2009

Modeling the Status and Threats to the Philippine Eagle in the Eastern Mindanao Biodiversity Corridor

Vicente B Calag, Professor
Sean M Fitzgerald, Ph.D,cand, *University of Massachusetts - Amherst*
James A Hafner, Professor Emeritus, *University of Massachusetts - Amherst*
Jayson C. Ibanez
Alicia Johnson, et al.

Modeling the Status and Threats to the Philippine Eagle in the Eastern Mindanao Biodiversity Corridor.

Vicente B. Calag [1], Sean M. Fitzgerald [2], James A. Hafner [2],

Jayson C. Ibanez [3], Alicia Johnson [2], Don Sluter [2]

[1] *College of Science and Mathematics, University of the Philippines Mindanao, Mintal, Davao City 8000. Email: v*calag@yahoo.com
[2]*Department of Geosciences, University of Massachusetts, Amherst, Massachusetts USA.Email:*hafner@geo.umass.edu*/www.emcc-philippines.org*
[3] *Philippine Eagle Foundation, Ruby St., Marfori Heights, Davao City 8000. Email: falcon2car@yahoo.com*

[forthcoming in Banwa 5-2, 2009]

Abstract

The Philippines is among the most endemic-rich areas for all global biodiversity hotspots. Conserving that biodiversity presents multi-scaled challenges including the critical need for habitat and species level documentation as a basis for identifying conservation targets. This paper contributes to that need by describing the use of computer modeling tools to synthesize and evaluate data on the status and threats to the Philippine Eagle *Pithecophaga jefferyi* in the Mt. Hamiguitan Protected Area, one of the key biodiversity areas in the Eastern Mindanao Biodiversity Corridor (EMBC).

A Composite Bio-geographic Analysis (CBA) model was used to model the dynamics and inter-relationships between species distribution, nest, habitat and land use change, population distribution and access to the PA. The CBA integrates biodiversity data, change probability, regression analysis, geographic modification algorithms and remotely sense imagery was developed for this purpose. A composite Threat profile or Areas of Critical Concern derived from this analysis identifies locations where one or more threat variables impinge upon Nest Habitat and/or the Mt. Hemaguitan Protected Area. This profile clearly defined areas where population pressure, access and declines in nest habitat are associated and pose growing threats to the integrity of Eagle habitat in Mt. Hamiguitan. This analysis has illustrated the benefits of computer modeling of biodiversity dynamics and reinforced the necessity for species level documentation as a foundation for defining conservation targets.

Introduction

Concern with a sustainable environmental future has become a central theme in the debate over development at global, regional, and local levels. Questions of preserving biodiversity, protecting endangered habitats and promoting environmental stewardship responsibilities have become increasingly central to that dialogue in Southeast Asia. Arguably, nowhere else are these concerns more paramount than in the Philippines, a biodiversity hot spot and one of the world's highest conservation priorities (Meyers et al, 2000).

The Philippines is among the most endemic-rich hotspots for all taxonomic groups, but has a high level of vulnerability due to significant levels of natural forest loss and the second highest population density per sq. km among global hotspots (Cincotta et al, 2000). While these metrics underscore the information needs of both public and private-sector conservation decision-makers, a finer scale of analysis is essential for defining specific conservation strategies and outcomes. That information must be species specific, assess status and change in natural habitats, and provide quantitative geospatially explicit targets for conservation action.

Biodiversity conservation presents multi-scaled challenges of which the species level presents the most consistent scale for identifying conservation targets (Brooks et al, 2004). While conserving individual species is at best doubtful, the main threat comes from habitat destruction. Action to protect those habitats and conserve the biodiversity corridors in which they are located is an approach currently being adopted in Philippine biodiversity conservation efforts. Critical to conservation action in these corridors are base-line assessments of species distribution, species habitat and evaluations of

threats to species and habitat viability at micro and corridor-wide scales. This agenda is a primary objective of a collaborative research partnership between the Philippine Eagle Foundation, the University of the Philippines Mindanao, Northern Mindanao State Institute of Science and Technology, and the University of Massachusetts Amherst (USA). This collaborative is working to document and assess the habitats, status and threat probabilities for endangered vertebrates in the Eastern Mindanao Biodiversity Corridor (EMBC), one of three top priority biodiversity corridors in the country. *(Ong, et al, 2002).* This paper profiles the creation of that collaborative, its primary goals and objectives, and how GIS and computer-based mapping technology has been used to create dynamic geospatial data files and model threats to the biodiversity of the Philippine Eagle *Pithecophaga jefferyi* in the EMBC.

Biodiversity Assessment and the Eastern Mindanao Corridor

The Philippines is among the top biologically diverse countries in the world in terms of unique terrestrial and marine plant and animal species per unit area (Mittermier et al 1999). The country has more endemic species than some larger mega diversity centers including 367 endemic species defined as Threatened-Critically Endangered, Endangered and Vulnerable (IUCN, 2004). Threats to these diverse marine and terrestrial ecosystems from habitat alteration, destructive development-related resource use and population pressure are arguably more extensive than elsewhere in the region (Brooks et al, 2004). Based on the extent of habitat loss and plant endemism as metrics for evaluating conservation priorities, Meyers et al (2000) identified the Philippines as one of top eight hotspots for biodiversity conservation in tropical forests. While this information is central to the tasks of resource conservation decision-makers, it must

also be available to local groups and stakeholders responsible for planning and implementing specific conservation plans and outcomes.

National legislative and policy initiatives were taken in the early 1990s to address the needs for improved protection, conservation and management of these endangered ecosystems. The National Integrated Protected Area System (NIPAS) and the Local Government Code (1991), created a system of endangered marine and terrestrial ecosystems, and mandated decentralized resource management by making local government units (LGUs), people's organizations and NGO's co-equal partners with the state in managing and protecting natural resources. In 2000 an independent initiative to encourage working public-private sector alliances to develop a more comprehensive approach to conservation was developed by the Critical Ecosystem Partnership Fund (CEPF) of Conservation International.

Human-induced habitat loss and fragmentation are major threats to biodiversity conservation. One approach to mitigating the negative effects of fragmentation is to improve habitat connectivity through creating biodiversity corridors. This strategy seeks to maximize biological survival through the establishment of a portfolio of projects which contribute to an integrated landscape-scale program of conservation. The corridor approach provides a practical and effective solution to the difficulty of maintaining extensive areas of pristine habitat. Because protected areas are often too small and isolated to maintain viable ecosystems and evolutionary processes, conservation efforts must focus on linking major sites across wide geographic areas in order to sustain these large-scale processes and ensure the maintenance of a high level of biodiversity. These corridors main function is to connect biodiversity areas through a patchwork of sustainable land uses, increasing mobility and genetic exchange among individuals of

fauna and flora even in the absence of large extensions of continuous natural habitat (www.cepf.org /Philippines).

The National Biodiversity Conservation Priority-Setting Workshop identified 19 terrestrial and nine marine regions (corridors) as top priority areas for biodiversity conservation in the country. Three priority biodiversity corridors for immediate study and assessment were identified in Luzon, Palawan and Mindanao (Ong, Afuang, & Ambal. 2002). The Sierra Madre biodiversity corridor including 40 protected areas spans nine provinces along a 1.7 million-hectare range in eastern Luzon. Strategies for its conservation include protected area management, capacity building, ecotourism and environmental education. In the far south is the biodiversity rich Palawan corridor, a part of the flora and fauna complex of Greater Sunda. After its declaration as a UNESCO biosphere reserve in 1991 it was the subject of a Strategic Environmental Plan requiring protection of key habitats, implementation of sustainable land use practices and evaluating coastal resource utilization patterns. The last of these Key Biodiversity Areas (KBA) is the Eastern Mindanao Corridor, a sub-region of the Greater Mindanao Biogeographic Region (CEPF, 2001: www.cepf.net). The EMC spans a large portion of Regions XI and XIII from Siargao Island to Davao del Sur (Figure 1). This ethno linguistically diverse region has multiple endangered habitats, at least 22 threatened species, and one of the largest blocs of dipterocarp forest in the country. Arguably, the EMC is unlike other priority diversity corridors in that little systematic documentation of its threatened habitats, endangered species and the vulnerability of those species has been undertaken (Bueser, Miranda and Bueser, 2002). It is in this context that a collaborative research program for a corridor-wide biodiversity assessment in Eastern Mindanao was initiated.

