GEOS421

Final Report

C.R.B.D. Project 2010: Barra del Colorado Baseline Coverage Analysis and Habitat Mapping

Carla Solano, Miguel García, Wayne Howse,

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Instructors: Colin Lynch and Wade Hawkins

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1. **Executive Summary**:

The NE of Costa Rica is an area which includes a number of protected and semi-protected areas, collectively managed as the Tortuguero Conservation Area. Included is the Barra Del Colorado Wildlife refuge and the Dr. Archie Carr Wildlife Refuge. In support of Governmental and nongovernmental conservation efforts in the region this project generated a land cover classification from satellite images of the NE of Costa Rica. Further, the project produced habitat maps and predictive mammal densities based on this classification for, the Barra Del Colorado and the Dr. Archie Carr as well as a small stretch of adjacent unprotected territory. The beneficiaries of the project include INBio (Instituto Nacional de Biodiversidad/ National Biodiversity Institute in Costa Rica), and COTERC (The Canadian Organization for Tropical Education and Rainforest Conservation). The goal of this analysis is to aid INBio in the development of a national land coverage classification of Costa Rica, and to support COTERC's large mammal monitoring program, via the project outputs, and their effort to formulate animal density estimates for the region. Further, the project addresses COTERC's stated need for a full land cover classification of the Barra Del Colorado Wildlife Refuge, the Dr. Archie Carr Wildlife Refuge, and the directly adjacent unprotected territory, and to note the anthropogenic influence in the area. The project was developed and executed between the January 14 and April 23, 2010, and the results show that there is a definite anthropogenic presence in the region.

2. Rationale:

Background:

The spatial context of the project makes it highly suitable for GIS analysis. Generating a thematic land cover map from the satellite images, taking account of the anthropogenic influence in the area, and developing habitat maps and predictive densities requires a variety of inputs, spatial modeling approaches and analysis for which GIS is a well suited tool.

Literature Review:

This project referenced a number of studies and texts related to specific aspects of the project and approaches taken.
In particular studies referenced included:
Rule-Based Integration of Remotely-sensed Data and GIS for Land Cover Mapping in NE Costa Rica (K.L. Driese, 2001) – An informative

presentation of the strengths and limitations of classifying satellite imagery in general and images of the tropical forests of NE Costa Rica specifically. Of particular interest was the use of ancillary data in this study in addressing the challenges of discriminating spectrally indistinct cover types.

Rectification of Digital Imagery (K. Novak, 1992) – Presents a discussion of three rectification methods. Important to this project, is the support this article lends to our contention that relief displacement in the images of the study area will not negatively impact the classification.

Georeferencing from orthorectified and non-orthorectified High-resolution satellite imagery (J. Willneff, 2006) – Again, this paper supports the argument that relief displacement is not a factor in this project and our decision to geo-rectify the images without orthorectifying them is justified and sound.

GIS Application for Gorilla Behavior and Habitat Analysis (H.D. Stelkis, 2005) – this paper describes a case study where-by GIS facilitates the combination of data of various sources and types for advanced modeling, exploration and analysis. Of particular interest was the application and creative approach to data limitations and challenges associated with utilizing satellite images of the tropics to study the environment.

Predicting Mammal Species Richness and Abundance Using Multi-Temporal NDVI (B. Oindo, 2002) – this study covers the application of remotely sensed data to monitor, access and predict mammalian abundance. This study demonstrates that remote sensing and land cover classification can be applied to help support predictive estimates about species richness. Importantly, this study also makes the recommendation that data of a finer spatial resolution would improve that accuracy of the result.

Text References:
For material covering remote sensing in general we referenced:

- Remote sensing and image interpretation (Lillesand, 2007) – an extensive look at remote sensing and its applications
- Fundamentals of Remote Sensing: A Canadian Center for Remote Sensing Tutorial (NRCAN) – An introduction to remote sensing and it's applications

For material covering Image Analysis in the tropics, with specific reference to cloud cover we referenced:

- GIS Methodologies for developing Conservation Strategies: Tropical Forest Recovery and Wildlife Management in Costa Rica (Savitsky, 1998) – Discusses the challenges of working with satellite images of this area in particular the chronic cloud cover.

- Remote Sensing for Natural Resource Management and Environmental Monitoring (Ustin, 2004) – Again presents a disscussion of the applications of remote sensing, and the challenges of cloud cover in images of the tropics as well as the challenge of ditinguishing/discrimating between spectrally indistinct cover types.

