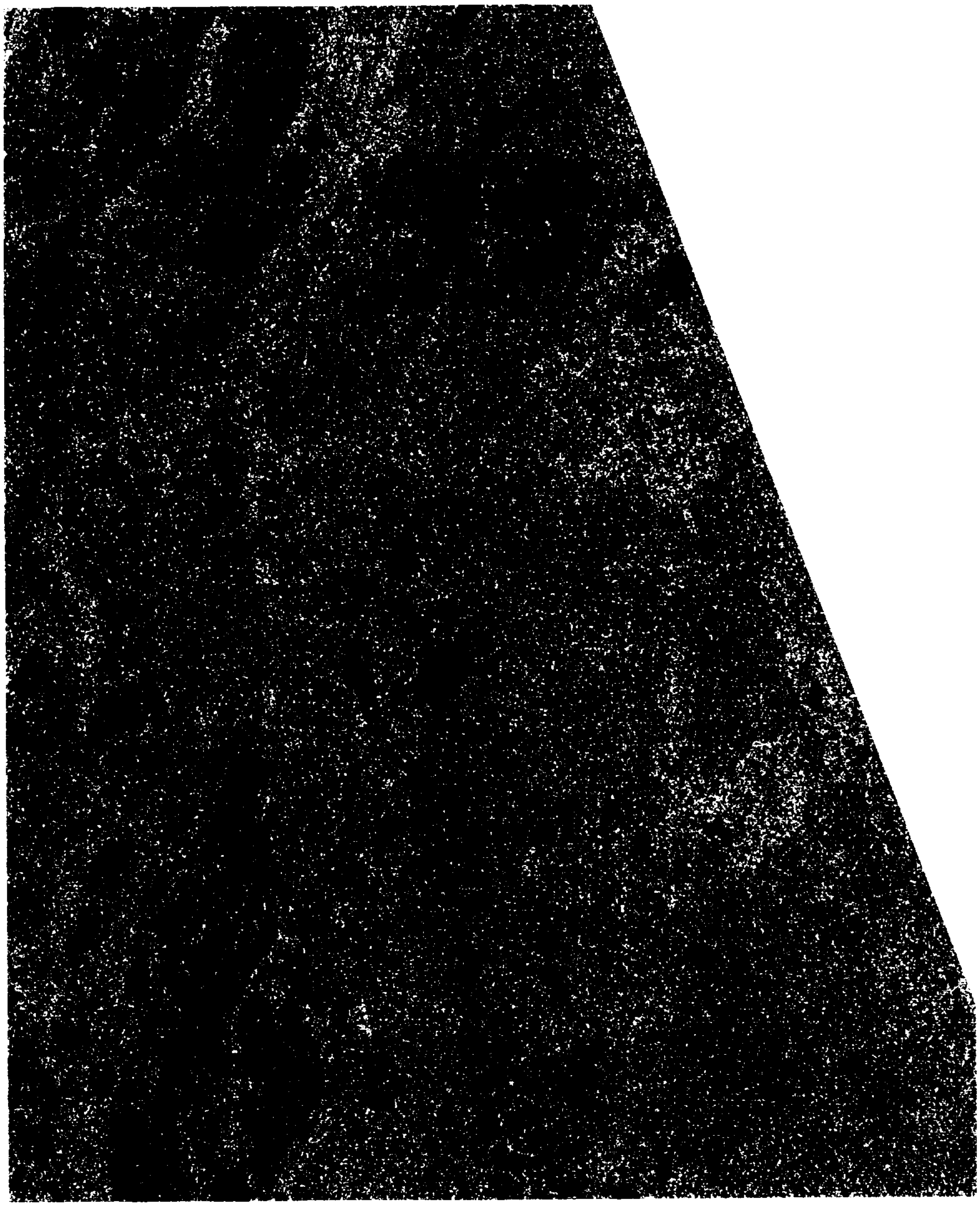

Figure 3. Radarsat image of SE test site with density slice (3x3 median filter; image height 52 km, north at top). Low backscatter in blue (DN 1-30), moderate backscatter in green (DN 31-65), moderately high backscatter in yellow (DN 66-80), and high backscatter in red (DN >80). Red zones correspond to probable flooded marshes. Blue zones are open water.