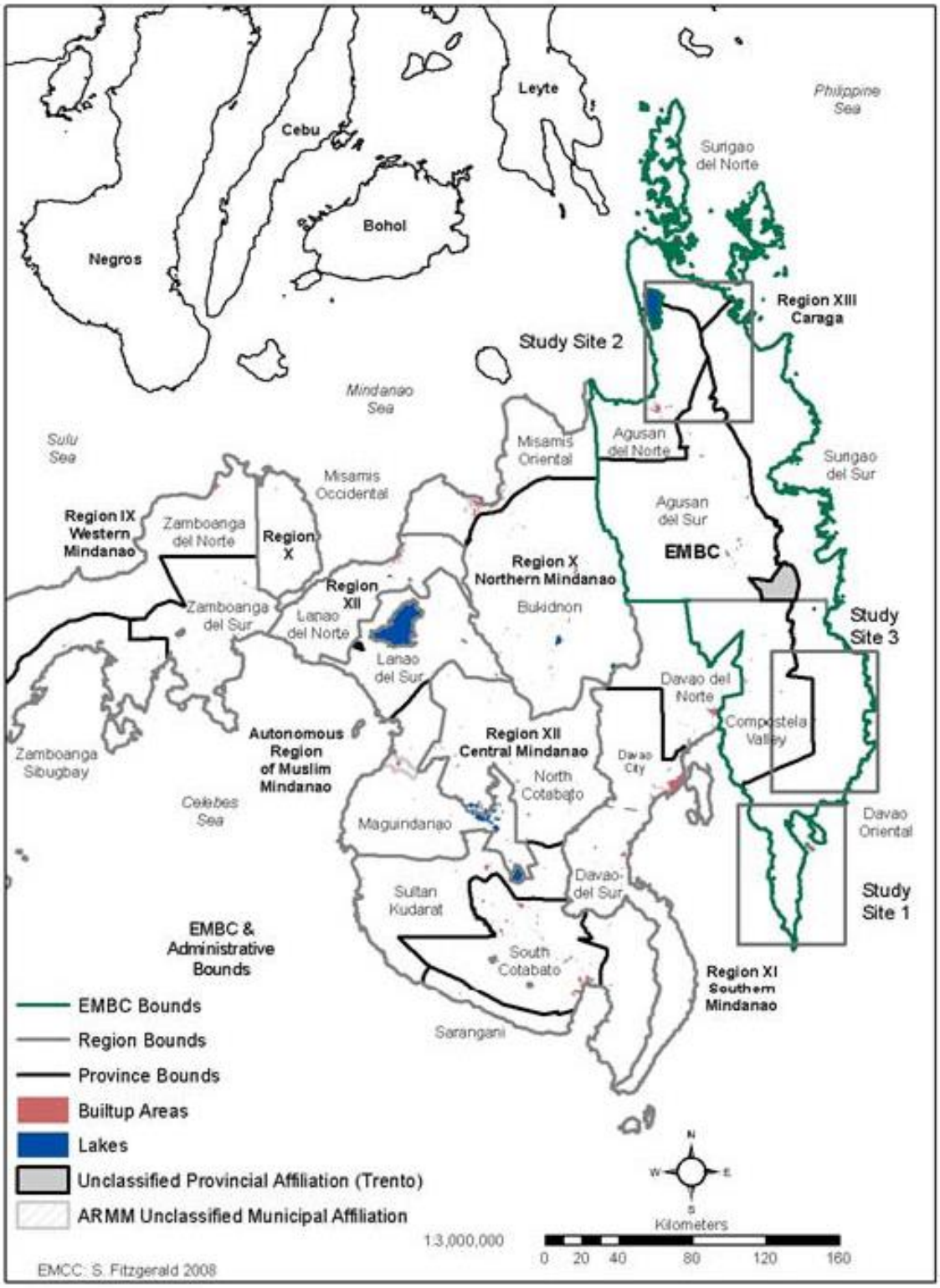

Fig.1- The Eastern Mindanao Corridor

The Research Collaborative

The foundations for the research partnership have evolved from several separate but related initiatives. A decade ago the University of Massachusetts Geoscience Department began exploring ways to share its expertise in applied Geoscience and geographic information systems technology to problems which complimented the curriculum and research strengths of Philippine universities in Mindanao. In 2004 an institutional agreement with UP Mindanao was implemented to support its interest in establishing teaching and research capabilities in geospatial mapping and Geographic Information System (GIS). A package of GIS software, training materials and on-line technical support for UPM's efforts to build this research and training capability was also part of that agreement. The initial research focus of that agreement was to apply GIS technology to assessing land use/land cover change on the Mt. Apo Nature Reserve. Subsequent discussions with the Philippine Eagle Foundation related to its CEPF funded Eastern Mindanao Corridor Biodiversity Assessment and Archiving Project (EMCBAAP) created a framework to integrate these two related interests.

The long-term goal of the EMCBAAP has been to establish a network of protected areas (PA) in the EMBC with managed habitat corridors connecting these PAs to facilitate wildlife migration, and consequently secure species survival for the long term. To realize that goal, the EMCBAAP defined three medium-term research objectives; (1) to assess biodiversity in three study sites in the Eastern Mindanao Corridor; (2) establish GIS laboratories for mapping and data analysis, and (3) complete GIS-based data analysis of land cover, species diversity and threat profiles for endangered species in the protected area study sites. The project's study areas are Mt Hilong-hilong, Mt Puting Bato- (Kampilili), and the Mt. Hemaguitan Range Wildlife

Sanctuary in the EMBC (Fig. 1). These objectives were also designed to facilitate PEFs goals of engaging local communities and stakeholder groups in building consensus on strategies for biodiversity protection and conservation of these areas (PEF, 2005). The intersections of these related interests led to the formation of this collaborative research program to address the complimentary interests of the cooperating partners.

The initial phases of this collaborative were implemented in early 2005. The Philippine Eagle Foundation as the primary research organization, assumed the lead role in defining and implementing a research agenda. Those tasks included designing a field data methodology and gathering data on species habitat, distribution and threat variables. The initial phase of field research began on the Mt. Hemaguitan Wildlife Sanctuary in Davao Oriental in early 2005. To facilitate its objective of creating GIS facilities for mapping and data analysis, the PEF solicited the support of UPM in developing and housing a GIS laboratory at the Bago Oshiro campus in Davao City. It also receives technical GIS support from the Northern Mindanao State Institute for Science and Technology (NORMISIST). The University of Massachusetts Amherst agreed to assist in start-up activities at UPM's GIS laboratory and provide technical assistance for GIS analysis of biodiversity data gathered by PEF. Those responsibilities have included the development and application of computer generated analytical modeling and mapping tools for assessing species distribution, habitat change and threat probability matrices for study sites. Those outputs are directed toward enabling EMCBAAP to realize its medium term research objectives. The following section briefly outlines the structure of the UMA approach to the modeling and analysis of change in biodiversity conditions in the EMBC.

The Composite Bio-geographic Analysis Model

The task of integrating complex processes and inter-relationships between habitat, species and threats has been incorporated into a Composite Bio-geo-graphic Analysis Model or CBA. This analytical model is the primary framework for data assembly and analysis of the key components of the biodiversity assessment being conducted by EMCBAAP. It incorporates field data being generated by the wildlife biology field teams, outputs from land use/land cover classifications of satellite imagery, and biophysical data on habitat characteristics. A simplified graphic representation of that model is presented below, Fig.2. The general flow of data inputs and analytical steps begins with Data Management. At this initial stage, data inputs and modeling is being focused on the Philippine Eagle *Pithecophaga jefferyi* and appropriate prey species. This involves basic biodiversity data collection, analysis and synthesis of species, habitat, and threat data gathered by PEF staff in the field. Those data become inputs into three initial subcomponents of the CBA: threat profiles, habitat profiles, and species profiles.

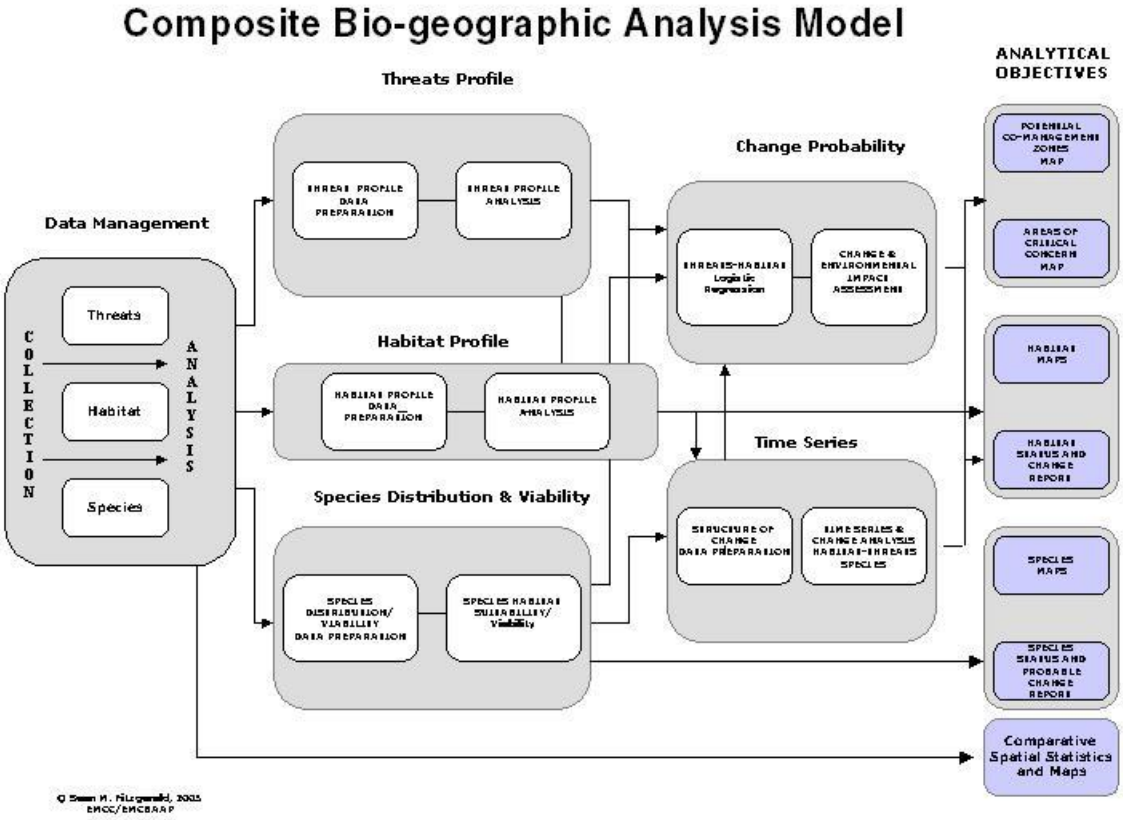

Fig. 2- The Composite Bio-geographic Analysis Model

To assess the areas of most critical concern for the Philippine Eagle population, a change probability routine using regression analysis and probable geographic modification algorithms is used. That is validated by a time-series and change analysis using remotely sensed imagery and census data. The environmental impact upon habitat by threats also results from this component of the CBA. The habitat maps will also assist PEF field teams in assessing probable species locations based on a habitat profile derived from long-term field observations. The species profile will provide various geo-statistical indicators- maps of the current and probable population distribution and viability of the Philippine Eagle.

Furthermore, this analysis will produce spatial probability maps of species' ecological niches and additional spatial suitability maps. Presence and Absence analysis and critical error assessments will compliment the analysis of smaller sample sizes. Finally, the habitat and threats profiles will be tested against a Multi- Criteria Multi-Objective Spatial Decision Analysis for further validation. The entire CBA runs seamlessly through integration of software tools, and common file types for ease of implementation, and is documented in both a step-wise procedural guide, and various technical appendices.

The final column defines the Analytical Objectives of the CBA. They represent outcomes intended to satisfy some of the essential objectives of the EMCBAAP. These results are produced in appropriate map, graphics and statistical formats with accompanying explanatory and interpretative comments. 'Habitat Maps' and "Status Profiles' delineate the geospatial distribution and boundaries of Eagle habitats and changes in status of those habitats. Change analysis is intended to illustrate differences

in defined Eagle habitat as measured on 1999 and 2003 satellite imagery. A second set of analytical outcomes concerns *Species maps* and *Species Status* and *Probable Change*. The initial focus here will be on defining the geospatial distribution of the Philippine Eagle *Pithecophaga jefferyi* derived from PEF records, field observation, and statistical measurements of change probabilities for that distribution matrix. A third set of analytical outcomes is concerned with *Areas of Critical Concern* or those locations which analysis has indicated are highly threat sensitive. This 'threat matrix' can be represented as single or multi-factor threats from demographic change, accessibility, and expansion of commercial agriculture, logging or mining activities for example. Finally, suggestions of appropriate 'buffer zones' or areas bordering designated PAs will be delineated to support EMCBAAPs goal of formulating policy recommendations for species and habitat protection.