For material covering wildlife and habitat data collection and analysis we referenced:

- GIS Methodologies for developing Conservation Strategies: Tropical Forest Recovery and Wildlife Management in Costa Rica (Savitsky, 1998) – Again, this was good introduction to the concepts and practices applying GIS to Wildlife Management.
- *Museo de Historia Natural Noel Kempff Mercado, Santa Cruz, Bolivia* (D. Rumiz), in Conservation Geography: case studies in GIOS, Computer mapping, and activism (C.Convis, 2001) – This study illustrates the application of GIS to conservation in Bolivia. Applying field data, ancillary values and parameters, to a land coverage of the Noel Kempff Mercado National Park in Bolivia, this study identified habitat and estimated densities for the Maned Wolf in the area.

Additionally, we met with Carina Butterworth from the Geomatics department at SAIT Polytechnic, and Adrian Faraguna of the SAIT BGIS early in the project. Both of these individuals offered us insight and tips regarding research and resources. Importantly, we have also relied on the input from our client mentors for direction and guidance.

Summary:

Existing research proves project feasibility. That land-cover classification using ASTER images is realistic. That cloud cover in satellite images of the tropics is common, and that it can be mitigated. Additionally, that land-cover classifications are often the beginning phase of larger analysis and mapping projects.

3. Project Implementation and Methods:

The analysis for the project included:

The Land-Cover Classification (see appendix 4) – the original L1A ASTER satellite images supplied by INBIO were georectified, then mosaiced and color balanced using ENVI. Additionally, a cloud mask was built and applied. The Classification was originally attempted applying a Normalized Difference Vegetation Index (NDVI) however preliminary results proved unsatisfactory. The project subsequently acquired 75 ground training areas from INBio which facilitated the successful production of a supervised classification of the satellite images. Maximum Likelihood was the classification method chosen as it returned the comparatively best results. Post processing included Sieving, Clumping, and Majority Smoothing/Analysis. The final land cover map was converted to vector in ENVI, clipped to the buffered study area layer (The Barra Del Colorado Wildlife refuge, the Dr. Archie Carr Wildlife Refuge, and the directly adjacent unprotected territory shape, buffered by 1km) and additional editing was performed in ArcMap. This included hand editing of the unclassified areas (masked clouds which existed in the mosaiced image but not in the area of image overlap of the individual images). The classification was overlaid on the original separate images with the unclassified areas set to hollow symbology - to view the underlying image - and then reclassified where possible. In the end we generated 9 classes with a 93% + accuracy for all classes with exception of the Bare Earth class at 72% for an overall accuracy of 81%. In addition just 9% of the total classification was unclassified (masked clouds) or shadow. Constraints included the image resolution (30 Meter) and the accuracy and temporal resolution of the training areas.

The Development of Habitat Maps and Predictive Densities – Four mammals were chosen by COTERC for the project to develop habitat maps and predictive densities within the study area. These mammals were the Jaguar, White-lipped Peccary, Central American Spider Monkey, and Baird's Tapir. The analysis involved applying habitat parameters given to the project group by COTERC to the land cover classification map. A model was developed for the construction of the habitat maps (Appendixes 5 – 9) against which density figures supplied by COTERC were applied to generate the predictive density estimates for each of the four mammals within the study area (see appendix 1 for predictive densities). Additionally, a core habitat analysis was conducted for the habitat areas of the four mammals with the intent of focusing conservation and research efforts. The habitat and density values are constrained by the accuracy of the classification and the provided parameters.

Terrain Analysis – This analysis was conducted to illustrate the topography of the study area and to assess the potential impact of relief displacement on the classification. The study area is mostly low lying and flat, and the analysis thereby demonstrates that relief displacement is not a significant adverse impact on the results of the classification. A terrain model (TIN) was built using a regional contours shapefile, clipped to the study area. The resolution of this these contours while a constraining factor in the accuracy and portrayal of the study area topography is non-the-less sufficient for the purposes as here outlined.

Elevation Analysis – This analysis was conducted both as an exploration of the study area and in anticipation its employment and utility in the development of the habitat maps. The goal here was that we could use the elevation in conjunction with the classification to help delineate habitat regions for species that prefer elevation. The later proved not to be as the parameters supplied by COTERC did not cite elevation as a variable for those levels within the study area. The Resolution of the DEM used as the basis of this analysis was coarse (1242 x 1242 meters) and again while is a definite constraint on the analysis is not a significant negative influence considering the purpose of the analysis for this project.

Hydrological Modeling – This analysis was performed in an attempt to support and clarify the delineation of flooded vegetation (Swamp Forest) from Forest in the classification. The original attempt to acquire information confirming the location of the swamps and lagoons in the study area proved fruitless. This included attempts to acquire vector data delineating these areas cited as used in previous studies (in particular the project group contacted Kenneth Driese of the University of Wyoming who was willing to share the this data used in a 2001 study of the area but was unable to locate it), and maps and/or atlases categorically defining the location of these features. The hydrological analysis while illustrating that the most of the study area is a large drainage basin is inconclusive as to the location of individual swamps and lagoons.

Project Website – Google-Sites was used to develop an online presentation which includes project overview, final report and analytical results, maps. COTERC does not currently have a GIS and the project website was an effective means of sharing the results of the project with them and in turn for COTERC to share the results with operations in Costa Rica and to link to their website should they choose. Here is the link: https://sites.google.com/site/crbdproject2010 .

4. Results and Analysis:

Results of the analysis show that there is a definite anthropogenic presence within the study area - agricultural activities account for approximately 13% of the study area. Additional research may show that encroachment and habitat fragmentation is a major influence on the wildlife in the region. While the images and classification clearly illustrate the agricultural activity within the area, categorically distinguishing natural grass from pasturage, and naturally occurring areas of bare soil from those indicating agricultural activity proved difficult. This difficulty in distinguishing spectrally indistinct cover types such as pasturage from natural grasses is a challenge cited by Ustin (2004) and Driese (2001). Driese notes that in this area "pastures range from open grass through a continuum of scattered to heavy tree cover within the herbaceous mix. The pasture grass itself ranges in height from closely cropped to several meters" (Driese, 2001). This class confusion proved to be a factor in determining relative measures and types of anthropogenic disturbance in the area and was also a consideration in determining and delimiting habitat areas. In developing the habitat maps the decision was made to ere on the side of caution and to consider all areas classified as grassland and bare earth as anthropogenic. In addition, our research indicates that the study area is swampy and the location of a number of lagoons (cf. Garrigues, 1996). The exact location and spatial extent of these areas remains undefined from the classification, and in the absence of relevant ancillary inputs it was decided by the project group to treat the classification of flooded vegetation as the location and extent of these forested swamps.

5. Conclusion:

The results of the project meet the project objectives and client needs. The regional land cover classification contributes to INBio's development of a national land cover inventory of Costa Rica, as well as COTERC's stated need for a full land cover classification of the Barra Del Colorado Wildlife Refuge, the Dr. Archie Carr Wildlife Refuge, and the directly adjacent unprotected territory, and further, to note the anthropogenic influence in the area. Additionally, the habitat mapping and the predictive mammal density estimates support COTERC's large mammal monitoring program, and their effort to formulate animal density estimates for the region.

6. Recommendations:

Future analysis could benefit from higher resolution imagery with less cloud obstruction, and more ground truthing data, to help distinguish spectrally indistinct cover types, as well as data clearly indicating the location of areas of permanent and seasonal inundation. With more recent or older data a comparative temporal element could be added to the analysis as well.

7. Lessons:

Technical lessons learned over the course of the project include a fuller appreciation of the technical methodologies, models and approaches of a GIS project, the effectiveness and efficiency of model-builder, and the paramount role of data and data management. Further to this, we gained a richer practical awareness of GIS as an analytical and decision making tool. Importantly, conducting a project in an academic setting gave us the opportunity to develop project and team management strategies and approaches in absence of the usual levers and incentives found in industry.

8. Data inventory:

Please refer to Appendix 2

Works Cited

Driese, K. (2001). Rule-based Integration of Remotely-sensed Data and GIS for Land Cover Mapping in NE Costa Rica. *Geocarta International, Vol. 16, No.1* , 37-46.

Garrigues, R. (1996). *National Parks*. Retrieved 03 15, 2010, from Costa Rica: http://www.angelfire.com/bc/gonebirding/crnps.html

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NRCAN (n.d.) Fundamentals for Remote Sensing: A Canadian Center for Remote Sensing Tutorial

Oindo, B. (2002) Predicting Mammal Species Richness and Abundance Using Multi-Temporal NDVI. *Photogrammetric Engineering and Remote Sensing, Vol. 68, No. 6, June 2002, 623-629.*

Rumiz, D. (2001). Museo de Historia Natural Noel Kempff Mercado, Santa Cruz, Bolivia *Conservation Geography: Case studies in GIS, Computer mapping, and Activism*, 2001

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Stelkis, H.D. (2005) *GIS Application for Gorilla Behavior and Habitat Analysis.* Retrieved January 24, 2010, from ArcNews: http://www.esri.com/news/arcnews/summer05articles/gis-applications.html

Ustin, S. L. (2004). *Remote Sensing for Natural resource mangement and Enviromantal Monitoring.* Hoboken, NJ: John Wiley and Sons Inc.