Research Outcomes

The tasks of field data collection, synthesis and analysis are an on-going process. The evaluation of data sets within the CBA was also iterative. As new data was added to the various modules the relationships within those modules were modified and revised outcomes produced. Because of social and political conditions in Hilong-hilong and Putting Bato, data collection and the completion of analytical results from those sites was delayed. Therefore, our analysis here is limited to the Mt. Hemaguitan study site. The principle results of the CBA analysis for this area will focus on:

- Eagle habitat and nest sites
- Access to habitat
- Population change and distribution

- Nest Habitat Change
- Areas of Critical Concern

Eagle Habitat and Nest sites

The identification and delineation of Eagle habitat is one foundation for a comprehensive assessment of biodiversity conditions. Bueser et al (2003) have summarized the existing knowledge about Philippine Eagle numbers, distribution and related habitat characteristics in Mindanao. They note that this species was observed in isolated patches of very heterogeneous habitat; closed- and open-canopy dipterocarp forest, montane-mossy forest, and non-forest landscapes where field crops, upland rice, tree crops, grassland and residential activities were present. All of the thirteen nests they identified were on forest edges, nine were within 100 meters of the forest edge, on steep slopes or ravines, and associated with mature dipterocarp forest (ibid; 132). Our analysis has further refined those habitat criteria to include elevations of 750-1590 meters, slopes of >60 deg., a southern (SW, SE) nest exposure, and the abundance of prey species. For the purpose of illustration we have used an Eastern Mindanao land cover classification for 2001-2002 produced by DENR, Figure 3.

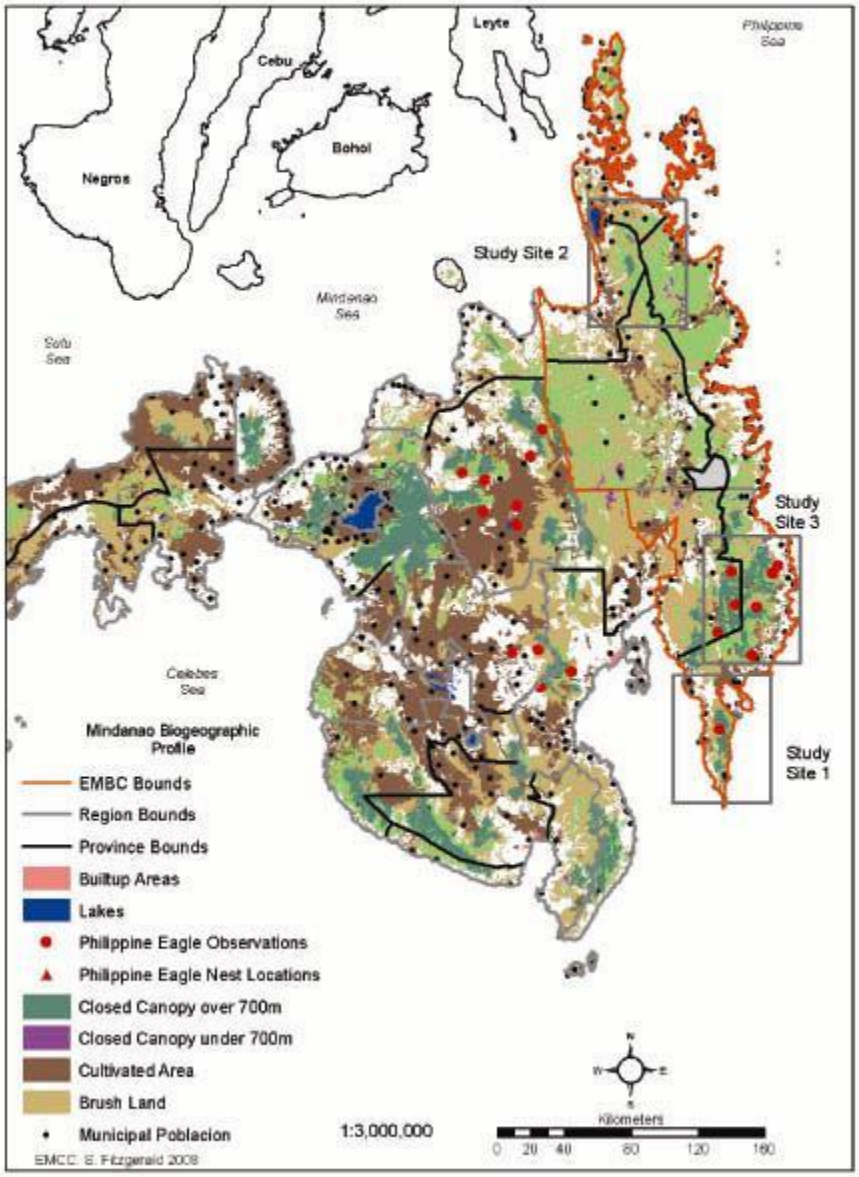

Figure 3 .- Eagle Sightings,Nests and Land Cover in the EMC and Mindanao, 2005.

This map shows the dispersed and fragmented areas of 'closed' and 'open' canopy forest consistent with eagle habitat in the Eastern Mindanao Corridor. 'Active' Eagle nests and Eagle observations identified as of 2005 are shown in locations within or on the edges of 'closed canopy' forest. Two of those locations confirmed by PEF field observations in early 2006 are in closed dipterocarp and montane mossy forest in the Mt. Hamiguitan Range Wildlife Sanctuary. One is within the northern boundary of the protected area, and the second is outside of that boundary to the south. Those sites are also within the elevation, slope and nest orientation criteria for eagle habitat noted above.

The Philippine Eagle Foundation has defined more specific known nest sites, eagle observations and nest habitat criteria for the Mt. Hamiguitan site. Figure 4. The Biogeomorphology of Eagle Nest Habitat displayed in Figure 4 illustrates those criteria associated with one nest location and one Eagle observation. The population pressure areas we have delineated represent a 'vector' of potential disturbance that suggests areas where nest habitat disturbance is probable. Areas where nest habitat has seen growth are very fragmented and disturbed but are generally found in areas to the south and east where population pressure is considerably less. This type of data can serve to create a geographic template that may help field research efforts or enable public policy decisions. It also suggests how creating 'buffer zones' may pose one challenge for the planning, implementation and management of a system of interconnected biodiversity corridors within the EMC.

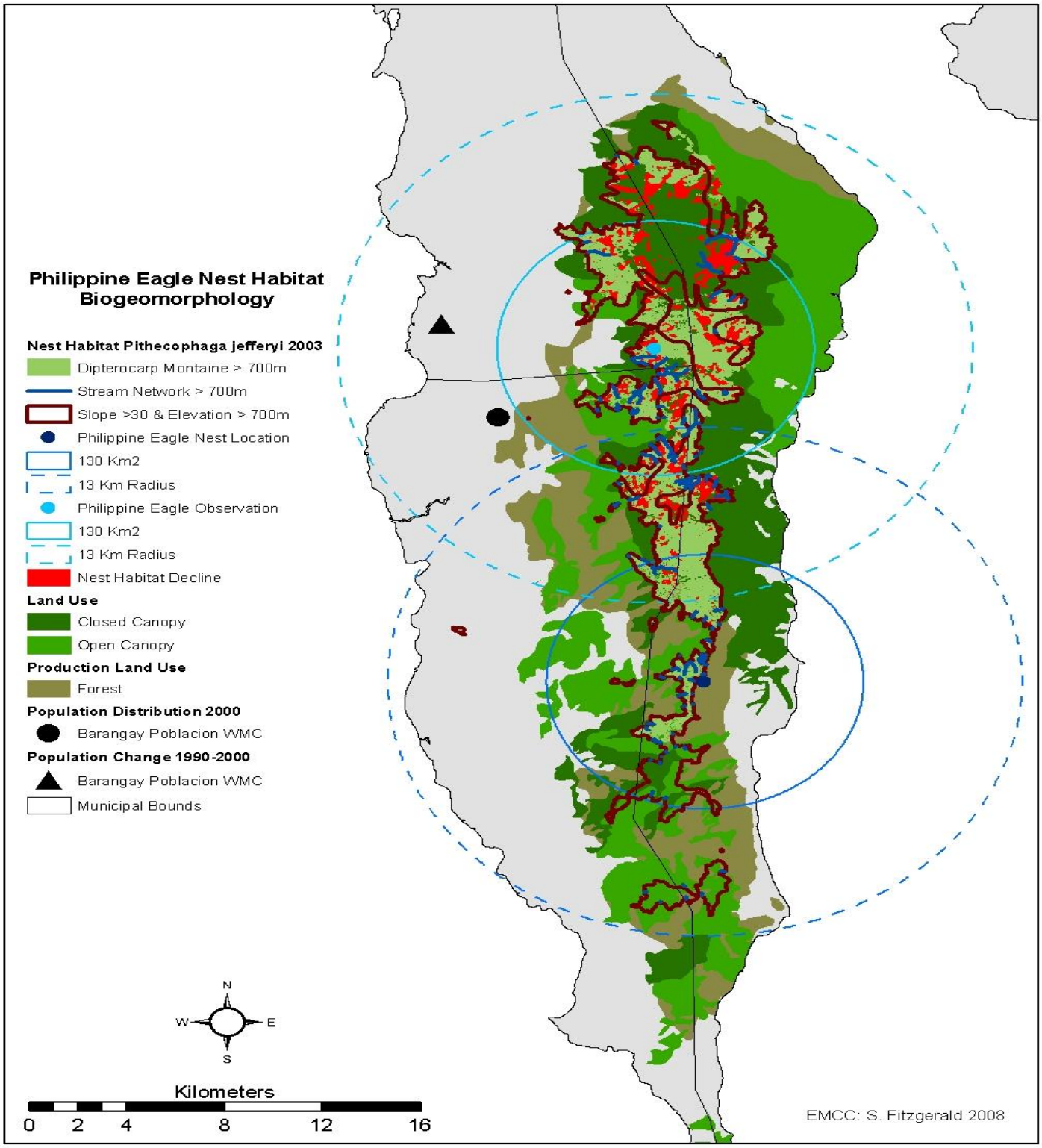

Figure 4.- Biogeomorphology of Eagle Nest Habitat

Access to Habitat

While habitat fragmentation is an important threat to species viability, other variables were considered in evaluating the threat matrix for eagle populations. Based on current and archived PEF field observation records it has been determined that where access to habitat is <500 meters that distance represents a distinct threat to known habitat. The nature of the access threat can facilitate or enhance hunting, harvesting forest and non-forest products; land clearance, and exploratory mining surveys. In this context, Access has been measured by the existing network of national, provincial and barangay roads, logging and mining access routes and foot trails that approach or penetrate the boundaries of the Protected Area. No weighting for road quality, width or seasonality has been assigned to specific routes or route segments. Using that network to represent access, an overlay on existing habitat provides one aspect of an index of potential access threat. These relationships between known habitat and access routes are shown below in Figure 5. The network of highways and roads within the study area were extracted from provincial and municipal sources in 2005 and augmented by on-site field- mapping of local transport routes. This network displays both a linear and dendritic pattern. Linear segments of the National and provincial highway system link towns along the Davao Gulf in San Isidro and Governor Generoso, and in a more truncated pattern on the Pacific coast in Mati. There is a distinct pattern of dendritic or finger-like route segments extending inland from that network throughout the area. Most notable are the route segments located in Maputi and east of Talisay extending toward or impinging on the PA boundary. In Mati a similar

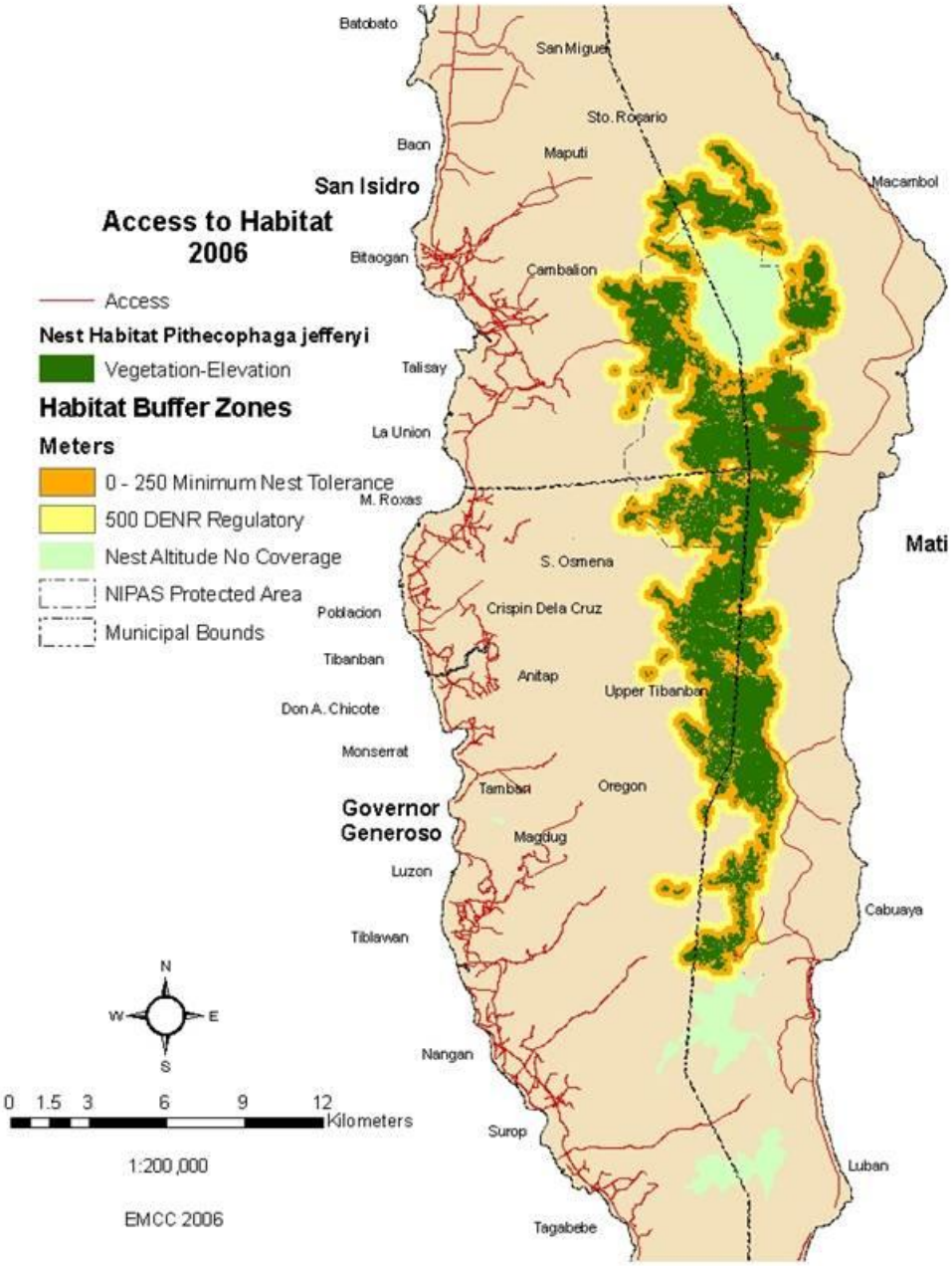

Figure 5.- Access to Habitat in Mt. Hemaguitan

pattern exists where route segments have actually penetrated areas of nest habitat and the PA boundary. A similar pattern exists around Cabuaya. This suggests access is increasing toward the southern PA boundary. There are also potentially significant access threats to habitat and that boundary at several points. Two of these are east of Bitaogan and Talisay on the Davao Gulf coast and a third below Macambol. As will be shown below, these are both areas of high population change between 1990 and 2000.

An area of critical access can be noted where route network segments have already penetrated the PA boundary above *barangay* Cabuaya and into two fragments of forest habitat. East of Talisay an area of critical access is within the PA boundary and only 1,000 m. from the edge of habitat inside the Mt. Hemaguitan Range Wildlife Sanctuary. This type of evidence reinforces arguments that access poses a potential threat to habitat while supporting consideration of areas where 'buffer zones' may mediate that threat.

Population Change and Distribution

Population change and distribution have been identified by PEF as one of the key variables posing a potential threat to Eagle habitat. As the primary anthropogenic threat to habitat, the size and proximity of human population to PAs and habitat poses a potential threat to those areas and species viability. Where areas of population pressure can be identified they represent a 'vector' of potential disturbance that suggests where nest habitat disturbance is a probable result. Where that growth encroaches on PA boundaries and habitat it represents an area of critical concern for

species habitat and viability. Over the decade 1990-2000, the population of Davao Oriental increased at a rate of 1.64 per cent, the lowest among the six provinces and two largest urban areas in Region XI (NSO, 2000). Those areas with the highest annual percentage rates of change (3.1-7.0 percent) over that decade were concentrated in the provinces' northern tier of *barangay* and the municipal areas of Candaleon, Crispin Dela Cruz, Lapu Lapu and San Roque. Percentage changes in population between the 1990 and 2000 census for municipal and *barangay* administrative units bordering the Mt. Hemaguitan Protected Area have been plotted as a continuum, Figure 6. Maximum change values for this period ranged from +77% to –27% with a mean of +8-12% over this period. While much of the area bordering the PA boundaries has experienced population changes in the mean range of 0-1.4 percent, several areas of critical concern have been identified. Two locations of significant population change adjoining the PA (protected area) boundary were identified in San Isidro and Cabuaya, Mati. That growth in San Isidro brackets the NIPAS boundary of the protected area, the established nest habitat change outside of the PA infringes on the 250 meter minimum nest tolerance of the Philippine Eagle. Areas of population change in the mean range (8-12%) also infringe on the eastern boundary of the PA in Mati, and inland from La Union in San Isidro.

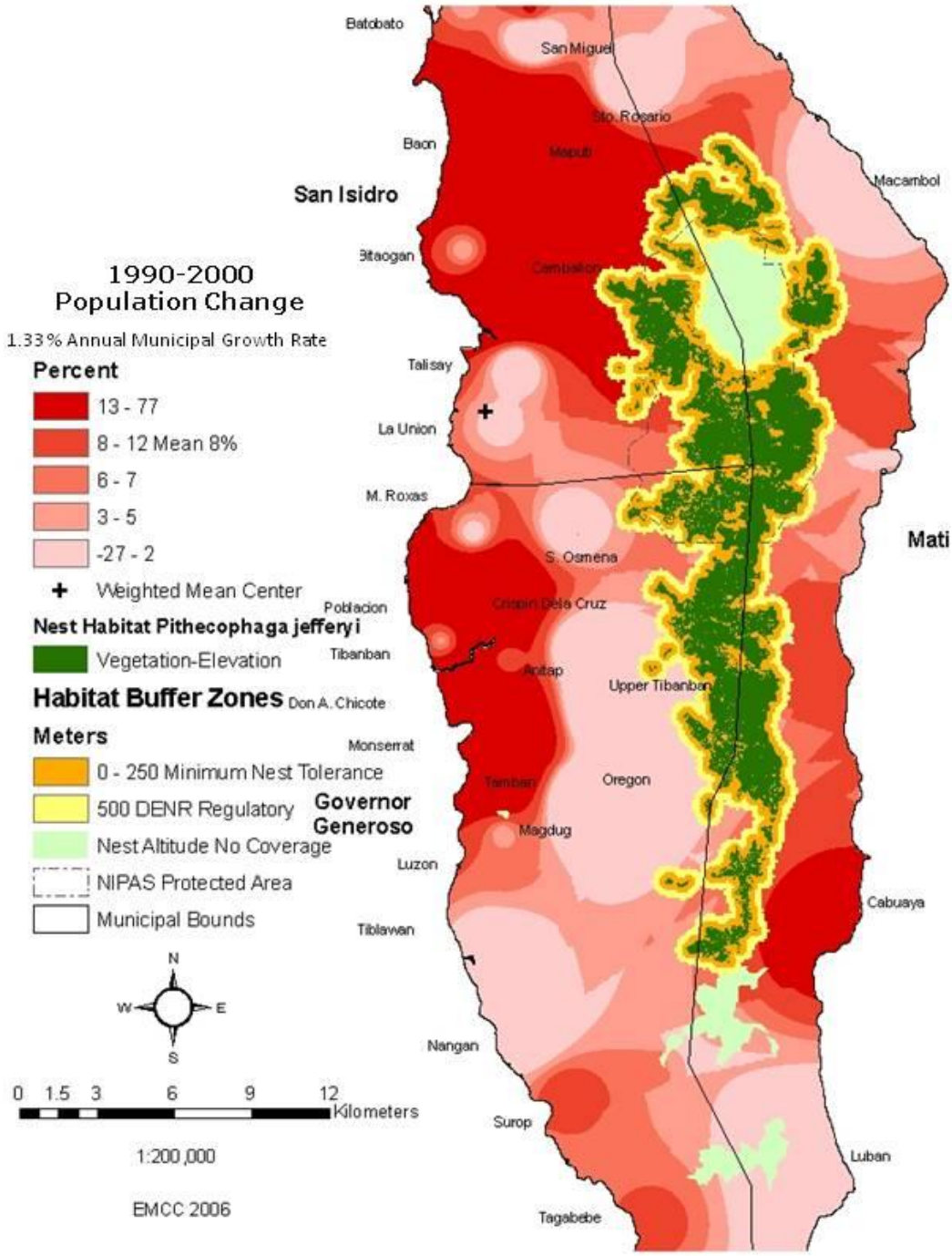

Fig. 6- Population Change (%) in Davao Oriental: 1990-2000

While much of the area bordering the PA boundaries has experienced population changes in the mean range of 0-1.4 percent, several areas of critical concern have been identified. Growth around Crispin Dela Cruz - Lapu Lapu on the Davao Gulf indicates an inland directional trend in population expansion toward delineated eagle habitat. Where that trend is reinforced by changes in access, it may represent a potential future area of critical concern. In the case of San Roque that pattern overlaps an area of habitat and is also associated with changes in access (Fig. 4), both potential threat factors. This type of geospatial analysis of potential population pressure on protected areas and habitat may also be of importance in considering the criteria and locations of a system of 'buffer' zones to preserve the integrity and viability of these areas

Nest Habitat Change

The criteria used to define nest habitat for the *Pithecophaga Jeffreyi* have included elevation, vegetation complexes and orientation. The Philippine Eagle Foundation (PEF) has established the 600-1800 meter elevation range as the optimum Philippine Eagle habitat. The distribution of this habitat over the Mt. Hemaguitan system for the period 1999-2003 was derived from analysis of satellite imagery and on-site ground observation. The 2003 Nest Habitat and Difference images have had cloud cover from both images combined and used to remove areas of both images for more uniform habitat coverage in statistical analysis, Figure 7.