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Appendix 1 – Predictive Mammal Densities Estimates:

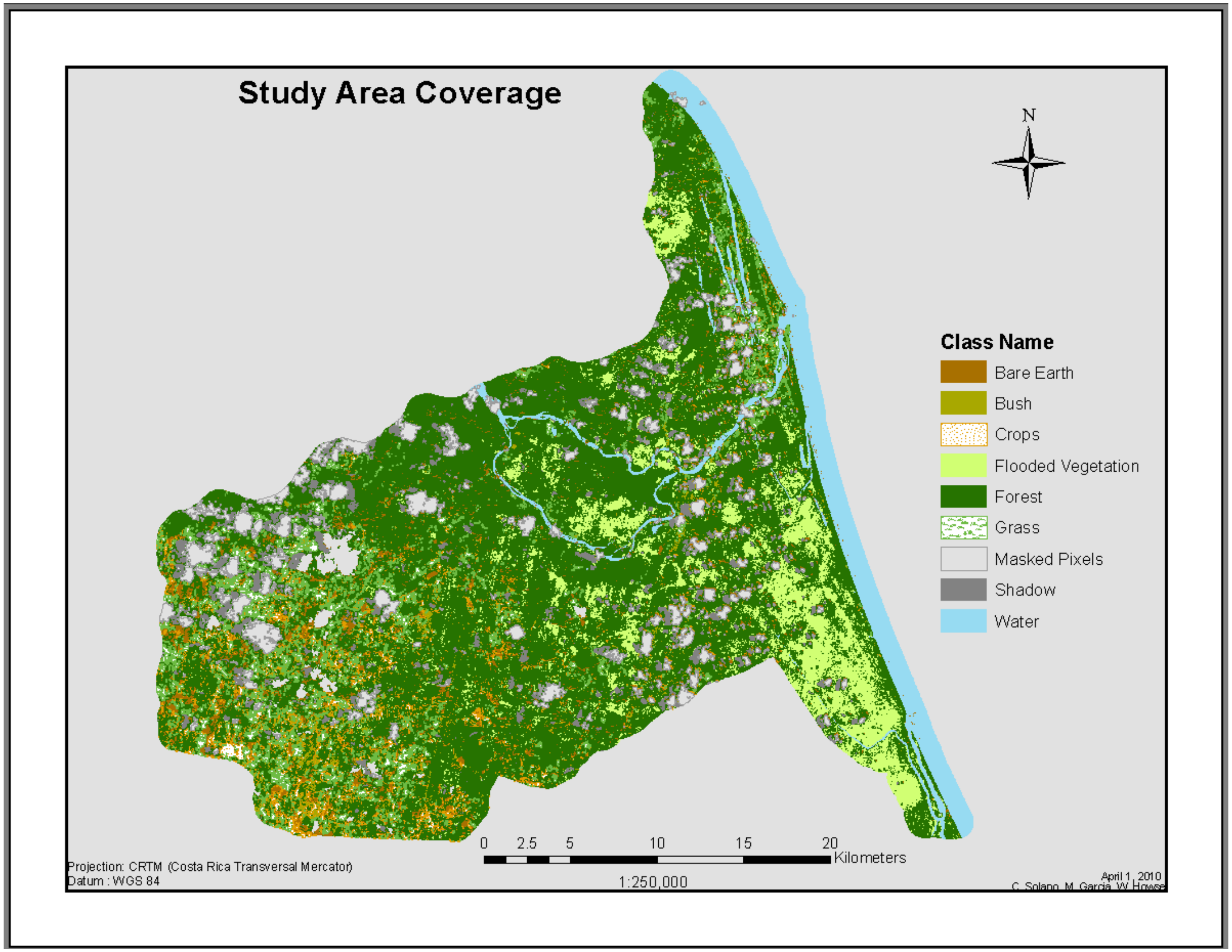
Mammal	**Predictive Density Estimates for Study Area**	**Inputs and Parameters (from Kym Snarr)**
Jaguar (*Panthera onca*)	9.6 males 15.2 females	"Male jaguars have home ranges with which range from 28-40 km2 (Rabinowitz and Nottingham 1986) with females having smaller ones (about 1/3 smaller); can we show the range in the literature"
Baird's Tapir (*Tapirus bairdii*)	255 individuals	"Range from 0.05-1.33 ind/km2 (Brooks et al 1997) so can indicate the range in the literature"
White-Lipped Peccary (*Tayassu pecari*)	3610 individuals	"~ 10 ind/km2 (Keuroghlian et al. 2004; Cullen 1997; Desbiez 2007)"
Central American Spider Monkey (*Ateles geoffroyi*)	4640 individuals	"As BCWR offers minimal protection at best, and there is encroachment + migrant + other poaching, the pop'n density to be used = 20-30ind/km2"

Appendix 2 - Data Inventory:

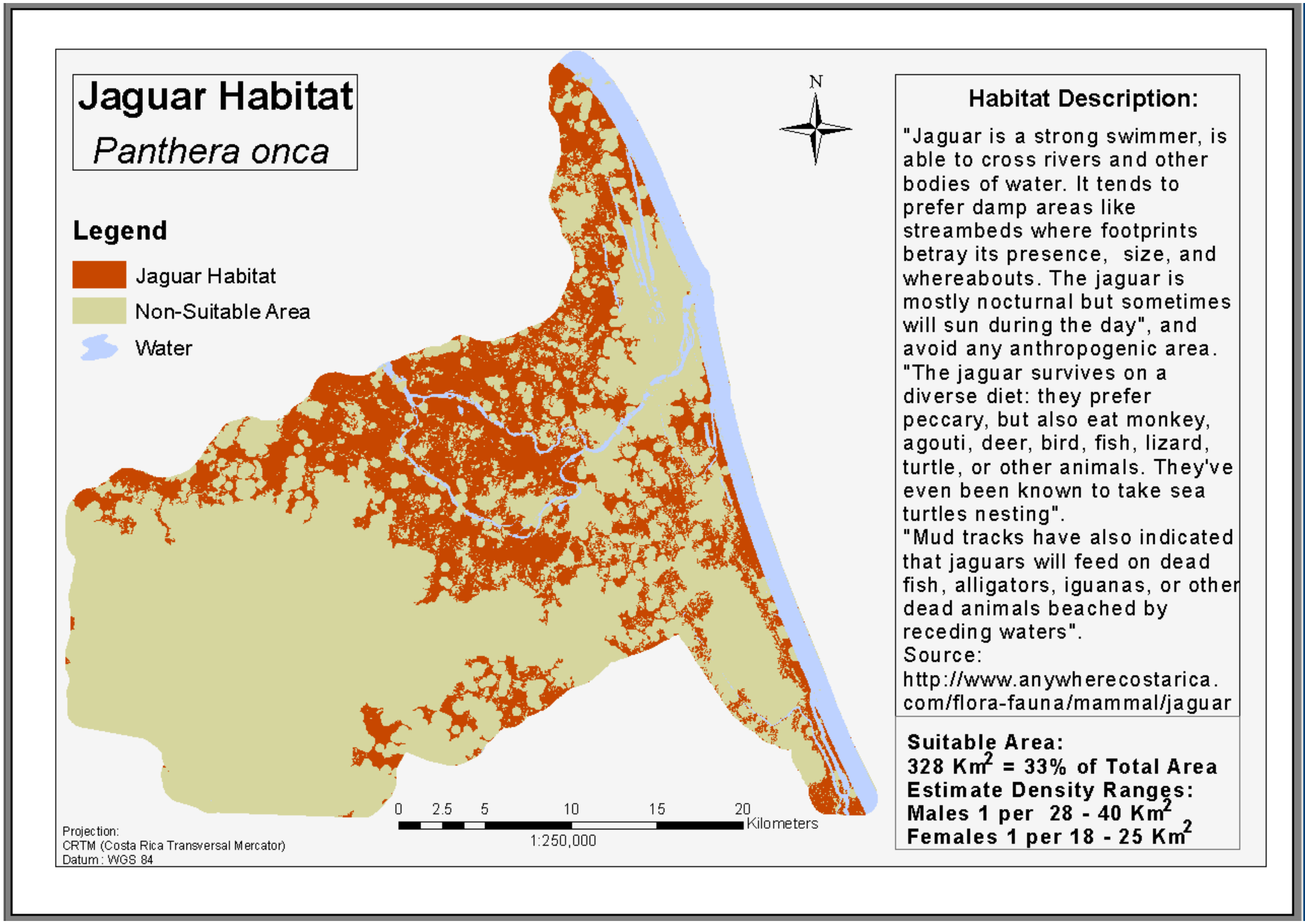
Final data Products							
File Name	**Data Type**	**Spatial Extent**	**Projection**	**Datum**	**Comments**	**Source/role**	**Location**
FinalVectorClass	Vector/Polygon	Buffered study area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
StudyArea	Vector/Polygon	Barra Del Colorado Wildlife Refuge +	CRTM, Central Meridian: -84.0	WGS84	Attribute table in Spanish	Project output – edited from client supplied shape	CRBD2010_Final Data.mdb
BufStudyArea	Vector/Polygon	Study Area +1km buffer	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Curvas_Contours	Vector/Line	Regional	CRTM, Central Meridian: -84.0	WGS84	Attribute table in Spanish	client supplied shape	CRBD2010_Final Data.mdb
Rios_1	Vector/Line	NE Costa Rica	CRTM, Central Meridian: -84.0	WGS84	Attribute table in Spanish	client supplied shape	CRBD2010_Final Data.mdb
Rios_Rivers	Vector/Line	Costa Rica	CRTM, Central Meridian: -84.0	WGS84	Attribute table in Spanish	client supplied shape	CRBD2010_Final Data.mdb
CentralAmerica	Vector/Polygon	Central America	CRTM, Central Meridian: -84.0	WGS84	Attribute table in Spanish	client supplied shape	CRBD2010_Final Data.mdb
CR_Boundary	Vector/Polygon	Costa Rica	CRTM, Central Meridian: -84.0	WGS84	Attribute table in Spanish	client supplied shape	CRBD2010_Final Data.mdb
FinalClassifaction	Image/tiff	NE Costa Rica	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
HabIntersect	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Jaguar_Habitat	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Pecari_Habitat	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
SMonkeyHab	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Tapir_Habitat	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Crops	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Water	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Shadow	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Masked_Pixels	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Bare_Earth	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Flooded_Vegetation	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Grass	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb
Bush	Vector/Polygon	Study Area	CRTM, Central Meridian: -84.0	WGS84		Project output	CRBD2010_Final Data.mdb