Areas shown in green delineate that habitat for 2003 while areas in red define the locations and extent of habitat decline between 1999-2003. It is evident that over this period a significant decline in nest habitat has taken place within the NIPAS boundary of

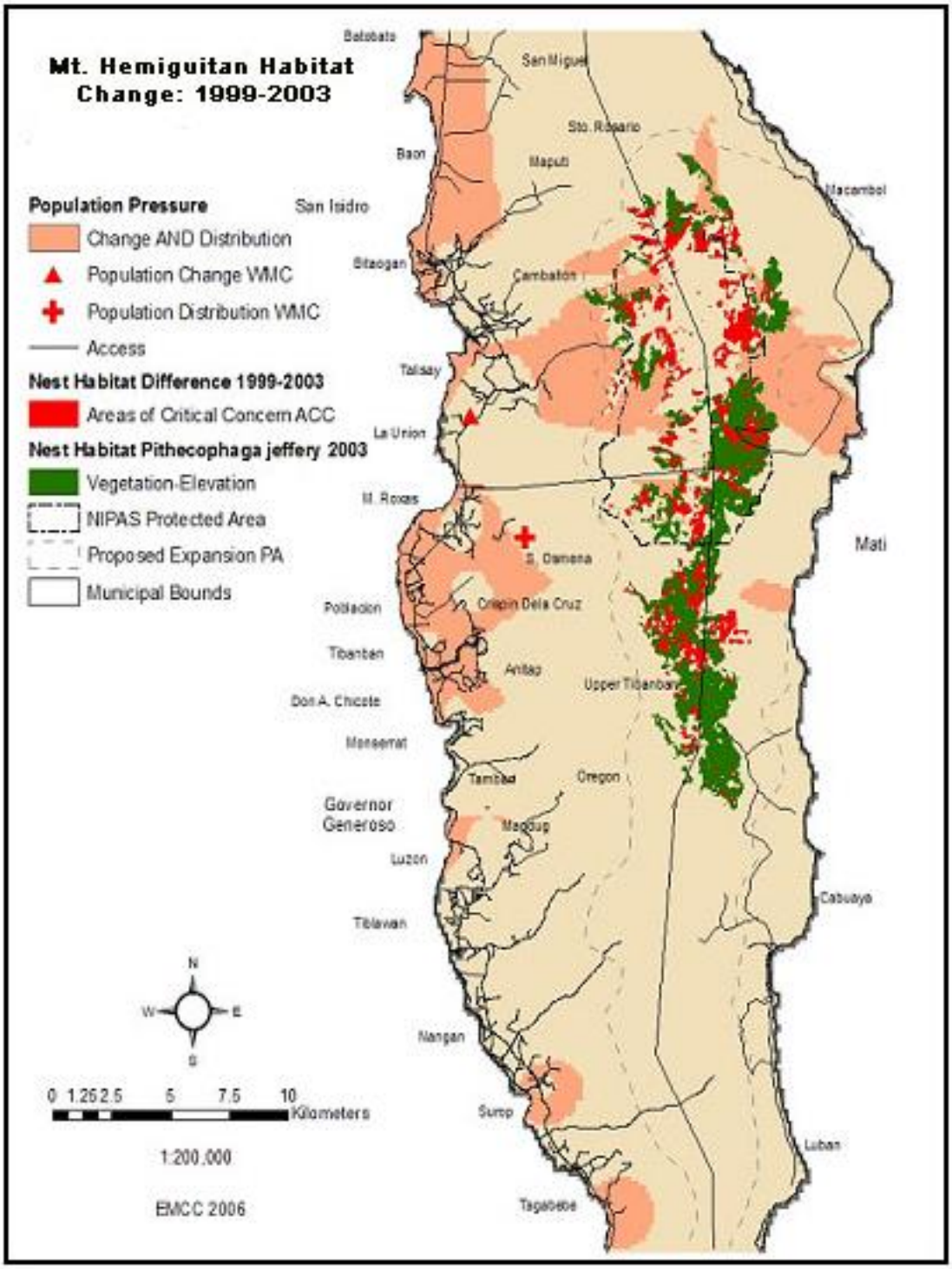

Figure 7- Nest Habitat Change,1999-2003

Mt. Hemaguitan. Comparable declines outside of that boundary are also evident to the south. There is a notable association of these declines with areas of population pressure (growth above the mean) in sections of San Isidro bordering the PA, and in Mati further east. Those declines also correspond to areas where ACCESS has reached or penetrated the PA boundary, especially east of Talisay, San Isidro and in Mati.

Areas of Critical Concern: Population, Access and Nest Habitat

Areas of Critical Concern are defined as locations within the study area where one or more threat variables impinge upon Nest Habitat and/or the Mt. Hemaguitan Protected Area (PA). Population change/distribution, Nest Habitat and ACCESS are shown in this map to identify or delineate Areas of Critical Concern, Fig.8. Population change/distribution is shown for areas greater than the mean and where there is a locational association with existing land transport routes; ACCESS. This image also identifies areas of change or decline in Nest Habitat between 1999 and 2003. The principle observations drawn from this data include:

- Population pressure in San Isidro and Mati has impinged upon both nest habitat and the boundary of the Mt. Hemaguitan Protected Area.

- Declines in nest habitat are evident throughout the Mt. Hemaguitan NIPAS and extending south into the proposed expansion of the PA. Those declines in San Isidro and Mati are clearly associated with areas of population change above the study area mean. The nest habitat difference is based on comparative analysis of 1999 and 2003 satellite imagery adjusted for common cloud cover.

- Access route segments in San Isidro and Mati show a geospatial continuity with declines in nest habitat and areas of high population change, reinforcing their designation as Areas of of Critical Concern.

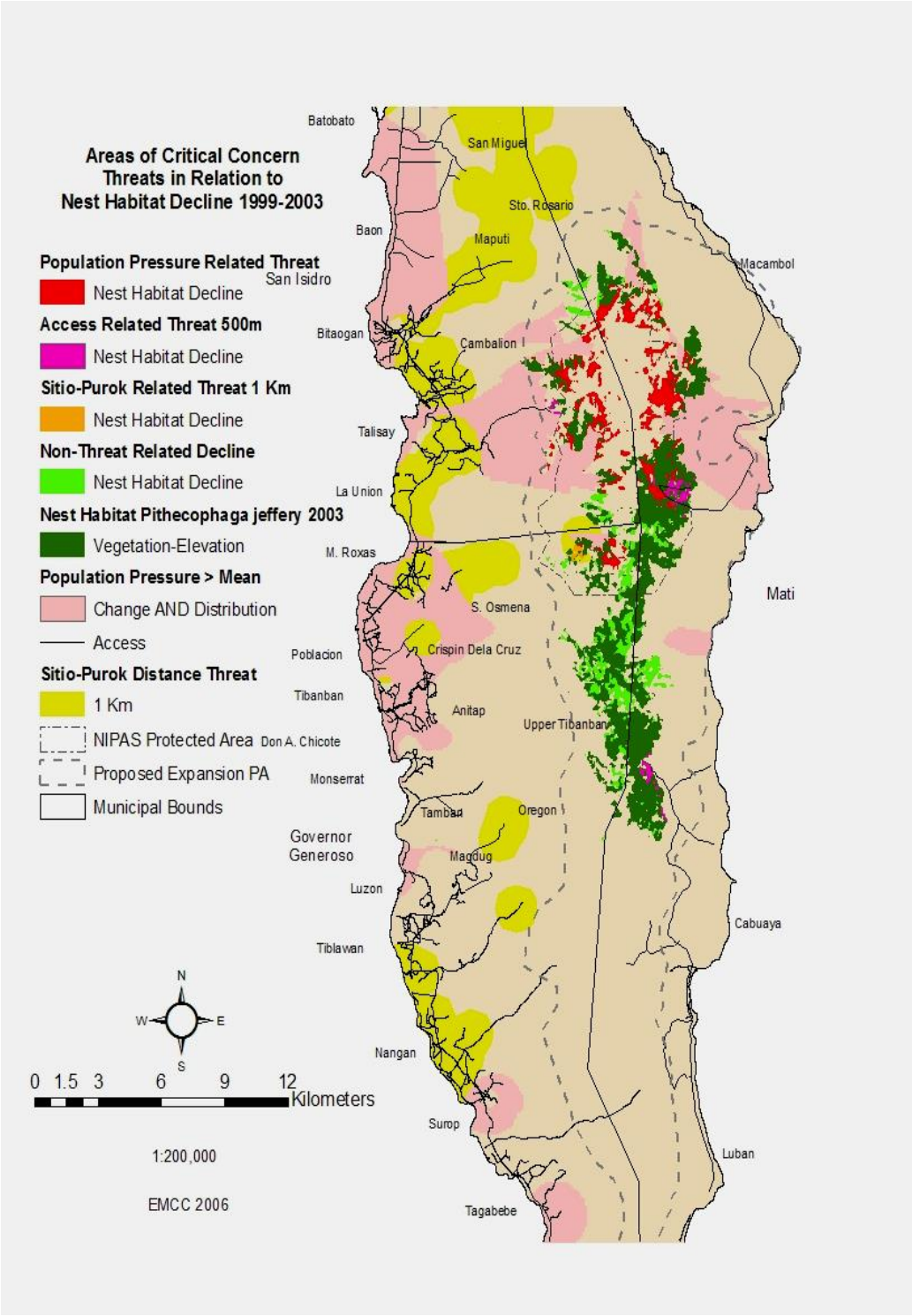

Figure 8.- Mt. Hemiguitan Areas of Critical Concern

This composite Threat profile map identifies areas within or bordering the Mt. Hamiguitan Protected Area where population pressure, access and declines in nest habitat are associated. These *Areas of Critical Concern* define locations which analysis has indicated are highly threat sensitive and illustrate single or multi-factor threats to eagle habitat and existing nest sites. This can support EMCBAAPs goal of engaging local communities and stakeholder groups in building consensus on strategies for biodiversity protection and formulating policy recommendations for biodiversity conservation in these areas (PEF, 2005). Apart from these conclusions are potential suggestions about issues to be considered in developing a plan for the conservation of the Mt .Hamiguitan Protected Area.

Conclusions

This paper has outlined a collaborative research program for biodiversity assessment in the Eastern Mindanao Corridor and some of the results of that work. This research partnership is perhaps the first to use species and site-specific analysis to examine biodiversity issues at a corridor-wide scale in the Philippines. The focus has been on the Philippine Eagle *Pithecophaga jefferyi* given its endangered status and the relatively large amount of prior research already completed (Bueser at al, 2003). The Composite Bio-geographic Analysis (CBA) approach employed incorporates site and species-specific data inputs into three analytical modules: threat profiles, habitat profiles, and species profiles. To assess the areas of most critical concern for the Philippine Eagle population, a change probability routine using regression analysis and probable geographic modification algorithms is used.

The model outputs address three components of the biodiversity assessment, habitat delineation and change, species distribution and threats to eagle habitat and viability. This analytical approach has two important values; it is replicable and adaptable to species other than the Philippine Eagle. The strengths of this approach lie in the use of a seamless integration of satellite imagery processing, computer mapping technology and direct field observation and data collection. These analytical components address Brooks (2004) argument that the multi-scale nature of biodiversity requires that conservation targets be defined at the species, site and corridor levels. It also responds to the goal of the EMCBAAP to provide a biodiversity knowledge base for the EMC that will facilitate PEF's engagement of local communities and stakeholder groups in building consensus on strategies for conserving these protected areas.

Acknowledgements

The analyses presented in this paper is based on data sets collected by the wildlife biology teams of the Philippine Eagle Foundation, data processing done at the University of the Philippines Mindanao and the Northern Mindanao State Institute of Science and Technology. We extend our appreciation for their contributions and continuing commitment to this pioneering effort. Our gratitude to the Philippine-American Educational Foundation (PAEF), The Philippine Eagle Foundation, Clark Labs at Clark University, and the Geosciences Department, University of Massachusetts for financial, facilities use and in-kind software contributions to this project.

REFERENCES

Brooks, Thomas et al. 2004. Philippine biodiversity conservation: global priorities and local targets. Agham Mindanaw, 2:1-10

Bueser, G.L.L., et al. 2003. Distribution and nesting density of the Philippine Eagle Pithecophaga jefferyi on Mindanao Island, Philippines: what do we know after 100 years? *Ibis* 145: 130-135

Cincotta, R.P., Wisnewski, J & Engleman, R. 2000. Human population in the biodiversity hotspots. Nature 404: 990-992

Fitzgerald, Sean. 2008. Preliminary Overview of EMCC Project Modeling. Alternative And Composite Biogeographic Analysis with Applications in Compromised Analytical Environments: Mapping Human Influence on Nest Habitat of the Philippine Eagle in the Eastern Mindanao Biodiversity Corridor. In http://www.geo.umass.edu/faculty/sf/webovsmf1p.pdf

Forester, D.J., Machlis, G.E.. 1990. Modeling human factors that affect the loss of biodiversity. Conservation Biology. 10(4); 1253-1263

Gatil-Bueser, Kharina, Hector C. Miranda Jr, Glen Lovell Bueser 2002. *Nest Site Selection of Philippine Eagles Pithecophaga jefferyi in Mindanao Island, Philippines*. Davao 2002.

Kennedy, R,S. 1977. Notes on the biology and population status of the monkey eating Eagle of the Philippines. The Wilson Bulletin, 89 (1): 1-20

Lovell, G.L. 2003. Distribution of nesting density of the Philippine Eagle Pithecopaga Jefferyi on Mindanao Island. Philippines: what do we know after 100 years. Ibis 145: 130-135

Menon, S.2001. Identifying conservation-priority areas in the tropics: a land-use change Modeling approach. Conservation Biology. 15 (2) 501-512

Meyers, N. 1988. Threatened biotas: "hotspots in tropical forests. *The Environmentalist* 8:1-20

Meyers, N., Mittermeier, R.A., Mittermeier,C.G., Fonseca, G.A.B. & Kent, J. 2000 Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

Munroe, D.K. 2004. Modeling spatially and temporally complex land-cover change: The case of western Honduras. The Professional Geographer. 56 (4);544-559

NSO, 2000. *Davao Oriental:* The Slowest Growing Province in Southern Mindanao. Quezon City: National Statistical Office

Ong, P.S., Afuang, L.E. & Rosell Ambal, R.G.(eds.) 2002. Philippine Biodiversity Conservation Priorities : a Second Iteration of the National Biodiversity Strategy and Action Plan. Department of the Environment and Natural Resources-Protected Areas and Wildlife Bureau, Conservation International Philippines, Biodiversity Conservation Program-University of the Philippines Center for Integrative and Development Studies, and Foundation for Philippine Environment, Quezon City, Philippines.

Ong, P.S. Heany, L.R., In: Hotspots. Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions.(R. Mittermeier, N. Myers, C. Mittermeier eds.) , 1999,308-315

Philippine Eagle Foundation 2005, *Towards Biodiversity Conservation within the Eastern Mindanao Corridor: Biodiversity Archiving and Assessment Project (EMCBAAP): A log frame Worksheet*. Davao: Philippine Eagle Foundation, 2005.

Reyes- Boquiren, A. 2002. Saving the Philippine Hotspots- Are We Succeeding? A Social Science View from the Ground. Kasarinlan, Vol. 17, No 1, 2002: 91-113

Rossiter, D,.G. 2006. Technical note: analyzing land cover change with logistic regression. In R.D.G. Rossiter: itcn nl: http//www. Itc.nl/personal/rossiter

Figures

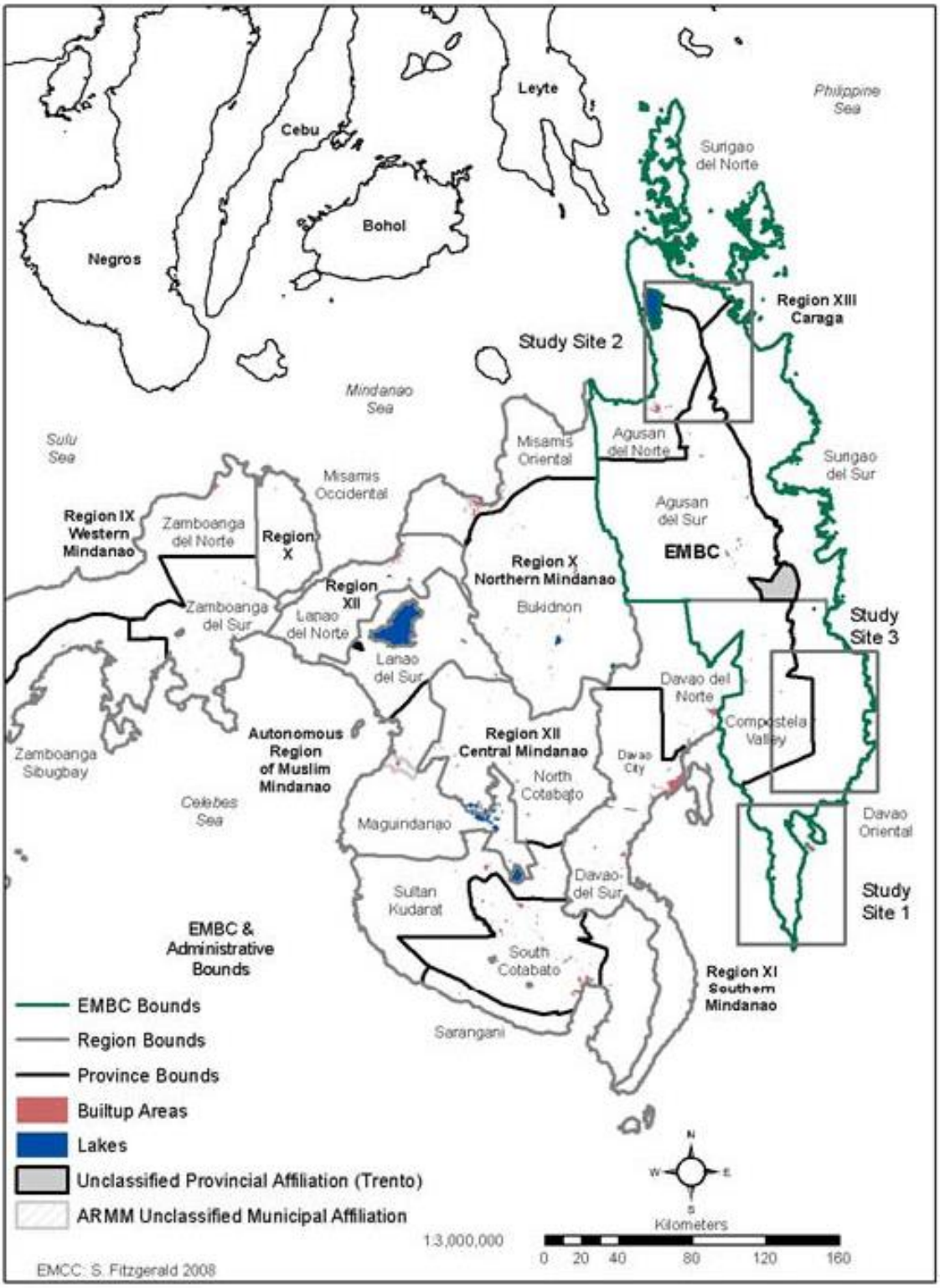

Figure 1.- The Eastern Mindanao Corridor

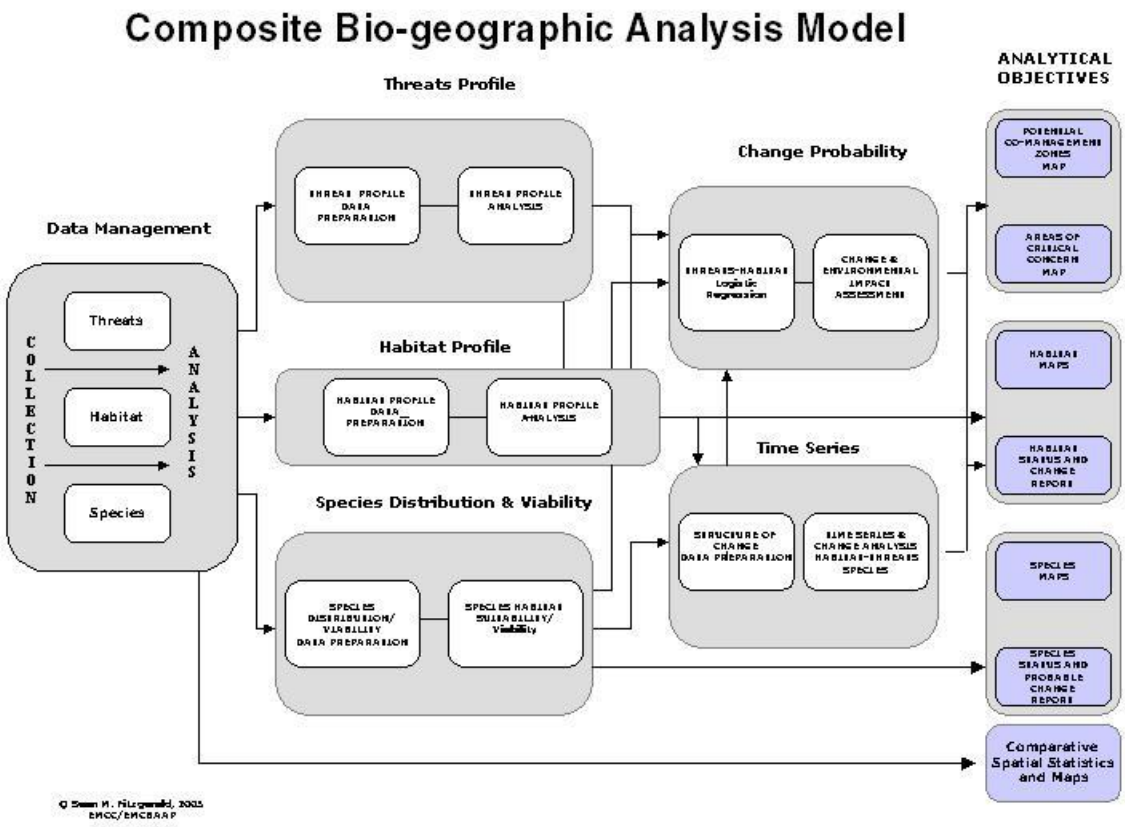

Figure 2.- Composite Bio-geographic Analysis Model

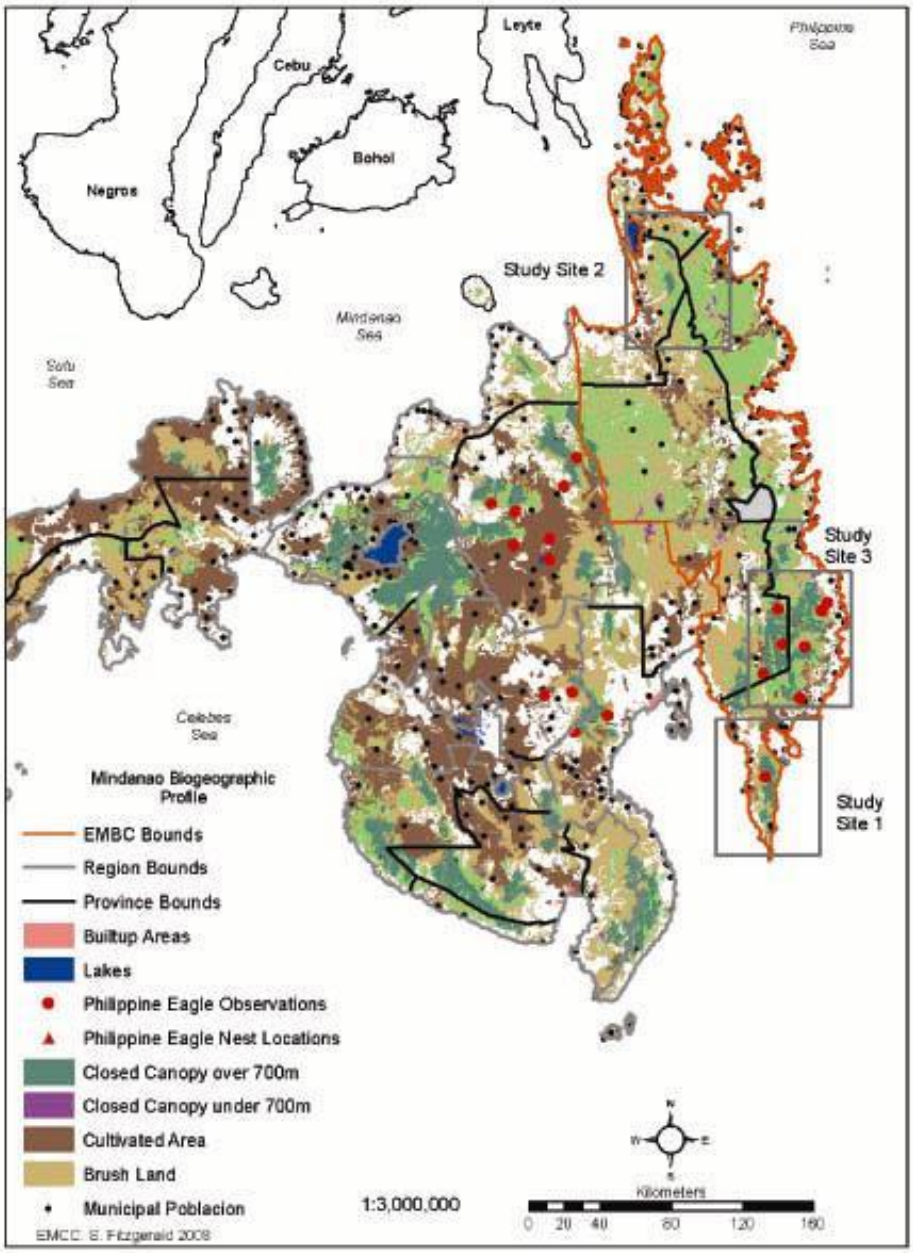

Figure 3.- Eagle Sightings, Nests and Land Cover in the EMC and Mindanao, 2005.

Figure 4.- Biogeomorphology of Eagle Nest Habitat

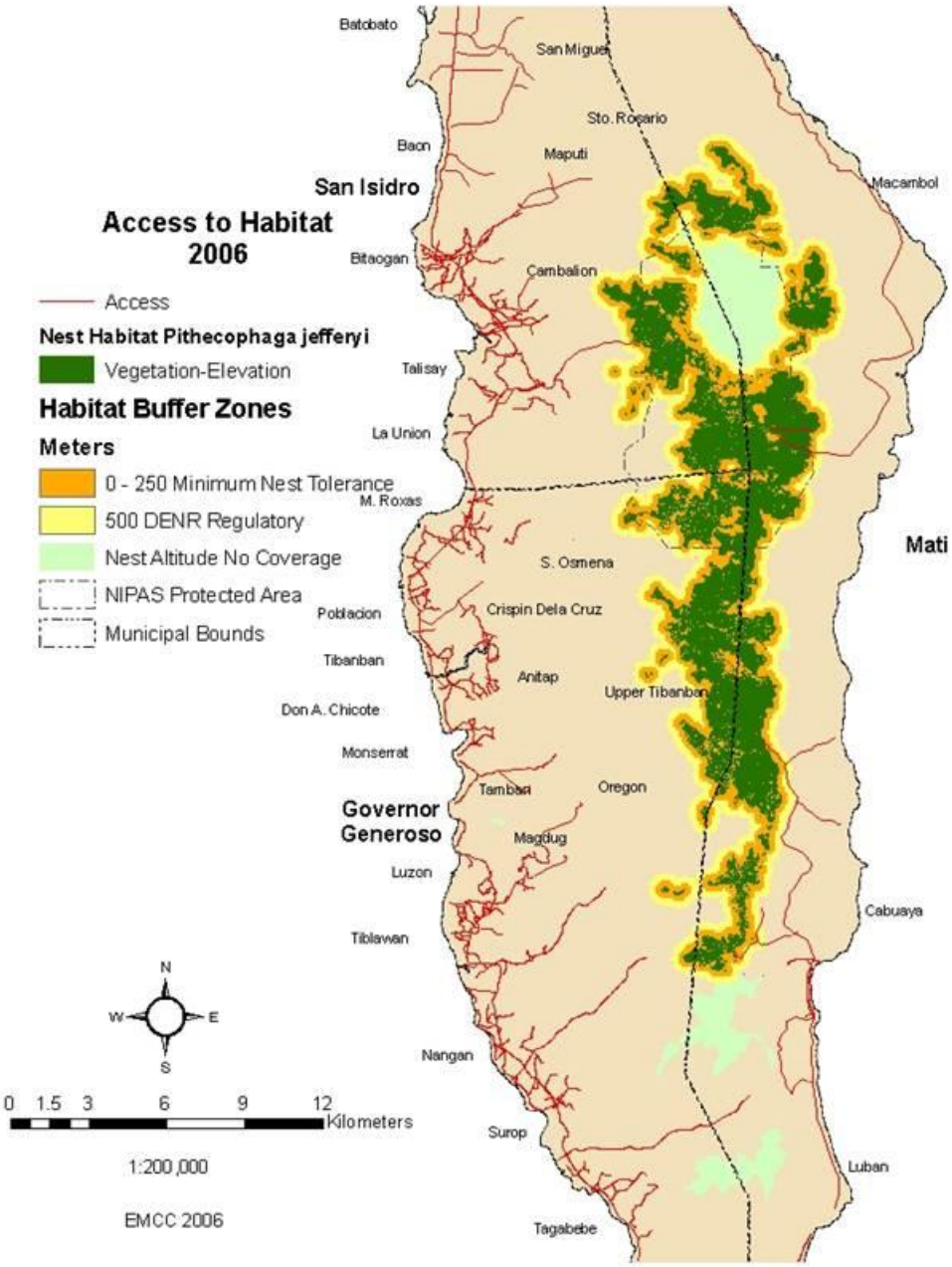

Figure 5.- Access to Habitat in Mt. Hemaguitan

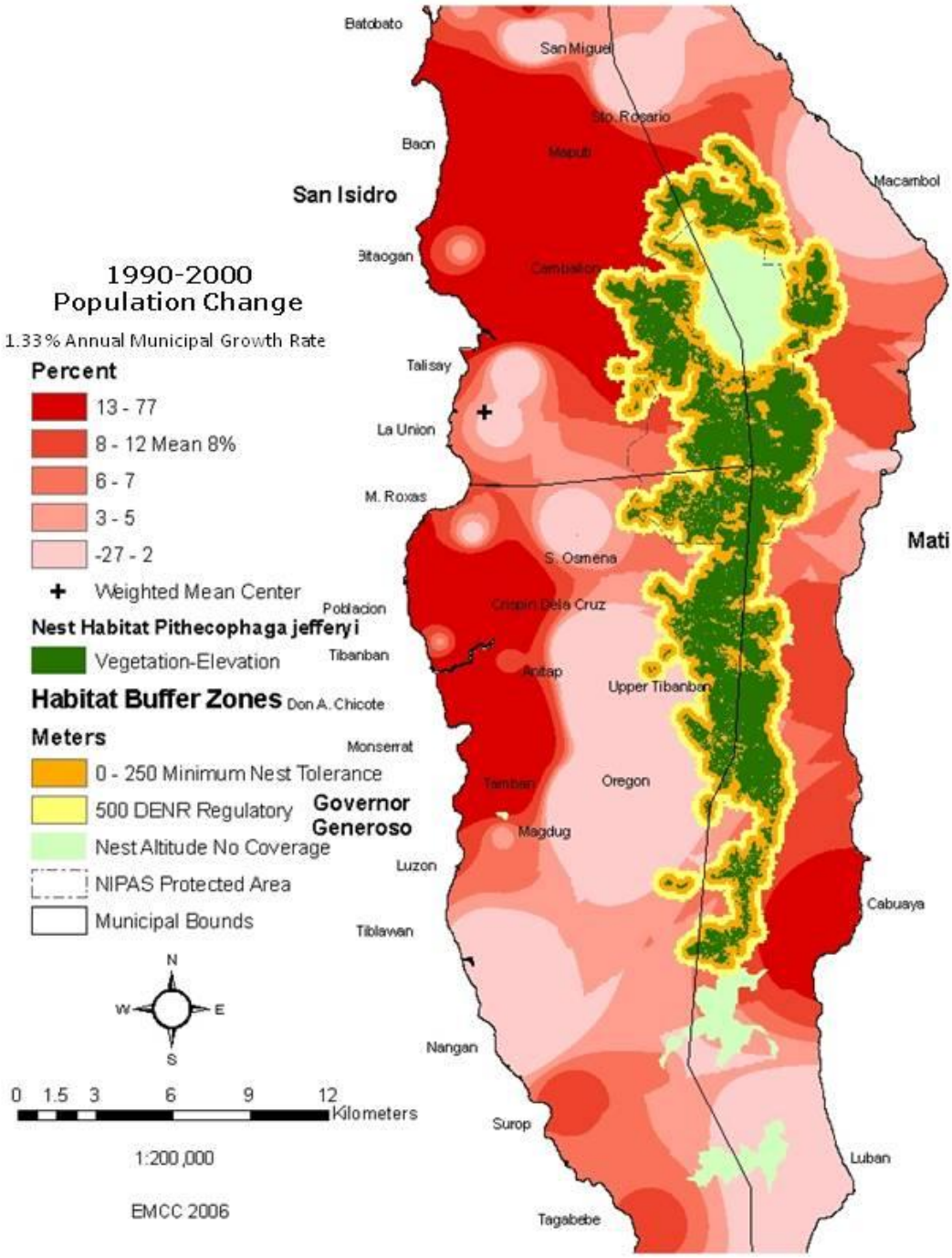

Fig. 6- Population Change (%) in Davao Oriental: 1990-2000

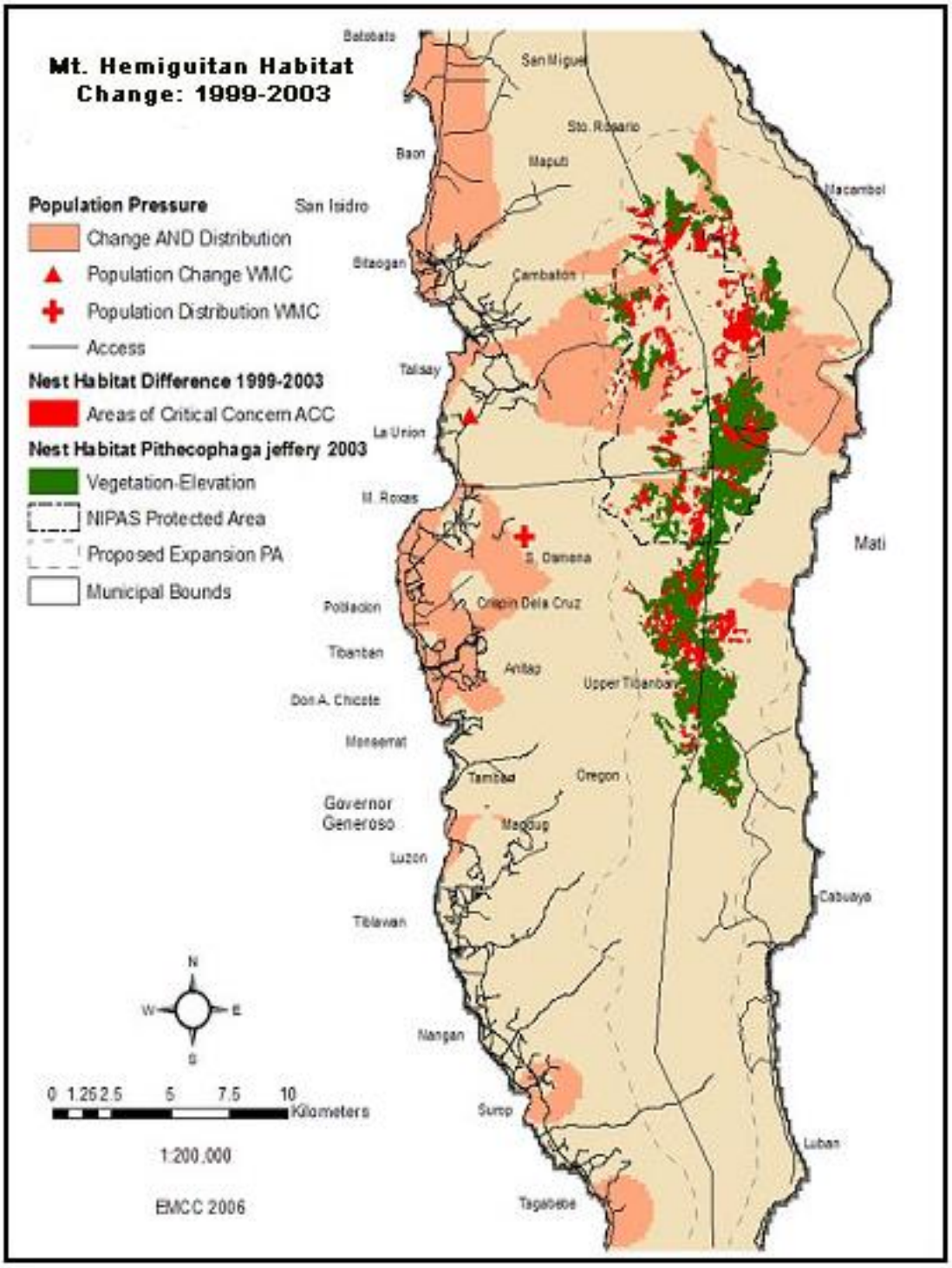

Figure 7- Nest Habitat Change

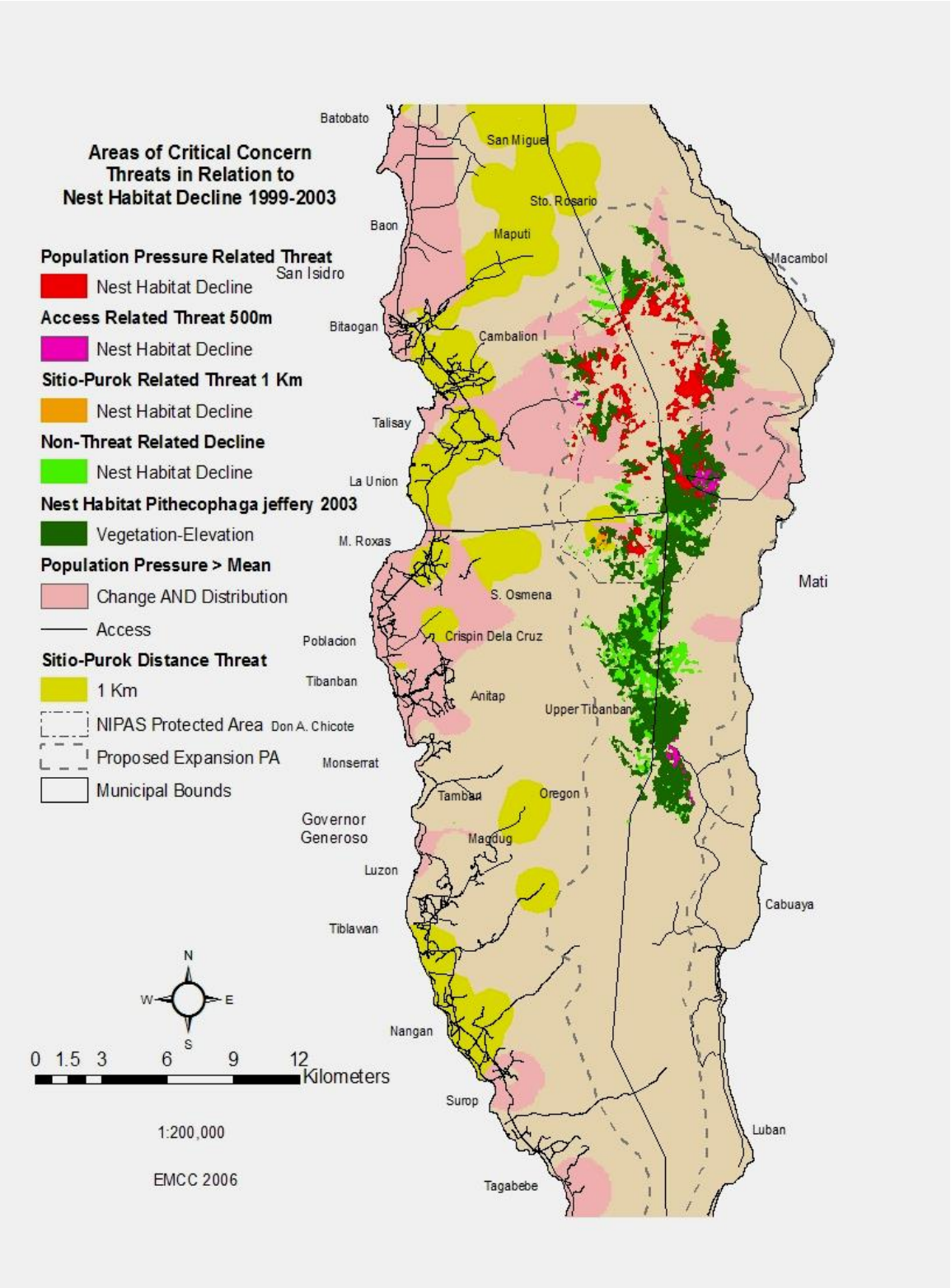

Figure 8.- Mt. Hemiguitan: Areas of Critical Concern