Appendix 3 - Study Area Inset Map:

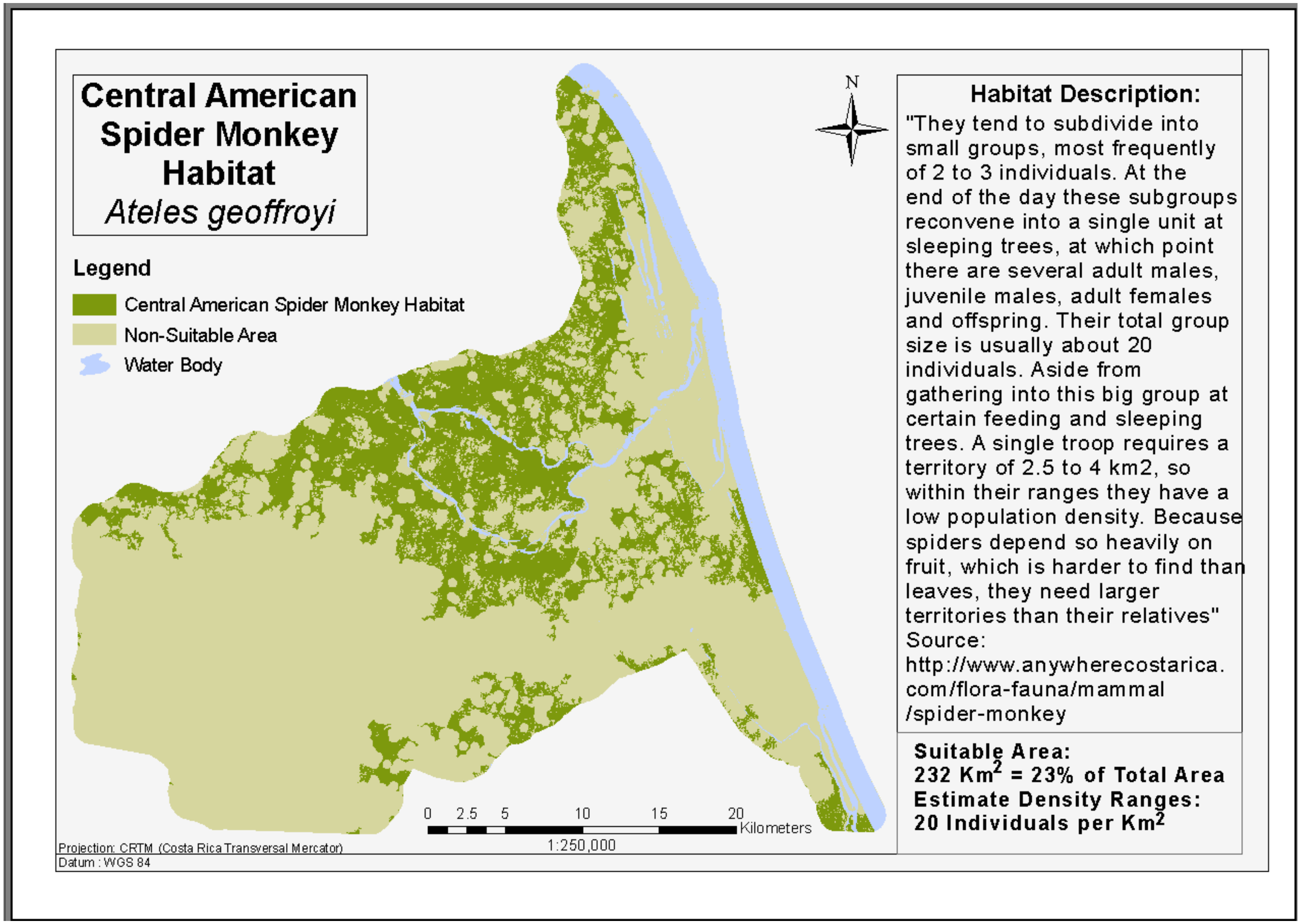
Appendix 4 – Study Area Coverage:



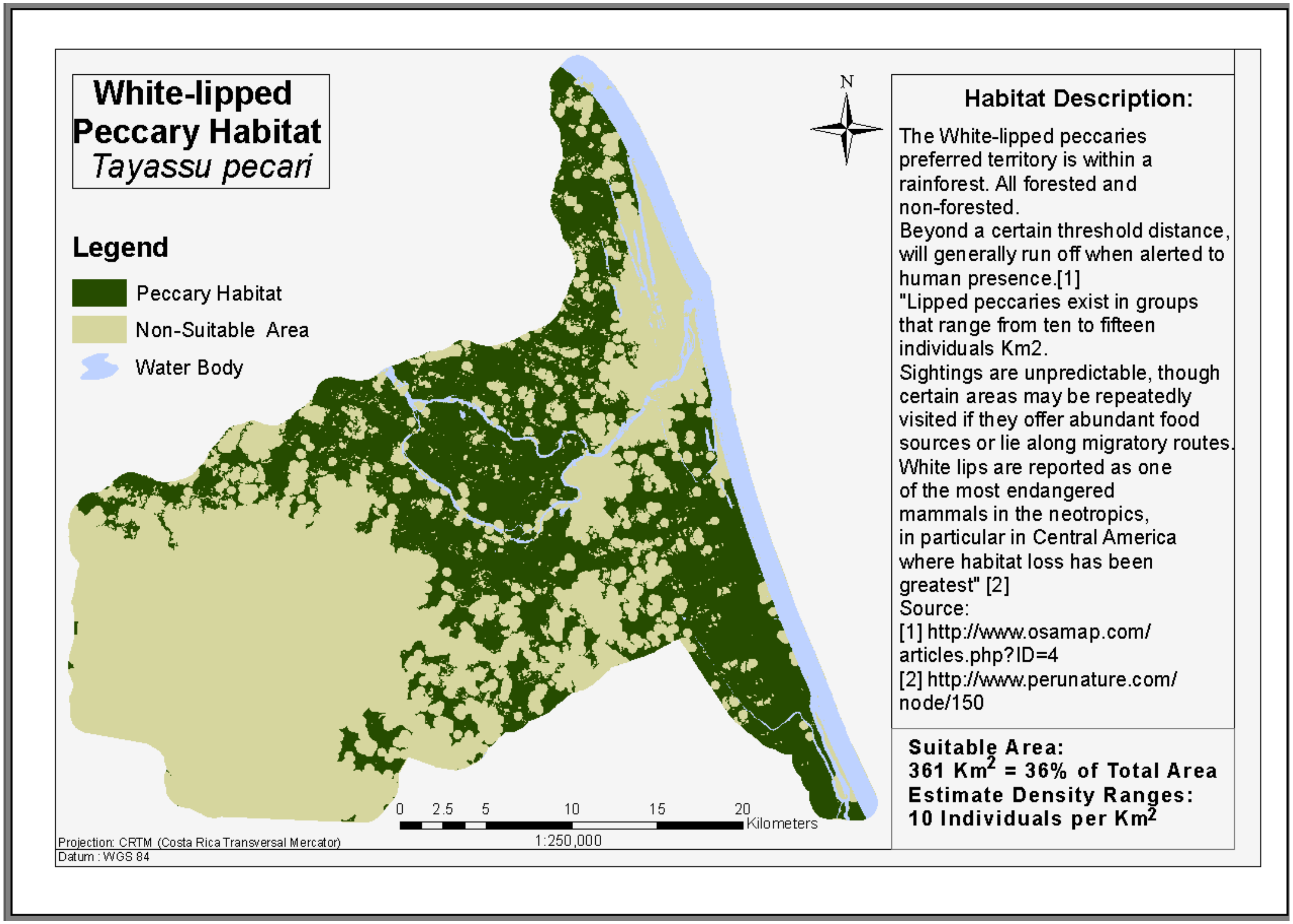
Appendix 5 - Jaguar Habitat Map:



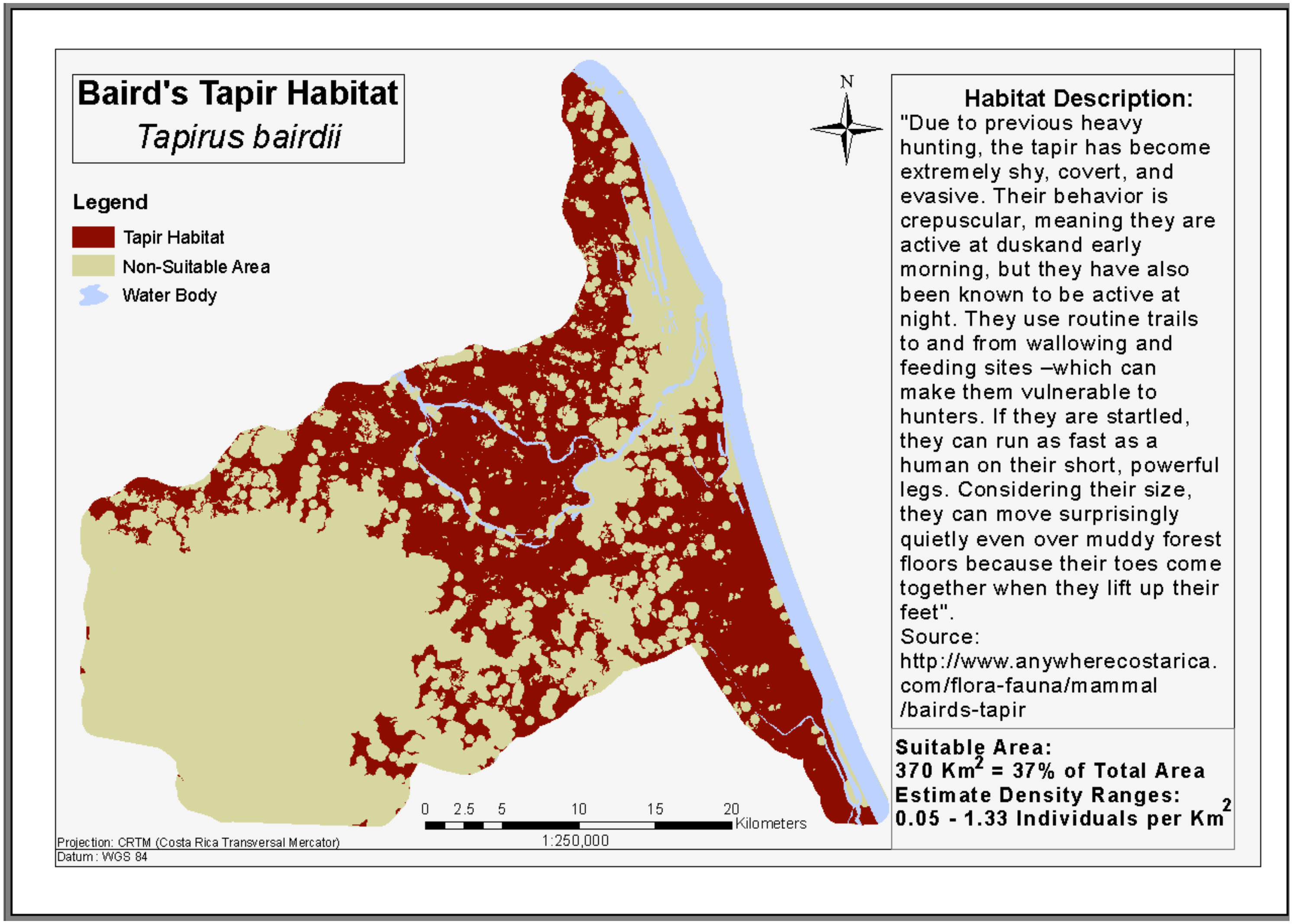
Appendix 6 – Central American Spider Monkey Habitat Map:



Appendix 7 – White-Lipped Peccary Habitat Map:



Appendix 8 – Baird's Tapir Habitat Map:



Appendix 9 – Core Habitat Map: