LINKING SOCIAL AND ECOLOGICAL DYNAMICS FOR BIRD CONSERVATION: PROTECTING THE ENDANGERED SIERRA MADRE SPARROW IN CHICHINAUTZIN, MEXICO.

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ABSTRACT

Birds are one of the best studied animal groups in the world but are also amongst the most endangered. The wealth of ecological information has shown habitat protection to be vital to bird biodiversity, but habitat loss and degradation continue to defeat conservationists.

Community-based biodiversity conservation efforts have been recently recognized as an important option for safeguarding ecosystems while reducing land use conflicts arising from the material, cultural and spiritual needs of local inhabitants. Community involvement is particularly critical for conservation in anthropogenic habitats. Few studies have linked the ecological impacts of community land use practices with the auto-ecological requirements of dependent bird species. In this study I examine the conservation possibilities for the endangered Sierra Madre sparrow (*Xenospiza baileyi*) by considering three basic elements: the ecological requirements of the bird, the effects of traditional land use practices in shaping the habitat, and the economic and social conditions that influence current and future land use decisions. I draw on ecological field studies, on traditional ecological knowledge systems, and studies of the political ecological context that influences local practices.

The studies were carried out from 2000-2003 and employed a combination of ethnographic, participative and spatial-ecological approaches to address human-land interactions and their impacts on the sparrow habitat. Social data were obtained through nine workshops which included site visits, transect walks, participatory mapping, oral histories and semi-structured interviews. Ecological data were obtained from landscape ecology analysis, vegetation post-disturbance assessments and detailed bird's nest-site selection analysis.

Results indicate that local people, principally herders, hold a rich knowledge of fire use to achieve diverse purposes, including pasture renewal, grassland maintenance and grass species selection, and prevention of dangerous fires. In order to accomplish their goals, herders have established rotational fire and grazing regimes that consider timing, frequency, location and extent of these disturbance-based practices. This rotational system was found to benefit the Sierra Madre sparrow by maintaining the grassland at the scales needed by the sparrow for nesting. Multiscale habitat recommendations for the species' conservation were derived from this socio-ecological interaction and dynamics.

Unfortunately, external conservation perspectives and interests and internal land tenure conflicts have altered this rotational regime and local perspectives on resource management that threaten the resilience of this social-ecological system. Consequently, traditional ecological knowledge on grassland management can be on risk of disappearing and, with it, important native grasses and grasslands are being made vulnerable. The survival of the Sierra Madre sparrow in particular and of associated biodiversity in general, is in peril if these conflicts are not solved in a relatively short time. A community-based fire co-management program is recommended to promote integrative bird conservation-local development scenarios.

RESUMÉ

Les oiseaux sont parmi les animaux les plus étudiés à travers le monde, mais ils sont également ceux qui courent le plus grand risque d'extinction à travers les continents. Bien que les connaissances écologiques sur ces animaux aient influencé les efforts de conservation en identifiant l'importance de la protection des habitats, la perte et la dégradation de ceux-ci continuent à contrer l'action des écologistes.

L'effort communautaires en conservation de la biodiversité a été récemment reconnu comme étant une option efficace dans la protection des écosystèmes destinés aux besoins matériels, culturels et spirituels des communautés locales. Cependant, peu d'études en conservation des oiseaux ont rapporté les relations entre l'utilisation des terres par la communauté et les besoins des espèces d'oiseaux. Dans cette étude, j'adresse cette question en examinant les possibilités de conservation pour une espèce menacée, le Bruant Sierra Madre (*Xenospiza baileyi*), en intégrant le système de connaissance écologique traditionnelle qui détermine l'utilisation et la conservation des terres et le contexte politique et écologique qui influence ces relations.

Cette étude a été conduite durant les années 2000 à 2003. Pour adresser la complexité inhérente à l'étude des interactions et des impacts de l'utilisation des terres et de la conservation du Bruant Sierra Madre, j'ai utilisé une combinaison d'approches et de techniques ethnologiques, participatives et d'écologie spatiale. Les données sociales ont été recueillies au cours de 9 ateliers qui incluaient des visites de sites, des marches de transects, de la cartographie participative, l'écoute d'histoires orales et des entrevues semi structurées. Les données écologiques ont été obtenues par des analyses en écologie du paysage, des études de la végétation après perturbation et des analyses détaillées de la sélection des sites de nidification.

Les résultats de cette étude indiquent que la communauté locale, principalement les éleveurs, détiennent d'importantes connaissances sur l'utilisation du feu à des fins variées comme le renouvellement des pâturages, l'entretien des prairies, le contrôle d'espèces nuisibles et la prévention d'incendies dangereux.

Pour atteindre ces objectifs, les éleveurs ont établi un régime de rotation de feu et pâturage local en fonction du moment, de la fréquence et de la place de feu ou *chamusquinas*. Ce régime de rotation local s'avère bénéfique pour le Bruant Sierra Madre en maintenant un couvert de prairie à l'échelle régional, favorisant une mosaïque de conditions successionelles à l'échelle du paysage en incluant des parcelles de prairie matures composées d'espèces spécifiques qui favorisent le succès reproductif de l'oiseau.

Malheureusement, des perspectives et des intérêts de conservation externes et des conflits de propriété terrienne ont altéré ce régime de feu, menaçant ainsi la résilience socio-écologique de cet écosystème. Conséquemment, les connaissances relatives à l'utilisation du feu et de la gestion de la pâturage se perdent et d'importantes espèces de prairie disparaissent. La survie du Bruant Sierra Madre, ainsi que celle la biodiversité qui s'y rattache, est mise en péril si ces conflits ne sont pas résolus relativement rapidement. Un programme de co-gestion communautaire des feux est recommandé pour promouvoir des scénarios qui intègrent la conservation des oiseaux et le développement local.

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LIST OF ACRONYMS

AGN- Archivo General de la Nación

CCA- Comisión para la Cooperación Ambiental.

CEHAM- Centro de Estudios Históricos y del Agrarismo en México.

CI- Confidence interval.

COCODER- Comisión Coordinadora para el Desarrollo Rural.

CONABIO- Comisión Nacional para el Conocimiento y Uso de la Biodiversidad en México.

CORENA- Comisión de Recursos Naturales (previously known as COCODER).

DF- Distrito Federal.

DFA- Discriminant function analysis.

GEA- Grupo de Estudios Ambientales A.C.

GEMA- Grupo de Estudios del Medio Ambiente.

GPS- Global Positioning System.

INEGI- Instituto Nacional de Estadística, Geografía e Informática.

IUCN- The World Conservation Union.

LANDSAT ETM- Landsat Enhanced Thematic Mapper (Remote sensing data).

NTFP- Non-timber forest products.

RBC- Representación de Bienes Comunales.

RGBCMA- Representación General de Bienes Comunales de Milpa Alta.

UAM- Universidad Autónoma Metropolitana.

UNAM- Universidad Nacional Autónoma de México.

SEMARNAT- Secretaría del Medio Ambiente y Recursos Naturales.

SD- Standard deviation.

SE- Standard error.

SMS- Sierra Madre sparrow.

SPOT IRS-1-C- Satellite pour l'Observation de la Terre. IRS-1-C is a civilian satellite providing highest spatial resolution information.

TEK- Traditional ecological knowledge.

WCMC- World Conservation Monitoring Centre.

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[+] Rest on peace.

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CHAPTER 1

INTRODUCTION

1.1. Background information

Everyday we witness the loss of significant ecological resources (McNeely and Scherr, 2001). These losses are often coupled with losses of traditional cultural practices that defined human-ecosystem interactions in cultural landscapes[1] (Farina, 2000; Davidson-Hunt, 2003). The extinction of species, the impoverishment and marginalization of local communities and the loss of cultural and traditional knowledge are constant realities (Berkes, 1999). This is one part of a wider ecological crisis (Soule, 1986) and current trends point at a threatening future for biodiversity and society unless new management skills and commitments are established. Hence, the development of integrated approaches to the conservation of biodiversity is an important research area. Success could contribute not only to the preservation of biodiversity, but also to the perpetuation and development of human communities.

The Sierra Madre sparrow (*Xenospiza baileyi*) (hereafter, SMS) is an element of Mexico's biodiversity. It is currently listed amongst the most endangered bird species in the world (Birdlife International, 2000) because of the disruption of cultural practices that sustain its habitat. Historical and current evidence indicates that, as its limited habitat is transformed, this bird species is vanishing (Dickerman et al., 1967; Collar et al., 1992;

[1] According to Davidson-Hunt (2003, p.21) *"Cultural landscape is defined as the physical expression of the complex and dynamic sets of relationships, processes and linkages between societies and environments"*. For Farina (2000, p. 313) *"Cultural landscapes are geographic areas in which the relationships between human activity and the environment have created ecological, socioeconomic, and cultural patterns and feedback mechanisms that govern the presence, distribution and abundance of species assemblages"*. The concept of cultural landscape is used in this thesis to underline the interdependency of diverse vegetation stages with human interests.

Cabrera and Navarro, 2000; Cabrera et al., 2006). Presently, the remaining population is estimated at less than 5000 individuals occupying a fragmented area of subalpine grasslands of approximately 1000 ha in central Mexico (Cabrera et al., 2006).

Actions to conserve this species are urgently needed, but the conditions are especially challenging. Notably, the species depends on habitat that is anthropogenic, but cultural practices (rotation of fire and grazing) are in decline and are thought by local conservation authorities to be damaging to the environment. Land tenure is communal and it is disputed in certain areas; this conflict threatens the system with resource overexploitation. Lastly there is little scientific and public awareness of this poorly known and non-charismatic species because it has no commercial or subsistence value and its conservation is not likely to bring material benefits to local groups (Stankey and Shindler, 2006). These conditions make it difficult to undertake SMS conservation under a conventional approach.

SMS conservation requires innovative approaches that recognize and integrate a myriad of social and ecological interactions in a holistic framework (Gómez-Pompa and Kaus, 1992; Toledo et al., 2001). My work draws on literature on various contemporary approaches to conservation (Ehrenfeld, 2000). These include traditional ecological knowledge (Berkes, 1999), socio-ecological resilience (Berkes and Folke, 1998; Gunderson and Holling, 2002; Berkes et al., 2003), sustainable and cultural landscapes (Fry, 2001; Davidson-Hunt, 2003; Tress et al., 2005), landscape ecology (Bastian and Steinhart, 2002), community-based conservation (Western and Wright, 1994; Berkes, 2004), adaptive co-management (Folke et al., 2002) and conservation geography (Bonta, 2003).

These approaches seek the co-occurrence of biodiversity and human community development through dynamic and adaptive processes, mediated by cultural practices that confer resilience to ecosystems, enhance species richness and satisfy material and cultural needs of local communities (Berkes, 2004; Potschin and Haines-Young, *in prep.*).

1.2. Research statement

This thesis reports on a conservation study of the endangered SMS that describes, analyzes and integrates biological, ecological and social information. Specifically, it first considers the basic ecology of the sparrow to understand core habitat needs. It does so by examining the reproductive strategy and habitat requirements of the bird and then considers which of these requirements are related to human activities. Second, the thesis considers the human role in shaping the landscape, notably, what human land managers do on the land, why they do it and when, and with what ecological consequences. Third, the study documents in detail the traditional ecological knowledge system (*sensu* Berkes, 1999) of landscape management at the appropriate spatial and social scales to understand how local knowledge, cultural values and social institutions contribute to land-people interactions. Lastly, the thesis considers the links between human activities that are relevant to SMS conservation and conditions that promote, support or threaten these activities. This provides the foundation for recommendations for a conservation strategy.

The thesis makes contributions to knowledge in several areas: avian ecology and conservation; disturbance management for habitat renewal; customary practices on the use and regulation of communal resources; and community-based biodiversity conservation.

1.3. Thesis outline

The thesis begins with two chapters that provide a synthesis of information on the SMS's natural history, ecology, threats and conservation needs (Chapter 2); and a site description that addresses the biophysical, historical and cultural importance of the study area, as well as the socio-environmental background for conservation (Chapter 3). Three inter-related, empirically-based chapters follow. Chapter 4 begins by examining SMS's nest site selection strategy at three hierarchical spatial scales and its relationship with breeding success. Practical habitat management recommendations at each spatial scale are derived that will favour the conservation of this species. This chapter establishes the ecological basis of the species' habitat management needs that are considered in the following chapters of this thesis.

Chapter 5 determines how local land use practices (mainly burning and grazing but also agricultural expansion) impact, spatially and temporally, the structure and dynamics of the landscape with emphasis on the bird's breeding habitat. The same chapter also examines how this habitat recovers under current disturbance management practices and finally discusses management recommendations based on the species' requirements and current land uses practices.

While Chapters 4 and 5 show the strong linkages of human activities with the condition and dynamics of this landscape, Chapter 6 examines the people's traditional ecological knowledge system, principally the ethnoecological knowledge of grasses and customary practices on fire use and grazing management; and the diversity of cultural, historical and political factors influencing people's perceptions and capacities to manage and conserve this communal territory.

Chapter 7 concludes the thesis by linking the main findings into a synthetic framework-model that describes the contribution of each part of the study to an integrated understanding of SMS's conservation problem and possibilities. This leads to recommendations for conservation practices at the local level, and a discussion of the implications of the findings for policy formulation and community-based conservation initiatives.

CHAPTER 2

THE SIERRA MADRE SPARROW

(*Xenospiza baileyi*, Bangs, 1931):

NATURAL HISTORY, ECOLOGY AND CONSERVATION NEEDS

2.1. Introduction

The Sierra Madre sparrow (*Xenospiza baileyi*) is a Mexican endemic considered as one of the most endangered birds in the world (Birdlife International, 2000). Since its description in 1931 by Bangs, the species has been the subject of few studies with a focus on taxonomy, natural history and general ecological relationships (Collar et al., 1992; Cabrera, 1999; Oliveras de Ita et al., 2001). This chapter summarizes field observations and previously published information on the Sierra Madre sparrow (Cabrera, 1999; Cabrera and Escamilla, 2000; Cabrera et al., 2006; field observations in 2000-2003) to identify information gaps and conservation needs.

2.2. Sierra Madre sparrow's description

The Sierra Madre sparrow is a small bird, around 130 mm in total length with a reddish brown back, a striped head with grayish sides, black streaks on the white breast and yellowish flanks, and a distinctive large black spot on the breast (Blake, 1953; Howell and Webb, 1993). Sexual dimorphism has not been studied. Juveniles have yellowish belly and a dark brown back. The bill is gray in adults and yellow with brown in juveniles (Figure 2.1).

2.3. Distribution

The species has been found only in two disjunct areas of the Sierra Madre Occidental: the high mountains of southern Durango and northern Jalisco, and the central area of the Transverse Volcanic Belt south of the Mexican Valley (Miller et al., 1957; Collar et al., 1992; Cabrera and Navarro, 2000) (Figure 2.2).

Historical distribution. The species has not been registered in the northern localities since 1951 (Howell and Webb, 1993; Lammertink in litt., 1999 cited in Birdlife International, 2000). Little, and imprecise, information is available on the environmental conditions at historical localities previously reported:

Cienega Tableterra, Durango (23° 43' N; 104° 40' W). Bailey and Conover (1935) and Pitelka (1947) reported collecting the species at this locality. Habitat conditions were not clearly reported, but indicate the existence of wet mountain grasslands probably located in accumulation plains (J. Jiménez de Azcarate, *personal communication*). These grasslands were reported to be surrounded by a woodland landscape intermixed with shrubby-xeric vegetation (Bangs, 1931; Collar et al., 1992).

San Juan, Durango (8 km west of El Salto, *precise locality not identified*). Miller et al. (1957) reported observing the species there but did not provide information about environmental conditions. Howell (1991, cited in Collar et al., 1992) believed grasslands were the dominant vegetation type due to the presence of grassland remnants close by.

Sierra de Bolaños, Jalisco (21° 41' N; 103° 47' W). The species was reported in that area in 1888 (Pitelka, 1947) but without ecological information.

Current distribution. The SMS is now believed to be confined to small and patchy areas in the high mountain plains (above 3000 m.a.s.l.) south of the Mexican Valley (Cabrera et al., 2006). Until recently, it was believed to occur only in the locality of La Cima, at the border of the Distrito Federal and the State of Morelos (Wilson and Ceballos-Lascurain, 1993). However, a recent ecological and distributional study over the entire southern area of the Mexican Valley (Cabrera et al., 2006) has allowed to identify new occupied localities: El Capulin (Estado de México), surroundings of volcanoes Acopiaxco, Comalera-San Bartolito, Yecahuazac and Tlaloc (Distrito Federal) and Xuchio and Otlayuca (Estado de Morelos). This is important for the conservation of the species since the new localities have a higher level of ecological integrity than La Cima.

2.4. Natural History

The SMS is a resident species. It nests at the base of large bunchgrass tussocks, close to but not on the ground (Cabrera and Navarro, 2000; Hernández, 2002). Males start vocalizing in mid April to establish territories and attract females, and breeding occurs until the end of August. It is possible that the species re-nests or has two clutches per season, but this is likely rare (Cabrera, unpublished data). The nests are made of moderately coarse grass with a few forbs and are lined with fine grass and grass rootless (Dickerman et al., 1967; Hernández, 2002) (Figure 2.3). Hernández (2002) reports that the external layer of nests is built principally with rigid roots of the grass *Muhlenbergia* *macroura*, intermixed with stems of diverse native herbs (e.g., *Commelina diffusa*, *Stevia monardifolia*) and horse and coyote hair.

Availability of nest building materials has recently been identified as important for bird conservation (Hansell, 2001). It is unclear how *Muhlenbergia macroura* roots become available to breeding SMS. Is it through the activity of digging mammals such as moles and badgers? Or is it through the traditional practice of root extraction for broom confection by local people? If the latter is a primary source, maintenance of this traditional practice should be promoted.

SMS's clutch size is on average three pale greenish blue eggs with small black spots concentrated at the wider end. In the spring and summer, males are conspicuous, singing from the tip of tall grass tussocks or from isolated trees and fences. In other seasons, they are more secretive. There are no quantitative data on feeding habits, but Dickerman et al. (1967) found Coleoptera and spiders in digestive tracts. Individuals have been observed feeding on seeds in oat and potato fields (Cabrera and Escamilla, 2000), as well as on moths, flying ants, earthworms and caterpillars (Oliveras de Ita et al., 2001).

2.5. Population

The SMS can be locally common, but it is now limited to a very few sites where remnant grassland fragments remain: La Cima (Collar et al., 1992; Wilson and Ceballos-Lascurain, 1993; Oliveras de Ita et al., 2001), Chichinautzin (Cabrera, 1999; Cabrera and Escamilla, 2000), Milpa Alta-San Juan Tlacotenco and El Capulin (Estado de México) (Cabrera et al., 2006).

Population density has been estimated at 2.89 males per hectare in La Cima (Oliveras de Ita et al., 2001) and 0.5 pair per hectare in Milpa Alta (Chapter 5 of this thesis). The difference may be related to the size of the grassland fragments, which are 40 ha at La Cima and 500 ha at Milpa Alta-San Juan Tlacotenco. Based on this information, the total population of this sparrow is obviously very small.

2.6. Habitat

Initial descriptions of SMS's habitat at the northern localities confirm the preference of this species for high altitude grassland in mountain landscapes. In the article describing the species, Bangs (1931, p. 88) quoted Bailey's description of the species habitat in Durango:

> *"...it is a rugged mountain region, broken by precipitous canyons, and with expanses of park. There is much pine, with thorny shrubs and some gnarled oaks intermixed. Below the springs was a small marsh, some fifty feet long by perhaps twenty across, grown tall grass, dead at this season of the year (March). In this little marsh there were a dozen or more of the birds*".

Pitelka (1947) described SMS's habitat as a "*...grassland among pines in mountainous areas at altitudes of 8000 to 9000 feet*" (p. 202).

The first SMS habitat description at La Cima (Wagner, 1947 cited by Pitelka, 1947, p. 202) presents it as dry grass of about 60 to 80 cm in height, occurring secondarily over open plains in areas otherwise covered by pine forest. Dickerman et al. (1967; p. 54) described the same grassland as a *"primary association of medium and tall* *bunch-grasses of Epicampes macroura, Festuca amplissima, Stipa ichu* and *Muhlenbergia affinis,* interpersed with *Pinus montezumae".*

Historical descriptions emphasize the patchy nature of this ecosystem occurring in small areas within pine forests. What is not clear from past descriptions is whether the northern grasslands were associated with marshy mountain ecosystems, and whether the grasslands at the southern localities were secondary in origin after deforestation events. Observations at southern localities indicate that grasslands can get damp at the peak of the rainy season (Jiménez de Azcarate, *personal communication*, 1999), and diverse authors have classified these grasslands as secondary plant associations (Rzedowsky, 1978; Velázquez et al., 2000b) resultant from forest clearing and maintained through fire and grazing (Velázquez, 1993). Recent studies (Cabrera et al., 2006; Chapters 4 and 6) indicate that regional grasslands have been maintained for centuries for diverse cultural and subsistence reasons.

The SMS' habitat has been described as a complex and temporally variable vegetation mosaic composed of eight plant communities, of which five comprise medium to tall bunchgrasses (Cabrera et al., 2006, p.214). Based on abundance (Cabrera et al., 2006) and breeding activity data (Chapter 5), SMS prefers the tall bunchgrassland communities dominated by *Festuca lugens- Muhlenbergia quadridentata* and *Stipa ichu* (Figure 2.4).

2.7. Threats and conservation status

Intensification of productive practices and the adoption of new land uses are the main threats to grassland habitats in the areas still occupied by SMS. Areas of subalpine bunch grassland have been reduced by 50 % in the last 15 years (Cabrera, 1999; Velázquez and Romero, 1999; González, 2000) as a consequence of agricultural encroachment (mainly for oat and potato fields) (Figure 2.5), tree plantation as part of land conservation programs, and urban expansion. In the remaining grasslands, intensification of livestock production results in an increased fire regime and grazing pressure and is likely threatening the ecosystem integrity and local ecological processes relevant to its maintenance and permanence (Cabrera et al., 2006). These land use trends are discussed in greater detail in Chapter 4. SMS area of occupancy (see IUCN, 2000 for a definition) is now approximately 800 ha (González, 2000).

Sierra Madre sparrow demographics may also be limited by high predation rates at the nesting state as discussed in Chapter 5. Finally, the use of agrochemicals in the region may be directly linked to mortality (Oliveras de Ita et al., 2001).

Considering those threats and limiting factors, the SMS has been classified as an endangered species by national scientists (Diario Oficial de la Federación, 2000; Cabrera et al., 2000; Cabrera and Navarro, 2000) and the international community (CCA, 1999; Birdlife International, 2000). This classification is based on well-established criteria (IUCN, 2000) and the reasons have been summarized as follows: the extent of suitable habitat is "extremely small" and "within this range inappropriate management is causing continuing and rapid declines" (Birdlife International, 2000, p. 241).

Limited conservation planning and recovery action has followed SMS classification as an endangered species, a pattern common to most small, non charismatic or non exploited species (see Ceballos and Márquez-Valdelamar, 2000; Stankey and Shindler, 2006). Cabrera et al. (2006) characterized SMS habitat in detail and identified priority areas for the species' conservation at landscape scale. The priority areas include core grasslands for breeding and corridors that could facilitate population interchanges between isolated core areas (Figure 2.6).

Developing a focused and integrative conservation research and action program is now the priority, and it is the focus of this thesis. As remnant core grasslands are held and used by local indigenous communities, habitat protection through other mechanisms than the establishment of protected areas needs to be explored. In Chapter 3, I present the social and environmental context of the region's grasslands, including linkages and dynamics that make them a priority for bio-cultural conservation (Toledo et al., 2001).

Figure 2.1. Adult individual of Sierra Madre sparrow captured in Milpa Alta's grasslands. Photograph: L. Cabrera, 2001.

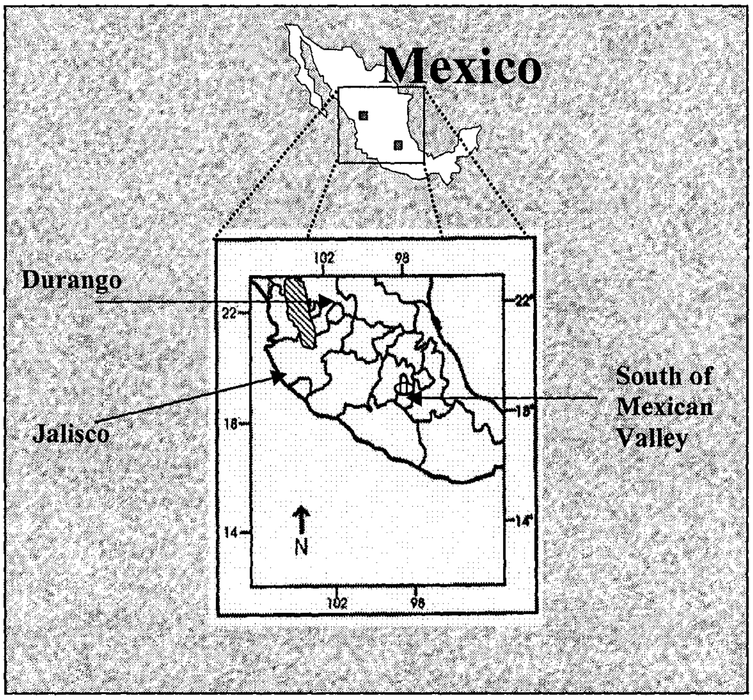

Figure 2.2. Historical [pattern] and present [pattern] distribution of *Xenospiza baileyi* in Mexico. From Howell and Web, 1993.

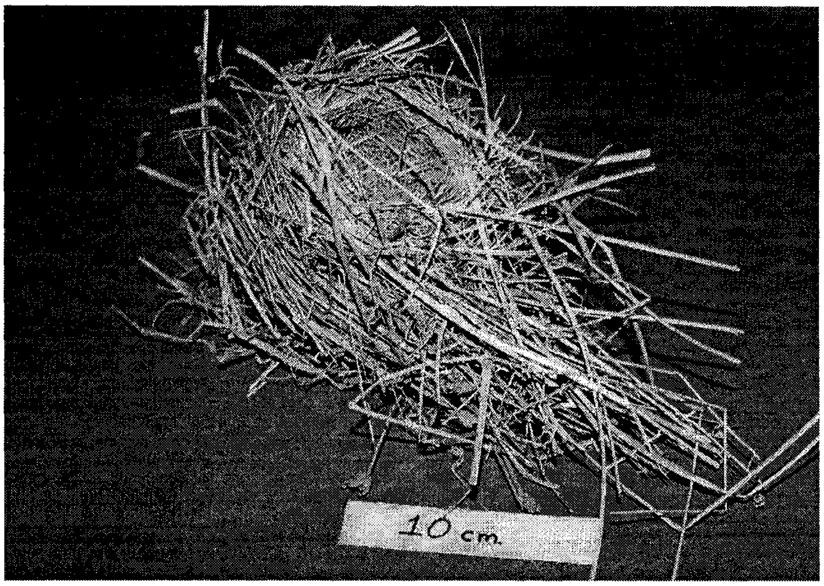

Figure 2.3. Nest of Sierra Madre sparrow. Photograph: G. Hernández, 2001.

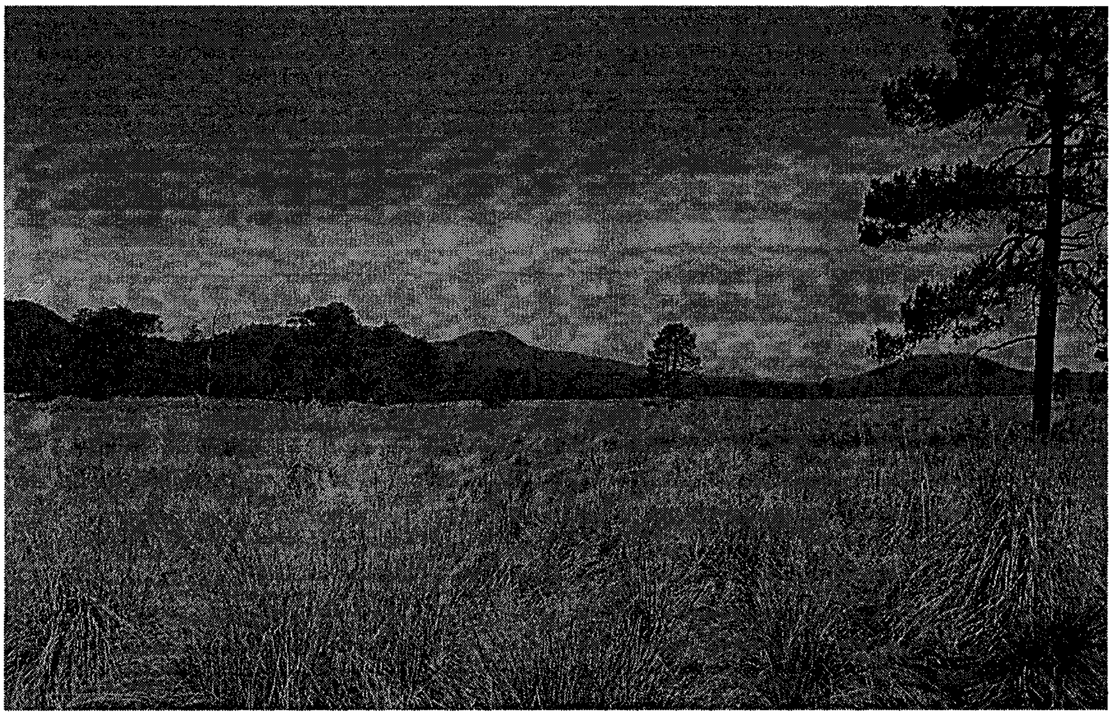

Figure 2.4. The *Festuca lugens- Muhlenbergia macroura* community in the Milpa Alta region is the preferred habitat of the Sierra Madre sparrow in the south of the Mexican Valley. Phototograph: L. Cabrera, 2002.

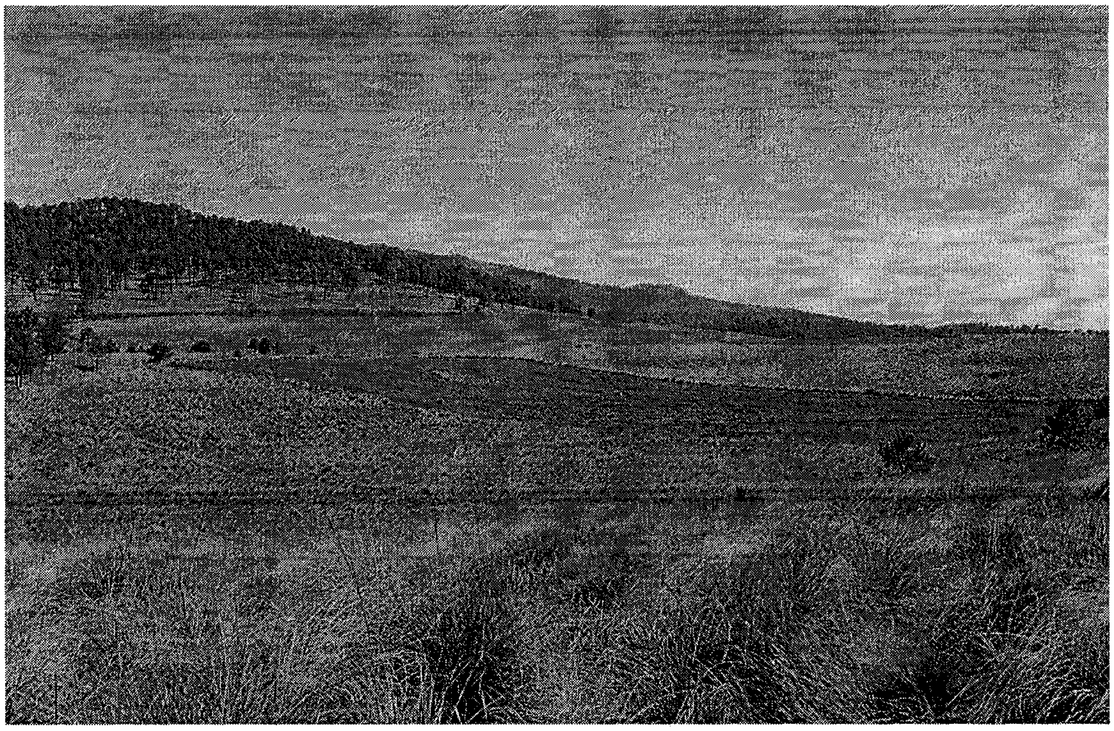

Figure 2.5 Agricultural field at the north of the Sierra Madre sparrow's core habitat in Milpa Alta. Photograph: L. Cabrera, 2002.

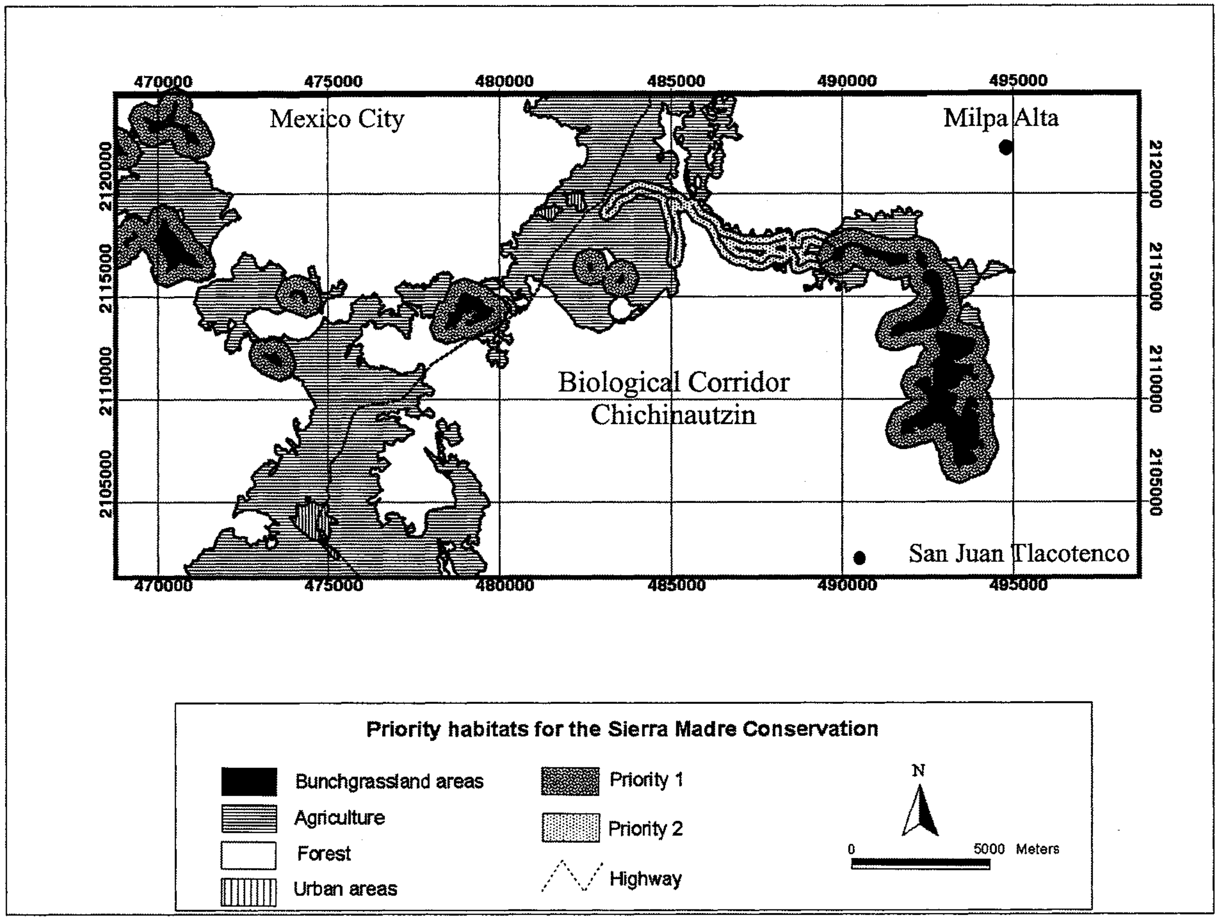

Figure 2.6. Selected areas for the Sierra Madre sparrow's conservation in the South of the Mexican Valley. From Cabrera, et al., 2006.

CHAPTER 3

THE STUDY SITE

MILPA ALTA AND SAN JUAN TLACOTENCO: TERMINAL TOWNS AT THE EDGE OF TRADITIONS AND CONSERVATION

3.1. Introduction

This study was conducted in the communal grasslands of the Milpa Alta Municipality, located at the south east of Distrito Federal and San Juan Tlacotenco, at the north-east of the Tepoztlán Municipality, Morelos (Figure 3.1). By examining the historic, social and biophysical characteristics of the region, this chapter will provide the social and natural backgrounds that make the region important for conservation. The chapter presents firstly a biophysical description of the region with emphasis on its biological and ecological importance, but also on the main environmental threats the region is facing and how conservation is being implimented.

Second, it presents ethnographic information on the origin and foundation of these communities, to then explain how current communities are socially organized to protect and use local resources. At the end of the chapter, the environmental and social challenges to conserve the Sierra Madre sparrow are addressed. The information is derived from personal observations and findings but also from previous work (Velázquez, 1993; Cabrera and Meléndez, 1999; Cabrera et al., 2006).

3.2. Biophysical environment and conservation status

3.2.1. Physiography

The study area corresponds to the southern limit of the Mexican Valley (Ezcurra, 1990), a physiographic unit located in the central-eastern part of the Transversal Mexican Belt (Moore, 1945; Goldman and Moore, 1946). The topography is irregular and consists of recent lava shoulders, lava ridges, a high number of craters and valleys (Lugo, 1984). The Sierra Ajusco-Chichinautzin, of Holocene origin, forms the southern border of the Valley of Mexico (Lugo, *op.cit.*). Three hundred volcanoes have been reported to occur in this region (Bloomfield, 1975; quoted by Velázquez and Romero, 1999). The main volcanoes in the study area are Tlaloc, Chichinautzin, Yecahuazac, Zilcuayo and Oclayuca. Numerous intermountain plains are located in valley bottoms and are formally the SMS's habitat if covered by tall bunchgrasses.

The soils have been classified for the region as Andosol and Litosol (INEGI, 1978). Andosols have developed from volcanic materials such as sands and ashes; they are dark brown and well developed. Litosols are poorly and superficial soils characteristic of deep mountain slopes undergoing erosion. In lower proportions, there are Regosols, Cambisols, Feozems and Fluvisols (Velázquez and Romero, 1999).

The dominant climate is temperate, sub-humid, mild to cool, with a mean annual temperature ranging from 5 to 18 °C. The coldest month is February (up to -3 °C) and June the warmest (up to 22 °C) (Velázquez, 1993). The mean annual rainfall is *ca.* 800 mm.. The altitude of the southern Valley of Mexico ranges from 2950 - 3600 m and from 3000 to 3100 m for the subalpine grasslands.

3.2.2. Biodiversity and landscape vegetation communities

The south of Mexican Valley is recognized as an extremely rich area on both endemic Neotropical and Neartic species (Rzedowski, 1978; Ceballos and Galindo, 1984). Local biodiversity ranges *ca.* 3000 plant species (Rzedowski and Rzedowski, 1989) and 350 vertebrate species, representing 2 % of the global biodiversity (Velázquez and Romero, 1999). Vertebrate richness is represented by an interesting amphibian community of 24 species; in addition to 56 reptile species, 195 bird species and 59 mammal species (Velázquez and Romero, *op cit*). A high percentage of these vertebrate species are endemic to Mexico and even endemic to the region. Between the most particular species in the region are the endemics Volcano Rabbit (*Romerolagus diazi*) and Sierra Madre sparrow *(Xenospiza baileyi*), both restricted to the region and under the category of *endangered* (IUCN, 2000).

The high species diversity responds to the variety of vegetation types in the zone. Seven landscape vegetational units occurring in different geomorphic classes and shaped by local managerial practices have been distinguished in the entire south of Mexican Valley (Velázquez, 1993): fir forest, pine forest, mixed forest, mega-rosette vegetation, subalpine bunchgrassland, meadows and semi-natural vegetation.

The **Fir Forest** or *"oyametal"* is represented by the plant community *Senecio angulifolius-Abies religiosa*, distributed principally in escarpments, canyons and slopes of volcanoes. The forest structure is generally dense with soils covered with abundant mosses. Main human activity reported in the past consisted on logging to obtain cellulose by paper-maker companies. The fir forest is a very restricted community and considered as the climax vegetation state in the region (Velázquez et al., 2000b). The **Pine Forest** or *"bosque de coniferas"* is a semi-open tree cover dominated by the species *Pinus hartwegii*, accompanied by the bunchgrassland *Muhlenbergia quadridentata* in the herb layer. It covers the subalpine slopes of the main volcanoes above 3000 m.a.s.l., dominating the landscape appearance. Burning and grazing for pasture renewal and fuel reduction are the main land use practices in this ecosystem. Timber from dead trees, firewood and edible and medicinal plants are extracted by local *comuneros* from the abundant pine forests.

Mixed Forests or *"encineras"* are widely distributed in the altitudinal level below the pine forest (2600-2900 m a.s.l.) and are represented by the tree species *Alnus firmifolia, Quercus laurina* and *Pinus montezumae* principally, with a developed herb cover composed of the grasses *Muhlenbergia quadridentata, Muhlenbergia macroura* and *Calamagostris tolucensis.* A great richness of vascular plant species is reported for this vegetation type (Silva, 1998). This plant community occurs on deep slopes, lava flows and hillsides. Firewood extraction and charcoal production are frequent activities practiced in this ecosystem type. Mushrooms are specially recognized as a delicacy extracted from this type of forest.

The **Mega-Rosette** vegetation type is restricted to the rocky footslopes of the volcano Pelado, in the nearby municipality of Tlalpan. The plant community's characteristic species is the endemic agave-related *Furcraea bedinghausii*, distributed over the rocky-xeric slopes of this volcano. Flowers from this plant are appreciated by local inhabitants for local consumption. The **Subalpine Bunchgrassland** or *"zacatonal"* densely covers valleys and flat terrains such as crater bottoms and accumulation plains. Some isolated pine trees of *Pinus montezumae* and *P. hartwegii* occur sparsely across grasslands. The main grass species present in this community are *Festuca tolucensis, Festuca lugens, Calamagrostis toulcensis, Poa annua* and *Muhlenbergia quadridentata* (see Cabrera et al., 2006 for a detailed description). Burning and grazing are the main managerial practices shaping this community. Raw material, roots, and tips are extracted actively from grasslands by *comuneros* for local trade and construction. Mushrooms from grasslands are also appreciated as an edible resource with trade value.

The **Meadows** or *"praderas"* are dominated by the grass *Stipa ichu* and the ground cover herb *Potentilla candican,* which is indicative of this community. Meadows develop on poorly drained soils in flat valleys. Because of its appearance as open areas, touristic activities used to occur in this community (i.e., camping and open air activities). These meadows differ from the grazing prairies composed of *Verbena teucrifolia* and *Muhlenbergia vaginata* which are favoured by herders for sheep production *(personal observation*).

Finally, the **Semi-natural vegetation** or *"campos de cultivo"* (agricultural fields) are abundant and generally found near human settlements. Fields can be created over natural flat terrains across the region (generally over grassland areas), and on low to medium mountain slopes (*cerros*), frequently in a terrace system. Main crops cultivated within the mountainous region are oats (*Avena sativa*) and potatoes (*Solanum tuberosum*). Maize (*Zea mays*) and *nopales* (*Opuntia streptacantha)* are also found close to human settlements.

3.2.3. Conservation status, threats and needs

Milpa Alta holds one of the most important natural areas in the Distrito Federal. Because of its particular flora and fauna, cultural and historical significance, but most importantly for its contribution to the regional water and climate cycles, two official protected areas have been established over Milpa Alta (partially) and San Juan Tlacotenco (entirely) lands: the 37, 302 ha Biological Corridor Chichinautzin (Diario Oficial, 1988) and the 24, 000 ha National Park El Tepozteco (Diario Oficial, 1937) (Figure 3.2).

Additional denominations emphasizing the biological importance of the region have been made to support its conservation value. The entire south of the Mexican Valley was declared Area of Ecological Conservation in 1988 by the official environmental agency COCODER (CORENA, 2000). In 1996, the region was declared by the scientific community as a priority area for biodiversity conservation in Mexico (CONABIO, 1996). In 1999 and 2000 the region was considered as one of the most important areas for bird conservation in North America for having a rich avifauna, including endemic and globally endangered bird species, including the Sierra Madre sparrow (CCA, 1999; Arizmendi and Márquez-Valdelamar, 2000).

It is not clear whether these denominations have achieved their conservation goals or have rather created more negative environmental and social impacts. For example, in the community of Huitzilac, a population settled within the Chichinautzin Corridor, Frias (2003, p.159) reported that local *comuneros "defied restrictions on forest use and went involve in clandestine practices for household and commercial purposes"*. In Frias' study (p.150), Huitzilac's *comuneros* frequently mentioned they ignored they were living in a protected area. This has caused inconformity by local communities and more environmental deterioration when protectionist rules limit *comuneros* traditional productive activities.

Additionally, land use change and deforestation are evident across the region by urbanization and agricultural expansion, derived principally from a long "tradition" of centralization of political power, capital and services in the Mexican capital since pre-colonial times (Ezcurra, 1990). The more than 20 million persons settled nowadays in the basin are exhausting and degrading local, regional and national natural resources, affecting the quality of life of millions and the viability of ecosystems and ecological processes.

Evidences of what might be called "environmental and social degradation" in the Mexican Valley are tangible: fragmented habitats (Velázquez and Romero, 1999; Cabrera et al, 2006), land abandonment, lost of traditions and intensification of local land use practices (CEHAM, 1992; GEA, 1992; Cousineau, 2002; Frias, 2003; Cabrera et al., 2006). This critical environmental-social situation in the Mexican Valley has attracted the attention of the United Nations at the point that the Valley of Mexico is ranked as one of the globally threatened regions, besides the Amazonia, Kenya and the North Sea (Aguilar et al., 1995).

It is thus imperative to conserve the entire region for the ecological and social benefits it brings at the regional and local scales. At the regional scale, this region represents a critical element for the well functioning of Mexico's capital city. At the local level, the region represents a critical pool of communal resources of importance for local livelihoods, while at the same time being considered the center of cultural survival and identity for the ancestral indigenous communities of Nahuatl origin in Central Mexico.

3.3. Ethnographic Context

3.3.1 History and foundation

Milpa Alta

According to local testimonies, Milpa Alta means "*altar surrounded by mountains*" [2]. This ancestral meaning mirrors the current physical and cultural identity of *Milpaltecos*. For *Milpaltecos*, Milpa Alta owns its existence to the surrounding mountains, to the *monte*[3]. In figure 3.3 Horcasitas (1972) illustrated well how Milpa Alta is encircled by the main mountains of the Federal District, Morelos and Puebla Mexican states. Milpa Alta is one of the most distant and isolated human settlements with reference to the capital city. It is formally located at the northern limit of the Sierra Chichinautzin and considered as a very traditional town. *Milpaltecos* consider their town as a "terminal town", which means the last town from the rest of the towns, from the city. "*There is no one else [settled] after us, just our monte, we were the last town to be conquered, in fact we were not... but also we were the last town to count with services*"[4].

These words enclose core ideas on how the people are geographically and culturally embedded in the landscape, that, as we will see along this chapter, they refer to belong, to have originated from, to defend against, but paradoxically marginalized as well. This is the challenge many communities living in and depending from mountainous

[2] Key informant interview FCH, summer 2001, Milpa Alta town.
[3] *Monte* is the vernacular name used locally to refer to the communal forested land in the mountains, including grasslands, different forest types and cultivated fields.
[4] Key informant interview VCH, summer, 2001, Milpa Alta town.

ecosystems are dealing with, as Berkes et al. (1997) documented for people from the mountain ecosystems of India and Canada.

In Milpa Alta, past and present are constantly interwoven in one indissoluble reality. *Milpaltecos* proudly relate their history with the purpose to reaffirm their ethnic origin and the foundation of the communal land (see Flores, 1992). According to local testimonies and published research, the first inhabitants occupying this land were of *Chichimeca* origin near the year 1117. Near 1400, the Aztecs under the commandment of Hueyitlahuilanque dominated the *Chichimecas* and established a new *Señorio* denominated Malacachtepec Momozco. According to local testimonies, the Momozcas were not overthrown by the Spaniards, but negotiated the acceptation of the new government to maintain the Momozca territory under control (CEHAM, 1992).

Malacachtepec Momozco was founded in 1555 when its territory was recognized by the Spaniard authorities as *La Asuncion Milpalta.* An authentic ethnic testimony of such land legacy is found in the *Titulo Primordial de La Asuncion Milpalta* which establishes the limits of the nine original families occupying this land, and the rights and responsibilities of Momozcas to take care and defend their territory for the future generations (AGN, n/d.; Caballero, 2003; Gómezcesar, 2004). The Milpa Alta's Nine Towns, locally self-denominated *"pueblos originarios"* (original towns) are distributed at the north of the *monte comunal* and are Villa Milpa Alta, Santa Ana Tlacotenco, San Juan Tepenahuac, San Francisco Tecoxpa, San Jeronimo Miacatlan, San Agustin Ohtenco, San Lorenzo Tlacoyucan, San Pedro Atocpan and San Pablo Oztotepec[5].

The town denominated San Salvador Cuauhtenco, even though it is included within the current political limits of the Milpa Alta's municipality, is not recognized as

[5] Key informant interview JF; interview and oral histories; summer 2001, Milpa Alta.

one of the Nine Towns as *originario* Momozca and founder of the Milpa Alta's territory[6]. According to *Milpaltecos*, San Salvador is a migrant settlement that belonged to Xochimilco (the current municipality at the north of Milpa Alta) and occupied Momozca's western border lands. San Salvador Cuauhtenco has claimed property rights on 7,000 of the 27,000 ha Milpa Alta declares as communal land since the middle 16th century[7] (see Chapter 6 for details). This has resulted in an acute and deep-rooted conflict between the Milpa Alta's Nine Towns and San Salvador Cuauhtenco, impeding the official land entitlement of the communal territory by *La Secretaría de la Reforma Agraria*[8]. For this reason, Milpa Alta lacks the official *Estatutos Comunales* which establishes *comuneros*' rights and obligations to utilize and conserve the communal resources. Traditions are playing the role of land use regulation in this community (see details of the conflict and social institutions in Chapter 6).

San Juan Tlacotenco

San Juan Tlacotenco is the southern neighbouring town of Milpa Alta's Nine Towns. Its original name was Tepecuytlapilco, which means, "*where the mountain ends, the tail of the mountain*"[9]. Similarly to Milpa Alta, San Juan Tlacotenco is geographically isolated and distant from the Municipality of Tepoztlán, but properly nailed in the heart of the *sierras* Chichinautzin and Tepoztlán. The Sierra Chichinautzin can be appreciated as natural background of the town. One of the main streets of the town ends up in a

6 Limits established for Milpa Alta in the Primordial Titles.
7 Key informant interview JF, personal interview, summer 2001, Milpa Alta.
8 It is the Mexican authority responsible for land distribution, registration and regulation.
9 Key informant interview JGR, personal interview, San Juan Tlacotenco, summer 2002. See also Romero (2002).

spectacular cloud forest patch inhabited by species characteristic of this ecosystem[10]. San Juan is a traditional mountainous town that can be considered as another *terminal town* in the sense of *Milpaltecos*.

San Juan Tlacotenco is, according to its elders as a very antique town with its origins in pre-Hispanic times. According to the recent archaeological discovery of the Chimalacatepetl cave in San Juan Tlacotenco, Olmecas could have been the first civilization of Morelos (Romero, 2002). But uncertainty exists on Tepoztlán's first human settlements. Sánchez (1998) considers Tepoztlán as a transit area used for migratory groups moving between the valleys of Mexico and Morelos. Archaeological evidence indicates a Tolteca-Chichimeca group settled during the 10th and until the 12th century in Morelos' lands (including Tepoztlán), when they were invaded by the Xochimilcas group (natives from the south of Distrito Federal, very close to Milpa Alta). During the middle of the 14th century, the Mexicas dominated the Valley of Mexico and funded Mexico Tenochtitlan in 1325. Numerous indigenous groups settled in Morelos were progressively dominated by the Mexicas, including Tepoztlán in the middle of the 15th century (Sánchez, 1998).

After the dramatic Cortes' conquer of Tepoztlán in 1521, *tepoztecos* lived a turbulent period of land recognition by the Spaniard government. In 1648, the Spaniard Viceroy granted the unoccupied lands (or *tierras baldias*) to Tepoztlán. The Testimony of Primordial Titles of Land Composition and Boundaries of Tepoztlán (*Testimonio de los Titulos Primordiales de Composición de la Tierra y Linderos del Pueblo de Tepoztlán*) depicts the Tepoztlán's territory including its 7 towns (or *pueblos sujetos*): Santa

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[10] Personal observation, summer 2002, San Juan Tlacotenco.

Catarina, San Juan Tlacotenco, Santiago Tepetlapa, San Andres de la Cal, Ixatepec San Salvador, Amatlan de Quetzacoatl and Santo Domingo (Sánchez, 1998; Ruiz, 2001).

However, contrary to Milpa Alta's primordial titles written by indigenous hands, the Tepoztlán's titles are late colonial Spanish-language documents certifying land repartition by the New Spain (Haskett, *personal communication*). There is a myth about the existence of original primordial titles. Local testimonies obtained during this study indicate the original titles were either burned during the Mexican Revolution (1910-1917) or are purposefully hidden by people from the Tepoztlán Municipality[11]. Discontent has been expressed by San Juan Tlacotenco's community members about what is proclaimed in the Tepoztlán's titles from 1648. San Juan Tlacotenco's *comuneros* believe these titles do not recognize appropriately their land boundaries and the origin and independence of this ethnic group (see AGN, 1921). A long history of struggles for land recognition continues nowadays between San Juan Tlacotenco's *comuneros* and the Tepoztlán Municipality. It is described in detail in Chapter 6 of this thesis.

3.3.2. Social Organization

Milpa Alta and San Juan Tlacotenco's communities are composed by *comuneros* or legitimate descendents of native inhabitants of the region, usually living in the region for several generations (see Frias, 2003). The *comuneros* are the legitimate owners of the land. Thus, being *originario* is the structural axel of the social organization of these towns. For *comuneros*, the outsiders that settle in one of the towns are considered *avecindado* or *fuereño*, which means people from outside. Even *comuneros* that have

[11] Interview with JO, summer 2002, town of San Juan Tlacotenco.

lived abroad for a long time and return to town are considered as *fuereños* and treated as such[12].

The Milpa Alta's *comuneros* are represented by *La Representacion General de Bienes Comunales de Milpa Alta* (RGBCMA) (The General Representation of Communal Lands of Milpa Alta) founded in 1987 by an active and organized movement of *comuneros* that was defending intensively the communal land against external pressures from urbanization and deforestation[13]. The RGBCMA is since then the ultimate decision-making organ, which through the General Assembly attends the community's matters in town as well as the issues related to the conservation and use of communal resources.

The RGBCMA is based in the Villa Milpa Alta town and counts with a democratically elected General Representative, Mr. Julian Flores. The RGBCMA has a hierarchical organizational structure to attend the particular needs of the Nine Towns more efficiently (Figure 3.4). A group of elders or *Consejo de Ancianos* was mentioned to exist and assist *comuneros* in important community matters[14]. The RGBCMA is networked regionally with diverse indigenous organizations, such as for example the *Alianza de Pueblos y Comunidades Indígenas del Anahuac* (Alliance of Towns and Indigenous Communities of the Anahuac) which is composed of all indigenous communities from the south of the Mexican Valley.

The main objectives of the RGBCMA are fundamentally to find a solution to the persistent agrarian problem with San Salvador Cuauhtenco and to obtain the official land entitlement of the 27,000 ha of communal lands. Additionally, the RGBCMA aims at

[12] Interview with RA and J, summer 2002, San Juan Tlacotenco. See also Cousineau (2002) for more details on people's land abandonment.
[13] Oral history; summer 2001, Milpa Alta communal lands.
[14] Interview with FCH, summer 2001; Milpa Alta.

promoting the rescue of traditions and cultural values, and to participate in programs and activities oriented toward the conservation and sustainable use of the *monte*[15]. *Comuneros*, for example have participated within official programs of reforestation and fire fighting and prevention for approximately twenty years (COCODER, 1988).

The community of San Juan Tlacotenco is coordinated through the *Representacion de Bienes Comunales* (RBC) (Representation of Communal Lands) located in the same town of San Juan. The RBC counts with one *Representante General* (Main Representative), Mr. Antonio Alvarado, and one *Representante Auxiliar* (Assistant of the Main Representative). The RBC of San Juan does not recognize the *Comisariado de Bienes Comunales de Tepoztlán* (the Tepoztlán Municipal's authorities) as main communal authority. Divisionism and internal struggles derived from this conflict have affected the organizational capacity of San Juan.

The main objectives of the RBC of San Juan Tlacotenco are oriented toward legitimating their communal territory by redefining land boundaries and reach independence from the Tepoztlán Municipality (see chapter 6 for more details on the conflict). A second priority of San Juan is water. As San Juan Tlacotenco has no water pipe system, main organizational efforts by the RBC and community members are oriented towards obtaining funds for rain water collection systems (cisterns above and underground ≈ *ollas de agua*) and facilitate water transportation by trucks. Management of funds to support comuneros' productive activies is also a priority in the RBC's work agenda. Regarding environmental matters, the RBC is actively involved in forest

[15] These goals were stated frequently by diverse *comuneros* in the different activities carried out in this study.

conservation issues, principally through fire fighting-prevention, tree plantation and vigilance programs.

San Juan's *comuneros* reported contributing to collective work (*cuatequitl*), which can principally benefit the town (i.e., improvement of roads and public schools) or contribute to cultural-religious activities. However, GEA (1992) reports that this activity is disappearing and that little collective work takes place in the *monte*. Organized civic groups for forest protection were reported by Paz (2002) to be operating in San Juan at the end of the 1990's, but were not identified during this study

3.3.3. Population and productive activities

Milpa Alta

Milpa Alta is one of the largest rural municipalities of the Distrito Federal with a surface of 28,464 ha, covering 19.2 % of the entity's total area and holding the highest proportion (32 %) of conservation area in the Distrito Federal. The total population of the entire municipality of Milpa Alta reaches 96,744 persons with an average annual population growth rate of 4.2 % (INEGI, 2000). Based on the limits established in the Primordial Titles, the nine towns have declared to own 27,000 hectares of land, most of it being communal lands (25,099 ha). Also, 1,795 hectares are declared as *ejidal*[16] (Servicios Forestales y Ambientales, 2002).

[16] *Ejido* is the main legal mechanism for which land use rights are granted for collective benefit (see Alcorn and Toledo, 1998).

Milpaltecos main productive activities have been related to extraction of non-timber forest products (NTFP) and traditional agriculture since pre-colonial times[17]. Extraction of NTFP has been observed and reported for this region: medicinal and edible plants, mushrooms, resin and grasses in the form of forage and thatch material (see Van Zantwijk, 1960 and Romeau, 1994 for more details). These activities have been practiced principally for self consumption and local trade since memorial times. Hunting is practiced locally, principally of mammals of medium (deer and bobcat) and small size (rabbits, skunks), birds (quails) and snakes. The main purpose of hunting is for food and traditional medicine preparation. *Comuneros* have reported hunting from outsiders as undesirable since it is practiced only for sport and recreation[18].

Milpa Alta has not been a town culturally interested on commercial timber exploitation (but see chapter 6 for details). The locals utilize some forest-derived resources such as firewood and some timber obtained from dead trees for house construction. Charcoal production from local oak forests was a popular and traditional activity and practiced for local consumption. However, this activity is now banned by the local environmental legislation and was not recorded to have occurred recently.

Agricultural activities in Milpa Alta are basically seasonal or *de temporal* (dependant from rains). Many *comuneros* practice *agricultura de traspatio,* which consists in growing basic crops such as corn and diverse beans in small parcels in the back of their houses. This activity is oriented toward local consumption and can include the production of domestic animals, usually hens and pigs. Cultivation of crops at

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[17] These productive activities apply to the people who work as local farmers and or utilize communal resources to support their livelihoods. Recent studies have shown that many inhabitants of these towns have migrated out of their native lands to work or study in the main cities (Cousineau, 2002).
[18] Participatory workshop # 1, summer 2001, Milpa Alta communal land.

commercial levels has expanded during the last twenty years, mainly the *nopal verdura* (*Opuntia ficus*) cultivated over the lowlands of Milpa Alta[19], and forage plants (*Avena sativa*) and potatoes (*Solanum tuberosa*) grown over the plains of the *monte comunal*[20]. There is a growing disinterest in the land by new generations of *comuneros*, who seek for better opportunities of development out of their native lands by studying and working in the main cities.

San Juan Tlacotenco

San Juan Tlacotenco is one of the seven towns of the Municipality of Tepoztlán and it is located at the northeastern limit of the Municipality; it is the northernmost town of the state of Morelos (INEGI, 2001). Because of the conflict for land recognition mentioned above, there is not a clear estimation and physical demarcation of San Juan Tlacotenco's territory. The Tepoztlán Municipality is calculated as covering 27,900 hectares, i.e., 5.6 % of the total state surface. San Juan's population is estimated at approximately 2,000 inhabitants (Romero, 2002), which represent 6 % of the total Municipality's population of 32,921 (INEGI, 2001). Land tenure in the Tepoztlán Municipality corresponds at 92.5 % to communal land and 7.5 % to *ejidal*. However, Rodríguez (1987 quoted in GEA, 1992) mentions that 5.4 % of Tepoztlán surface is privately owned.

The main productive activities currently documented in San Juan are similar to those practiced by *Milpaltecos*, with the difference of some products and activities. For example, people are cultivating Agapando flowers (*Agapanthus* spp.) and producing

[19] Personal interview RT, summer 2001; Milpa Alta.
[20] Personal observation and oral history, summer 2001, Milpa Alta.

hand-made tortillas to sell in municipal markets. Local testimonies indicated that in the past, San Juan depended importantly on livestock rearing activities for meat production[21]. Although this activity seems to be decreasing in importance nowadays, pastoralist occupations still constitute the principal source of income for many families[22].

Similarly to Milpa Alta, forest products are only extracted for local consumption and based on dead trees. Firewood is traditionally extracted for self-consumption and local trade. San Juan's forests were commercially exploited during the 1930's for commercial charcoal production. People from San Juan were locally known as *carboneros*, which means people that produce and sell charcoal (≈ *carbón*)[23]. This activity ended dramatically in San Juan when internal community groups manifested the negative environmental impact of charcoal production (see Paz, 2002 and Chapter 6 for more details).

Many people from San Juan rely on external incomes generated both by working in major cities and by migrating to Canada to work in agriculture-related jobs[24]. Youth's interests are focused on studying and working in other activities, unrelated to the communal lands. There is a trend of land abandonment similar to the one found in Milpa Alta.

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[21] Key interviewers RA and BR, summer 2002, communal grasslands of San Juan Tlacotenco.
[22] Key interviewer GR, summer 2002, communal grasslands of San Juan Tlacotenco.
[23] Key interviewer AA; summer 2002, San Juan Tlacotenco.
[24] Key interviewers AA, Profesor Romero; summer 2001, San Juan Tlacotenco.

3.4. Milpa Alta and San Juan Tlacotenco: cultural and natural capital for conservation.

Milpa Alta and San Juan Tlacotenco's communal lands are undoubtedly cultural traditional landscapes, i.e., territories constructed by numerous journeys from people who have lived, relied on and worked in the land (Horcasitas, 1972; Flores, 1992). People from these towns have historically contributed to the maintenance and conservation of diverse vegetation types and plant and animal species in the *monte comunal*. There are also experienced and respected knowledge holders and valuable traditions and organizations that make possible the social functioning of this landscape.

A degree of social-ecological resilience may have been attained in this region according to theoreticians such as Folke et al. (2002) and Berkes et al. (2003). Even though the ecological system has been disturbed through burning, grazing, logging, NTFP extraction, and the social system is being affected by lost of traditions, knowledge and land abandonment, people and the natural context seem to resist, recover and adapt to external changes. This has been proclaimed as a valuable social and natural capital needed for successful community-based conservation (Merino, 2004; Berkes, 2004; Berkes et al., 2005).

These *terminal towns* should be considered as an active and integral component of the landscape and, hence, be integrated into conservation initiatives and actions. The conservation of the SMS cannot be achieved in this region in an isolated manner. Its conservation must thus be conceived within a holistic and more balanced approach by looking at the intersections of land uses and interests with the species requirements to assess conservation possibilities according with the functioning of these Mexican cultural landscapes. This approach is innovative in bird conservation efforts and corresponds with what have been suggested as research priorities for effective biodiversity conservation (Ruth et al., 2003).

The following Chapter (4) presents in detail the species' habitat needs for reproduction. It examines the bird's nest-site selection strategy as influenced by the spatial and temporal variation caused by the traditional land use practices in the grasslands. The chapter establishes the ecological basis for habitat management and integrative conservation recommendations are presented.

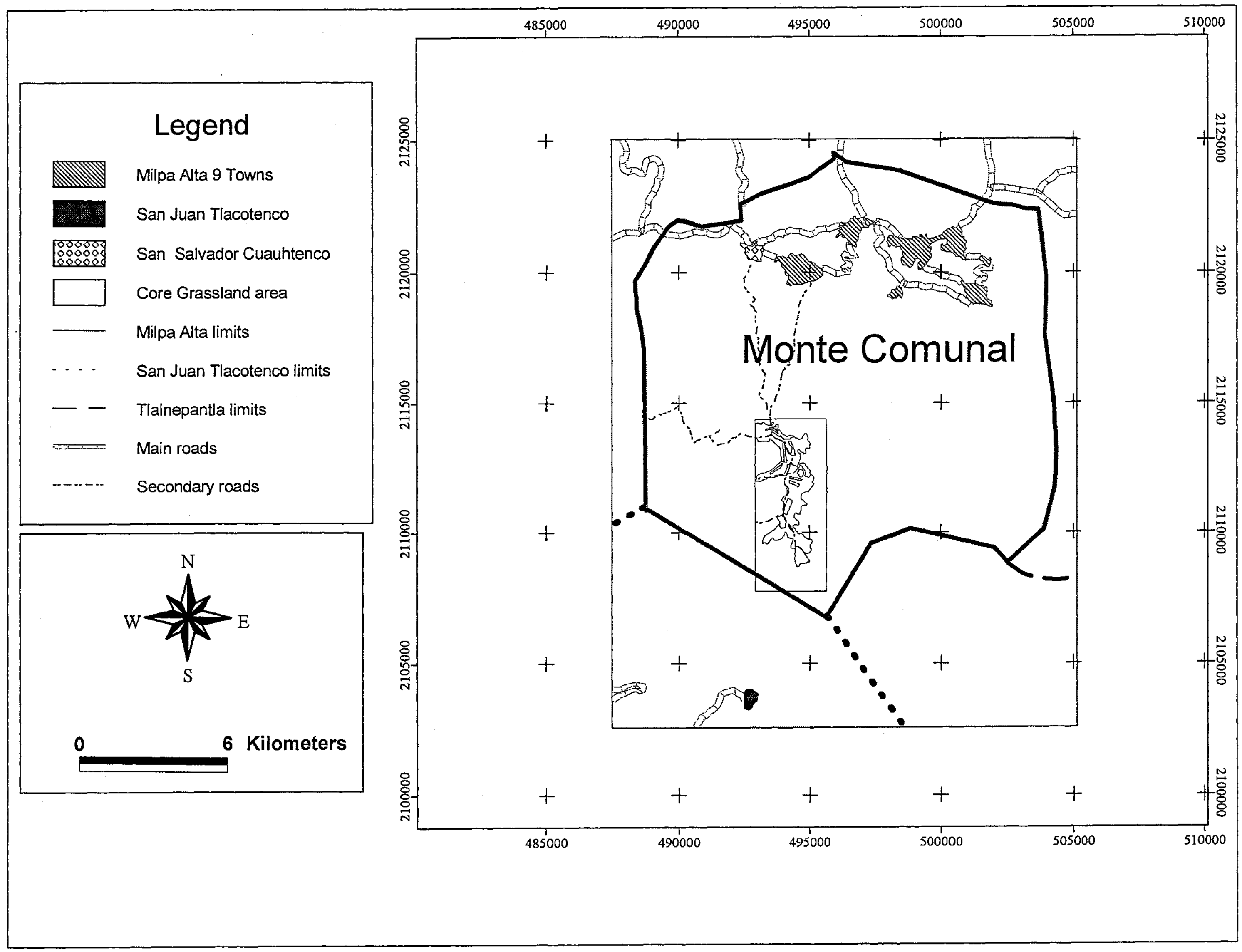
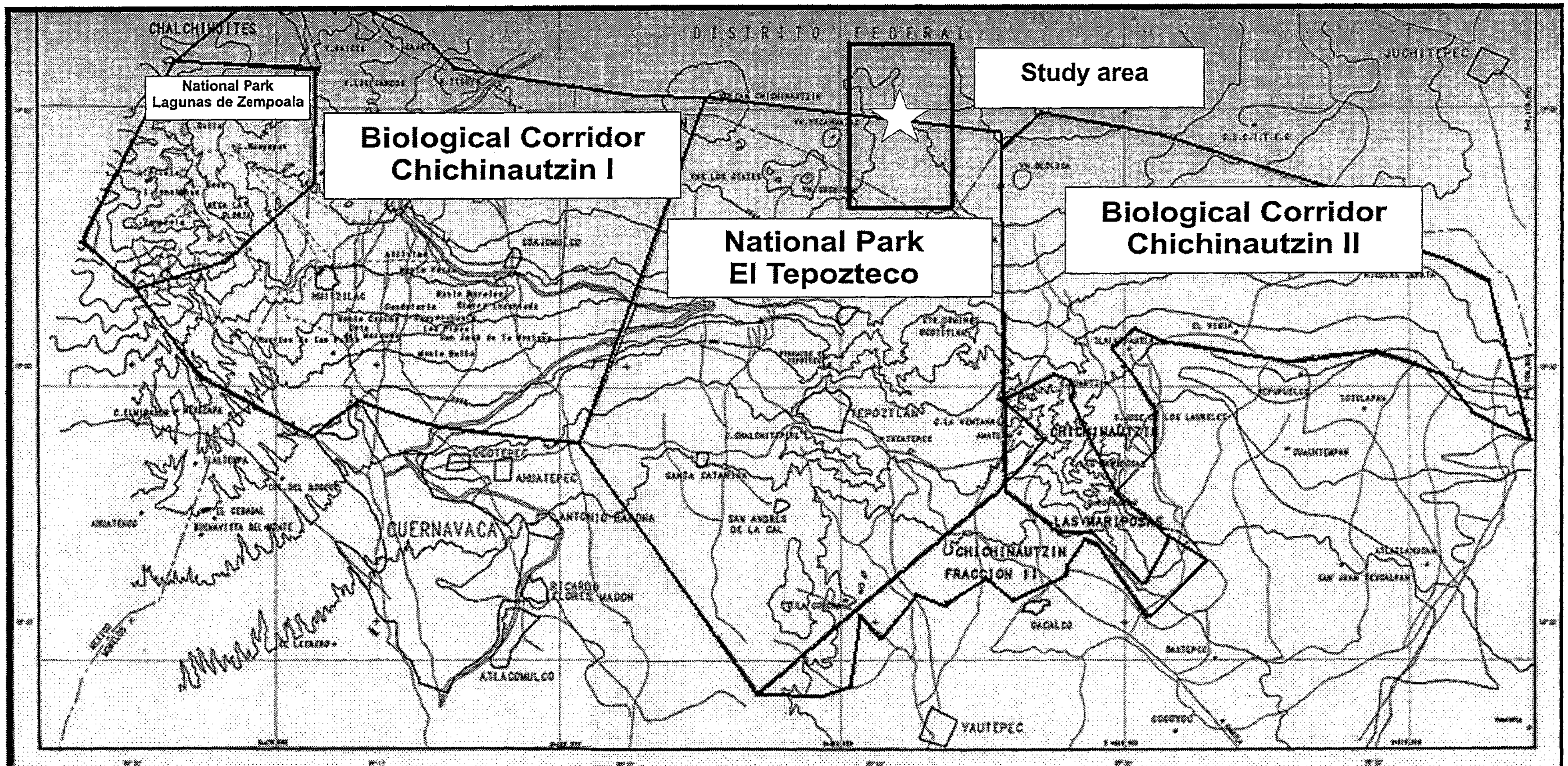


Figure 3.1. Study area location within the Milpa Alta (Distrito Federal) and San Juan Tlacotenco's (Estado de Morelos) limits.

Figure 3.2. Official limits of the protected areas at the South of the Mexican Valley. From left to right: National Park Lagunas de Zempoala, Biological Corridor Chichinautzin Section I, National Park El Tepozteco and Biological Corridor Chichinautzin Section II. The communal grassland under study corresponds to the box located at top-centre of this map. Map obtained and adapted from the Comisión Nacional de Areas Naturales Protegidas (CONANP). [Available online]: http://chichinautzin.conanp.gob.mx/donde_estamos/mapa_cobio.htm



	Lagunas de Zempoala	Chichinautzin	El Tepozteco
Category:	National Park	Biological Corridor	National Park
Surface (ha):	4,669	37,302	24,000
Decree:	19/5/1947	30/11/1988	22/1/1937
Location:	Mexico-Morelos	Morelos	Morelos
Scale:	0——I——I 10,000 m.		

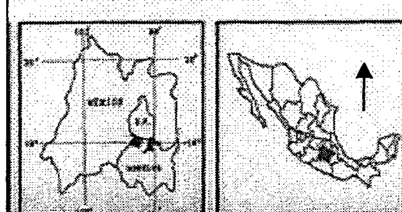


Figure 3.3. Graphical representation of Milpa Alta or Malacachtepec Momozco: an altar encircled by mountains. San Juan Tlacotenco is the closest southern neighbouring town. From Horcasitas (1972; p. xiii).

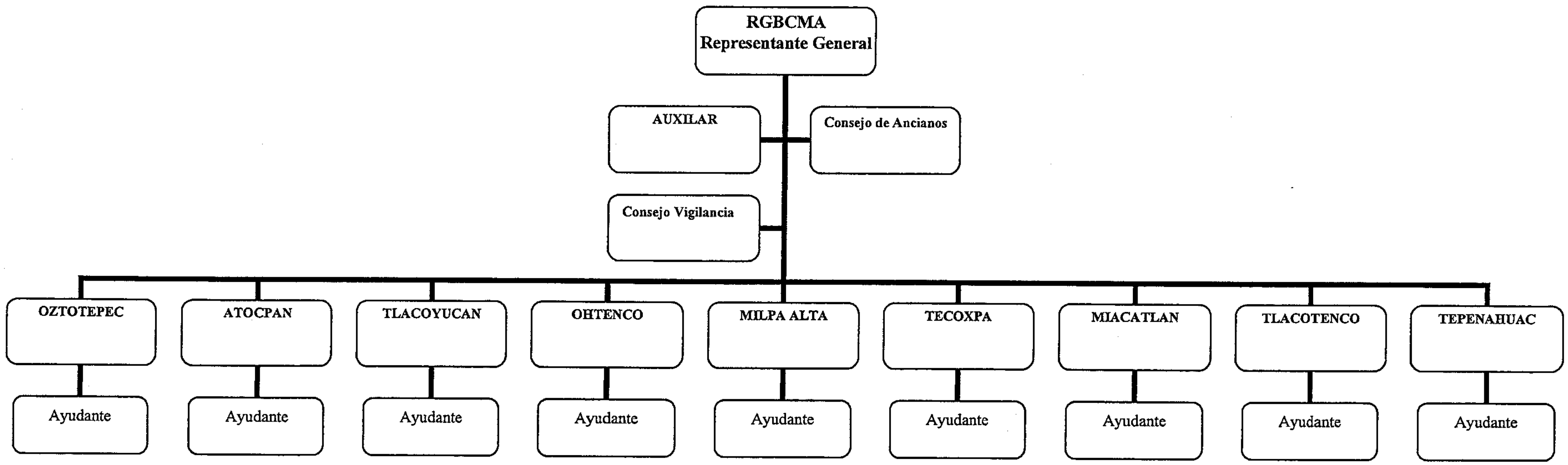


Figure 3.4. Organizacional structure of the Nine Towns of Milpa Alta (*Representación General de Bienes Comunales de Milpa Alta,* RGBCMA). The San Juan Tlacotenco' structure is conformed by *La Representación de Bienes Comunales,* leaded by the main representative and one assistant. San Juan Tlacotenco depends officially from the municipality of Tepoztlán (Estado de Morelos).

CHAPTER 4

NEST-SITE SELECTION AND BREEDING SUCCESS IN THE ENDANGERED SIERRA MADRE SPARROW (*Xenospiza baileyi*): A MULTIPLE SCALE ANALYSIS.

4.1. Introduction

The Sierra Madre sparrow (*Xenospiza baileyi*) is one of the most endangered bird species in the world with an estimated population approximately on 5,000 individuals (Collar et al., 1992; Birdlife International, 2000) and restricted to about 30 km^2 of high-elevation bunchgrass habitat in Central Mexico (Cabrera et al., 2006). Traditionally, the species' habitat has been managed for pastoral activities by local herders through burning and grazing, but as mentioned in the precedent chapters, recent economic and technological changes (e.g., variation in commodity prices and mechanization) have led to an increase in fire frequency and livestock grazing intensity (Cabrera, in prep.). Both factors may negatively impact the quality of available habitat. In addition, conversion to agricultural fields and urban development has decreased habitat availability (Cabrera, 1999; Velázquez and Romero, 1999; Cabrera et al., 2006).

4.1.1. Nest site selection

Recovery planning for the Sierra Madre sparrow is impeded by our limited understanding of its biology, including nesting habitat characteristics that are known to be a primary determinant of breeding success and, consequently, of population dynamics parameters in many bird species (Martin, 1993; With, 1994; Hansell, 2001). Various factors such as climate and exposure (With and Webb, 1993; Hoekman et al., 2002), availability of nesting material (Hansell, 2001), and predation (Martin, 1993) are known to influence nest site selection in birds. Predation has been particularly well studied and shown to be the primary source of nest losses and nestling mortality across a wide range of species, habitats, and geographic locations (Martin, 1993). It is presumably the main driver of nest site selection in a majority of bird species (Martin, 1993; Siepielski et al., 2001).

Three primary, but not mutually exclusive hypotheses have been presented to explain how breeding site selection operates in birds in the context of nest predation avoidance. The *total-foliage hypothesis* proposes that *"predation risk decreases with an increase in total vegetation in the nest patch because greater foliage density inhibits transmission of visual, chemical or auditory cues by prey"* (Martin, 1993; p. 524). The hypothesis operates at the level of the supporting structure and immediate vicinity of the nest. *The potential-prey-site hypothesis* states that an increase in the density of sites preferred by the prey reduces the probability of predation because a predator's efficiency declines as the number of potential preying sites increases (Liebezeit and George, 2002). This hypothesis operates at the level of the patch where the nest is located.

Finally, a *landscape-context hypothesis* suggests that nest predation varies across landscapes because diversity and density of predators vary according to the type and spatial arrangement of habitat patches surrounding the nest sites (Andrén, 1995; Stephens et al., 2003). Each hypothesis is supported by a number of empirical studies. Recent and ongoing changes in SMS's habitat impact that habitat at each spatial scale and may, therefore, affect nesting performance through one or more of these mechanisms. General implications of nest-site selection on breeding success are discussed at the end of the chapter at the light of possible adaptive consequences.

4.1.2. Multiscale studies for biodiversity conservation

The SMS's habitat is heterogeneous. Relevant ecological processes for species survival like for example habitat selection (Cody, 1985; Kotliar and Wiens, 1990) have been demonstrated to be influenced by landscape pattern (Turner, 1989). In the case of nest site selection on birds, diverse theoretical studies suggest that species are able to respond to environmental variation at diverse particular spatial scales, generally to those scales in correspondance with their own life history traits and spatial perception of the landscape (Hansen and Urban, 1992; Wiens et al., 1993). The hypotheses of nest site selection mentioned above are a clear example of this multiscalar relationship.

Although the importance of spatial scale in ecology has been recognized some decades ago (Allen and Starr, 1982; Wiens, 1989), it has been until recently that the multiscale habitat concept has attracted conservationists' interests for its potential on the formulation of more complete, practical and coherent habitat management recommendations for endangered species (Storch, 2003). Under this view, multiple scale studies are urged to be incorporated into contemporary biodiversity conservation science to analyze species-habitat relationships at the spatial scales relevant for the species, including landscape management practices that shape species' habitats. However, "*this approach has not widely perceived by land managers and conservationists*" (Storch, 2003, p. 315) even though it figures between the more frequent recommendations for "avian conservation science for the new millennium" (Ruth et al., 2003). This study will contribute to this body of literature aiming to unveil meaningful habitat recommendations for the conservation of the SMS.

4.2. Research statement and goals

This chapter reports on the habitat structure and nesting success of the SMS at three spatial scales: the physical characteristics and conditions of grass clumps where the nest is located, the structure and composition of used grassland patches, and the type and amount of land cover adjacent to the breeding patches. A better understanding of the Sierra Madre sparrow's nesting ecology at multiple scales will support the development of an effective habitat conservation plan for the species in relation to current landscape conditions and shaping forces (Lindenmayer, 2000; Luck, 2002).

4.3. Methods

4.3.1. Spatial data

The SMS favours the *Festuca lugens-Muhlenbergia macroura* grassland community, while other open degraded grassland communities (e.g., *Stipa ichu* and *Senecio cinerarioides-Muhlenbergia macroura*) are rarely used (Cabrera et al., 2006). As mentioned in the precedent chapter, during the breeding season the preferred habitat is found in a mosaic of three conditions: mature ($\geq$ 2 y without fire), recovering ($\approx$ 1.5 y after fire) and recently burned ($\approx$ 0.5 y after fire). Annual maps (2001-2002) of these grassland conditions and adjacent land covers are presented in figures 4.1 and 4.2 and were used in this chapter as the spatial framework for the nest site selection analysis.

4.3.2. Nesting data

In 2001 and 2002, nesting assessment consisted of searching systematically for SMS nests from early May until mid August (i.e., covering most of the breeding season;

Oliveras de Ita et al., 2001; Cabrera, unpublished data) in grassland patches representing the three post-fire conditions. Opportunistically, behavioral clues such as singing by males and food carrying to find nests were considered as supportive evidence of nesting.

To estimate territory size and density, the distance between each nest and its closest neighbor was calculated using Arc View vers. 3.2a and, assuming that territories were circular and centered on the nest, the average of these distances as the diameter of nesting territories were used. These are likely unrealistic assumptions but in the absence of having found all nests, the method provides a maximum estimate of territory size.

Each nest found was visited at 3-4 day intervals until fledging or failure. Nesting was declared successful if inferences of at least one nestling fledged could be made. Nesting success was estimated through the number of young fledged and Mayfield's (1975) probability index. Breeding success between grassland conditions was compared using the software CONTRAST (Hines and Sauer, 1989).

4.3.3. Multiple scale habitat characterization

After nest failure or fledging, the vegetation and physical characteristics at the nest site were measured at three spatial scales following a nested design (Table 4.1). At the *plant scale* 10 randomly selected grass clumps were characterized along each of three randomly located 100 m transects running through each of the grassland conditions in each year (n_{total} = 180 plants). The survey method (Braun-Blanquet, 1932) was used to quantify characteristics at the *habitat scale*. 29 10 X 10 square plots centred on the nests were characterized and compared with seventeen plots located at random over the study area. 50 m radius circles centred on each nest were used for characterization at the *landscape scale*. A radius of 50 m was chosen to avoid overlap between neighbouring nests (although 5 overlapping nests from 2001 and 4 from 2002 were excluded from the analysis; n = 22), and because this size roughly corresponded to individual mobility within a breeding season (Cabrera, data unpublished) and to estimated territory size (see Results). The same characteristics were assessed at 25 random points separated by at least 100 m representing unoccupied sites (generated for each year using the software *Animal Movement*; Hooge and Eichenlaub, 1997). The number of unoccupied sites characterized was typically higher than occupied ones because more variability was expected among the former, and because most of the study area was unoccupied (Hatten and Paradzick, 2003).

4.3.4. Statistical analysis

Habitat characteristics at nest sites and unoccupied sites were compared using Mann-Whitney U-tests or G-tests, as appropriate (Sokal and Rohlf, 1981). Logistic regression analysis (SAS, 2001) and discriminant function analysis (DFA; McGarigal et al. 2000) were performed to identify variables that best discriminate occupied and unoccupied sites.

Additionally, logistic regressions (SAS, 2001) were used to explore the effects of individual variables on nest success at the three different spatial scales. The statistical programs Statistica (ver. 5.1) and SPSS (ver. 10.05) were used for U-test and DFA analysis; and SAS (vers. 8.02 and 9.1) to perform logistic regression analyzes.

4.4. Results

4.4.1. Nesting biology

Thirty-one active nests were found (15 in 2001 and 16 in 2002), 26 at the incubation stage and 5 at the nestling stage. In 2001, all nests were in the three mature grassland patches (Figure 4.3), while in 2002, they were found both in mature (n = 9) and recovering (n = 7) patches (Figure 4.4). Nests were not distributed amongst conditions in proportions of their relative coverage (pooled 2001 and 2002 data: $\chi^2 = 8.47$, DF = 1, $p = 0.01$).

A territory density of 0.37 pairs/ha was estimated in 2001 and 0.54 pairs/ha in 2002. These are conservative estimates since they are based on estimated maximum average territory size (see Methods). Small sample size prevented meaningful statistical analysis, but a visual inspection of Figure 4.4 suggests that nests are less tightly clustered when nesting occurred also in recovering grasslands.

In the 31 nests found, 73 eggs or nestlings were recorded. Assuming there was no partial loss of clutch or brood before nests were found, the modal clutch size was 3 eggs (range 2.0; mean 2.35 ± 0.66 SD). Nineteen nests (61 %) reached the nestling stage (at the age of 3 days or less as the visits were spaced by up to three days), and 18 (58 %) reached the fledging stage with a total of 44 youngs produced (mean fledgling per breeding attempted = 1.41; mean fledgling per successful nest = 2.44).

With the exception of one nest (one fledge was found dead, one fledge alive and the other abandoned the nest), all other losses were of entire clutches or broods. Predation at the egg stage accounted for most losses (46 % of 13 nests lost, including a female predated at the nest with the eggs), followed by an ice storm (23 %), egg perforation by *Cisthotorus platensis* (15 %), trampling by cattle (8 %), and botfly infestation (8 %).

Overall daily nest survival probability was 0.9605 ± 0.0107 SE, for an overall survivorship over the incubation period (15.2 days) of 0.5415. Daily nest survival probability was significantly higher in mature than in recovering grasslands (0.967 ± 0.01092 SE vs. 0.9323 ± 0.0327 SE; Z = 60.10, $p < 0.00001$). Accordingly, survivorship over the incubation period was over two times higher for nests located in mature grasslands (0.5466 vs. 0.2520).

4.4.2. Multiple scale nest site selection

SMS individuals built their nests primarily in pure clumps of the bunchgrass *Festuca lugens* (26 nests or 84 %), and less frequently in multispecific grass clumps (i.e., *Festuca lugens* with *Muhlenbergia macroura* and *M. vaginata*). Plants occupied for nesting were taller and wider in cover than unoccupied plants (Table 4.2). The logistic regression model (Likelihood ratio $\chi^2 = 105.58$, DF = 3, $p < 0.0001$) indicated that nesting plants were 26 % taller (CI = 0.11, 0.63), 169 % wider in cover (CI = 1.22, 2.34), and 42 % wider in basal diameter (CI = 0.25, 0.70) than unoccupied plants.

Univariate statistics revealed significant differences between occupied and unoccupied sites for six habitat scale variables (Table 4.2). Nesting sites were characterized by taller vegetation (i.e., grass height, herb height), higher cover values of bunchgrasses and less recently burned vegetation. A logistic regression analysis revealed that grass height and ground cover were the primary factors that distinguished occupied from unoccupied sites. Finally, a DFA identified eight variables that significantly contributed to differentiate between nesting and unoccupied sites: nests sites were surrounded by taller grasses and shrubs and denser covers of other plants and shrubs, while unoccupied sites were rockier with higher ground cover vegetation and higher covers of recently burned and grazed vegetation. Only one variable, grass height, was significant in all three analyses (see Table 4.2).

Landscapes characteristics of nesting and random sites (± 50 m radii) are found also in Table 4.2. In general nesting areas were dominated by mature grassland, while other habitat types were underrepresented (F = 23.15, p = 0.0001). Furthermore, nesting sites were significantly farther from agricultural fields than were random unoccupied sites (F = 21.03, p = 0.0001). A logistic regression model indicated that SMS nesting probability increased one time [1.000, 1.001] when nests were located at greater distances from agricultural fields (Wald χ^2 = 9.33, DF = 2, p = 0.0094) and when there were scarce recently burned grassland within the nest landscape (Wald χ^2 = 4.94, DF = 1, p = 0.02) (see Table 4.2).

4.4.3. Nest site selection and nesting success

Few nest site characteristics helped predict SMS's nesting success (Table 4.3). At both the plant and the landscape scales, neither univariate tests nor logistic regression models revealed significant differences between successful and failed nests. However, for patch scale characteristics U tests and DFA analysis indicated that failure was significantly more likely in more open and inclined grassland sites with higher ground cover and less lava outcrops that showed greater levels of soil erosion (Table 4.3). The logistic regression models indicated that failure was significantly more likely in more open habitats covered with shorter, more heavily grazed grasses.

4.5. Discussion

This study has provided an array of information at different scales with high applicability for the Sierra Madre sparrow's breeding habitat management. In the following sections, each part of this chapter is discussed and followed by global conclusions.

4.5.1. Territory density and nesting success

The conservative value estimated for SMS's territory density in this study (about 0.5 pair/ha) matches or is higher than those reported for other rare species of sparrows (Reynolds 1981; Herkert 1998, Perkins et al., 2003 and see Table 4.4). As nest densities in other grassland birds seems to be positively related to patch area and negatively to fragmentation, data on SMS breeding pairs for La Cima (1 pair/4-5 ha), a locality with very small-size bunchgrassland patches, confirms the potential adverse effects of fragment size on territory and nest density for this species (see Collar et al., 1992, p. 831).

Suitable nesting grassland at our study area was composed by the smallest patches unburned in 2001 and those that stayed unburned in 2002 plus the 1.5 years post fire recovering grassland patches. The presence of recovering grasslands in 2002 might however have favoured the expansion of potential nesting habitat, thus promoting a higher density of breeding pairs. Current fire regime is possibly causing lower nest density values by reducing nesting habitat size.

At a density of about 0.5 pair/ha, used grassland patches (i.e., mature and recovering patches) could have contained about 30 pairs in 2001 and 150 in 2002. Even if nest density were several times higher than our conservative estimate, the number of pairs in the study area would still be in the hundreds. As my study site is the likely the largest and best preserved area (i.e., relatively low grassland fragmentation and degradation) where the SMS survives (Cabrera et al., 2006), the current global population size estimate of 5,000 individuals is likely optimistic. The species may be even more imperilled than currently thought.

Nesting success and survival probability observed in this study were generally higher than those reported for another population of SMS (Oliveras, et al., 2001) and several other sparrow species (see Table 4.4 for comparison and references). Variation in the breeding performance of grassland birds has been related to habitat loss and fragmentation (Koford, 1999; Chalfoun et al., 2002; Herkert et al., 2003; Perkins et al., 2003), habitat management practices that alter vegetation composition and structure (Rohrbaugh et al., 1999; McCoy et al., 1999; Chase, 2002), and modification of interspecific associations (Wheelwright et al., 1997). The lower breeding performance of La Cima's SMS population (Oliveras de Ita et al., *op cit*) compared to our study area likely reflects a reduced level of ecological integrity at La Cima. Grasslands at La Cima were greatly reduced, fragmented and degraded in the last four decades through conversion to agricultural fields and construction of an extensive road network (Dickerman et al., 1967, Oliveras de Ita et al., 2001; Cabrera et al., *op cit*).

In the absence of information on re-nesting rate and adult and juvenile survival it is not possible to assess the demographic status of SMS populations. However, it is possible that the grassland area at Milpa Alta-San Juan Tlacotenco represents a source habitat for the SMS, whereas La Cima and the surrounding small scattered patches may constitute sink habitat[25]

4.5.2. Nest site selection at multiple scales

The SMS exhibited non-random nest site selection at all scales investigated and relevant management implications can be derived in accordance with literature (Rotemberry and Knick, 1999; Storch, 2003). The presence of tall and wide tussocks of *Festuca lugens* is key to nest site selection. *Festuca lugens* distribution is limited to central and northwestern Mexico, with disjunct populations in southwestern Mexico and Central America (Ackerman and Smith, 1987). Availability of suitable plants for nesting varies across the landscape and between years because of current local land use practices, mostly burning and grazing (see Chapters 3 and 5). Plants selected as nesting sites require 2 to 3 years without fire to reach the height, width and thickness preferred by the sparrow. SMS seems to recognize and exploit mature *Festuca* plant structural characteristics for nest location and concealment. Nests were well concealed in the great amount of leaves that covered the nests, just leaving a small "entrance" between the leaves.

Literature indicates that high vegetation cover around the nest and nest orientation reduces thermal stress for small birds, thereby increasing nesting success and survival of adults (Martin and Rouper, 1988, Hoekman et al., 2002). In addition, SMS likely benefits

[25] "*Source habitat is defined as productive patches that serve as source of emigrant individuals, which disperse to less productive patches called sinks*" (Dunning et al., 1992, p. 172). Generally source habitats are represented by large and continuous habitats, while sinks habitats by small and scattered habitat patches resultant from habitat fragmentation (Donovan et al., 1995). Source-sink habitat relationships have been mostly treated within metapolulation models (Hanski and Gilpin, 1991), indicating that many species seem to depend on these relationships for their maintenance in currently highly modified landscapes.

from mechanical protection afforded by the sharp and resistant nature of mature dry *F. lugens* leaves. These structural characteristics have been found only in this grass species in the entire region (Cabrera et al., 2006). SMS nest site selection at this scale is consistent with the total-foliage hypothesis (Martin 1993), where *Festuca lugens* characteristics likely inhibit transmission of information to potential predators.

At *habitat scale*, the birds chose denser and taller vegetated grassland areas compared to conditions found at randomly selected sites. Mean grassland cover at nesting sites (70 % of the terrain) corresponded to the typical structure reported for this subalpine grassland type at maturity (Rzedowski, 1978; Velázquez, 1993). The more open structure and higher cover values of short plants characterizing random unoccupied sites reflects the impact of excessive fire, trampling and grazing on habitat availability as suggested by different authors (Cruz, 1969; Rzedowski, 1978; Hofstede, 1995; Laterra et al., 2003). Preference for dense habitat in this sparrow can be coherent with the potential-prey-site hypothesis (Martin, 1993) where the existence of a high density of potential nest-sites (the tussocks or clumps) may reduce the encounter of nests by predators searching in many similar plants.

At the *landscape scale* the aerial extent and composition of suitable breeding habitat varied greatly from one year to the next. As mentioned above, in 2002, a grassland successional stage (the recovering grassland) that was not present in 2001 appeared in large patches. Tussocks in these patches had reduced cover and thickness and the nests were generally more exposed and visible than in mature patches. Availability of large areas of recovering grassland may be advantageous to the SMS as areas in mature conditions seem to be typically limited, likely limiting the species' population dynamics.

Even though SMS's reproductive success in recovering grassland was lower than in the mature grass, birds breeding there are nonetheless likely important in the species' population dynamics. If further data confirm this, it will be possible to conclude that the species responds adaptively to fire (Pylipec, 1991; Mushinski and Gibson, 1991; p.242) by tracking the grassland succession until it reaches an adequate level of development. Such response has been documented in Baird's sparrow (Pylipec, 1991) and Greater Prairie-chicken and Dickcissel (Knopf, 1994).

The spatial distribution of nests at the landscape level suggests a certain degree of avoidance of the deep edges of highly transformed sites. This has been reported for shrubland-grassland and forest birds (Angelstam, 1986; Wiens, 1989; Donovan et al., 1997) and seems to be an adaptive response to increased predation activity along edges of grassland patches due to changes in predator communities (Powell and Collier, 1998; Winter and Faaborg, 1999; Winter et al., 2000). From this study, it is suggested that the SMS might represent an "interior-breeding species" (Winter and Faaborg, 1999; Johnson and Igl, 2001) of mature grassland remnants, which makes the species more susceptible to drastic land use changes and increases its risk of extinction.

4.5.3. Nest site selection and breeding success: exploring an adaptive relationship

An adaptive and evolutionary hypothesis is suggested from these findings and observations when relating nest site selection to nesting success. Even though the SMS exhibited a consistent nest site selection pattern across the spatial scales analyzed in this study, supporting the nest concealment, the needle in a haystack and the landscape hypotheses and arguments (Martin, 1993; Filliater et al., 1994), when related to nest success, only four variables at the *habitat scale* were statistically significant. SMS nest success was negatively related to an increase of short grasses, ground cover plants, slope and soil erosion. SMS nest success thus, might be interpreted as a *possible* adaptive trait for selecting sites with a higher cover of taller bunchgrassland and associated vegetation, with lower grazing impact and also with avoidance of recently burned vegetation. This particular result may constitute a valuable hypothesis for further experimental and long-term studies and shade more light into the SMS's nest-site selection and conservation implications (see Renfrew et al., 2005 for similar suggestions).

Previous studies on grassland sparrows have found a similar relationship between nest-site selection and success, to mention for example, Powell and Collier (1998) found higher nesting success for the Belding's sparrow at the patch scale, particularly at sites covered with taller and denser vegetation than habitats where nesting failure occurred. Similar results have been reported by Bedard and LaPointe (1984) for the Savannah sparrow, Misenhelter and Rotenberry (2000) for the Sage sparrow in a southern California sage scrub and Renfrew et al. (2005) for grassland birds specialists.

Suggestion of causal mechanisms operating on SMS nest site selection can be made. Alterations of breeding habitat conditions by overgrazing and excessive fire may represent the main factors that reduces grassland height and creates progressively plant death, promoting a more open and shorter grassland physiognomy as demonstrated by other similar types of grasslands (Benítez-Badillo, 1987; Hofstede, 1995; Laterra et al., 2003). Grassland birds under these conditions might be forced to use poorer quality nesting sites or to nest in high densities using overlapping conditions (Martin, 1993).

The opening of grassland cover might increase detection probability of nests, fledges and/or parents by specific predators (Farina, 2000; Chalfoun et al., 2002). In this study for example, terrestrial nest predators inferred from feces left in some predated nests or from physical damage evidences observed at the supporting plant and/or nests, may indicate that main predators impacting SMS range from small to medium native mammals such as Ringtails (*Bassariscus astutus*), Opossums (*Didelphis virginiana*) and Weasels (*Mustela frenata*). Shepherd's dogs were commonly observed in the study area and might represent potential predators of SMS nests as has been suggested by Oliveras de Ita et al. (2001). Aerial predators could as well have been responsible for some nest losses. For example, Kestrels (*Falco sparverius*) were observed flying (floating, suspended) above SMS territories attempting to discover nests or parents around the nests.One SMS female was found killed near its nest apparently by a bird predator. The degree of openness of the grassland at this scale might represent a selective factor to avoid visual and olfactory detection of nests and parents by local predators (Martin, 1993; Donovan et al., 1995).

Although a relationship between nest site selection and nesting success was not found in the other spatial scales, the importance of what Martin (1993) had called fixed nest site preferences, which may interact synergistically to promote higher breeding performance can not be neglected. Literature on nest site selection and nesting success has frequently shown inconsistencies on this choice-consequence relationship (Kilgo et al., 1996; Misenhelter and Rotenberry, 2000; Wilson and Gende, 2000; Siepielski et al., 2001). Different studies have inferred for example, that the lack of relationship between nest sites used by successful and unsuccessful species can be associated to factors not considered in the study but with potential impact on the relation, such as the amount of and the distance to the edge in the landscape (Thogmartin, 1999; p. 920), the amount of available habitat, the predators and their preferences for particular species' nests to predate (Lahti, 2001), nest appearance (Martin, 1987; Hansell, 2001), and another components of fitness not measured (e.g., territoriality, survivorship, and gene flow) (Misenhelter and Rotenberry, 2000).

As edge effects have been considered as main influencing factors of nest-site selection and consequently of nesting success, Lathi (2001) recommends that more experimental work looking at the predator communities might be a more proactive approach to unveil the edge effects on nesting success. Inconsistencies have also been suggested to come from differences in data set and methods. Different authors have suggested that the criteria used to classify nest sites and the unequal and small sample sizes in the analyses may play a role in finding negative relations between choice and consequence (Powell and Collier, 1998; Hall and Mannan, 1999; Wilson and Gende, 2000). This might represent a practical and analytic problem in studies with rare and endangered species, which usually are limited by small sample sizes.

There is a long way to go from a comprehensive understanding of the determinants of nesting success from nest site selection studies (Wilson and Gende, 2000; p. 323) due to the enormous variation reported in the literature on nest site selection. Even though the sometimes frustrating and contradictory evidences seem not to conduce to the establishment of solid relationships between patterns and processes, empirical studies still strengthen and validate some of the pre-established positions and hypotheses. From here, major agreements and recommendations have emerged recognizing *"that* *predation is a critical factor in the evolution of many aspects of nesting biology"* (Wilson and Gende, 2000; p. 323) and that we need to perform more integral and experimental studies to establish more solid causal relationships of nest failure and avoid them by habitat management (see Herkert and Knopf, 1998; Norment, 2002; Ruth et al., 2003).

4.6. Conclusion

This chapter demonstrates that the SMS selects sites for nesting considering micro to macro habitat characteristics. Sites selected provided protection to nests accordingly with theories and previous studies on bird's nest-site selection. Such protection to nests resulted from a particular combination of physical and spatial characteristics of grasslands that may help to prevent encounters from different types of predators and reduce nest exposure to adverse environmental conditions. This study reveals possible consequences of the SMS's nest-site selection pattern on breeding performance, aspect of grand relevance for conservation science and bird species conservation. Nevertheless, our results on this relationship deserve further experimental examination.

The multiscalar approach followed in this study allowed a better recognition of the SMS's habitat needs that can be translated into grassland management and policy recommendations. This might entails first, towards a fire management planning initiative of 3-year burning rotation scheme, to promote higher densities of mature *Festuca* plants and favour higher sparrow nest densities across this landscape. If big mature grassland fragments were found to predict higher SMS nesting probabilities, then grassland size management can represents a first step on conservation action. This study suggests in accordance with Johnson, et al. (2004) that the extent of grassland based in the current fire regime should be re-oriented to promote a more balanced patch-size mosaic of the three grassland conditions, maximizing when possible the extent of mature grassland stands. In this way, biodiversity conservation and traditional pastoralism may better co-exist.

Second, land use changes in the form of commercial agriculture into the Milpa Alta-San Juan Tlacotenco's core grassland area should be avoided and redirect spatially to the rural interface. This might require scaling-up conservation planning and actions at regional scales where more intensive land uses and changes may occur without threatening native grassland biodiversity. Management activities such as restoration of grassland can emerge from this study, targeting the northern part of this region where habitat loss and fragmentation have occurred in order to increase habitat amount and connectivity across the entire landscape.

The study invites ecologists to consider this kind of approach to broad their spatial domain (generally at micro-plot scale) to more operational scales (e.g., landscape) where resultant conservation actions will benefit widely biodiversity and ecological and social processes.

In the following Chapter 5, the impacts and relationships of land use practices on the SMS's habitat are explored in detail, principally in terms of the spatial extent, preferred grassland successional stage, and time and conditions of grassland to recover after human disturbance. This chapter will provide one of the first assessments of fire and grazing impacts on landscape heterogeneity and grassland recovery with practical management recommendations for bird conservation based on local human-land interactions.

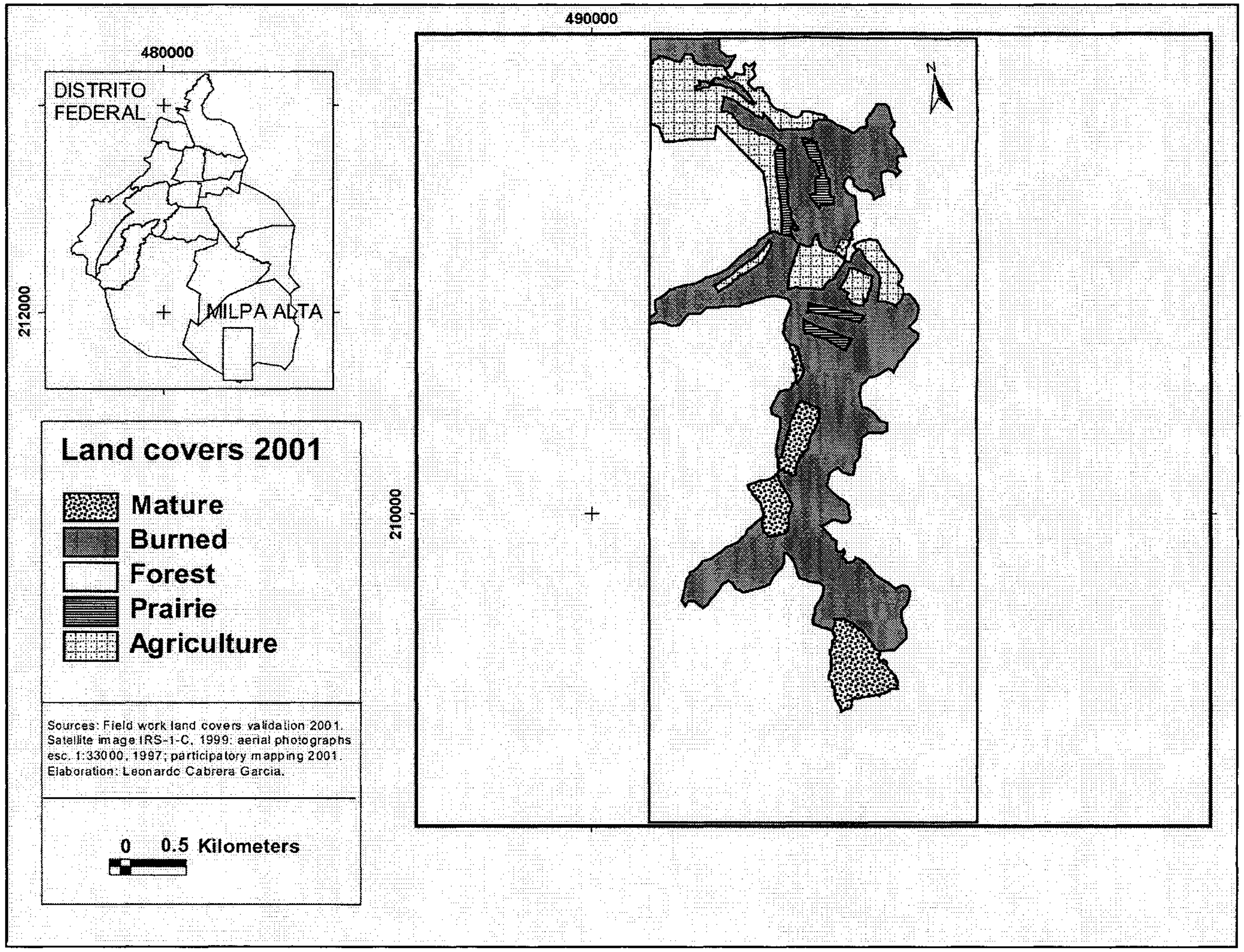


Figure 4.1. Landscape conditions (2001) at the Sierra Madre sparrow's habitat in Milpa Alta-San Juan Tlacotenco.

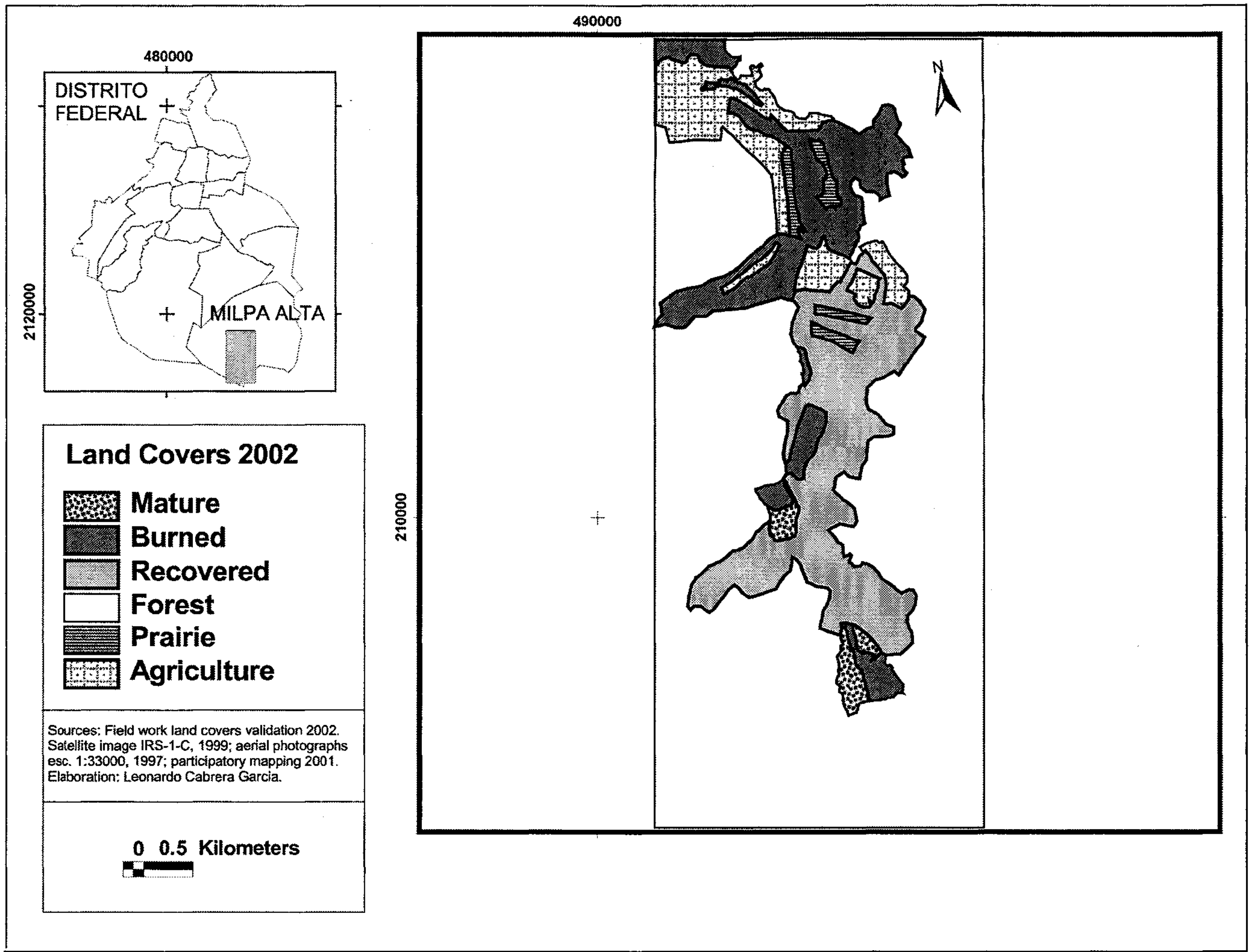


Figure 4.2. Landscape conditions (2002) at the Sierra Madre sparrow's habitat in Milpa Alta-San Juan Tlacotenco.

Table 4.1. Variables measured at SMS's nests and random sites at the three different spatial studied.

Variable	Description (unit)
Plant scale	**Variables registered at the nest supporting plants and at random plants.**
Height	Height of the bunchgrass (m.)
Cover	Cover of the bunchgrass (m).
Diameter	Diameter at the base of the plant (m.)
Habitat scale	**Variables registered at 5m-radius circles from the nests and at random sites.**
Grassland physiognomy	Degree of openness of the grassland structure (1=open, 2=semi-open, 3=close or dense)
Land form	Topography (1=flat terrain, 2= undulating terrain)
Species dominance	1= *Festuca lugens* as dominant, 2=*Muhlenbergia macroura* as dominant.
Bare soil	% of the ground without vegetation.
Rock outcrops	% of the ground covered by solid lava outcrops.
Rocks	% of the ground covered by a variety of rocks
Ground cover	% of the ground covered by plants measuring <.05 m height.
Herb cover	% of total herb strata covering the circle.
Herb height	Mean height of the herb strata in the circle (m.)
Grassland cover	% of the ground covered by bunchgrasses.
Grassland height	Mean height of the bunchgrasses in the circle (m.).
Others herb cover	% of the ground covered by herb plants measuring ±.15 m
Other herb height	Mean height of other herbs present in the circle (m.).
Shrub cover	% of the ground covered by shrubs.
Shrub height	Mean height of shrubs present in the circle (m.).
Fire cover	% of ground/vegetation burned the year of evaluation.
Grazing cover	% of bunchgrass' leaves browsed by livestock.
Dungs cover	% of ground covered by livestock' dungs.
Soil erosion cover	% of ground eroded either by water or overgrazing.
Landscape level	**Variables registered with ± 50 m-radius circles located at nest and random positions.**
% Mature grassland	% Extent of mature grasslands within the ± 50 m ratio.
% Burned grassland	% Extent of burned grasslands within the ± 50 m ratio.
% Recovered grassland	% Extent of recovered grasslands within the ± 50 m ratio.
% Forest	% Extent of forest within the ± 50 m ratio.
% Agriculture	% Extent of agriculture fields within the ± 50 m ratio.
% Prairie	% Extent of prairies within the ± 50 m ratio.
Distance	Distance from the nest to the nearest agricultural field (m.)

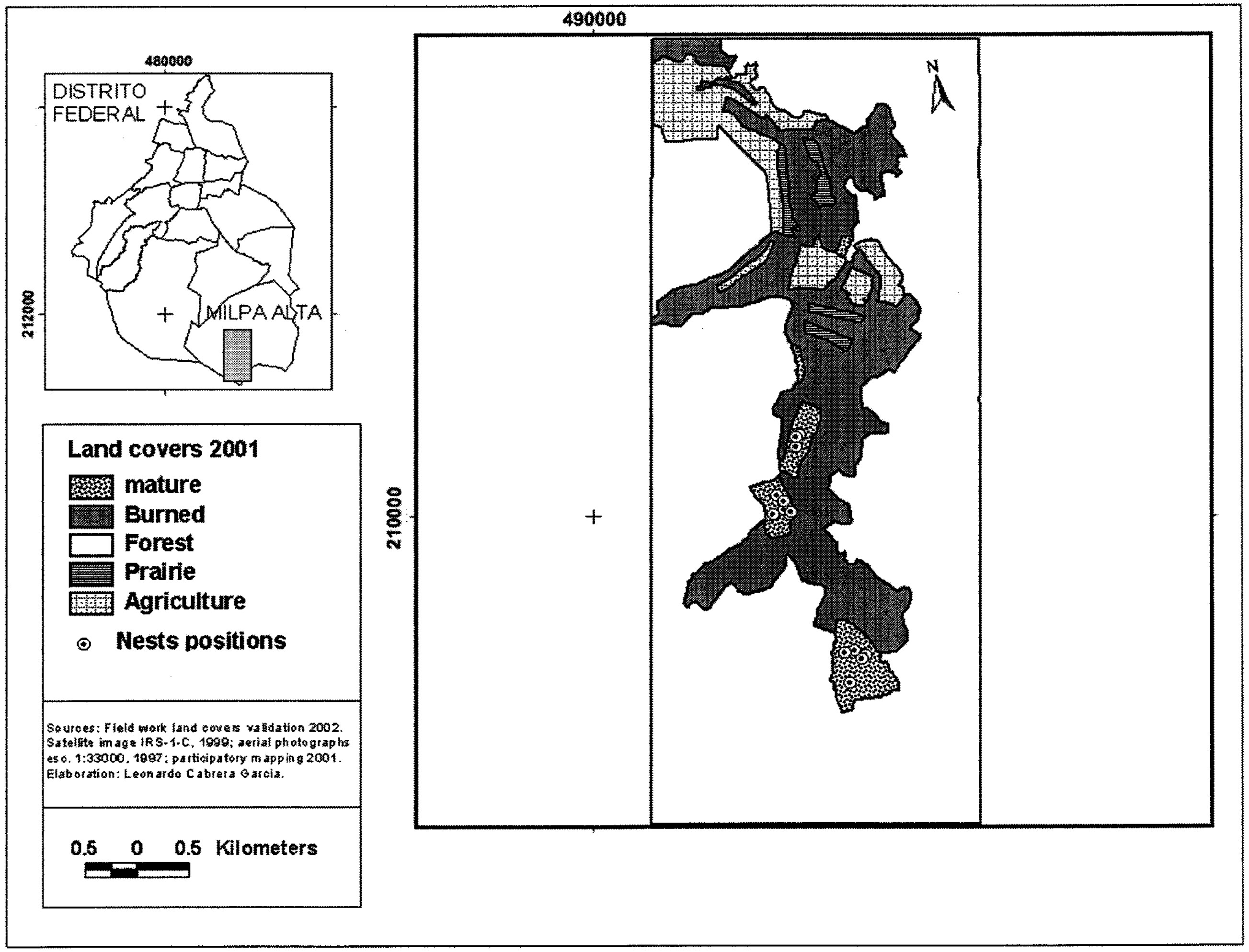


Figure 4.3. Sierra Madre sparrow's nests locations in 2001.

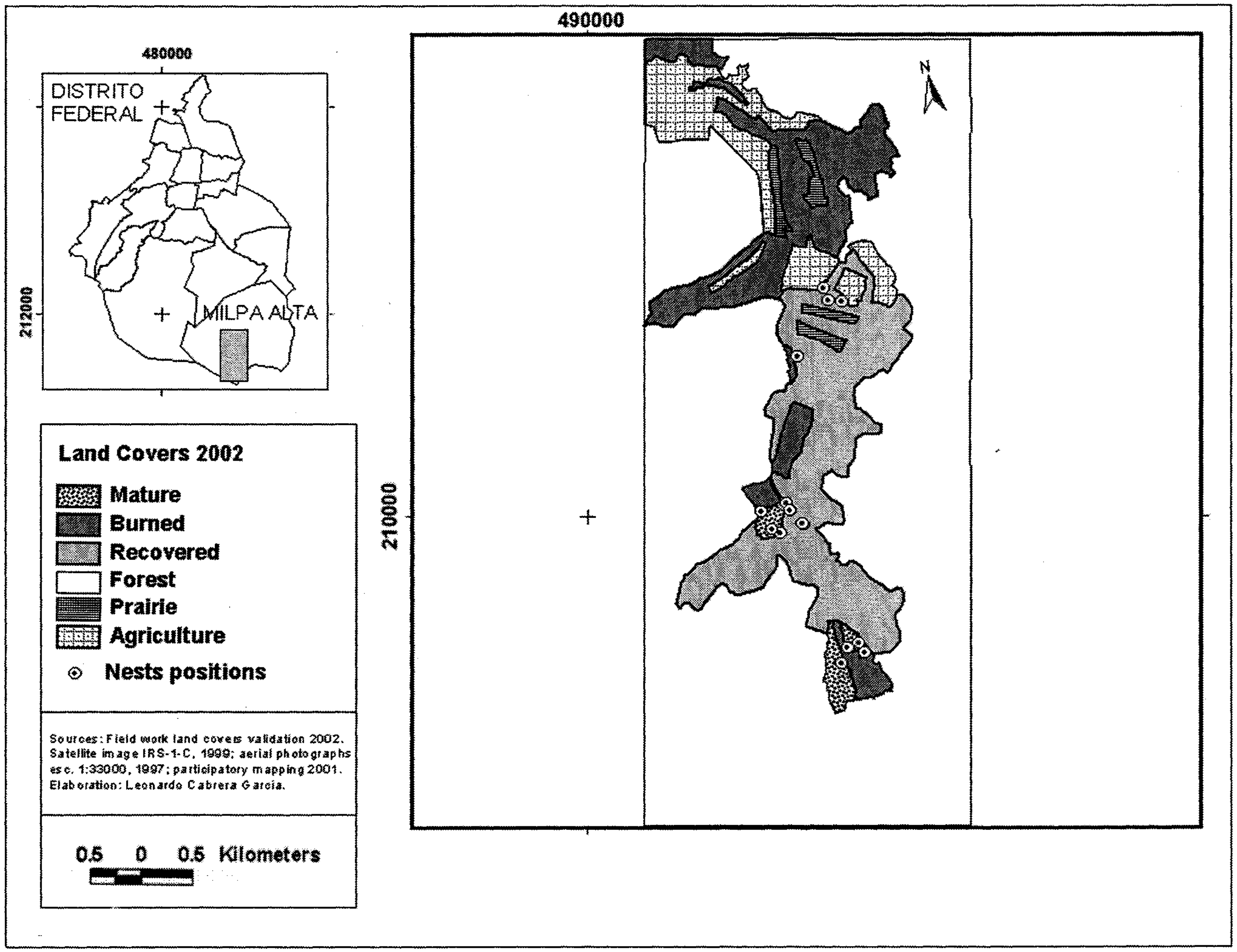


Figure 4.4. Sierra Madre sparrow's nests locations in 2002.

Table 4.2. Calculation of mean, standard deviation, U-test, DFA and logistic regressions for the variables measured at SMS nests and random sites at the three different spatial scales.

Scale/Variable	**Occupied Sites (mean ± SD)**	**Random Sites (mean ± SD)**	**U**	**P**	**Wilk's lambda**	***F***	**P**	**Wald χ^2**	**Logit *P***
Plant scale									
Height	1.01 ± 0.16	0.79 ± 0.17	1008.5	**0.0001**	0.830	42.92	**0.0001**	9.0	**0.003**
Cover	3.10 ± 1.43	2.19 ± 1.95	1499.5	**0.0001**	0.971	6.20	**0.014**	10.13	**0.002**
Diameter	2.16 ± 1.03	2.04 ± 1.3	2458	0.271	0.999	0.279	0.598	11.20	**0.0008**
Habitat scale									
Grass cover	0.67 ± 0.16	0.48 ± 0.21	118	**0.003**	0.359	0.65	0.42		
Grass height	1.01 ± 0.15	0.75 ± 0.14	44	**0.0001**	0.58	31.64	**0.0001**	10.46	**0.001**
Herb cover	0.78 ± 0.08	0.74 ± 0.18	236	0.81	0.356	0.94	0.33		--
Herb height	0.95 ± 0.15	0.75 ± 0.17	110	**0.001**	0.365	0.05	0.81		--
Others cover	0.08 ± 0.09	0.02 ± 0.01	168	0.065	0.450	12.47	**0.0001**		
Others height	0.30 ± 0.25	0.14 ± 0.14	144	**0.016**	0.36	0.003	0.95		
Fire cover	0.04 ± 0.11	0.25 ± 0.37	121	**0.001**	0.42	10.95	**0.0001**		--
Grazing cover	0.12 ± 0.22	0.17 ± 0.24	172	0.08	0.487	14.71	**0.0001**	7.28	0.06
Ground cover	0.15 ± 0.05	0.27 ± 0.2	175	0.10	0.516	20.15	**0.0001**	9.35	**0.009**
Bare soil cover	0.06 ± 0.18	0.03 ± 0.03	173	0.09	0.363	0.18	0.67		--
Dungs cover	0.01 ± 0.017	0.04 ± 0.11	185	0.13	0.362	0.28	0.59		--
Soil erosion	0.05 ± 0.10	0.03 ±0.05	238	0.82	0.359	0.60	0.44		--
Grassland physiognomy	1.79 ± 0.49	1.58 ± 0.50	NA	-	0.364	0.77	0.78		--
Land form	1.44 ± 0.57	1.47 ± 0.51	NA	-	0.360	0.50	0.48		--
Species composition.	1.31 ± 0.47	1.29 ± 0.46	NA	-	0.362	0.26	0.60		
Landscape scale			**t-test**						
Mature grassland	5602 ± 3025	1423 ± 2921	4.81	**0.0001**	0.660	23.15	**0.0001**	-	-
Burned grassland	393 ± 914	3291 ± 3869	-3.79	**0.001**	0.778	12.82	**0.001**	4.94	**0.02**
Recovered grassland	1798 ± 2975	1230 ± 2878	-2.47	**0.020**	0.990	0.441	0.51	-	-
Agriculture	138 ± 500	1727 ± 3168	0.66	0.51	0.893	5.40	**0.025**	11.86	**0.008**
Distance to first agricultural field	1835 ± 1106	663 ± 602	4.58	**0.0001**	0.682	21.03	**0.0001**	9.33	**0.009**

Table 4.3. Calculation of mean, standard deviation, U-test, DFA and logistic regressions for the variables measured at SMS successful and failed nests at the three different spatial scales.

Scale/Variable	**Successful nests (mean ± SD)**	**Failed nests (mean ± SD)**	**U**	**P**	**DFA Wilk's lambda**	***F***	**P**	**Wald χ^2**	**Logit *P***
Plant scale									
Height	1.02 ± 0.16	1.0 ± 0.16	111.5	0.82	0.99	0.03	0.85	0.73	0.34
Cover	3.34 ± 1.41	2.78 ± 1.45	81	0.15	0.96	1.15	0.29	0.10	0.74
Diameter	2.37 ± 1.14	1.88 ± 0.81	87.5	0.24	0.94	1.78	0.19	0.54	0.45
Habitat scale									
Grass cover	0.67 ± 0.19	0.68 ± 0.11	87	0.49	1.0	0.01	0.91		
Grass height	1.01 ± 0.15	1.02 ± 0.15	91	0.61	0.99	0.02	0.87		
Herb cover	0.81 ± 0.07	0.75 ± 0.09	67	0.11	0.87	3.76	*0.06*		
Herb height	0.98 ± 0.17	0.91 ± 0.12	75.5	0.23	0.94	1.63	0.21		
Others cover	0.07± 0.09	0.08 ± 0.1	97	0.82	0.99	0.09	0.76		
Others height	0.33 ± 0.29	0.26 ± 0.18	90	0.59	0.97	0.61	0.44		
Fire cover	0.03 ± 0.12	0.05 ± 0.10	88.5	0.36	0.99	0.19	0.66		
Grazing cover	0.12 ± 0.22	0.12 ± 0.23	95.5	0.76	1.0	0.002	0.96		
Ground cover	0.12 ± 0.05	0.19 ± 0.02	35.5	**0.002**	0.66	13.61	**0.001**	7.13	**0.007**
Bare soil	0.08 ± 0.24	0.02 ± 0.02	79.5	0.29	0.97	0.62	0.43		
Dungs cover	0.01 ± 0.01	0.01 ± 0.02	84.5	0.40	0.96	1.04	0.31		
Soil erosion	0.02 ± 0.06	0.09 ± 0.13	64	**0.03**	0.881	3.63	*0.06*		
Grassland physiognomy	1.88 ± 0.48	1.66 ± 0.49	82	0.25	0.95	1.37	0.25		
Land form	1.23 ± 0.43	1.75 ± 0.62	56	**0.01**	0.79	6.88	**0.01**		
Species composition	1.41 ± 0.50	1.16 ± 0.38	77	0.16	0.93	1.97	0.17		
Landscape scale			**t-test**						
Mature grass	5334 ± 3025	5922 ± 3354	0.43	0.66	0.99	0.19	0.66	0.05	0.81
Burned grass	223 ± 425	598 ± 1283	0.88	0.39	0.95	0.91	0.33	0.80	0.36
Recovered grass	2069 ± 2984	1473 ± 3092	-0.45	0.65	0.99	0.21	0.65	0.21	0.64
Agriculture	186 ± 645	81 ± 258	-0.51	0.61	0.98	0.23	0.63	0.13	0.71
Distance to first agricultural field	1626 ± 1130	2086 ± 1079	0.97	0.34	0.95	0.94	0.34	0.02	0.88

Table 4.4. Breeding data for some habitat-related species of sparrows from North America.

Species	Source	Breeding success	Mean fledge produced/ successful nest	Daily Mayfield probabilities	Number of nests
Sierra Madre sparrow	This study	58	2.44	0.96	16/yr
Sierra Madre sparrow	Oliveras, et al (2002)	35.71	--		14/yr
Grasshopper sparrow	Balent (2003)	52	1.3-2.3	0.24	4/yr
Grasshopper sparrow	Koford (1999)	10-28.5	--	0.91-0.95	14-38
Grasshopper sparrow	McCoy (1999)[1]	41.5	3.71	--	38/3yr.
Florida Grasshopper sparrow	Perkins (2003)	10-33	3.2	0.90-0.95	74/3yr
Grasshopper sparrow	Rohrbaugh, et al (1999)	--	3.7	0.25	38/4yr
Clay-colored sparrow	Koford (1999)	18-53.5	--	0.93-0.97	8-49
Vesper sparrow	Koford (1999)	21.3-27.1	--	0.94	6-7
Savannah sparrow	Koford (1999)	15.5 -22	--	0.93-0.94	4
Savannah sparrow	Weelwright, et al (1997)	50	--	0.94-0.98	-
Brewer's sparrow	Mahony, *data unpublished*	53.6	--	0.957	657/4yr
Brewer's sparrow	Reynolds, 1981	14	0.5	0.09	7/2yr.
Sage sparrow	Reynolds, 1981	56	--	0.40	17/2yr.
Field sparrow	McCoy 1999	47.2	3.23	--	99
Bachman's sparrow	Perkins, et al (2003)	7-38	3.13	0.89-0.96	40/3yr
Song sparrow	Chase (2002)[2]	29		0.95	196/2yr

[1] The reproductive success and number of young/successful nest values correspond to the pooled mean values of 3 years of nest monitoring by the author.
[2] These values correspond to the mean calculated from 4 years of nest monitoring by the author.

CHAPTER 5

LAND USE PRACTICES, HABITAT DYNAMICS AND CONSERVATION OPTIONS: EXPLORING HUMAN IMPACTS ON THE SIERRA MADRE SPARROW IN MILPA ALTA, MEXICO

5.1. Introduction

Grasslands are recognized as a source of goods and services that support flora, fauna, vital ecological processes and human populations worldwide (Henwood, 1998; White et al., 2000). Most remaining grasslands are subject to local economic or subsistence management practices, many of which have long histories and have contributed to determine the ecological attributes of the grasslands or even helped to avoid their conversion to competing land uses. Despite their economic and ecological importance, grasslands have in general received relatively little conservation attention (WCMC, 1992; Henwood, 1998; Gauthier and Wiken, 2003).

Few pristine grasslands remain anywhere in the New World's tropics, and all are threatened to some degree (Gauthier et al., 2003). The main threats grasslands face are gradual degradation caused by inappropriate managerial practices (e.g. heavy grazing and excessive use of fire) or total elimination through conversion to cultivation, industrial or urban uses (White et al., 2000). Improved grassland management and protection are required to retain or restore the goods and services they provide (Vogl, 1974; Henwood, 1998; Hoth, 2002).

Given the human use of grasslands and its impact, effective conservation strategies require an understanding of the role of local land use and management practices in shaping grassland ecology, in influencing the driving forces of ecosystem change, and in determining the compatibility or feasibility of conservation strategies (Sample et al., 2003).

This study addresses concerns about the driving forces that threaten the Milpa Alta-San Juan Tlacotenco grassland ecosystem and the Sierra Madre sparrow. These include traditional pastoralism and commercial cultivation. The first entails burning the vegetation for pasture renewal, controlling the structure and composition of this grassy landscape. The second has caused habitat loss: approximately 50 % of grassland area has been converted to oat and potato fields over the last 15 years (Cabrera, 1999; González, 2000). Human activities are the main disturbances affecting the ecosystem state, stability and resilience[26], and they may modify SMS's viability by altering its breeding success and individual survivorship through exposure to predators, adverse climatic factors and agrochemicals.

This chapter explores these effects and the interrelation of pastoral activities and ecological change in the grasslands. The study uses field assessments of human activities and driving forces in the theoretical contexts and working principles of landscape ecology and fire ecology to answer questions pertaining to the environmental heterogeneity induced by pastoral burning and the grassland recovery capacity after a fire event and subsequent grazing pressure. Effects of 1 and 2 are explored in the light of SMS breeding needs as presented in Chapter 4.

[26] According to Holling (1973) and Holling and Gunderson (2002; p. 50) *"stability is the ability of ecosystems to resist change when subject to disturbance"; and "resilience is the capacity of ecosystems to return to its pre-disturbance state"*. Both resistance and resilience contribute to the persistence of a system's state.

5.1.1. Landscape ecology, ecological processes and species persistence

The fundamental purpose of landscape ecology is to understand the effects of spatial heterogeneity on a wide variety of ecological and abiotic processes (Turner, 1989; Wiens et al., 1993; Turner, 2005). Landscape ecology focuses on the understanding of ecosystem structures, functions and changes. Recent efforts have shown that species persistence is linked to specific characteristics of landscape composition (e.g., habitat type and quantity) and configuration (e.g., patch size, patch number, patch isolation) that affect relevant population processes (e.g., reproduction, feeding and dispersal) (McGarigal and McComb, 1995; Villard et al., 1999; With and King, 2001; Fahrig, 2002).

Landscape characteristics are shaped by four categories of factors: abiotic conditions such as climate, landform and soil parent material; biotic interactions arising from organisms presence and history; human impacts (which may be seen as a particular category of biotic interaction); and natural disturbances (Forman and Godron, 1986; Turner, 1989). From the conservation standpoint, human impacts have been recognized as the most important factor determining contemporary landscape quality, pattern and dynamics (Pickett and White, 1985). Most landscapes around the world are now fragmented and reduced in size, resembling islands in a sea of agriculture and urbanism.

From a landscape ecology perspective, nature conservation efforts have thus aimed at the integration of the spatial dimension of ecological and cultural processes into innovative sustainable landscape models (Farina, 2000). A series of recommendations have emerged addressing such interdependency of spatial patterns and human activities for conservation planning of such cultural landscapes (Forman and Collinge, 1996; Sample and Mossman, 1997; Bissonette and Storch, 2003).

Elimination of native vegetation is the main threat to biodiversity and a catalyst for cultural-economic impoverishment. Preventing such destruction and promoting habitat restoration are thus priorities for environmentalists (Fahrig, 1997, p. 609; Askins, 2000; Ruth et al., 2003) and organizations concerned with social well-being and culture survival. Because many ecosystems are in fact cultural landscapes (Davidson-Hunt, *op. cit.*), where the distribution of elements is largely determined by human activities (e.g., grazing, hunting, forestry, cultivation), influencing land use decisions can contribute to maintain land cover heterogeneity, ecological processes and biodiversity.

In this study, social-ecological relationships will be discussed in light of the SMS's breeding habitat needs and spatial heterogeneity caused by current management activities.

5.1.2. Fire ecology, grassland management, and biodiversity conservation

Fire, both as a natural and anthropogenic process, is an important determinant of ecosystem conditions (Whelan, 1995; Boyd, 1999; Pyne, 2001a). Fire ecology focuses on the ecological role of fire (i.e., species and community responses), and on fire as a traditional management tool with a potential role for biodiversity conservation (Gadgil et al., 1993; Boyd, 1999; Stewart, 2002a, b). Fire ecology in temperate ecosystems has been particularly well documented in North America (Daubenmire, 1968; Vogl, 1974; Goldammer, 1990; Knapp et al., 1998; Bergeron et al., 2001; Rodríguez-Trejo and Fulé, 2003), Australia (Yibarbuk et al., 2001; Bowman and Vigilante, 2001; Bradstock et al., 2002), Madagascar (Kull, 2004) and in diverse regions of South America (Verweij, 1995; Hofstede, 1995), Africa (van de Vijver, 1999) and Asia (Dove, 2004).

Natural and anthropogenic fires contribute to the creation and maintenance of habitats of diverse groups of plants and animals from which local communities frequently depend for their subsistence (Boyd, 1999; Mistry et al., 2005). Fire is perhaps one of the most extensive types of natural disturbances and many of the world's natural habitats depend on periodic fires for their maintenance (Goldammer, 1990; Pyne, 2001a). In grasslands, fire eliminates thick impenetrable vegetation, limits encroachment by woody plants and, thus, maintains the habitats of dependent species through "habitat recycling" (Landsberg and Lehmkuhl, 1995; Herkert, 2002).

Empirical data show that two conditions are necessary to maintain grassland biodiversity in fire-dependant ecosystems: periodic disturbance, characterized by fire timing, frequency and intensity, and circumstances that allow ecosystem recovery following disturbance (i.e., sufficient time and limitation of other stresses) (Bannerman, 2000; Brawn et al., 2001). If those conditions are not met, fire can be deleterious (Pyne, 2001b; Rodríguez-Trejo and Fulé, 2003), especially in combination with heavy grazing (Verweij, 1995; Watkinson and Ormerod, 2001). A number of studies have shown that excessive burning and grazing can reduce grassland ecosystem resistance and resilience, and can alter vegetation structure and composition (Benítez-Badillo, 1987; Velázquez, 1992; Perevolovski and Seligman, 1998). Plant growth rate, productivity and vigour can decline (Verweij, 1995; Cabrera, unpublished data) and community structure can be altered (Hartnett and Fay, 1998; Valone and Kelt, 1999, Watkinson and Ormerod, 2001).

Vegetation recovery time may vary depending on the nature of stresses and grass species' natural history, but both economic productivity and biodiversity richness can be altered.

Animal species occupying fire-dependent ecosystems can also be affected by changes in the fire regime (Landsberg and Lehmkuhl, 1995; van de Vijver, 1999). Responses in North America's grassland birds are, in most cases, species specific (Gillon, 1983; Prodon et al., 1987; Bell et al., 1991; Vickery and Herkert, 1999; Herkert, 2002). For example, Henslow's sparrow (*Ammodramus henslowii*), Baird's sparrow (*Ammodramus bairdii*) and Grasshopper sparrow (*Ammodramus savannarum*) avoid recently burned areas and re-occupy recovering grasslands only after two to five years (Pylypec, 1991; Vickery and Herkert, 1999; Gordon, 2000; Herkert, 2002; Johnson et al., 2004). In contrast, the rare Mountain Plover (*Charadrius montanus*) is tightly restricted to recently burned grassland areas (Wershler, 1991).

5.1.3. Grazing ecology and grassland management

Grazing or the removal of biomass by wild and domestic animals is an integral part of grassland ecosystems (Askins, 2000). Grazing, like burning produces and maintains diverse types of grassy ecosystems across the world (Knapp et al., 1999; Perevolotsky and Seligman, 1998).

Previous studies have demonstrated that grazing plays an overriding role on the structuring and functioning of grassland ecosystems at diverse spatial and temporal scales (Samson and Knopf, 1994; Gauthier et al., 2003). Contrary to fire, herbivores are selective feeders removing specific species and plant parts, thus affecting species composition and structure of plant communities. This selective defoliation contributes to habitat diversity at the landscape scale supporting varied species assemblages. Grazing also contributes to the reduction of fine fuel accumulation, and as a consequence to the lessening of fire occurrence on grasslands (Ausden and Treweek, 1995).

Regardless its ecological importance, and as for fire, the beneficial role of grazing can be disrupted when its natural or historic regime is altered in intensity, season and grazer type by economic and conserva tion interests. Grazing intensity is polemic, principally in ecosystems under high human influence (i.e., ranching). Generally, excessive or absence of grazing have been considered deleterious. On the one hand, overgrazing often seriously limits the re-establishment of grasses (Verweij, 1995; Laterra et al., 2003), and when combined with excessive fire can cause habitat fragmentation, gap formation and gradual death of tussocks as Verweij and Kok (1995, p. 118) demonstrated for a Colombian Paramo. On the other hand, lack of grazing (i.e., by exclusion or land abandonment) is considered a major threat since certain grazing ecosystems might tend to increase fire proneness and others in the long run shift into shrubby stages and disappear (Frank et al., 1998).

Season-of-grazing is important for various ecological processes of grassland birds, principally if it occurs during the breeding season. Diverse studies have reported reduction of breeding performance when nesting cover is both decreased and destroyed by grazers when feeding and trampling occur (Mellink, 1994; Vickery et al., 1999; Rohrbaugh et al., 1999; Watkinson and Ormerod, 2001).

Grazing impacts on biodiversity are varied. Literature shows a variety of situations where some species are adapted to excessive, others to absence and a majority to low-intermediate levels of grazing (Ryder, 1980; Herkert, 2002). Grazing impacts should be examined contextually and in combination with the related factors governing grassland ecosystem structuring and functioning like for example fire, floristic composition, land use, and animal species responses to the gradient of conditions created by grazing (Milne and Gordon, 2003).

Conservation and recovery of threatened grassland biota will therefore depend on the adjustment of grassland management practices, particularly by regulating frequency and location of fires and the timing and intensity of grazing pressure. It has been argued that the successful formulation of integrated grassland management plans (Sample and Mossman, 1997), grassland restoration programs (Caturla et al., 2000), and fire and grazing policies (Perevolotsky and Seligman, 1998; Mystry et al., 2005) will depend on a better understanding of the multiple factors affecting the recovery potential of vegetation, both in composition and structure across temporal and spatial scales. This research seeks to contribute to knowledge about these processes.

5.2. Research statement and goals

The grassland under study is currently maintained through anthropogenic fire and grazing, and pressure leading to land conversion is increasing. Species conservation under this context will require an integral understanding of land use practices and their impacts on specific landscape attributes and vegetation conditions. Local support for conservation initiatives will depend on the value placed on the bird and its habitat by locals, and the extent to which its protection can be made consistent with other cost-benefit assessments land users make. To this end, the objectives of this chapter are to: a) determine, at the landscape level, the impacts of current land use practices on the spatial extent and distribution of SMS's breeding habitat; b) examine how dominant bunchgrass species (i.e., *Festuca lugens* and *Muhlenbergia macroura)* recover in size (height and cover) after a burn and how they are subsequently affected by grazing; and c) determine, at the community level, the impacts of fire and grazing on the nesting conditions required by the SMS.

5.3. Methods

This study used integrative (Farina, 2000; Bürgi and Russell, 2001; Tress, et al., 2003), community-based (Berkes, 2004) and hybrid research approaches (Murdoch and Clark, 1994) which combine diverse techniques from the natural and social sciences to understand human-nature relationships in a sustainability context. Three types of data were generated: social (i.e., local knowledge on land use, with emphasis in grassland origin and management), spatial (i.e., land use-land cover and nesting locations), and ecological (i.e., grassland post-fire recovery and SMS's breeding habitat suitability).

5.3.1. Social data

The research was conducted from 2000 to 2002 using structured and informal interviews, participant observation and participatory mapping (Mukherjee, 1993; Hay, 2000). These methods are described in detail in Chapter 6. Informants were asked about time since the last fire, fire location and season. Historical documents describing the landscape and land use provided a secondary source of information. Spatial information from these sources was cross-checked and integrated with remotely sensed and mapped data presented in the following section.

5.3.2. Spatial data

Land use assessment consisted of land cover mapping based on image analysis and ground truthing. A set of 10 aerial photographs (year 1997; scale 1:35 000) was interpreted to delineate land cover types, following Haines-Young et al. (1993). From the aerial photographs, a digital geo-referenced and oriented photo mosaic was drawn. Ground-truthing of these data was executed by visiting control points and through comparison with transect data. Three control points were taken per photograph and located using a Global Positioning System (Garmin, 12 XL). High resolution satellite images of the region (SPOT IRS-1-C, year 1999 and Landsat ETM, year 2000) were also used to verify land cover classifications and to explore temporal change.

The results obtained indicated a complex spatial arrangement of grassland types and conditions poorly revealed by photo interpretation and satellite image analysis. Therefore, we conducted a detailed ground characterization of grassland. This involved walking across the study area and making hand-drawn sketches of grassland conditions, which were then superimposed on the areas in the photo mosaic. Official records of fires[27] were integrated as well to complete data verification. This spatial information was transferred by conventional cartographic methods (Haines-Young et al., 1993) into land cover-land use maps for 2001 and 2002 and then into digital format (Arc View, vers. 3.2a).

[27] A data base was proportioned by R. Appel of the fires attended by CORENA during 2000-2002 for the study area.

Landscape composition (i.e., land cover type and total area) characteristics was derived from land cover-land use maps and related to the SMS's nesting sites by overlying nest positions. A transitional matrix of land cover change was produced to determine net losses of breeding habitat both by burning and agriculture expansion practices. Landscape configuration[28] (i.e., spatial distribution of habitat patches and sizes) was not statistically analyzed but considered as a spatial framework of relevance for the general understanding of the question of interests in this chapter.

5.3.3. Ecological data

Post-fire recovery assessment plots were established following a stratified random sampling method representing grassland categories and spatial pattern. Two grassland categories were identified in 2001: burned (i.e., presenting some evidence or record of recent burning) and mature (i.e., no such evidence). Each category was considered a sampling stratum (Ratti and Garton, 1996) and three replicates were defined for each category according to patches distribution. Three 10 X 10 m quadrats were located at random within each site, for a total of eighteen permanent plots: 9 plots in mature condition and 9 plots in recently burned condition (Box 5.1).

Each plot was marked with a buried metal stake, mapped on a local sketch map, geo-positioned using G.P.S. and oriented with a compass. Thirty tussocks (or *macollas*) were selected at random from each plot and each of the 540 *macollas* was tagged with special aluminium numbered bands and mapped on a grid plot map. Indicators of plant

[28] Landscape metrics on configuration were not calculated since our sample size consisted on two temporal landscapes, and this limits statistical analysis for the distinction of habitat fragmentation effects independent of habitat loss (Fahrig, 2003).

growth (i.e., height and cover) and grazing pressure (i.e., % of grazing observed on plants in each plot) were measured monthly for each plant from May 2001 to April 2002, except for July 2001. As some of the old plants were burnt in a fire on January 2002 and other plants were lost due to the accidental removal of their tags (i.e., cows trampling), the total number of plants evaluated from the beginning to the end of this study was 386 (1a-3c = 266; 51a-53c= 120).

Box 5.1. Matrix design showing the six study sites, the areas they were in, and the sample plot labels used in this study.

Grassland condition/ sites	**North site**	**Mid site**	**South site**
Recently burned grassland	3a, 3b, 3c	1a, 1b, 1c	2a, 2b, 2c
Mature grassland	53a, 53b, 53c	51a, 51b, 51c	52a, 52b, 53c

SMS nest locations (see Figures 4.1 and 4.2 of Chapter 4) were combined with land cover data to examine the impacts of land use on breeding habitat availability at the landscape level. To determine the impact of burning and grazing on nesting conditions at the plant level, characteristics of plants used for nesting in 2001 and 2002 (height and cover) were compared with characteristics of monitored plants (both recovering and unburned) collected monthly.

5.3.4. Statistical analysis

Means and standard errors were calculated for plants' height (m), cover (m^2) and grazing (%) to obtain monthly average values of post-fire recovery and grazing trends between grassland conditions (unburned vs. burned) and the main bunchgrass species (*Festuca lugens* vs. *Muhlenbergia macroura*). In order to estimate the recovery of plant characteristics suitable for SMS' nesting, the morphology (x = height and y = cover) of recovering plants within the sample plots corresponding to the peak (June 2001) and beginning (April 2002) of the SMS breeding seasons were compared with values for plants that had been used as nesting sites (data from Chapter 4). This comparison was statistically validated with t-tests (SPSS, 1999). *Festuca lugens* data were used as they are the main plant species selected for nesting. Two x-y plots were produced to visualize similarities between plants monitored in this study (recently burned and unburned without nests) with plants used by the SMS for nesting in 2001 and 2002.

5.4. Results

5.4.1. Land uses practices

The main land use practices reported and observed in the grasslands during this study were, in descending order of spatial extent and economic importance: grazing, cultivation, and conservation (Table 5.1). The grassland also provided thatching material, medicinal plants and food, principally mushrooms (see Chapter 6 for more details).

Herders were the main managers of the grasslands, and their main tool was fire used in a way that created a mosaic of patches in various post-fire successional stages.

Three main grassland categories were recognized by pastoralists based on the time since the last fire: recently burned or *zacatonal recien quemado* (i.e., < 0.5 year after fire), recovering or *el quemado del año pasado* (< 1.5 year without fire; present only in 2002), and mature or *zacatonal viejo*[29] (i.e., ≥ 2 years without fire). Respondents claimed that herders created this landscape mosaic deliberately to maintain the quality of grazing conditions at the landscape scale over the long run[30]. Herders move livestock primarily between patches of recently burned grassland, where animals graze under supervision (see Chapter 6).

Historical documents support what local voices said regarding the naturalness of grassland. A description of the region in the 1565 land title document called *Primordial Title* confirmed the existence of *"Llanos de Pastizal*[31]*"* at that time:

> *"that everyone living in the llanos, montes, caves and lava outcrops get together and make their houses to start the foundation of our lands". "...sons, we are in our lands within our limits...from this site the boundary turns towards the sunset, [to] the east, [it] gets to the llano and reaches a place called Octlayucan where the limits of Milpa Alta and Tepoztlán are". (Titulo Primordial de Asunción Milpalta, AGN., n.d.).*

The ancient linkage between people and grasslands has been internalized into local culture as evidenced by the folk name for grassland, *zacatonal* derived from the Nahuatl word *zacatl* meaning rigid and dry herb[32], and knowledge of the use of fire to maintain optimal grazing conditions.

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[29] Herders refer in different ways to the oldest grassland, for example *viejo*, *macizo* and *recio*.
[30] Detailed information on grassland management is presented in the Chapter 6 of this thesis.
[31] *Llanos de pastizal* is the ecological equivalent of open grasslands.
[32] In Dictionaire de la langue Nahuatl classique. Available online: [http://sites.estvideo.net/malinal/index.html]. Consulted on January 6th, 2006.

Local herders have also created areas of intensive grazing, called *baldíos*, where bunchgrasses were removed and a specific flora adapted to high levels of grazing by sheep and horses was established, for example the short-size grasses of high forage value like *Muhlenbergia pusilla*, *Aegopogon centroides*, and *Muhlenbergia vaginata*. *Baldíos* were found in flat terrains in the northern half of the study area, and are not burned for their maintenance.

Cultivation practices were also found within the study area. Oral testimonies[33] indicated that oat fields have been established largely after 1959 in the northern part of the grassland. Agricultural expansion is on-going, as indicated by an increase of 4 % of the cultivated areas at least from 1997 to 2003[34].

The local environmental agency (CORENA[35]) also maintained several forest conservation areas in this region. Prescribed fires were used in 2002 over small areas (< 5 ha) of mature grassland to create firebreaks to protect forest patches. Tree plantations were also initiated in 2001 by CORENA in grassland areas. The plantations were sparsely distributed across diverse grassland patches from the core grassland area (data on extent not available). In addition, local authorities of Milpa Alta maintained a grassland patch of about 10 hectares under protection from fire and grazing to allow natural forest cover expansion and conserve habitat of an endangered rabbit[36]. This patch was heavily vegetated by the *Senecio cineraroides* shrub, intermixed with tall *Muhlenbergia macroura* and *Festuca lugens* plants.

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[33] Participatory workshop # 1, Milpa Alta; summer, 2001.

[34] Based on the aerial photographs (1997), previous field work observations during 1997-1998 (see Cabrera and Escamilla, 2000), and digital satellite image analysis of 2000.

[35] CORENA is the *Comision de Recursos Naturales*, a governmental agency responsible for environmental planning and management in natural areas south of México City.

[36] This area is located at the north of the Zilcuayo volcano at 3400 m.a.s.l. and was not monitored for the post-fire recovery study. A single visit was made (summer, 2001) with the Milpa Alta's representative to show me local forest conservation actions.

This combination of land use practices (i.e., extensive and intensive grazing, cultivation, conservation) has produced a complex spatial mosaic dominated in the North by agricultural fields intermixed with grassland fragments in different successional conditions, and in the South by original grasslands (Figures 4.1 and 4.2 in Chapter 4).

5.4.2. Land use dynamics

Table 5.2 present the aerial extent of, and the annual transition dynamics between different land uses in 2001 and 2002. Recently burned grasslands dominated (67 %) the landscape in early 2001. As 63 % of these grasslands were untouched by fire in the following year, the area of recovering grassland increased through succession to 43 % in early 2002. Still, 45 % of the recently burned area in early 2001 was hit by fire and remained as recently burned grassland in early 2002.

SMS bred primarily in mature grasslands, though some individuals nested in recovering patches in 2002 (See figures 4.3. and 4.4 in Chapter 4). Mature grasslands decreased importantly from 2001 to 2002 (i.e., 10 % to 4 % of the total unforested area). Interestingly, 15 % of the loss was due to a prescribed burn conducted by CORENA for so-called conservation purpose. The 27 ha of mature grasslands present in 2002 were entirely the result of already mature grassland not being touched by fire, as no recovering grassland was present in 2001 that could have grown to a mature condition. This illustrates the conservation risk associated with maintaining a reduced amount of the grasslands in recovering condition. Land management prescriptions should thus favour the maintenance of a fair amount of grasslands in recovering, if not in mature condition.

Fire also led to a new configuration of grassland patches over the landscape. While mature habitat was found in five patches in 2001, it was limited to two in 2002. A

Fire also led to a new configuration of grassland patches over the landscape. While mature habitat was found in five patches in 2001, it was limited to two in 2002. A reduced number of optimal SMS breeding patches increases the risk of local extirpation through stochastic or catastrophic processes. However, this may be balanced by the ability of SMS to breed successfully in recovering grasslands bordering mature patches (see Chapter 4). Approximately 5 ha, or 1 % of the total area of grasslands, were converted to agricultural land from 2001 to 2002. Although this is a small area, the great difficulty to re-establish grassland once land has been altered makes this loss meaningful.

5.4.3. Fire and grazing impact on grassland post-fire recovery

Figure 5.1 (a, b) illustrates variation in plant height and cover through one year for both mature *Festuca lugens* and *Muhlenbergia macroura* plants and ones recovering after a fire. The figure shows how *Festuca* plants grew rapidly during the rainy season, ending in September, and was very limited afterwards. By contrast, burned *Muhlenbergia* plants did not recover after a year of monitoring. By the end of the evaluation period, recently burned tussocks of *Festuca lugens* had increased near the height of unburned grasses and surpassed the cover by 11 %, as opposed to a limited recovery of 78 % and 59 % of height and cover for *Muhlenbergia macroura.*

While growth of *Festuca* recently burned plants was at a maximum in the late rainy season, mature plants of both species showed a general decreasing trend in size and ground cover toward the end of the monitoring period (Figure 5.1 a, b, open symbols). Field observations indicate that this was likely due to dehydration of plants caused by the cold winter and dry spring conditions that used to "burn" the vegetation notably.

Unburned grasses during this time presented either elimination or bending down of blades' tips that reduced grassland's height. Grazing on unburned grasses was very low.

As more of the recovery vegetation became available in July and August, grazing pressure increased toward greener recovering plants (Figure 5.1 c), principally for *Muhlenbergia macroura* plants (Figure 5.1 a, b, full symbols).

5.4.4. Recovery of vegetation and its relation to SMS nesting conditions

Figure 5.2 shows *Festuca lugens* characteristics (height X cover) in burned and unburned conditions and their relation to the plants used for nesting by the SMS in 2001 (Figure 5.2 a) and 2002 (Figure 5.2 b). While in 2001 nesting occurred exclusively in unburned conditions because of the limited size of recently burned grasses, in 2002 nesting occurred additionally in 14 months-post-fire recovered *Festuca* grasses even though these plants were smaller than the selected for nesting.

5.5. Discussion

The grassland studied is of particular interest to conservation science and practice because of a combination of conditions: it is a communal land particularly rich in flora and fauna, including several endangered species (Velázquez, 1993), it is actively maintained by traditional land use practices, namely rotational fire and grazing and land use pressures are now changing. These conditions make local human support essential to a successful conservation program. Local support is however hard to obtain with non-utilitarian arguments or a rationale based on alternative land uses such as shared revenues from tourism (see Stankey and Shindler, 2004).

grasslands are valued by local inhabitants as a source of forage, food and raw material (see Escalante et al., 1998 for a similar approach taken for the Sierra Tarahumara's conservation). Then, the integration of spatial, social and ecological data in relation to grasslands helped to understand land use-landscape dynamics and their impacts on the maintenance or deterioration of this ecosystem. I discuss these two issues below and present management recommendations that will support the persistence of SMS habitat and make its conservation possible.

5.5.1. Land use and land cover changes

The studied grassland represents an ancient cultural landscape where owners of the land have interacted through generations with local resources as Aguilar-Robledo (2001) documented for the Huasteca Potosina in northern-central Mexico. Grasslands in particular have been maintained by local herders who manifested a rich traditional ecological knowledge on grassland and livestock management (see Chapter 6 for a detailed description). This study contributed to the understanding of how the rotational burning system in use plays a role in enhancing landscape heterogeneity by creating a matrix of grassland patches of diverse ages, and where grass tussocks exist in varied structural conditions (e.g., height, size, density). This mosaic ensures the continuous presence of both grassland patches at an optimal successional stage for cattle grazing (i.e., recently burned patches), and patches adequate for SMS breeding when grasses are left to recover (i.e., mature patches). For example, recent studies confirm the importance of this human-induced landscape heterogeneity on increasing the raptors' species diversity in Honduras (Anderson, 2001) and the Papua New Guinea's avian diversity (Thomas, 2006).

It has also been shown that traditional management systems based on rotational burning contribute to grassland maintenance through recycling of old grasses and fertilization of soil, and by excluding undesirable late successional stages (e.g., shrubs) (see Calder et al., 1992; Lewis, 1989 and Boyd, 1994; Kull, 2004; Mistry, 2005 for similar findings in New Zealand, North America, Madagascar and Brazil respectively). But pastoralism can also be a threat to grassland integrity when the fire regime is altered (e.g., increased frequency or change in timing), or when the grazing pressure is intensified because of high livestock density, and if it occurs early after fire and during the bird's breeding season (Benítez-Badillo, 1987; Calder et al., 1992; Rodríguez-Trejo and Fulé, 2003).

Data obtained suggested an attempt by herders to maximize forage availability by burning approximately 87 % of the grassland (or 68 % of the total unforested area) in 2001, of which 40 % was burned again in 2002 (but see the fire conflict in Chapter 6 for further details on fire causes). A dominance of burned vegetation thus delayed the maturation of the grassland and, consequently, reduced SMS's breeding habitat availability. Theoretical models show that species face significantly heightened risk of extirpation when their breeding habitat is reduced to less than 20 % of the total habitat area (Fahrig, 1997, 2001, 2002).

In the study area, which is the largest grassland area known where SMS subsists (Cabrera et al., 2006), only 13 % of the grassland (or 10 % of the total unforested area) was in optimal condition for breeding (i.e., mature) in 2001. This percentage was reduced to 5 % (or 4 % of the total unforested area) in 2002, although this low value might well be compensated by nesting in what seems to be sub-optimal breeding habitat (i.e., recovering grassland). To lower the risk of SMS extirpation, it would seem prudent to encourage a reduction of the grassland area burned each year, in order to maintain ≈ 140 ha (or 20 % of total grassland area) in mature condition.

The persistence of SMS in this grassland maintained by a rotational fire regime indicates that the sparrow and pastoralism can be compatible (see Gordon, 2000). However, the species' future is uncertain in view of new land uses, such as agricultural expansion, intensified pastoralism, potential urbanism, social conflicts and some official conservation practices that all have recently reduced and started to degrade the region's grassland area (Chapter 6 of this thesis).

Transitional analysis revealed a permanent loss of grassland by its transformation into agricultural fields and *baldíos*. According to local testimonies, grassland elimination started in the late 1950's and approximately 20 % of the original grassland has now been converted to these uses. The trend is on-going as shown by an expansion of agricultural fields by 4 % during this study.

SMS survival can be impacted by land conversion because the species is unable to nest in agricultural fields and *baldíos* (see Chapter 4), individuals' survival is directly impacted by agrochemicals (Oliveras de Ita et al., 2001) and indirectly by a change in the predators community, and their dispersion across the landscape may be limited by the presence of hostile environments (McGarigal and McComb, 1995; Fahrig, 1997, 2001). These negative effects might be reduced if mature grassland patches - preferred by SMS - are not in direct contact with agricultural fields or *baldíos*. This can be achieved by developing burn plans that maintain grassland areas in recently burned or recovering condition around non-grassland patches. However, many factors prevent the development of such large-scale prescribed burning plans, primarily the view of authorities that traditional burning practices are a threat to the environment (see Chapter 6), limited scientific understanding of fire behaviour in this ecosystem, and lack of appropriate resources to control fire evolution (see Rodríguez–Trejo and Fulé, 2003).

As discussed above, conversion of grasslands to agricultural fields and *baldíos* impacts SMS's survival likelihood by reducing breeding habitat availability and individuals' survival in the short term. But land conversion is also an issue in the long term as little is known about the potential for grassland restoration, and adequate techniques to conduct it in this environment. Therefore, if protection of the bird can be established as a priority, one of the first recommendations has to be the avoidance of habitat loss and the continuation of traditional grassland management practices.

Official conservation thinking and actions are also influencing the condition and evolution of the study area through tree plantation and fire prevention programs as it has been reported by Mathews (2003) for the Sierra Juarez in Oaxaca, Mexico. Literature on grassland conservation identifies tree plantation programs as an expression of a recurrent misconception of what needs to be conserved: forests (Henwood, 1998; Knapp et al., 1998; Rodríguez, 2004). Treeless areas such as grasslands are viewed by conservationists as deforested areas in need of being restored. Following this reasoning, authorities have developed over the last 20 years fire prevention programs (including fire prescription) in the forested area south of Mexico City (COCODER, 1988). This has resulted in a conflict where the authorities see fire as an overall destructive force to be used only where fire breaks and fuel reduction are needed to protect treed areas, while herders view fire as a creative force needed to maintain open habitat of socio-economic value. This corresponds with Kepe and Scoones' arguments (1999, p.50) on the creation of grasslands in South Africa where "*...perspectives on what is a desirable grassland landscape depends on who you are... and* [on the] *relations of power between different social actors, and the institutional relationships that underpin these*".

The forest conservation discourse has penetrated into local communities to the point that Milpa Alta's traditional authorities are now promoting forest succession in the grasslands. This negatively impacts the availability of SMS breeding habitat in the short term. But it may also have a longer term and more pervasive impact by changing locals' perceptions of the grassland and the cultural practices and values associated with it.

5.5.2. Post-fire recovery of the grasslands and breeding habitat suitability

Vegetative regrowth is an important mechanism of regeneration in grasslands that confers resistance and resilience to the system (Mushinsky and Gibson, 1991). In general, grassland structure recovered vigorously after a year attesting grassland fire tolerance and high productivity after disturbance. However, detailed data obtained in this study identified a diversity of factors that influenced the recovery of grasses after being burned.

In first instance, the season of burning has an important effect on post-fire vegetation recovery (Mistry, 1998; Morgan and Lunt, 1999). Burning close to the rainy season has been recommended to avoid prolonged exposure of soil and vegetation to adverse climatic conditions that would impair recovery once rain comes. In this study, the grassland monitored was burned primarily in the early spring dry season (March 2001) which seems appropriate in view of local seasonality and has been recommended as the "*normal practice in tussock grassland management for pastoral purposes*" (Calder et al., 1992, p.44). This fire however prevented SMS nesting on recently burned grassland in 2001 and limited it in 2002.

The observed post-fire recovery varied between the two main bunchgrass species, which may indicate a higher preference of livestock for *Muhlenbergia macroura* plants, which were more selectively grazed and limited in their recovery capacity. *Festuca* plants recovered faster due to their lower palatability (see Chapter 6 for details on traditional knowledge) and consequently suffered less grazing impact. As animals are controlled by herders to not eat this plant, a combination of intrinsic characteristics of grasses with local managerial practices could contribute to the higher post-fire recovery response of *Festuca* plants. The interaction of the lower degree of *Festuca*'s palatability with the high selectivity of cattle for *Muhlenbergia macroura* may bring important cascading benefits by allowing *Festuca* to succeed to older stages and increase its population (Ryder, 1980), promoting nesting habitat advantageous for the SMS.

Results from this study indicate that the recovery of SMS nesting habitat is still incomplete through one post-fire growing season, in this case fourteen months after burning. However, the SMS responded positively to this grassland successional stage as nesting occurred on recovering plants (see previous Chapter 4). This investigation suggests that the extensive recovering grassland found in 2002, could play a key role in the SMS breeding dynamics by increasing the availability of rejuvenated potential nesting areas (Bock and Bock, 1978; Mushinsky and Gibson, 1991; Pylipec, 1991). Extending the recovery time up to two years after fire is strongly recommended in this study in order to increase benefits at plant scale by allowing grasses to reach maturity to favour the SMS' breeding success, and at landscape scale by increasing habitat heterogeneity thus creating a more suitable landscape mosaic.

Maintaining moderate levels of grazing during the first year may also contribute to a faster recovery of nesting habitat while providing ecological (fuel reduction and increase of habitat heterogeneity) and social benefits as well (maintenance and conservation of derived grassland products) (Perevolotsky and Seligman, 1998). Social impacts of such conservation recommendations are explored on Chapter 6, but detailed further investigations are recommended.

5.6. Conclusion

The grasslands representing the SMS's habitat are spatially and temporally dynamic due to traditional management practices that enhance landscape heterogeneity by rotation of fires and grazing. Through these disturbance practices, the SMS's habitat has unintended preserved mainly by herders at regional and landscape scales.

Particularly the study underlined the need to balance the extent of burns to increase the suitable grassland condition for the SMS's breeding. Time and location of grazing pressure are also necessary to be adjusted to allow better recovery of grassland and avoid their future depletion.

Apart from recommending the improvement of management practices for a more sustainable use of grassland, the study suggests there is incompatibility of commercial agricultural expansion in the viability of the SMS since this implies habitat loss and fragmentation, which are the main catalysers for species extinction (Fahrig, 2003).

These findings helped to locate the current situation where this endangered species is on relation to local land uses, dynamics and change. The species survives opportunistically in a grassland successional condition that becomes available only under specific spatial and temporal conditions. This vegetation stage is located however, between two extreme management systems (pastoralism and agriculture) that in either way affect its development within such temporal and spatial variability. As the species may have survived in contemporary times within this habitat dynamism, new interests and perspectives on the land may eliminate this grassland stage if human exploitation increases and simplifies the landscape. Thus, landscape homogenization derived from agriculture expansion and over-utilization of grassland (dominance of recently burned grassland) should be prevented, since it would threat the social-ecological resilience of this ecosystem and exhaust the SMS survival possibilities.

Important methodological lessons for bird conservation can be derived from this study. First, the compilation and integration of social and ecological data within a spatial context helped justify the species conservation by obtaining a better understanding of the interdependencies of local land use practices on the maintenance of the species' habitat and also on the driving forces of landscape change. This level of understanding was facilitated by combining historical and current local information on land management in a more holistic manner than what classic ecological studies normally present.

Second, this kind of integrative approach helped to valorise the Milpa Alta-San Juan Tlacotenco grassland as a cultural landscape that has evolved by active use and has developed resistance and resilience mechanisms in accordance with local disturbance forces. Based on its dependence on human disturbance, its protection depends, in the long run, on the continuation of traditional management activities within an adaptive co-management framework (Calder et al., 1992; Foster et al., 2003; Foggin, 2004; Carlson and Berkes, 2005).

This study has underlined the twofold impacts of land use practices on the bird's habitat: they maintain and conserve the habitat, but also pose risks of damaging or eliminating it. The following Chapter (6) analyzes the local ecological knowledge related to grassland management, and considers cultural values, perspectives and interests that contribute either to conservation or to deterioration of the habitat.

Table 5.1. Milpa Alta-San Juan Tlacotenco's habitat classification.

Grassland succession stage[1]	Principal grassland species[2]	Ecological characteristics and uses[3]
Zacatonal macizo, recio, pasto sin quemar (Mature grassland).	Xoliman (*Festuca lugens*), Calzacatl (*Muhlenbergia macroura*), Zacahemanqui (*M. quadridentata*).	Grassland areas of *ca.* 3 years after last fire; patches of small-medium size (≈ 15 ha). Forage is of bad quality. Main uses are the conservation of grassland and the extraction of food, medicines and thatch material
Zacatonal quemado cada año, zacatonal tierno (Recently burned grassland).	Plumera (*Stipa ichu*), Zacahemanqui (*M. quadridentata*).	Grassland areas burned every year; patches of medium-big size (≈ 60 ha). Forage is of good quality. Main uses are as foraging areas for cattle.
Zacatonal quemado de hace un año (Recovered grassland).	Calzacatl (*Muhlenbergia macroura*), Xoliman (*Festuca lugens*), Zacahemanqui (*M. quadridentata*).	Grassland areas of 1.5 - 2 years after last fire; patches of big size (> 100 ha). Forage is of medium quality. Main uses are conservation and the extraction of food and medicine. Cattle can be located in these areas.
Zacatonal protegido (Protected grassland).	Calzacatl (*Muhlenbergia macroura*) and Jarilla (*Senecio cineraroides*).	Grassland area physically protected to promote forest succession and conservation; patch of small size (< 20 ha). Main use is forest conservation. Fire and grazing are excluded. Shrubs co-dominate in this grassland successional stage.
Llano or Baldio (Grazing prairie).	*Verbena teucrifolia, Muhlenbergia vaginata.*	Grassland cover has been eliminated; patches of small size (< 10 ha) dedicated to intensive foraging areas for sheep.

[1] Vernacular names in Spanish of grassland conditions determined from personal interviews and participatory workshops.
[2] Nahuatl (native Mexican dialect) names of grass species determined from personal interviews and participatory workshops.
[3] Based on author's personal observations, map area calculations (GIS, Arc View 3.2a), personal interviews and participatory workshops.

Table 5.2. Area extent (ha) and percent of temporal changes (2001-2002)* in the land covers studied in the Milpa Alta-San Juan Tlacotenco region. n.a. indicates the transition of land cover does not apply in that particular situation.

	Annual Transition 2001-2002						
Land Cover	1	2	3	4	5	*Total Extent (ha.) 2001*	*Percent extent 2001*
1. Mature grassland	27 (38.57%)*	43 (61.42%)*	n.a.	0	0	**70**	**10**
2. Recently burned grassland	n.a.	162 (35.76%)*	286 (63.13%)*	0	5 (1.10%)*	**453**	**67**
3. Recovering grassland	0	0	n.a.	0	0	**0**	**0**
4. Prairie	n.a.	n.a.	n.a.	24 (0%)*	0	**24**	**4**
5. Agriculture	n.a.	n.a.	n.a.	n.a.	127 (0%)*	**127**	**19**
Total Extent (ha.) 2002	**27**	**205**	**286**	**24**	**132**	**674**	
Percent Extent 2002	**4**	**30**	**42**	**4**	**20**		**100**

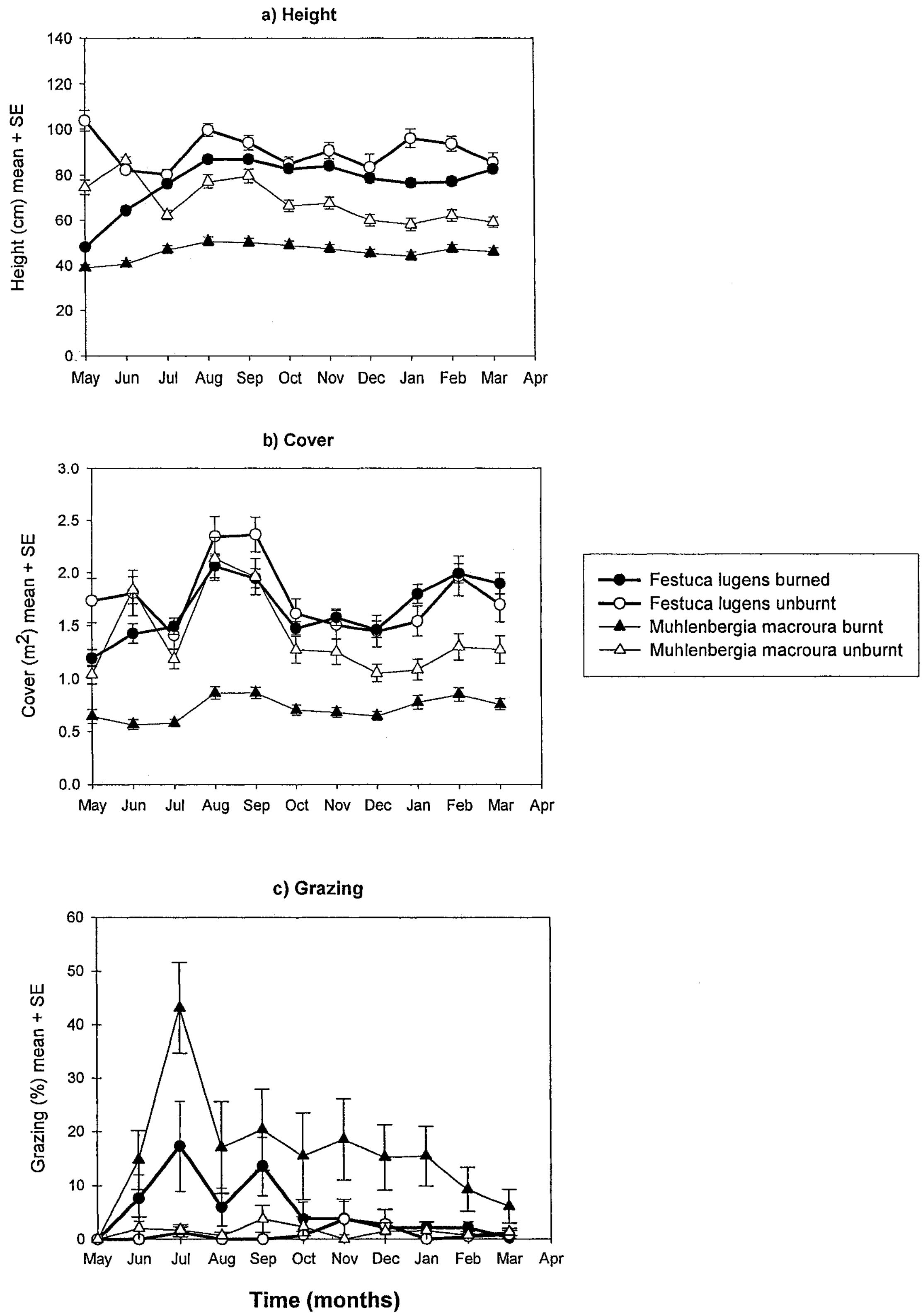
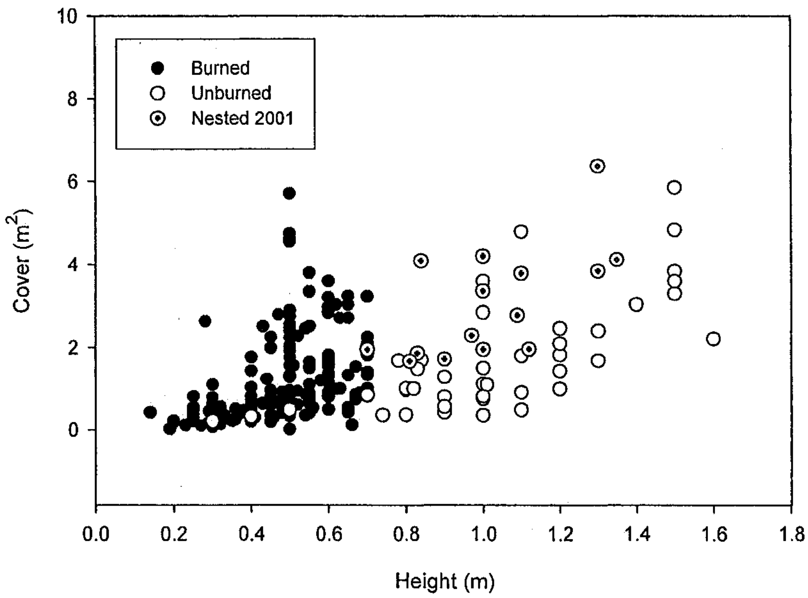


Figure 5.1. Post-fire growth and grazing impact on *Festuca lugens* and *Muhlenbergia macroura* from 2001-2002.

a) Recently burned conditions (May 2001)



b) 1 year post-fire recovery (April 2002)

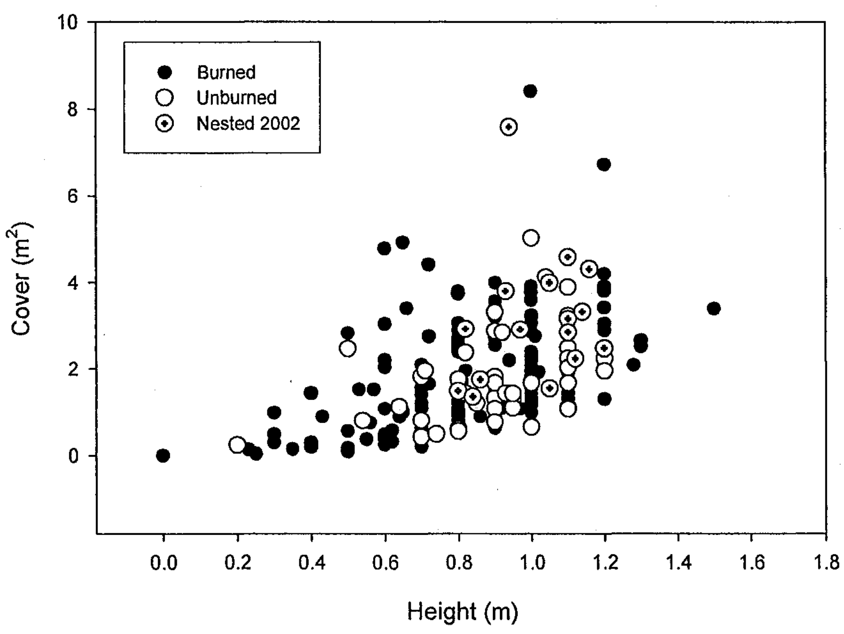


Figure 5.2. Comparison of monitored burned and unburned plants with those selected by the SMS for nesting in two temporal windows (2001, 2002) of the fire re-growth cycle.

CHAPTER 6

THE TRADITIONAL ECOLOGICAL KNOWLEDGE SYSTEM AND SOCIAL INSTITUTIONS IN THE INDIGENOUS COMMUNITIES OF MILPA ALTA AND SAN JUAN TLACOTENCO: INSIGHTS FOR COMMUNTY-BASED HABITAT MANAGEMENT AND CONSERVATION

6.1. Introduction

The Sierra Madre sparrow's habitat is controlled by disturbance-based traditional practices. The preceding chapters of this thesis demonstrated that burning the vegetation supports cattle rearing but also, incidentally, supports the SMS by providing habitat essential for the species nesting and breeding. In order to understand how this habitat can be managed to ensure the survival of the SMS, this chapter explores the social dynamics of grassland management in the communal lands of Milpa Alta-San Juan Tlacotenco. Specifically, it examines local knowledge systems and social institutions that influence grassland management practices and assesses these as a basis for conservation recommendations for the SMS.

6.2. Research statement and goals

Since the SMS habitat is both actively managed and own by local indigenous communities, this research is framed within the theoretical approach proposed by Berkes (1999; p. 13) for analysing traditional ecological knowledge (TEK) systems for resource management. This includes four levels of analysis: ethnoecological knowledge of species, the resource management system, the social institutions and political ecology relationships[37] (Figure 6.1). To this end, the present study has the objective of analyzing firstly the logic, knowledge and techniques of indigenous practices at the species and resource management levels. Use of fire use and grazing techniques are documented in detail. Human-land interactions are examined by looking at the social institutions, the historical land-defense movement, and working rules and norms used to regulate the use of local resources (Ostrom, 1990; Merino, 2004). Finally, the chapter analyses the political ecology (Blaikie and Brookfield, 1987; Bryant and Bailey, 1997; Berkes, 1999) of the described traditional management practices in the light of official conservation actions and perspectives, ancient internal tenurial conflicts and external pressures for land conversion.

Results from this chapter are expected to contribute valuable ecological and social insights into how to better manage this grassland ecosystem by including local understandings, the perspectives of diverse actors, cultural values and beliefs rarely considered in traditional bird conservation investigations (Gadgil et al., 1993; Berkes, 1999, 2004; Dudgeon and Berkes, 2003).

6.3. Methods

Methods were drawn from approaches of transdisciplinary nature used in TEK assessment (Grenier, 1998; Berkes, 1999; Zurayk et al., 2001; Gilchrist et al., 2005), participatory action research (Chambers et al., 1989; Chambers, 1993, 1994; Mukherjee, 1993; Lara et al., 1996; Allen et al., 1995, 1998; Moya and Way, 2001), community-based conservation (Western and Wright, 1994; Berkes, 2004), political ecology and

[37] Note that Berkes (1999) proposes cultural perceptions or "worldview" as the fourth level. Here, I have modified this for political ecology since historical and current political forces have shaped local resource management systems, institutions and conservation state on this territory.

common property studies (Ostrom, 1990; Sheridan, 2001; Simsik, 2002; Tucker, 2004). Diverse community members, from general audiences to particular herders, were involved in the study following a conceptual-methodological down-top model (Figure 6.2).

Field work consisted of visits to the *monte comunal* and local communities of Milpa Alta and San Juan Tlacotenco: January 2001; April to August of 2001 and 2002; and July to August 2003. The following section describes the steps employed to establish academic-community collaboration, and to collect, analyse and synthesize information.

6.3.1. Establishing relationships

Initial contact was made with several key groups: the communal authorities of Milpa Alta and San Juan Tlacotenco, CORENA, and two regional grassroots organizations, *Grupo de Educación para el Medio Ambiente, GEMA*[38] and *Grupo Yolnemilizotl*[39]. Field visits allowed encounters with diverse community members, including herders, local leaders and communal authorities. These preliminary contacts led to a formal presentation to the *Communal Assemblies* and community members in general.

Follow-up activities were designed to establish a common understanding regarding the communities' participation in the study and our responsibilities as external researchers, and to obtain permits to work in communal lands. Assurance was given that

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[38] GEMA is a grassroots organization dedicated to popular environmental education in the region of the Corredor Chichinautzin. Margarita Hurtado is the leader of the group and she is based in Cuernavaca, Estado de Morelos, México.

[39] Yolnemilizotl is an active local group working on environmental-cultural initiatives to preserve the communal resources and to rescue local traditions. Victor Chavira is the leader of the group and he is based in El Barrio de La Concepción, Villa Milpa Alta, Distrito Federal.

knowledge from the study would be shared with community members (Allen et al., 1998).

6.3.2. Workshops

A total of six workshops were held in Milpa Alta and three in San Juan Tlacotenco. The workshops were designed to meet local people and involve them in the study, to allow local concerns and ideas to be expressed and to build a sense of trust (Lara et al., 1996; Frias and Hurtado, 1998; Frias, 2003). These were organized through collaboration with community members and the GEMA and Yolnemilizotl groups. A total of approximately 270 persons participated in the workshops, 70 % of whom attended regularly while the remainder participated sporadically. The average attendance was 30 people per session.

Workshops were carried out in three phases: (1) diagnosis; (2) knowledge sharing; and (3) analysis, integration and delivery of information. Notes were taken at each workshop and sound and video tapes recorded activities with participant permission[40].

(1) Diagnosis. Participatory Diagnosis (PD) consisted of activities to identify local environmental problems and needs as they are understood by local people (e.g., interactive presentations, focus groups, games) (Frias and Hurtado, 1998; ACCES, 2000; Moya and Way, 2001). It also served to identify Key informant interviews with TEK on local management practices.

[40] Quoted testimonies in this chapter were originally in Spanish. The author translated them into English and he assumes the responsibility for fidelity to the original statements.

(2) ***Knowledge sharing.*** To obtain a more detailed understanding of TEK, the following techniques were implemented:

Participatory mapping and oral histories were used to collect pertinent spatial and historical information related to the communal resources and their importance, land uses, and traditional ecological knowledge on grassland species, ecology and management (see Mukherjee, 1993; Ardon, 2001). Special interest expressed by participants on land tenure problems and history of land defence was considered in these activities. Mapping and oral histories occurred both in the grasslands and in some *comuneros*' houses. Sketch maps of land limits, grazing areas, water point locations and other relevant spatial information were made on large paper sheets.

Scientific feedback activities were conducted in order to share information, knowledge and experiences with *comuneros* regarding the local biodiversity and the importance of the grassland. Researchers from local universities (UNAM and UAM) participated by offering interactive informative sessions (assisted by PowerPoint presentations) focused on biodiversity, natural resources conservation and community-based conservation experiences in Mexico. These activities were carried out in different fora as suggested by local *comuneros* (the Communal Houses of Milpa Alta and San Juan Tlacotenco, local elementary schools and local houses).

Focus group sessions were conducted as part of the workshops. Sessions were oriented to fill-in informational gaps and to triangulate particular information as needed. Issues and concerns that were raised by participants in the various activities (e.g., environmental problems such as hunting, land tenure conflicts and fire use) were also discussed. Sessions took place both in the villages and in the field (Berg, 1998; Hay, 2000).

(3) Analysis, integration and delivery of results. Final workshop sessions consisted of reflective group discussions centred on the integration of main study findings (Lara et al., 1996). *Comuneros*, local representatives and CORENA officials participated actively. PowerPoint presentations assisted with GIS served to share and discuss results obtained. A preliminary report was delivered to the *Representaciones Comunales* of Milpa Alta and San Juan Tlacotenco and to officials of CORENA. Previous material published by the main author of this thesis and a video documentary produced during this research[41] were donated to the local libraries, schools and Communal Houses of these two towns.

6.3.3. Complementary sources

Semi-structured interviews (40) were carried out to obtain further information on people's knowledge of grasses, grassland management, and the role of social institutions in conservation of communal resources (see questionnaire outline in Appendix 1 and the interviewers sample in Appendix 2). Informants were selected using a "snowball sampling technique" (Bernard, 1995 cited in Frias, 2003). The "snowball" began with

[41] A video titled "*Towards the SMS conservation, a participatory experience in Milpa Alta*"[41] was produced with the technical support of Edilberto Cabrera and his technical team from IFE (Instituto Federal Electoral, Mexico City, México) and elaborated with the local information generated up to that moment (July, 2001). The video was exhibited to *comuneros* and students of local schools with the aim to extend the information on the SMS and generate interest to participate in the research. The video is on VHS format and can be consulted in the Milpa Alta and San Juan Tlacotenco's public libraries and Representaciones Comunales' offices. The author of this thesis own the master copy of this digital material and may be consulted upon request at leonardo.cabrera@mail.mcgill.ca

comuneros identified in workshops as knowledgeable on grassland management, who then introduced me to other possible Key informants based on their personal networks. Interviews were presented in an informal manner to establish greater trust, dialogue and increase opportunities for locally relevant information to emerge (Rubin and Rubin, 1995).

Participant observation was carried out systematically throughout the study period. Participation in herding activities allowed the author to recognize herders' main movement paths and grazing areas, to observe grassland conditions and *comuneros'* activities related to the use and conservation of local resources. Participatory observation also occurred in diverse religious, familiar or political celebrations in the communities.

Secondary sources were extensively searched and consulted in local documentary centres, museums and universities. The material examined included local unpublished reports, official census data, antique maps and historical land tenure documents, basically copy of the Primodial Titles of Milpa Alta and Tepoztlán. Experts of titles were consulted directly[42].

6.3.4. Data processing and analysis

The data from written and tape-recorded field notes, images (video, photographs), maps, interviews and tape-recorded conversations were reviewed and analyzed systematically. Information relevant to the four levels of TEK was typed in a

[42] Personal communication was exchanged with Drs. Stephany Wood, Robert Hasket, Ivan Gómezcesar and Paula Caballero. Consult these authors' publications in the list of references for further details on primordial titles.

conventional computerized word processor package. Spatial data such as land boundaries and locations from the grazing system were transferred into a geographical information system using Arc View vers. 3.2a.

6.4. Results

6.4.1 Knowledge of grassland species

Community members demonstrated a precise knowledge of the taxonomy, uses, and ecological characteristics (texture and palatability, post-burn age, abundance and distribution) of the four bunchgrass species that dominate the landscape (Table 6.1). The main use of grasses was as forage for cattle, directly supporting the livelihood activities of some community members for whom livestock raising is an important economic activity. Herders were the main holders of TEK on grasslands. They reported to have learnt to herd as children and to have been taught the characteristics of the grassland species by their parents.

"There are good and bad grasses for the cattle" was a common statement recorded from herders. The grass called Zacahemanqui or "pelillo" (*Muhlenbergia quadridentata*) is the most valuable forage resource for herders. Consensus on the high palatability and cattle's preference of this grass species was consistently reported throughout the study. The grass called Xoliman (*Festuca lugens*) was consistently classified as bad, toxic and harmful for the livestock. A herder's statement mirrors the knowledge about these palatability characteristics[43]:

[43] Key informant interview GR, summer 2002; San Juan Tlacotenco.

> *"The animals like a lot the Zacahemanqui, it is very sweet. The Xoliman is very bad, the animals start to shake, to fall down, they get weak...there is no medicine to cure [them]...it's a very cold grass...it is poisonous... this is not good for us...that is why we have to watch over the animals all the time to avoid that they eat this plant"*

In addition to their use as forage, the Zacahemanqui and Calzacatl (*Muhlenebergia macroura*) grasses are highly valued by *comuneros* for a diversity of other purposes. For example, Calzacatl spikes are extracted from grasslands to produce crafts of high aesthetic and economic value, while Calzacatl leaves are used in the preparation of traditional dishes, mainly by covering the pot in which food is cooked (Figures 6.3 a, b). Root extraction was reported to occur for the production of brooms and similar products, although the activity was not observed during this study.

6.4.2. Knowledge of grassland management

Information was obtained on three aspects of the grassland management system: *the grazing system*, which consists of the ways herders occupy the land to exploit the resource, *the use of fire for grassland management,* and *grassland change and conservation.*

6.4.2.1. The grazing system

Grassland use at the landscape level is primarily determined by the current livestock grazing system generally called "free-grazing". The system consists of a series of footpaths (occasionally travelled by horseback) and foraging areas in the communal grassland and forest zones, used to herd the animals. A schematic representation of it is presented in Figure 6.4. The spatial distribution of these free-grazing areas is influenced primarily by the location of herders' *ranchos* and *corrales*, which was different in Milpa Alta as compared to San Juan Tlacotenco.

San Juan's *ranchos* are rustic fenced areas with simple shelters used to enclose animals at night. From *ranchos* located at the northern interface of the agricultural-forest zone, San Juan's herders walk for about 1.5 hours (starting at 6 am) along known paths to graze their livestock in grassland patches to the south (known locally as *Llano de Trincheras*) and to the west, in the plains surrounding the volcanoes Zuchio, Yecahuazac and Chichinautzin.

Instead of these distant *ranchos*, Milpa Alta's herders have small fenced cabins or *corrales* located in the proximity of the grassland areas. These *corrales* function as temporary shelters for both animals and herders. Herders from Milpa Alta were observed to either move their livestock on a daily basis between the town and the grassland or to stay for about three months in the *corrales*[44]. The main grazing areas used by Milpa Alta's herders included the most northern grassland remnants of *Llanos de Xoquiac* and *Cuauhtempa* and grassland patches surrounding La Comalera and San Bartolito volcanoes (Figure 6.5).

6.4.2.2. The use of fire for grassland management

Community members, particularly experienced herders, were found to hold traditional knowledge on fire use for grassland management. Fires are named locally as *chamusquinas*, which refers to the act of scorching the vegetation (Figure 6.6). *Chamusquinas* are considered by local herders to be necessary to eliminate undesirable weeds and old and unpalatable grasses, to promote fresh forage for livestock during the

[44] Key informant interviews VCH and JF, summer 2001, 2002; Milpa Alta town.

dry season, and to avoid large uncontrollable fires. This is illustrated by the words of a herder from Milpa Alta[45]:

> *"without fire, there is no grassland... [and] ... if there is no burning in several years, the grasslands would grow too much and would become too thick".* Another herder[46] from San Juan agreed by saying that *"grasses become too dry and heavy, they can accumulate lots of basura[47] that if a fire comes, it would turn into a tremendous fire very hard to stop".*

Fires were reported to be set during the dry season, peaking from February to March[48]: *"Fires are good when they occur closer to the rainy season",* was a unanimous consensus among local herders, *"In this way, burned vegetation and soil are less exposed to drought; thus soil is not too damaged by fire".* However, according to local testimonies and direct observation from the field, fires might also sometimes be ignited as early as November or January.

Herders reported grasslands are burned every two years. This technique is referred by herders as "*quemando por tramos*" or "*rolando el fuego*" [49]. *Rolando el fuego* consists of setting fire in grassland areas that herders consider need to be burned, principally those covered with tall, dense and dry grasses. Then, herders let the burned area regenerate for approximately 1.5 to 2 years. Through this method herders create a mosaic of grassland successional stages, in which only the recently burned grasses are under active pastoral use (Figure 6.7). This patchy spatial pattern determines the *location* of subsequent fires

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[45] Key informant interview JF, summer 2001; Milpa Alta town.
[46] Key informant interview BR, summer 2001; communal grassland San Juan Tlacotenco.
[47] *Basura* (literally "garbage") is used by *campesinos* to refer to the litter produced by the vegetation.
[48] Key informant interviews SC, summer 2002; GR, summer 2001; RA, summer 2002; communal grassland San Juan Tlacotenco; Workshop # 1, summer 2001, Milpa Alta; Key informant interview RAP, fall 2001, phone conversation.
[49] Key informant interviews SC and BR, summer 2002, communal grassland San Juan Tlacotenco.

and contributes partially to the existent fire regime. Herders explained that by burning in this way the green grasses will not be burned because the fire will stop naturally when it finds grasses not too dry or very short. Herders seemed not to watch over the fire but some herders were reported to have constructed fire breaks to prevent fires from escaping[50].

Although the technique of *rolando el fuego* was clearly practiced in the southern grassland patches near the Milpa Alta-San Juan Tlacotenco limits, testimonies and field observations indicate that the frequency of the fire regime has been reduced at *Llanos de Cuauhtempa* and *Xoquiac* within the communal lands of San Salvador Cuauhtenco and Milpa Alta[51]. Here, grasslands were burned two years consecutively and grazed intensively impeding their complete development (see details of grassland recovery in Chapter 4)[52].

The absence of fire was also reported by *comuneros* as a problem for grasslands and forests. According to diverse testimonies and personal observations, *"when grasses accumulated too many dry leaves and litter (basura), because they have been without fire for more than 4 or 5 years, fire goes into the soil and kills the roots of the plant"*[53]. *Rescoldo*, the resultant deep bank of ashes, is the evidence of a dead bunchgrass; these were shown by herders in the field and are commonly found.

Grassland patches with too few fires (more than 3 years without fire) and with excessive fire (every year) were documented in diverse parts of the landscape (see

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[50] Key informant interview RP, summer 2002; San Juan Tlacotenco town.
[51] Personal observation, summer 2001-2002; *Llanos de Xoquiac*, communal grasslands Milpa Alta.
[52] Data on previous (1996-2000) and posterior (2004-2006) fires to this study support the evidence of annual fires in this part of the region. Sources: CORENA database 1996-2000; field reports from Milpa Alta's *comuneros* 2005-2006.
[53] Key informant interview RA, summer 2002; *Llano de Morales*, San Juan Tlacotenco. Note: this grassland condition was reported to occur in some patches of *Llano de Morales* and *Trincheras* and was confirmed by personal inspection of grasses. However, it is the less common type in the landscape.

Figures 4.1 and 4.2 in Chapter 4). This fire regime alteration whether by excluding or by over-using fire is causing grassland change as described in the following section. Causal factors of such alteration are presented in the political ecology section of this chapter.

6.4.2.3. Grassland change

When asking whether changes had been noticed in the grasslands, herders repeatedly reported grassland deterioration, as indicated by the shorter stature of grasses, and the disappearance of important forage species:

> *"[...] when I was a kid, the grasses could cover the horse of my father, they covered me completely...mmm, nooo, they [the grasses] are very short now" (GR, interviewed 2001).*

Herders have also noticed the disappearance of important forage species they used to see across the pastoral landscape:

> *"[...] before there were other species of grasses, they were very good for the animals, but they have disappeared now, I have not seen them since about 8 years" (GR, interviewed 2001).*

In addition to the changes in the fire regimes described above, herders attributed grassland deterioration to grazing pressure resulting from the high number of animals in the *monte* and their impact (grazing and trampling) in recently burned grasses. An excess of animals was declared consistently by local *comuneros*:

"...if one sheep needs 3 ha. of terrain and a cow needs 5 ha or more, the land we have is not enough to feed all the animals we have", "this is causing a big problem when we consider animals' consumption has surpassed the [available] resources. This has caused a problem in the soils, [soil] is degrading in such way that the forest is [also] being lost[54]*"*.

Results of a random inspection of bunchgrasses (N= 378) revealed that around 70 % of grasses showed diverse degrees of tussock fragmentation due to a combination of overgrazing and excessive fire. From this percentage, about 43 % of grasses presented medium internal fragmentation, 25 % dying (75-95 % internal fragmentation) and 2 % of the plants were found dead (Figure 6.8).

6.4.3 Social institutions and communal resource management and conservation

Because of the communal character of the land where the SMS lives, local institutions in the form of norms and rules that regulate the use and conservation of grasslands are documented in this section. A central hypothesis is that the presence of local institutions is associated with better grassland conditions. Some principles related to successful institutions including land tenure, access and resource regulation are examined (Ostrom, 1990; Tucker, 2004; Merino, 2004).

6.4.3.1. Land tenure: the origins of land defence and conservation

Findings from this study indicate that to local *comuneros*, ownership of the *monte comunal* is legitimized by the *Titulos Primordiales* or Primordial Titles. This is a

[54] Key informant interview RA, summer 2002; communal grassland San Juan Tlacotenco; focus group session, summer 2002; San Juan Tlacotenco town.

"sacred" document that defines the boundaries of their territories and the canon of land defence[55]. For *comuneros*, the Primordial Titles represent a mandate from the past that calls on *comuneros* to take care of the land for the future generations, and perpetuate their historical memory as Momozca people [56].

Although *comuneros* made reference to the Primordial Titles as the legal proof of land tenure, in practice they identified their land limits based on what they were told by their ancestors and their generational-personal journeys across the landscape. Most of them were able to identify in the *monte* the *mojoneras*[57] that demarcate their territory, and to depict these in maps (Figure 6.9 a,b).

In spite of the historical importance given to land demarcation and territory defence, land tenure is unclear and weak in the communities studied. Milpa Alta and San Juan Tlacotenco are suffering from land disputes rooted in historical and complex overlapping land boundaries. Land is held in an atmosphere characterized by an active feeling of land defence against outsiders, but subject to intense episodes of internal

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[55] *Sepan hijos mios que hemos andado junto a nuestro lindero.....y subiendo por encima del cerro que se llama Teuhtli Xohuiyacatzin que es el lugar donde dan comienzo y acaban los límites. Ahí les fueron dadas flores en sus regazos, conformes todos, se hincaron de rodillas y lloraron; dijeron: demosle gracias a Dios. Luego les dijeron a sus hijos: sepan amados hijos, que es hasta aquí donde se cierran nuestros límites, y aquí, en estos papeles les dejamos senalado con esta llave para que todos los que son nuestros hijos lo vean. Después dijeron los viejos, aquí estamos los diez que estamos nombrado arriba, les decimos en presencia de Dios Nuestro Senor que ya esta realizada la obligación de haber señalado nuestros límites, redondeandolos y dandoles a cada pueblos lo que les pertenece, para nuestros hijos y nietos. [....] Esto sucedió en el ano de mil quinientos sesenta y nueve. Cuando se establecieron los linderos fue necesario que pasaramos por barrancas, pedregales, llanos y montes y cerros; y les dejamos dicho el trabajo que costo esta relacion, y se lo dejamos dicho en estos papeles para que sirva de ejemplo de cómo ya quedaron ustedes delimitados en redondo. Sepan hijos mios que estos papeles guardan al pueblo de Milpa Alta y sus sujetos* (AGN, T, vol. 3032, file 3: 28 p.).

[56] Primordial Titles of Milpa Alta; AGN, n.d.

[57] *Mojonera* is a physical mark employed to delimit a territorial boundary. It can consists on a pile of rocks, a wooden cross, a mark on a tree, a big tree, a mountain, a volcano or any particular feature of the landscape. Key informant interview JF, summer 2001; Milpa Alta town.

disputes. This has had paradoxical consequences for resource conservation and social institutions which are described in the next section on political ecology.

6.4.3.2. *Usos y costumbres*: a vivid tradition for communal land conservation

In both Milpa Alta and San Juan Tlacotenco, a number of empiric regulatory mechanisms such as traditional management practices, customs, beliefs and communal agreements were found to regulate the access to the commons and extraction of resources from the *monte comunal*.

Local voices from Milpa Alta recognized such regulations under the concept of *usos y costumbres*: *"For us [Milpaltecos], what counts is usos y costumbres, which are executed de facto, not de jure; it gives us benefits at a personal level"*[58]. According to this concept, decisions on the use of communal resources are based on customary knowledge and traditions which are reinforced by multiple cultural, religious and productive practices[59]. In this way, *usos y costumbres* have been validated and incorporated into the official decision-making structures governing communal local resources characterized by the *Representaciones Comunales*. In Tepoztlán, *usos y costumbres* relating to land access, land uses and conservation actions over the *monte* communal have been integrated into the *Estatutos Comunales*[60].

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[58] Key informant interviewVCH, summer 2001; Milpa Alta town.

[59] Key informant interview RT and Workshop # 1, summer 2001; Milpa Alta. Workshop # 7, summer 2002; San Juan Tlacotenco.

[60] *Estatutos Comunales* are based on the Mexican Constitution, the Agrarian Law and internal rules and traditions expressed by *comuneros*. Rights and obligations over land use and conservation of communal resources are explicitly mentioned.

6.4.3.3. Access to the commons and resource monitoring

In Milpa Alta and San Juan Tlacotenco, access to the commons is regulated by diverse norms and agreements embodied in their *usos y costumbres*. As illustrated by the following statements, this access is regulated by the *comuneros* with the aim of preventing intrusion by outsiders:

> "*...only* comuneros *can enter into the monte* comunal *and you can not extract anything from the monte without authorization of the Communal Representation*"[61].

> "*... although it is good to know what we have in the* monte, *we need to have* agallas[62] *to defend it [the land or the* monte*]...even with your own life*".

Numerous testimonies and observations provided evidence of active enforcement mechanisms used by people to restrict access to their lands. For example, the *Estatutos Comunales of Tepoztlán* (Propuesta de Estatutos Comunales, n/d) establishes as the first obligation of *comuneros* to denounce and to monitor illegal acts such as land sale, illegal wood cutting, *abigateo*[63], fire occurrence, hunting practices or any other suspicious activities in the *monte comunal*.

In San Juan, the *ganaderos* watch for any unknown persons or illicit actions while taking care of their animals, and demand proof of authorization of the *Communal Representation* of San Juan Tlacotenco from any outsiders encountered. Aerial and land surveillance by police helicopters and patrols commanded by the Tepoztlán's and San

[61] Key informant interview RT, summer 2001; Milpa Alta town.
[62] *Tener agallas* is a popular expression used in Mexico to express value to do something. An approximate meaning in English language (slang) would be "to have guts to do something".
[63] *Abigateo* is the name given to the act of steal livestock; it is hardly penalized.

Juan communal authorities are frequently seen scanning over these lands[64]. Similarly, in 2002, Milpa Alta established surveillance posts in the heart and periphery of the communal forest with the aim of controlling illegal access by hunters, *talamontes* (woodcutters) and other trespassers, and to detect fires.

Oral histories also attested to more confrontational methods to prohibit unauthorized access to and use of communal lands, such as blocking roads, hijacking bulldozers, destroying barbed wire meshes and agricultural fields, and other physical confrontations[65]. The abandoned and rusted bulldozer at the entrance of San Pablo Oztotepec is a silent reminder of former actions of Milpa Alta's *comuneros* against urbanization. *Comuneros* recurrently declared that by ringing the bells of the church, *comuneros* are alerted of external threats to the *monte* and gather with weapons to take immediate action.

6.4.3.4. Regulation on extraction of communal resources

In addition to restricting access to communal lands, internal regulatory mechanisms exist in both Milpa Alta and San Juan Tlacotenco aimed at controlling extractive practices of communal resources, such as grasslands and various forest resources.

6.4.3.4.1. Partitioning of grasslands for pastoral use

Livestock rearing based on communal pastures can be considered as the main extractive activity (when considering the pasture as a resource) in the *monte comunal.*

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[64] Personal observations, summer 2001-2002; Milpa Alta communal grasslands.
[65] Participant observation, summer 2002; Milpa Alta. Workshop # 1, # 2, summer, 2001; Milpa Alta.

Although grasslands are acknowledged by herders as communal and all the herders have the right to use them, in practice there are local agreements controlling the use of pastures. This is achieved through customary partitioning of areas at two levels: (1) among herders of the same town, and (2) among different towns. The words of an elder herder of San Juan Tlacotenco[66] illustrate very well the first of these two customary regulations:

> *"Every herder has his own place to locate his animals, here we have one, there we have another one and [in this way] the animals do not mix. My animals head up to Chichinautzin".*

In San Juan Tlacotenco grazing areas are influenced by, but not restricted to, the *rancho's* locations. In contrast, Milpaltecos use of communal pastures is influenced by the location of the town limits: *"every town has its own use zone, which goes from the borders of the town towards the* monte, *as if it were a strip-like area"*[67]. Accordingly, the following statement complements this by saying:

> *"San Lorenzo [used to graze] around El Tlaloc-Ocotecatl; over there [pointing towards the west zone] San Pablo Oztotepec; San Salvador Cuauhtenco [used to graze] over the Tulmiac area; Santa Ana [used to graze] on this side of Zilcuayo; we [from Milpa Alta] in the centre [of the monte] in el monte de Tlalnepantla. The animals graze well [here], we arrive where we have accustomed them [the animals], under the tallest trees' shade...here we would stay for three months"*[68]

In addition, participant observation indicates that herders and animals from Milpa Alta do not generally mix with those from San Juan Tlacotenco. A type of social boundary has

[66] Key informant interview JO, summer 2002; San Juan Tlacotenco town.
[67] Key informant interview VCH, summer 2001; Milpa Alta town.
[68] Key informant interview JF, summer 2002; Milpa Alta town.

been established between herders from different towns, delimiting their territory and forage extraction rights. In spite of these apparently rigid regulations, in practice herders from Milpa Alta and San Juan Tlacotenco have adopted also more flexible mechanisms when selecting grazing sites. If a herder arrives later than another one at the same place, the second one must move to another foraging patch free of animals.

6.4.3.4.2. Diverse communal forest resources

The extraction of certain communal resources like wood or soil is rigorously controlled by the *Representaciones Comunales*. In the case of wood, commercial tree exploitation is prohibited in the *monte comunal*[69]. Wood can only be extracted to cover household and religious needs, and diverse regulatory mechanisms exist to avoid excessive extraction. For example, selected extraction of beams (*orcones, solera, morillo, zincolote* y *tejamaniles*) for the construction of traditional storage buildings requires a written permit from the *Representación Comunal de Milpa Alta*. Trees are selected in person by the communal authorities of Milpa Alta who also assist in the extraction. A traditional ritual worshipping the main saint of Milpa Alta, *El Señor de las Misericordias* or *El Leñerito* is also performed when wood is extracted (LMF, interviewed 2005).

Restrictions exist for firewood which must come only from dead trees. The *Representación Comunal* of Milpa Alta has established limits on the volumes that can be extracted. For example, 2 m^3 of firewood is permitted for domestic cooking purposes[70] while 4 medium-size trucks of firewood are approved for the *Mayordomías,* the most

[69] Key informant interview FCH, summer 2001; Milpa Alta town.
[70] Workshop # 1, summer 2001; Milpa Alta. Workshop # 7, summer 2002; San Juan Tlacotenco.

important religious events worshipping the saints of the towns[71]. Unlike the timber products described above, no regulatory mechanisms for the extraction of non-timber products, such as grasses, mushrooms and medicinal plants, were documented either from the community or from the official environmental authorities. Overexploitation and extinction of some species of mushrooms was reported by elders who attributed this to the high number of uncontrolled harvesters and the lost of knowledge on how to properly collect the mushrooms without affecting local populations[72].

6.4.4 Political ecology of grassland management and impacts on conservation

Findings from this part of the study revealed two main conflicts in the region which have important impacts on the conservation, management and social institutions related to grasslands. These centre on the use of fire and conflicts related to land tenure. Each of these involves a complex pool of social actors with diverse interests and perspectives, the ecological and social dynamics of which must be understood in order to visualize conservation possibilities for the SMS.

6.4.4.1. Conflicts on the use of fire

Fire use in the SMS habitat has been polarized in two opposite perspectives: fire as a necessary element for grassland management and conservation; and fire as an evil and destructive force. As described in earlier sections, the first perspective is mainly held by herders who consider fire management an integral part of the pastoral system. In contrast, numerous testimonies and observations collected during this study indicate that

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[71] Key informant interview LMF, winter 2005; phone conversation Montreal-Mexico City.

[72] Personal observations, summer 2001-2002; communal grasslands. Key informant interviews SC, BR, summer 2002; communal grasslands.

the negative perception of fire is promoted primarily by official environmental agencies working on forest conservation at the local level (CORENA and SEMARNAT[73]), as reflected by the numerous official signs and propaganda banning fire or depicting fire as an enemy of the forest. In this vision, fire is seen as a threat to the forest and to the millionaire tree plantations across the region. This negative view is also held by the general public, environmental groups, and scientists. In some cases herders and community members in general can also hold this view to avert trouble, as shown by the following statement:

> *"...fire is the worst threat to the forest, also pests, but fire sweeps too much, it is evil. The ganaderos [the herders] think fire is useful to promote grass renewal, but [I think] the grass is vanishing...livestock grazing is not bad, but fire is*"[74].

In order to be "good", fires must occur under official control, while those ignited by non-officials are illegal and hence suppressed. Fires ignited by CORENA differ from the indigenous practices documented above. Specifically official fires occur in smaller areas where abundant fuel has accumulated. As official fire managers stated the aim is to ensure a fire that "*burns deeply and slowly*" so that the vegetation is completely burned[75]. In contrast, traditional burning consists on superficial and extensive fires, which are aimed on reducing damage to plants and soil[76].

Local herders generally disapprove of prescribed fires because they do not supply enough forage to support local cattle: "*we need more pasture than that promoted from*

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[73] SEMARNAP (*Secretaría del Medio Ambiente y Recursos Naturales)* is the principal Mexican institution responsible of environmental management and protection.
[74] Key informant interview SN, summer 2001; San Pablo Oztotepec, Milpa Alta.
[75] Key informant interview RAP, winter 2001; phone interview, Montreal-Mexico City.
[76] Key informant interview BR, summer 2002; San Juan Tlacotenco communal grassland.

the prescribed fires, [there] is not enough [food] for our animals". Herders argued that restricting pastoral activities to these small areas may cause more overgrazing due to higher concentration of cattle. For local herders, the location and area of burns are dictated by the movements of the livestock, a practice which avoids overgrazing. They frequently mentioned that *"we are like nomads, we moved all the time, we used to occupy different locations on a daily basis [...] our animals get angry if they are in just one place...we follow them, they know where to go...that's why we are moving all the time and can not stay there [in those small areas burned by officials]"*.

Herders reported that these changes affect the productivity of pastoral activities[77]. In particular they pointed out that preventing and prescribing small fires led to excessive biomass accumulation in some areas and more extensive fires to fulfill herders' forage needs in other areas. Words from a respected indigenous herder[78] from San Juan Tlacotenco well illustrate the problem of excessive biomass accumulation:

> *"[...] there have been grassland areas without fire for several years (4-5 y) that when the chamusquina came in, it provoked an immense fire that burnt [intensively] all the llano[79] and even some trees nearby".*

Local testimonies and detailed observations on grassland conditions also indicated that grassland successional change is taking place in specific sites of the landscape as a result of fire exclusion and changing perceptions from *comuneros* about fire use and

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[77] Key informant interviews SC, BR, RP, summer 2001-2002; San Juan Tlacotenco communal grassland.
[78] Key informant interview BR, summer 2001; San Juan Tlacotenco communal grassland.
[79] *Llano* is known locally as an open grassy place in the *monte*, easily distinguished by the lack of trees or by the existence of few and scattered trees.

conservation. For example, Milpa Alta's *comuneros*[80] have enclosed a grassland area to promote forest succession and protect the habitat of the endangered Volcano rabbit (*Romerolagus diazi*) from livestock and burning activities. The site when visited in 2001 was in a clear successional trend by presenting abundant shrubby plants interspersed with bunchgrasses (Figure 6.10).

6.4.4.2. Conflicts on land tenure

The participatory mapping and oral histories brought to light the existence of two deep-rooted land tenure conflicts between Milpa Alta and San Juan Tlacotenco and San Salvador Cuauhtenco[81], which have been at the heart of uncountable struggles for land titling and possession for several generations.

Figure 6.11 shows the location of the two disputed areas. The area contested between Milpa Alta and San Salvador Cuauhtenco includes 7,000 hectares of forest and grassland from what *comuneros* of Milpa Alta sustain is their ancestral land. For over 400 years, this area has been a land without official owners. As a result of this conflict, Milpa Alta's communal lands have not been officially titled by the Agrarian Mexican authorities.

The second dispute of about 2,000 ha concerns the northern limits of San Juan Tlacotenco and the southern of Milpa Alta's communal lands[82]. The *comuneros* of San

[80] Key informant interview RT and personal observation, summer 2001; Milpa Alta communal grassland. This site is not located within the limits of the study area. It is located in an upper plateau of the Tlaloc volcano at 3400 m.a.s.l., approximately 8 km east of *Llano de Morales*.
[81] Workshops 1, # 2 and # 6, summer 2001; Milpa Alta town. Workshop # 1 and # 3, summer 2002; San Juan Tlacotenco town. Key informant interviews AA and.JF, summer 2002; San Juan Tlacotenco and Milpa Alta towns respectively.
[82] Workshop # 1 and # 3 and Key informant interviews AA and AC, summer 2002; San Juan Tlacotenco.

Juan claim their limits extend further than the ones established in the Primordial Titles of Tepoztlán of 1648 and confirmed officially by the decree of Tepoztlán of 1929.

Both conflicts are based on what people said they were told by their elders and also by what has been proclaimed in their Primordial Titles. Conflict resolution has proven extremely complex and difficult because of the nature of the traditions, which are powerful elements that guide people's interactions and relations with their territory. The Milpa Alta–San Salvador Cuauhtenco's case has been taken to court and has passed through numerous unfruitful resolutions; the local people believe the conflict will never be resolved. In the MA-SJT case *comuneros* commented that they are looking for internal arrangements to resolve the conflict that would benefit both parties[83].

These long-standing land tenure disputes have unleashed a cascade of ecological-social consequences, both in the past and in the present. These include some "evident" episodes of environmental degradation due to unsuitable land-use (especially agricultural encroachment and commercial timber exploitation), as well as impacts on the integrity of the communal social institutions. These processes are therefore important for understanding the dynamics of grassland management.

6.4.4.2.1. Land use change and conservation

The land tenure conflicts have had contrasting impacts on land-use practices in the disputed areas. In the area disputed by Milpa Alta and San Salvador Cuauhtenco, grasslands were partially transformed by San Salvador's *comuneros* into agricultural lands (Figure 6.12). This change was considered negative by Milpa Alta's locals; elders

[83] Key informant interviews AA and JF, summer 2001 and 2002; Milpa Alta and San Juan Tlacotenco towns.

from Milpa Alta expressed the following during a participatory mapping at the conflicted area with San Salvador Cuauhtenco:

> *"...what we see here..., these lands were open [to cultivation] before 1959 by San Salvador Cuauhtenco, they sowed [them from here] towards the Tulmiac... the agricultural authorities supported San Salvador through credits granted for land cultivation. This is why we can see wide open this part of the land"*[84].

In contrast to this trend of agricultural expansion, grassland conservation has resulted in the area disputed between San Juan Tlacotenco and Milpa Alta. San Juan's herders stated they have continued using this land principally for pastoral purposes. Testimonies suggest that San Juan's *comuneros* have legitimized their rights to the disputed land through pastoralist activities:

> *"People from San Pablo [Oztotepec] recognize [their lands] until this part of the monte...[but] with proofs we are utilizing [the land]..how do we utilize it? We take care of our animals [here], here our animals graze...how can they [people from San Pablo] demonstrate they use the land? They have nothing."*[85]

Personal observations and land cover assessments made in this thesis (see Chapter 5) confirm that this area contains the largest grassland patch in the entire region, corresponding to the core SMS habitat area[86] and is subject to active traditional management for pastoral purposes.

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[84] Workshop # 1, summer 2001; Milpa Alta town.
[85] Key informant interview RA, summer 2002; *Llano de Morales*, Milpa Alta.
[86] See Cabrera et al. (2006) for details on habitat characterization and classification.

6.4.4.2.2. Forest overexploitation

The land tenure conflict also facilitated commercial clear-cutting of communal forests for about 30 years, starting in the 1940's in Milpa Alta-San Salvador Cuauhtenco contested area (Comalera-Yecahuazac) and then spreading out across the entire region. Numerous testimonies were given by *comuneros* regarding confrontations with the pulp and paper company *Loreto y Peña Pobre* who *"... took advantage of the [land tenure] conflict to cut down [the] forest, especially in the Comalera-Yecahuazac region"*[87]. According to diverse evidences found in this study, the logging company controlled the communal forests through a series of corrupt and violent acts against Milpaltecos. These included the negotiation with *comuneros* from San Salvador Cuauhtenco to exploit the disputed land by promising to support their land claims; bribing the communal leader of Milpa Alta to consent such exploitation; and excluding *comuneros* and their activities from the *monte*[88].

The commons were described by communal leaders as vulnerable during this period. The high social instability culminated in the assassination of the corrupted leader by the Milpaltecos *comuneros*. Diverse pressures to the commons followed after the commercial and privatized forest exploitation: road and highway expansion, land invasion, illegal timber extraction, official development projects (i.e., electricity lines), high-scale tourist initiatives (i.e., project of a recreation park) and massive luxury urbanization projects[89]. A similar process of weakening of communal institutions and

[87] Workshop # 2, summer 2001; Milpa Alta town.
[88] Key informant interview JF and oral histories, summer, 2001; Milpa Alta communal lands. See Del Conde (1982) for more details on the Milpa Alta's *comuneros* land defence movement.
[89] Workshop # 1 and # 2, summer 2001; Milpa Alta town.

ensuing environmental degradation (including commercial forest exploitation and urbanization) was vividly reported by San Juan Tlacotenco's *comuneros*.

6.4.4.2.3. Social institutions: impacts and resistance

Data on the land tenure conflict reveal that these past events of land use change and overexploitation occurred when weak local institutions were governing the commons, thus triggering internal political struggles, corruption of communal representatives and factionism. However, in the mid-1970's, new communal leaders emerged and started a legitimate community-based movement focused on the defence of the *monte comunal*, on the strengthening of communal organizations and on the rescue of *usos y costumbres* for collective benefit[90]. The group called "*Constituyentes de 1917*" represented the organizational roots of the contemporary movement for land defence and conservation of Milpa Alta's commons, today represented by *La Representación General de Bienes Comunales de Milpa Alta*, the maximum communal authority and decision-making body.

Despite this movement, the commercial exploitation of the *monte comunal* aroused economic interests among many *comuneros* by changing their perspective from one of collective benefit to one of individual benefit[91]. This, along with immense waves of urbanization, represents a new challenge for the social institutions today.

6.5. Discussion

This research showed that community members of Milpa Alta and San Juan Tlacotenco have knowledge at two primordial levels: practical, at the level of grassland

[90] Focus group, summer 2001; Milpa Alta town.
[91] Key informant interview PCH and focus group, summer 2001; Milpa Alta town.

plants and grassland management systems; and cultural-political, expressed both at the levels of communal resource access and utilization, as well as of the historical struggles undertaken for land defence and conservation. Analysis of these knowledge systems have clear impacts on the conservation of communal grasslands and as a consequence on SMS habitats needs.

6.5.1. Use of grasses and SMS conservation

In general local *comuneros,* and particularly herders, retain a rich ethnobotanical knowledge on the taxonomy and use of several grass species, as do other traditional pastoral communities (Brown, 1997; Osunade, 1999; Kepe and Scoones, 1999; Fernández-Giménez, 2000). Grasses represented an important forage appreciated by herders, but were also a source of diverse materials and products of economic and cultural importance. These data suggest little conflict of interest between grass use and the conservation requirements of the SMS. In Chapter 4, it was found that approximately 90% of SMS' nests were constructed on the grass Xoleman (*F. lugens*). In contrast, the two grass species actively used by *comuneros*, Calzacatl and Zacayemanqui are not selected by the sparrow for nest location (with the exception of a small percentage located in intermixed Xoleman and Calzacatl plants). Therefore, the extraction of spikes and roots from Calzacatl and the high preference of livestock for Zacayemanqui do not compromise the availability of SMS' nesting structures.

These results should be taken with caution since a massive extraction of spikes or plants (in the case of root extraction) could reduce grassland cover and plant height, thereby impacting the SMS's nesting requirements at the patch scale (see Chapter 4). A second concern could arise if herders were to eliminate the Xoleman grass, which is poisonous to livestock but crucial for the nesting and production of successful clutches by SMS (Chapter 4). Nonetheless, there were no testimonies, physical evidences or plans to eliminate or control this species, nor does massive extraction of grasses appear to be a concern at the present time.

6.5.2. Grassland management and SMS conservation

While it is reasonable to conclude that the current use of grasses poses no threat to SMS conservation at the patch scale, the management of grasslands at the landscape scale is of more concern. Data from Chapter 4 and 5 sugest that Xoleman plants may require a three year period of fire exclusion and a reduction of grazing pressure to establish a grassland cover which adequately conceals SMS nests. This indicates that the nature of the fire regime in particular and of the grassland management system in general (i.e., fire rotation and grazing pressure) are especially important for maintaining the SMS's breeding habitat across scales (see Pons et al., 2003; Sample et al., 2003 for similar findings with for example grassland birds from USA).

The findings on TEK for grassland management indicate that the "free grazing system" provides the conditions needed for the SMS habitat. This is achieved through the constant rotation of grassland patches for grazing and the use of the *quemando por tramos* fire regime. Furthermore, the rotative aspect of the system appears to be promoted by the dispersed spatial distribution of ranchos, towns and watering points, and of the herders' paths and herd locations (see Copolillo, 2000). Overall, these characteristics of the grazing system correspond to some of the general principles of sustainable communal pasture management, principally those on maximizing the efficiency of grazing and livestock condition (weight gain) without depleting the forage resource (Niamir-Fuller, 1990; Bojórquez, 2000; Primavesi and Primavesi, 2002; Fernández and Swift, 2003; Hoffman, 2004).

However, despite the apparent compatibility between the free grazing system and SMS habitat, field observations (Chapters 5 and 6) indicated that these principles of grassland management are not equally applied throughout the landscape, with important consequences for SMS conservation. In the southern grasslands of Milpa Alta-San Juan Tlacotenco, more traditional practices prevail. Here, *quemando por tramos* creates a mosaic landscape in which livestock can graze green patches, while other grassland areas recuperate from fire and suffer less grazing pressure. As a result, suitable SMS nesting habitat was found in this region (Chapter 4).

In contrast, in the north, particularly in the Milpa Alta-San Salvador Cuauhtenco region, the traditional free-grazing system is being altered by diverse actors, perspectives and interests (see next section of this discussion for details on the fire conflict). The grasslands show signs of deterioration, including smaller and fragmented grasses, frequent *rescoldos* and loss of *Festuca lugens*, the main breeding structure selected by the sparrow. This has reduced the availability of suitable breeding habitat for the SMS, where no nests were found in the annually-burned grasses (Chapter 4).

These findings suggest that traditional grassland management practices incorporating *rolando el fuego* and herd mobility need to be maintained in order to generate suitable SMS nesting habitat needed for the species to increase its breeding performance (Chapters 4 and 6). As a consequence, conservation actions should target fire management practices at the landscape scale in order to ensure SMS survival. This will require balancing the extent of the different grassland conditions and the grazing pressure. Having greater areas of preferred SMS breeding habitat than that registered in this study would certainly increase the density of breeding pairs and the reproductive success of the species. In addition, as high livestock density was of concern for local participants, lowering it, principally for a period after the *chamusquina*, would reduce the grazing pressure and allow a better post-fire recovery of grasses (Benítez-Badillo, 1987; Morgan and Lunt, 1999; Watkinson and Ormerod, 2001; Gordon, 2000; Wahren et al., 2001).

The implementation of such recommendations could lead the system towards a more sustainable state with positive effects on grassland conservation and associated biodiversity as reported in diverse grassy ecosystems across the world (Lewis, 1982; Calder et al., 1992; Turner, 1999; Brockett et al., 2001; Stuart-Smith et al., 2002; Bowman, 2002; Herrando et al., 2003). However, as discussed in the next sections, successful implementation of these conservation measures will be a challenge due to the complexity of perspectives and actors involved in the local land management.

6.5.3. Social institutions and political ecology: possibilities and pressures for community-based SMS habitat conservation.

6.5.3.1. The use of fire: confrontations between traditional knowledge and official paradigms.

One of the main threats to the traditional-free grazing system is the "anti-fire" narrative promoted by a number of environmental government agencies active in the region and elsewhere in rural Mexico (Pyne, 1998; Mathews, 2003, 2005). The main managers of the grasslands have been condemned and in a certain way marginalized by the dominant anti-fire ideology, being blamed as enemies of the forest and incendiarists causing environmental degradation as it has happened in other regions (Morrison et al., 1996; Bollig and Schulte, 1999; Niamir-Fuller, 2000; Bowman and Vigilante, 2001; Moore et al., 2002; Kerven, 2003; Kull, 2002a). As a consequence, herders in this study claim to be ready to abandon this traditional activity if needed or requested. Such an outcome would have a highly negative impact on grassland maintenance and on SMS conservation by the eventual extirpation of this socio-ecological component of the system (Walker and Abel, 2002; Pons et al., 2003; Berkes et al., 2003).

A second problem with the anti-fire narrative is that the intervention of CORENA in prescribing and controlling fires but especially in criminalizing fire use, seems to have caused resistance from herders who "*by continuing burning defend their right to this land management tool*" (Kull, 2004; p.184). Excessive fires can also be both a manifestation of possession and control over contested resources (the land tenure conflict) as well as an expression of discontent against unsuitable external managerial practices such as tree plantations, which can be used by outsiders to claim land (see Unruh, 1995a, p.223). Finally, the natural context has played its role in feeding and shaping the fire conflict as well. Grasslands provide the natural background where fire's anonymity and self-propagation can occur (Kull, 2000, 2002a, b).

A call for a demystification of adverse fire effects and for a better understanding of the underlying causes of environmental degradation has been made (Benítez-Badillo, 1989; Pyne, 1998, 2001b, 2004; Fernández-Giménez, 2002; Kull, 2002b; Rodríguez-Trejo and Fulé, 2003; Rodríguez, 2004; Mistry et al., 2005) with the aim of generating more integrative and legitimate scenarios of fire use. To this end, empowerment of local users by establishing community-based management alliances has been suggested (Meredith, 1998; Niamir-Fuller, 2000; Moore et al., 2002; Keith et al., 2002; Kull, 2004; Mistry et al., 2005). Such changes in policies governing fire use and management are clearly necessary for the promotion of grassland and SMS conservation in Milpa Alta.

6.5.3.2. Impacts of land tenure on grassland management and conservation

In addition to changes in the fire-regime, insecure land rights is a second factor which has led to substantial pressures on grasslands in Milpa Alta. Studies from diverse parts of the world showed that insecurity in property rights promotes open access to resources causing environmental degradation (Unruh 1995b; and Unruh, *personal communication*; O'Flaterty, 2003; Nygren, 2004; Segura, n/d;). Consistent with this, data from this thesis shows that, on a regional scale, land tenure disputes have led to problems of land speculation, agricultural expansion, commercial forest exploitation and urbanization, as well as the conversion and fragmentation of grasslands.

Despite this overall result, an interesting paradox regarding the role of land tenure conflicts and the state of conservation-degradation arises when considering the contrasting ecological outcomes of the disputed areas in the Milpa Alta-San Salvador Cuauhtenco and the Milpa-San San Juan Tlacotenco's areas. In the first case, the agriculture frontier has expanded at the expense of grasslands and forests, in conjunction with heavy pesticide use and illegal logging. Furthermore, frequent fires over spatially limited areas are leading to grassland fragmentation, deterioration of tussock structure and changes in species composition that limit SMS's breeding habitat (Cabrera et al., 2006). In contrast, the Milpa Alta-San Juan Tlacotenco's contested area has not suffered drastic land use changes because it is actively used by San Juan's pastoralists for livestock rearing. These grasslands are considered the most important in the world for SMS survival (Cabrera et al., *op cit.*).

This suggests that land tenure conflicts can cause environmental deterioration by land use change and intensification of practices when land tenure limits are unclear and highly contested land is controlled by one of the groups (San Salvador Cuauhtenco); or environmental conservation, as in the case of San Juan Tlacotenco-Milpa Alta, when tensions are lower and herders have used the land under customary tenure in a more flexible, freedom of movement, low cost activity, such as pastoralism (Köller-Rollerfson, 1993; Niamir-Fuller, 2000; Blench, 2001; Fernández-Giménez, 2002).

From a conservation perspective and in agreement with Alcorn's (1995) first recommendation to transit to sustainable conservation scenarios, this finding suggests that the resolution of the San Salvador Cuauhtenco-Milpa Alta tenure conflict should be given priority. Furthermore, any future conflict resolution should pay extreme attention to the potential environmental consequences since perspectives on land and land use among San Salvador Cuauhtenco's *comuneros* (i.e., commercial agriculture, intensive livestock production) contrast with those of Milpa Alta (i.e., pastoralism, gathering of NTFP's, conservation) (CEHAM, 1992; Cousineau, 2002; Gómezcesar, 2005; Espinoza, 2005).

6.5.3.3. Social institutions: resilient mechanisms for grassland conservation

Comuneros have developed and enforced diverse principles that characterize long-enduring common property institutions, principally those related to land defence, access and regulation on the use of resources for its conservation (Weinberg, 1996; Rosas, 1997; Alcorn and Toledo, 1998; Chapela, 2002; Concheiro, 2003; Tucker, 2004).

The interest in conserving the *monte* is based on the historical memory of being *originarios* and *comuneros,* who under the mandate proclaimed in the *Titulos Primordiales* have promised to defend the land with their own lives for the benefit of future generations (Gómezcesar, 2005). This shared historical vision of ethnicity and community constructed from the *monte*, although mostly aimed at strengthening land defence against outsiders, is recognized as valuable social capital with important implications for collective action and ecosystem resilience (Russell, 2003). In this way, "*conditions may develop to favour the development and consensus of rules for management of the commons*" (Merino, 2004, p. 286). Consistent with this, *comuneros*, through the Communal Representations, have regulated access and uses from communal resources only to community members, as evidenced by activities such as patrolling and monitoring, grassland partitioning and norms controlling the use of wood.

Although these elements correspond with the principles of successful institutions (Ostrom, 1990; Leff and Carabias, 1993; Colding et al., 2003; Tucker, 2004), the findings also revealed periods of weak institutions due to particular historical and political contexts, principally those related to land disputes and contrasting perceptions on the use of fire. There were also clear evidences of free access and overexploitation of forest[92] and non-forest resources of high importance for local livelihoods and ceremonial-cultural practices. In parallel with erosion of TEK, these weaknesses can represent an initial episode of the tragedy of the commons (Hardin, 1969; Dietz, et al., 2003).

The SMS's habitat has benefited from the existence and enforcement of such social institutions that have played a role on limiting external intrusions and drastic land-use changes and the continuation of traditional pastoral activities. Particularly herders' agreements for grassland partition may play a role on the conservation state of grasslands as documented in other Mexican grasslands (Sluyter, 2000; Lazos, 2001; Aguilar et al., 2002; Guillén et al., 2002; Quintanar, 2004) and elsewhere (Fernández-Giménez, 2000; Banks, et al., 2003). Undoubtedly, strengthening of *usos y costumbres*, social organizations and regulatory mechanisms over these domestic resources' use is strongly recommended to approach more sustainable community-based management scenarios (Berkes et al., 2000b; Wilshusen et al., 2002; Dolšak and Ostrom, 2003; Merino, 2004).

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[92] La Jornada, consulted 2006/03/09
http://www.jornada.unam.mx/2006/03/09/049n1cap.php

6.6. Conclusion

The SMS conservation is challenging. In spite of its current endangered status and diverse declarations calling for its conservation, effective measures have not been adopted and the species' habitat is vanishing (Cabrera et al., 2006; and see Brooks et al., 2002 and Herkenrath, 2002 for additional discussion on species lost). The interest in conserving this species has required a more complete interdisciplinary understanding of the social, cultural and political aspects influencing the conservation-degradation state of the habitat it depends on for its survival.

This research has given the opportunity to learn that communities of Milpa Alta and San Juan Tlacotenco have conserved the grasslands and associated native species through traditional management practices and social institutions (Dietz et al., 2003; Tucker, 2004). Such practices are crucial for conservation of the SMS and deserve recognition and further consideration within local conservation efforts (Gadgil and Berkes, 1993; Gilchrist et al., 2005). However, this study also showed that SMS habitat is threatened by an anti-fire paradigm that labels local users as enemies and forests as victims (Simsik, 2002), and by a land tenure conflict that plays a role in the conservation-degradation state of the grasslands.

The conservation of the SMS requires policies and managerial efforts at diverse social-ecological levels, including the variety of actors and interests depicted in this study (see Alcorn, 1995, Gibson, et al., 2000; Brown, 2003; Barton-Bray et al., 2003). The decriminalization of fire use, the resolution of the Milpa Alta-San Salvador Cuauhtenco land tenure conflict, the strengthening of local social institutions and the empowering of community-based organizations for collective resource conservation are here recommended as priority actions for the longe term conservation of this unique and particular bird species.

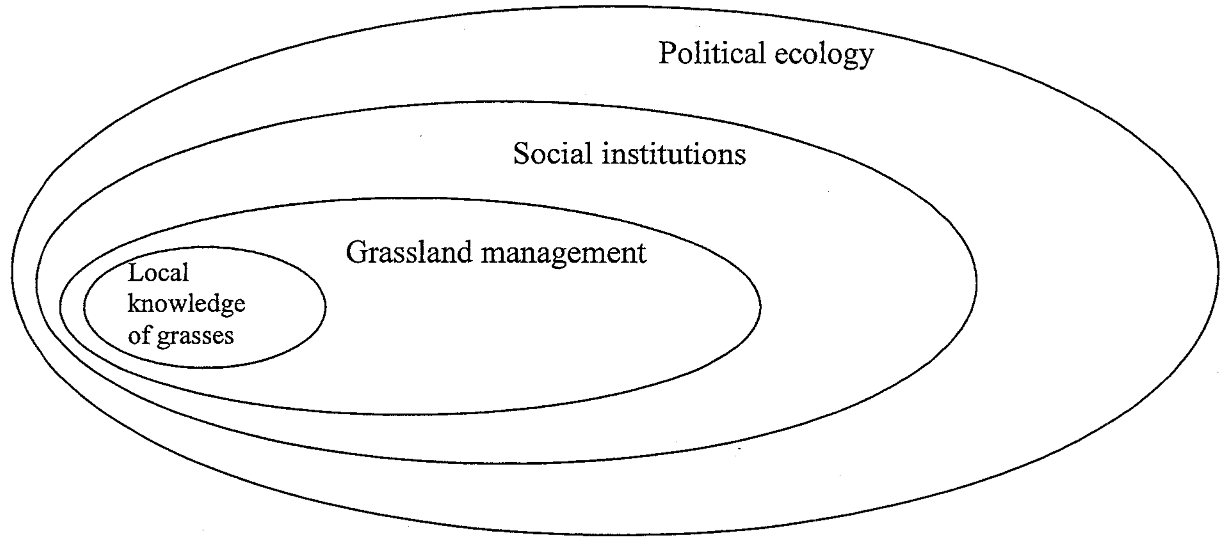


Figure 6.1. Conceptual theoretical model of TEK analysis in this research. Modified from Berkes (1999, p.13).

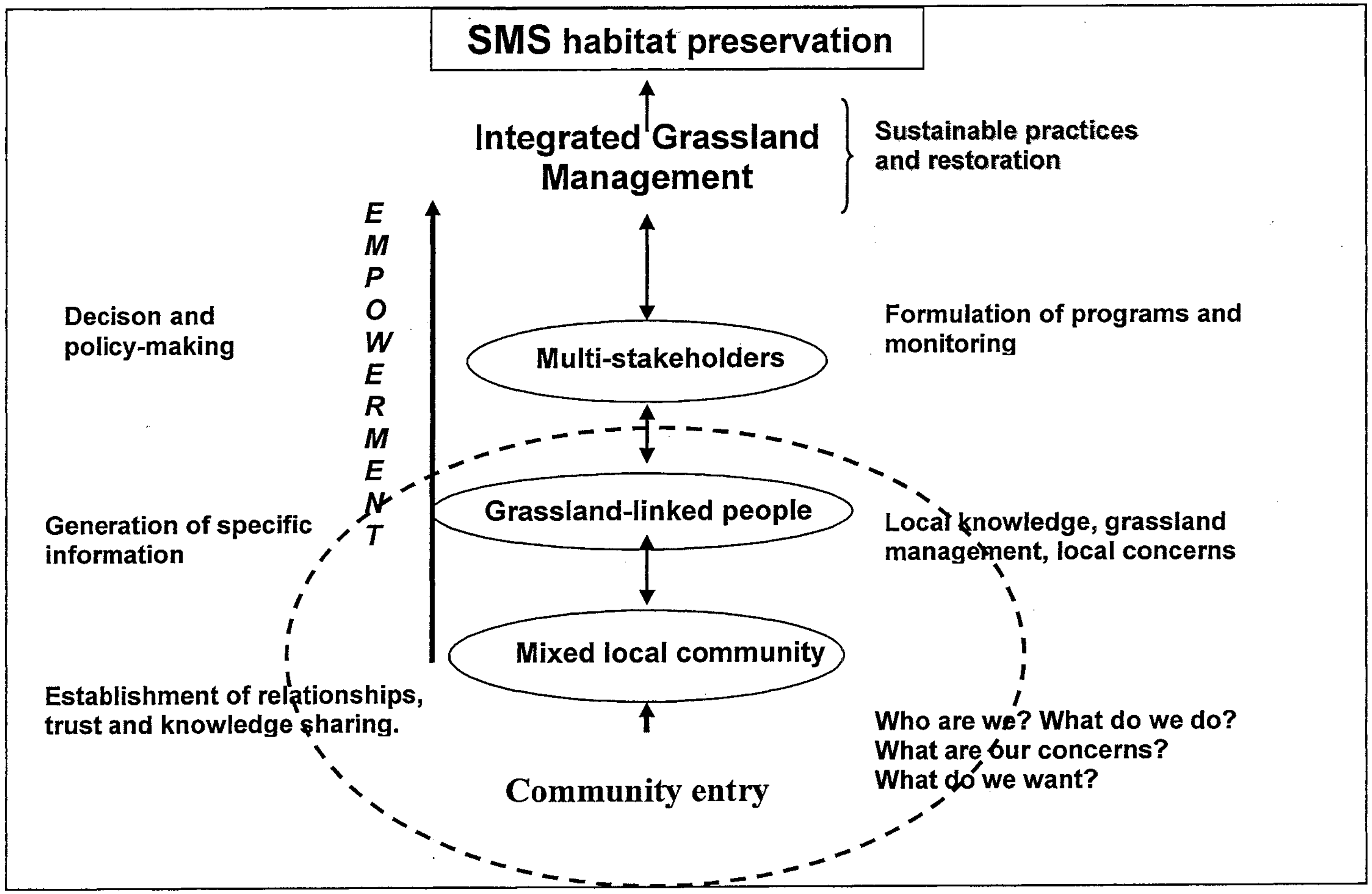


Figure 6.2. Global conceptual-methodological model followed in the study. The doted circle shows the stage achieved in this study.

Table 6.1. Bunchgrass species recognized and classified by *comuneros* of Milpa Alta and San Juan Tlacotenco[1].

Local and scientific names	**Relevant distinguished characteristics**	**Abundance status and distribution**	**Main uses**
Zacahemanqui; *Pelillo*. *Muhlenbergia quadridentata*	It is classified as a warm and soft grass.	It is considered to become rare; it was more abundant before and easy to find.	Forage highly appreciated by herders. Main use is forage for sheep and cattle. Broom elaboration and filling for packages are secondary uses.
Calzacatl; Zacahuapac; Malinal; Zacacoyotl; *Zacate de casa* *Muhlenbergia macroura*	It is sweet; warm.	It is considered abundant and widely distributed.	Forage of regular quality for sheep and cattle. Leaves are important source of raw material; roots are extracted for elaboration of brooms and *escobetas*; spikes are used to produce crafts.
Xoleman, Xoliman, *Navaja*; *Hierba mala; hierba brava*. *Festuca lugens*	It is classified as cold, hard and poisonous grass for the cattle.	It is considered to become more abundant and widespread.	Forage of bad quality. It is suitable only after a period of time (1-2 weeks) of being burned (*no muy tierno*). It is used as raw material for roofs.
Plumero (a). *Stipa ichu*	It was not mentioned as of importance for animals.	It is rare in the study area; but some plants were registered near to the agricultural fields.	The spikes are used for ornamental purposes.

[1] The species are ordered from very good and desirable species at the beginning of the table, to those considered toxic and undesirable at the bottom.

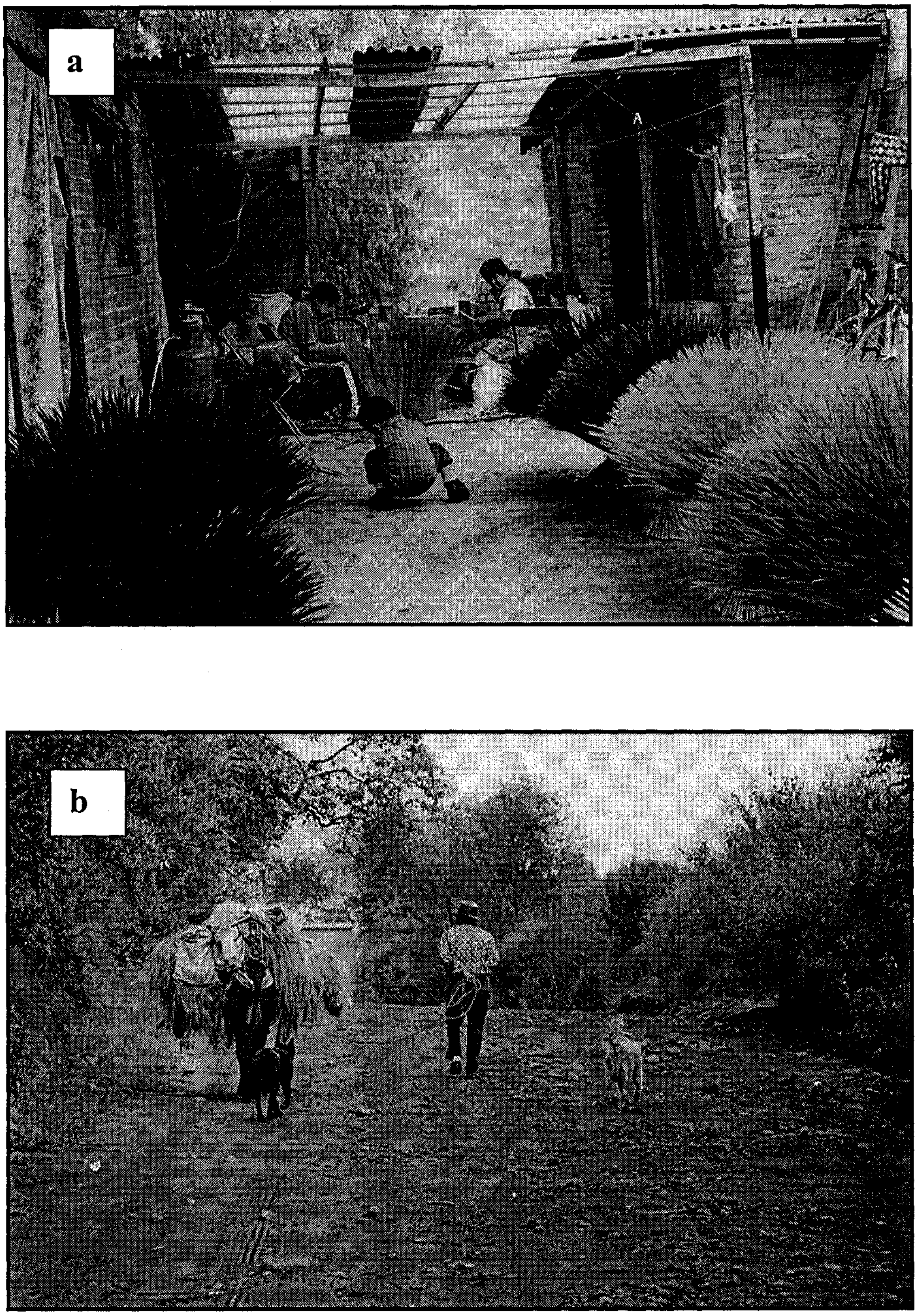


Figure 6.3. Traditional uses of grasses by *comuneros* of Milpa Alta. (a): A family of Milpa Alta works in their home preparing crafts from Calzacatl (*Muhlenbergia macroura)* spikes. (b): An elder from San Pablo Oztotepec (Milpa Alta) transports leaves from Calzacatl as raw material. Photographs: L. Cabrera, 2001.

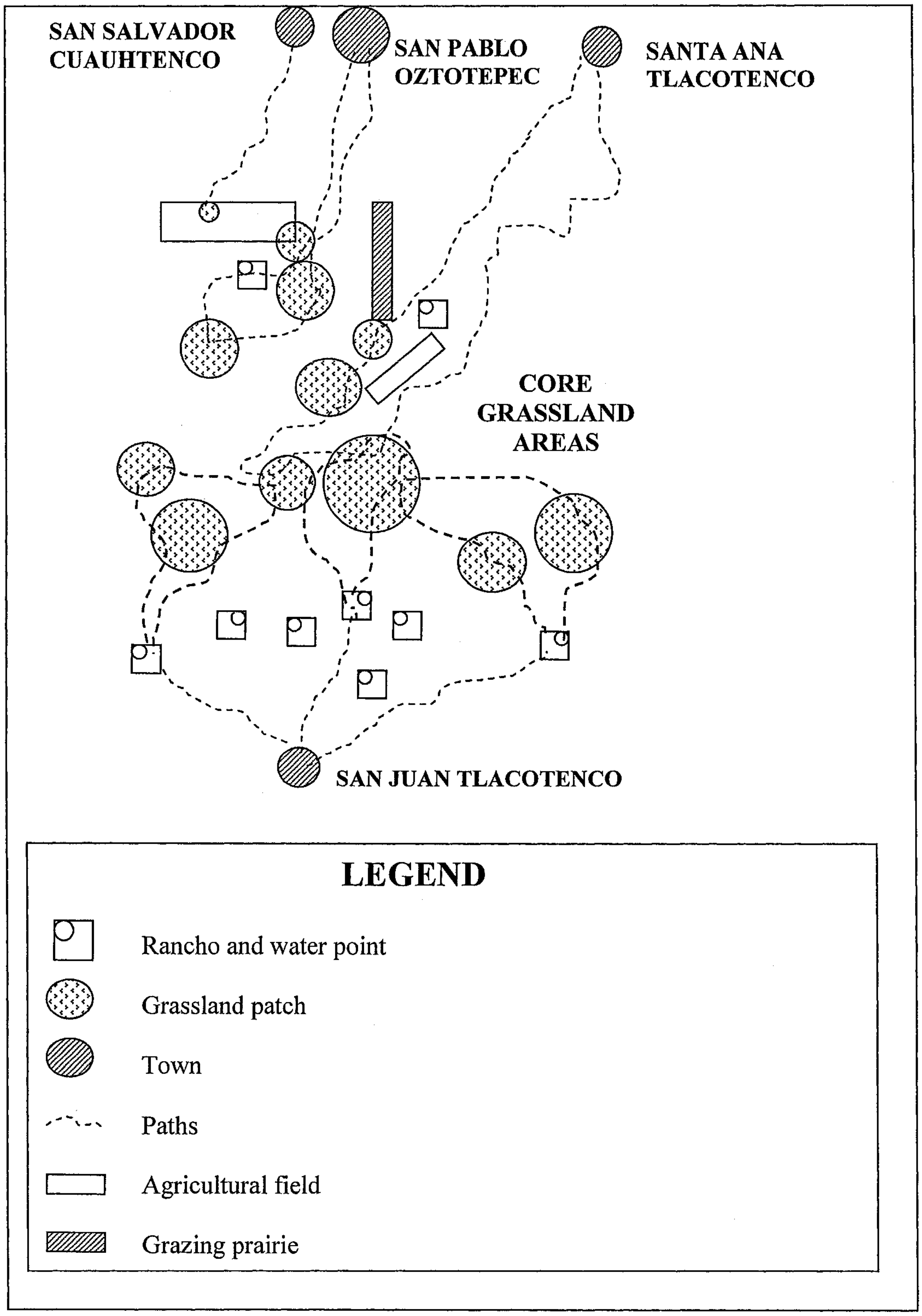


Figure 6.4. Schematic representation of the grazing system employed by the Milpa Alta-San Juan Tlacotenco's herders. Paths are based on observations, shared journeys and interviews.

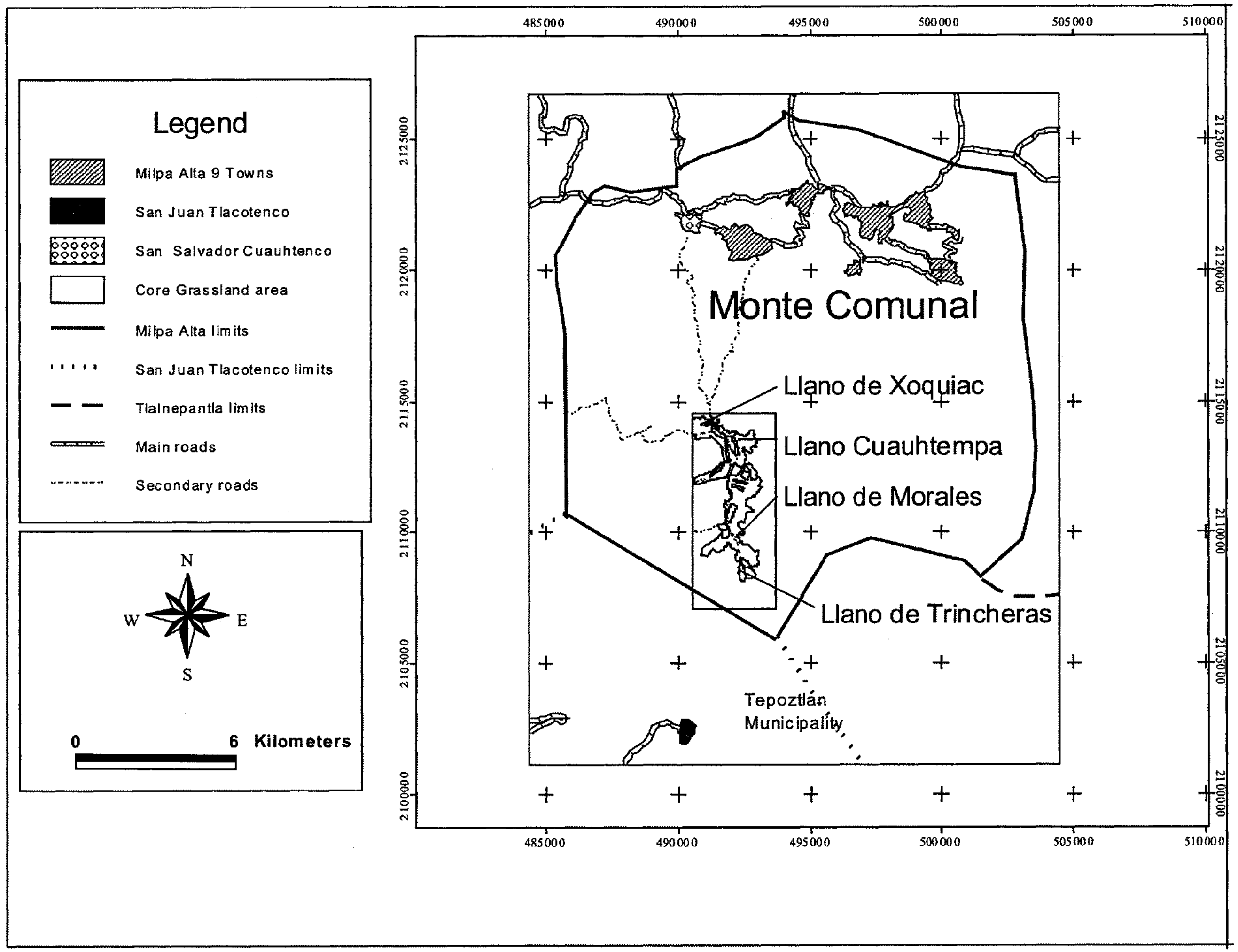


Figure 6.5. Location and traditional names of "llanos" in the Sierra Madre sparrow's habitat.

Figure 6.6. *Chamusquina* in Llano de Cuauhtempa, Milpa Alta, Mexico. Photograph: Leonardo Cabrera, 1999.

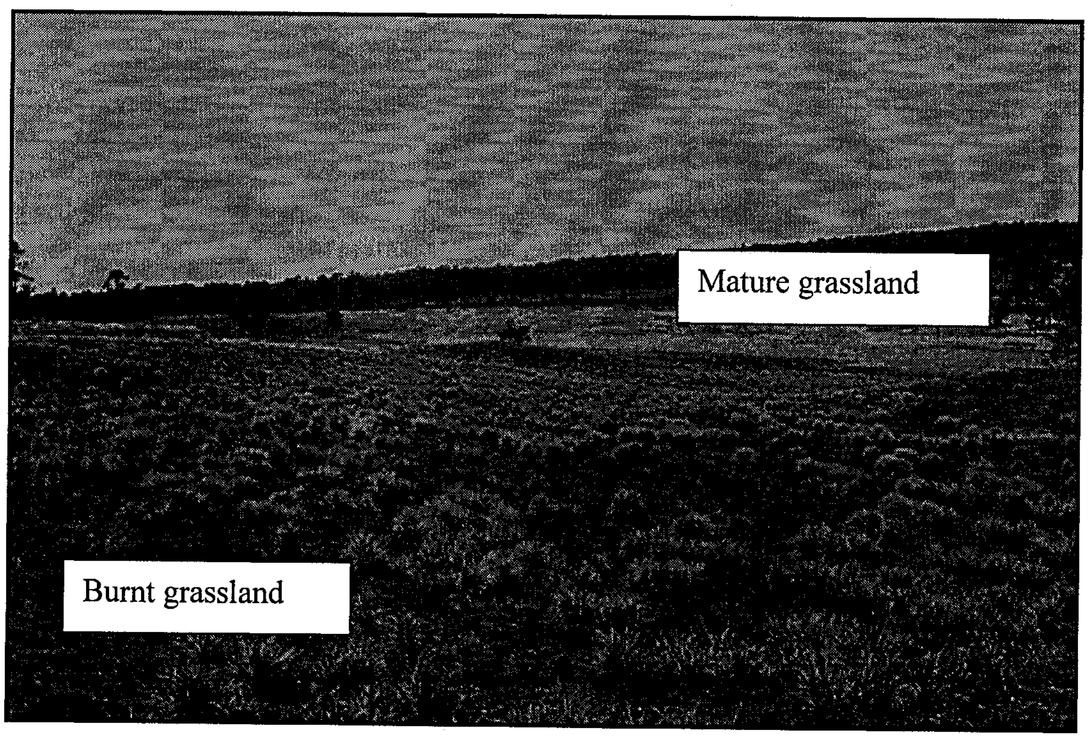


Figure 6.7. Grassland mosaic produced by the practice of *rolando el fuego* or *quemando por tramos* at Llano de Morales, Milpa Alta, Mexico. Photograph: Leonardo Cabrera, 2001.

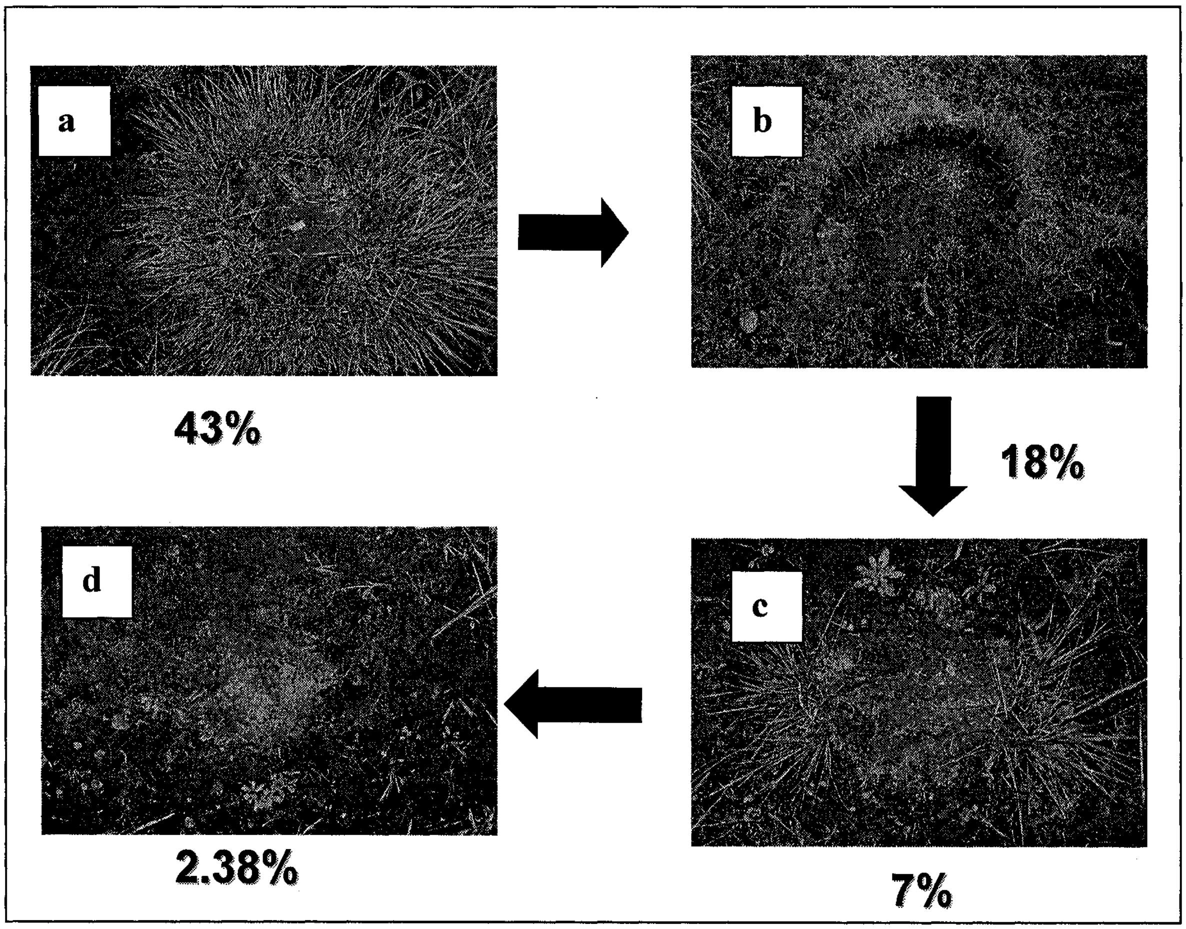


Figure 6.8. Evidences of grassland fragmentation at Milpa Alta-San Juan Tlacotenco's communal lands. Pictures from **a** to **d** show the fragmentation degree of plants observed and the % of plants found in each category. **a** indicates plants with 50% of fragmentation; **b** indicates 75%; **c** indicates 90 %; and **d** shows the plants found death with evidences of *rescoldo.* Photographs: Leonardo Cabrera, 2002.

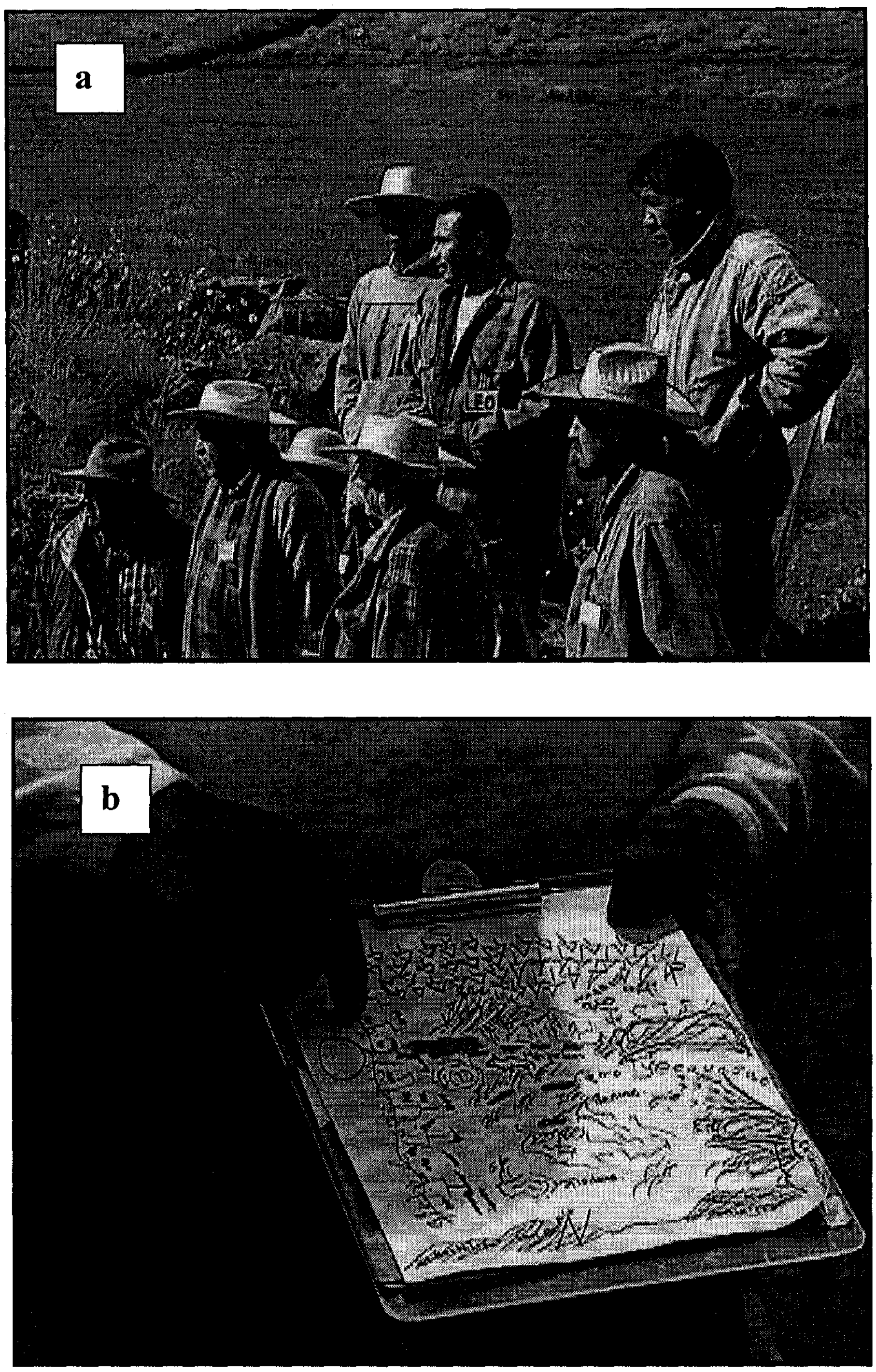


Figure 6.9. **a**. Oral histories on land defence and conservation exposed by *comuneros* of Milpa Alta at the disputed area with San Salvador Cuauhtenco. **b**. Map drew by *comuneros* showing Milpa Alta's communal lands limits and landscape features at Llano de Morales, Milpa Alta. Photographs: L. Cabrera, 2001.

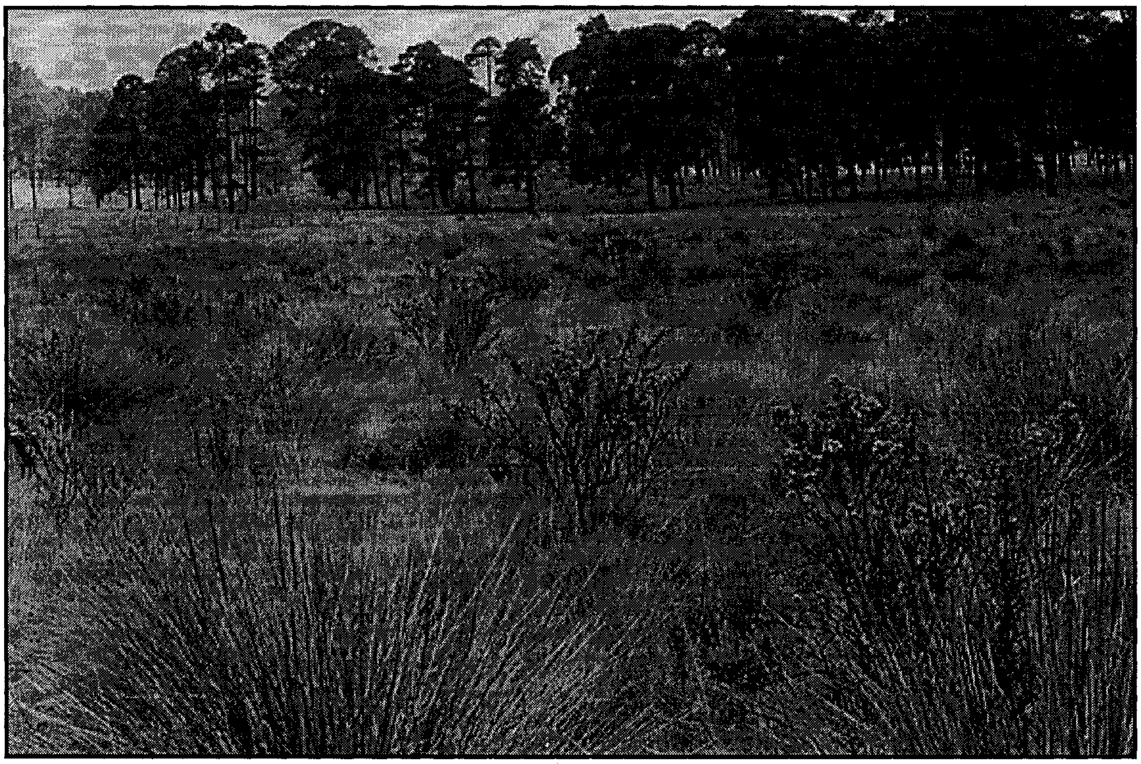
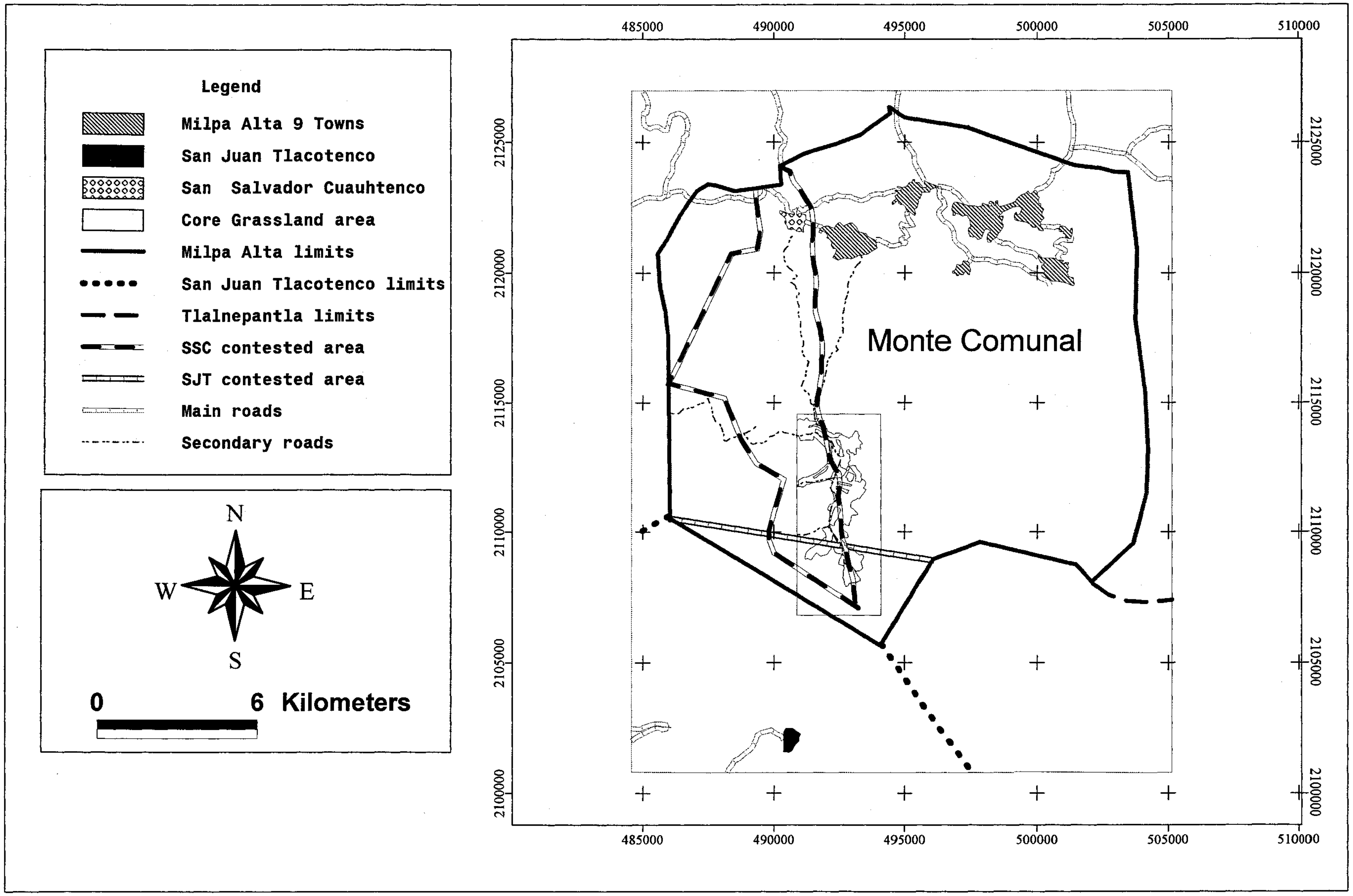


Figure 6.10. Fenced grassland area managed by Milpa Alta's *comuneros* to avoid fire and grazing impacts and protect forest succession. Photograph: L. Cabrera, 2001.

Figure 6.11. Location of areas under tenurial conflict (Milpa Alta-San Salvador Cuauhtenco-San Juan Tlacotenco) on relation to the core distributional area of the Sierra Madre sparrow's habitat.


Legend
Milpa Alta 9 Towns
San Juan Tlacotenco
San Salvador Cuauhtenco
Core Grassland area
Milpa Alta limits
San Juan Tlacotenco limits
Tlalnepantla limits
SSC contested area
SJT contested area
Main roads
Secondary roads
N
W
E
S
0
6 Kilometers
Monte Comunal
485000
490000
495000
500000
505000
510000
2125000
2120000
2115000
2110000
2105000
2100000

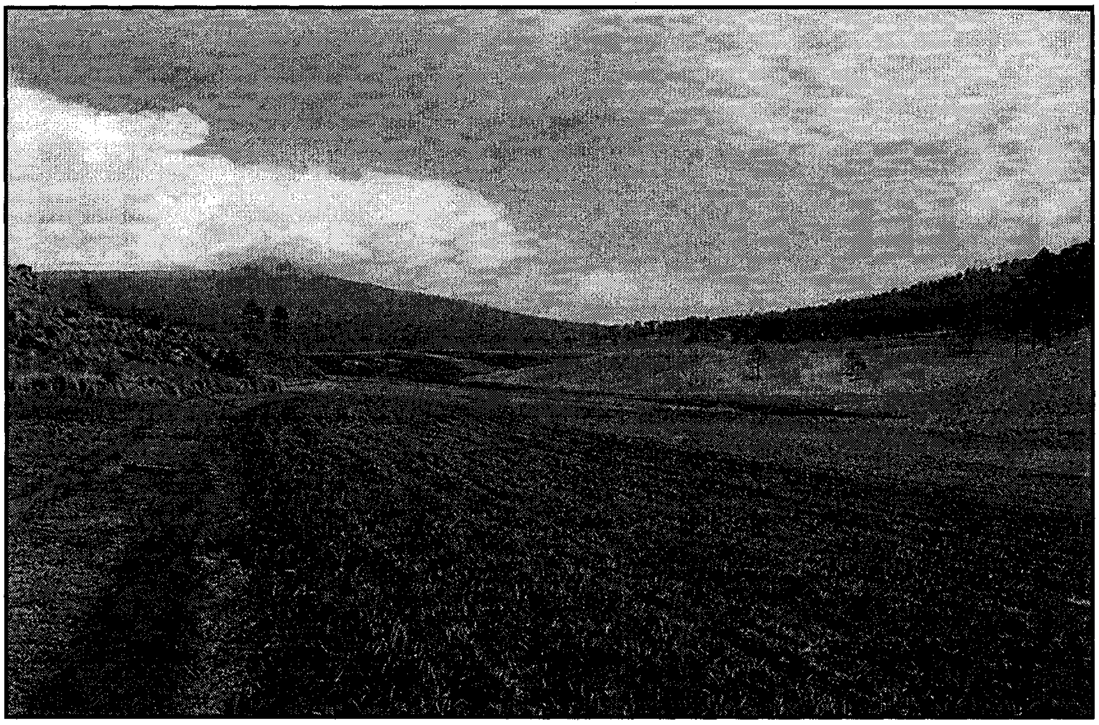


Figure 6.12. Land use change on the Milpa Alta-San Salvador Cuauhtenco disputed area. Extensive agricultural land had eliminated native grassland. Photograph: L. Cabrera, 2001.

CHAPTER 7

THESIS CONCLUSIONS

This thesis has examined comprehensively the conservation situation of the Sierra Madre sparrow in the last known of it refuges in Central Mexico. The SMS is vanishing because of loss and degradation of habitat, two factors mentioned repeatedly in the scientific literature as main catalysts of species extinction (Fahrig, 2000). Understanding the ecological impacts of these processes has required natural science investigations, but understanding the causal factors, and the options for conservation initiatives, has required social science investigations of factors related to land use, land users, and livelihood options.

This broad perspective allows an integrated examination of habitat changes and of land conservation, and can lead to proactive conservation planning and more efficient implementation of actions. It is from this perspective that the core argument of this thesis was established and the three overall goals were reached. First, Chapter 4 examined the bird's response to human-induced modifications of its habitat; second, Chapter 5 aimed to understand the impacts of local land use practices on the species' habitat integrity and recovery dynamics, and finally, Chapter 6 looked at the social, cultural and political dimensions of habitat management and conservation by uncovering factors that have facilitated the maintenance of this habitat, but also of those that are threatening its permanence.

This chapter summarizes the thesis findings and presents an integrative model synthesizing them. Future research directions are considered at the end of this chapter.

7.1. Chapter summaries

Chapter 2 presented the critical situation of the species in light of external and internal pressures that claim its habitat for new uses (agriculture, urbanism), and reduce remaining habitat quality through intensification of traditional practices (burning and grazing), fire suppression for forest conservation and tree plantation (Cabrera, et al., 2006). Because it occupies a reduced and fragmented habitat that is actively managed for extractive purposes, the species may rapidly collapse unless appropriate measures are taken.

While Chapter 2 underlined the species' conservation situation, Chapter 3 exposed the ecological, historical, and cultural context of the SMS' habitat, broadening the perspective on the species' conservation problem. It is clear from this chapter that the SMS's habitat is anthropogenic and that the local indigenous communities of Milpa Alta and San Juan Tlacotenco have played a critical role in maintaining the habitat by practicing their traditional land use and resource management through centuries. The communities posses a rich traditional ecological knowledge and have an historical relationship with the land that position them as key stewards of this cultural landscape and important potential contributors to the conservation of the SMS.

However, Chapter 3 also showed how official conservation authorities have over-looked traditional resource management practices, cultural values and the needs of the local communities while imposing protectionist measures targeting forest conservation. This results in social conflicts and environmental degradation. A similar situation was described by Mathews (2003) for Oaxaca, Mexico.

Chapter 4 explored how pastoral practices in the Milpa Alta-San Juan Tlacotenco area may impact the likelihood of survival of the SMS by examining a key process for avian demographics, that is, nest site selection and breeding success (Martin, 1993). This chapter makes an important contribution to the ornithological and conservation literature in two ways. First, it adds empirical evidence to the debate on bird nest-site selection by showing that SMS favour breeding sites that may offer protection from predators and adverse environmental conditions. This finding supported the three hypothesis explored (Martin, 1993; Liebezeit & George, 2002; Stephens et al., 2003) which state that birds select safer sites in response to habitat variability at different scales and a selective regimen driven by predation.

Second, this chapter provided specific habitat management recommendations at the three spatial scales studied. By using a multi-scale approach, meanigful conservation recommendation were produced by identifying a series of interlinked environmental conditions which can favour the species' breeding performance and population dynamics. Because these conditions are produced by the pastorals' rotational system, this study evidenced the positive role of cultural practices and managed ecosystems for biodiversity conservation.

In Chapter 5, I examined the impacts of burning and grazing -- the two main activities practiced over the grassland for pastoral purposes -- on structural landscape attributes and on vegetation conditions that are of primary importance both for the SMS nesting success and for the continuation of local livelihood activities. The analysis reveals that current practices are having a significant impact on the landscape integrity and the spatial dynamics of this ecosystem. By using the traditional rotation of fire and grazing, local herders create mosaics of different grassland successional states that achieve diverse ecological and cultural-economic purposes. Land use rotation in Milpa Alta-San Juan Tlacotenco can be considered as a social-ecological practice based on traditional ecological knowledge that increase landscape heterogeneity, and whose main purpose is to create patchiness for the extraction of multiple resources (Berkes, et al., 2000, p. 1254). The SMS and other grassland-dependant species –including the endangered Volcano Rabbit, *Romerolagus diazi*-- benefit from this disturbance management regime that maintains and renews their habitat at landscape scale.

Hence, this analysis helped me find an answer to one of my original questions. The SMS still exists in this part of its range because its habitat has been and remains important for local communities' livelihoods and is maintained by them. This highlights the cultural-ecological linkages that must be considered in the development of integrative conservation scenarios.

Resource rotation has been reported as a sustainable succession management practice used by diverse indigenous groups of the world (Gómez-Pompa and Kaus, 1992; Alcorn, 1993; Berkes, et al., 2000b; Toledo et al., 2003; Colding, et al., 2003; Eastmond and Faust, 2005). However, in pastoral ecosystems diverse factors related to the grazing system may compromise the resilience of the environment (Niamir-Fuller, 1999). This chapter also revealed some characteristics of the current Milpa Alta-San Juan Tlacotenco's resource rotation system that may threaten grassland maintenance and, consequently, the SMS. Primarily, the size of the mosaic's constituent patches was uneven as large areas of grassland were burned to create extensive feeding patches for livestock, and small areas of unburned vegetation remained as small and isolated patches.

It thus appears that the rotational system used now in this region intended to maximize forage production at a cost to other resources. This may not have been the case in the past, but recent population growth and economic changes have likely led to an increase in fire frequency and extent. This habitually leads to landscape homogenization and overexploitation, and may hamper long-term resilience.

The analysis in chapter 5 also explored the resilience capacity of grasslands by measuring post-disturbance response. Grasslands responded vigorously to burning by growing back quickly. This matched local people's TEK and is the foundation of their justification for land management practices. However, the study identified that grassland recovery after fire was not complete within a year potentially because grasses are subjected to a sustained grazing pressure. According to specialized literature on grasslands resilience, if the system is recurrently disturbed before being able to fully recover, for example because of land use intensification or land use change, it may gradually take longer to reach a mature stage, loose some biophysical functions (e.g., soil protection; rainfall-use efficiency) and experience changes in species composition. Jointly, those factors diminish the ecosystem resilience on the long term (Walker and Abel, 2002).

From chapters 4 and 5 important habitat management recommendations have emerged aimed at the conservation of the SMS, but how can these recommendations take place? While in Chapters 4 and 5 I identified important dimensions of grassland management that affect the SMS, it is clear that conservation action will not succeed if the social dimension of this system is not understood and integrated (Meredith, 1998; Potvin, et al., 2001). This dimension was considered throughout this research, and results are synthesized in Chapter 6. By analysing local people's ecological knowledge of grassland management, cultural values and perspectives and interests in the conservation of this land, this chapter gave voice to local communities and helped show how they may affect, and be affected by, external conservation interests and actions (Rakotovao, et al., 2001). The chapter attempted to integrate valuable local knowledge and perspectives in the development of such grassland management recommendations with biological and social objectives (Berkes, et al., 2000a). Hence, communities' participation at all the decision-making levels is recommended (Alcorn, 1995; Zazueta, 1995).

The main findings of Chapter 6 unveiled the historical roots and current expression of land conservation by the indigenous people of Milpa Alta-San Juan Tlacotenco. Similar histories have been presented by Warman (2003) and Toledo (2003) for other regions of in Mexico. This chapter showed Milpa Alta-San Juan Tlacotenco's *comuneros* as inheritors of a rich cultural legacy and ethnic identity that ties them to their communal territory, to the *monte comunal*. Their deep sense of land ownership and defence is nurtured by the Primordial Titles, a historical memory that has enable these communities to develop community-based organizations and social institutions aimed at preserving the communal territory (Wood, 1991, 1998; Florescano, 2000; Hasket, 2004; Gómezcesar, 2005). This chapter also suggested how through powerful traditions in the shape of *usos y costumbres*, *comuneros* may have learnt and adapted to changing conditions to better use and protect local resources (Berkes, et al., 2000a). Hence, I argued that history and tradition may confer social resilience to this system that, linked to the ecological resilience of grasslands, may help to explain the state of conservation of this cultural landscape and the unusual persistence of the endangered SMS on these lands.

However this chapter also raised an interesting paradox regarding the factors and actors affecting the fragile balance between conservation and degradation of this land. While local organizations, institutions and traditional grassland management practices, under the figure of pastoralism, pursue the first, internal (land tenure conflicts) and external pressures (land use change-intensification and official conservation actions) have initiated the second. In this context, fire, which is the main renovator force of grassland, has been given the opposite reputation by the conservation authorities, who claim fire is an enemy of forests and condemn peasants as irresponsible and incendiarists.

The land tenure and fire use conflicts in the Milpa Alta-San Juan Tlacotenco communal lands pose a threat to the social-ecological resilience of this grassy landscape. Since these conflicts occur principally over the SMS' habitat, influencing its spatial and temporal dynamics, the conservation actions suggested in this thesis may proceed only if these conflicts are resolved. It is hoped that this information will help with that resolution.

Based on the main findings of this thesis, it appears that there are three avenues the SMS' habitat may take (Figure 7.1). The resolution of the land tenure conflict Milpa Alta-San Salvador Cuauhtenco-San Juan Tlacotenco may have two distinct outputs. If the contested land is granted to Milpa Alta, traditional grassland management practices are likely to continue and may be subject to integrative conservation actions, some of them identified in this thesis. The likelihood of success is greater when local organizations and users of the land are empowered through co-management initiatives that require local participation. The conditions for this to occur are favoured when people have control and certainty over the land (Ostrom, 1990; Gibson, et al., 2000; Tucker, 2004). Under this scenario, conservation of the SMS may occur within a co-management approach through *"a continuum problem-solving process that includes extensive deliberation, negotiation and joint learning"* (Carlson and Berkes, 2005, p. 65). This is feasible since some of the required steps have already been completed in the content of this dissertation, including the definition of the social-ecological system, the priority problem to solve, the management tasks that will address them, and the participants and decision-makers who must be included (Carlson and Berkes, 2005).

However, the conservation of the SMS may not succeed if the land tenure conflict favours San Salvador Cuauhtenco, the town that has shown more commercial interests over the land; nor it will occur if no action is taken and pressures over the grassland continue. In the first case, the SMS may vanished rapidly if the grassland is converted to agricultural fields as has occurred in other parts of the region (Cabrera, et al., 2006) and elsewhere (Collar, et al., 1992). In the second case, but with high risks of extinction, the SMS may persist longer while the grassland exists in the suitable breeding conditions identified in this thesis (Chapter 4).

7.2. Emergent themes and future research directions

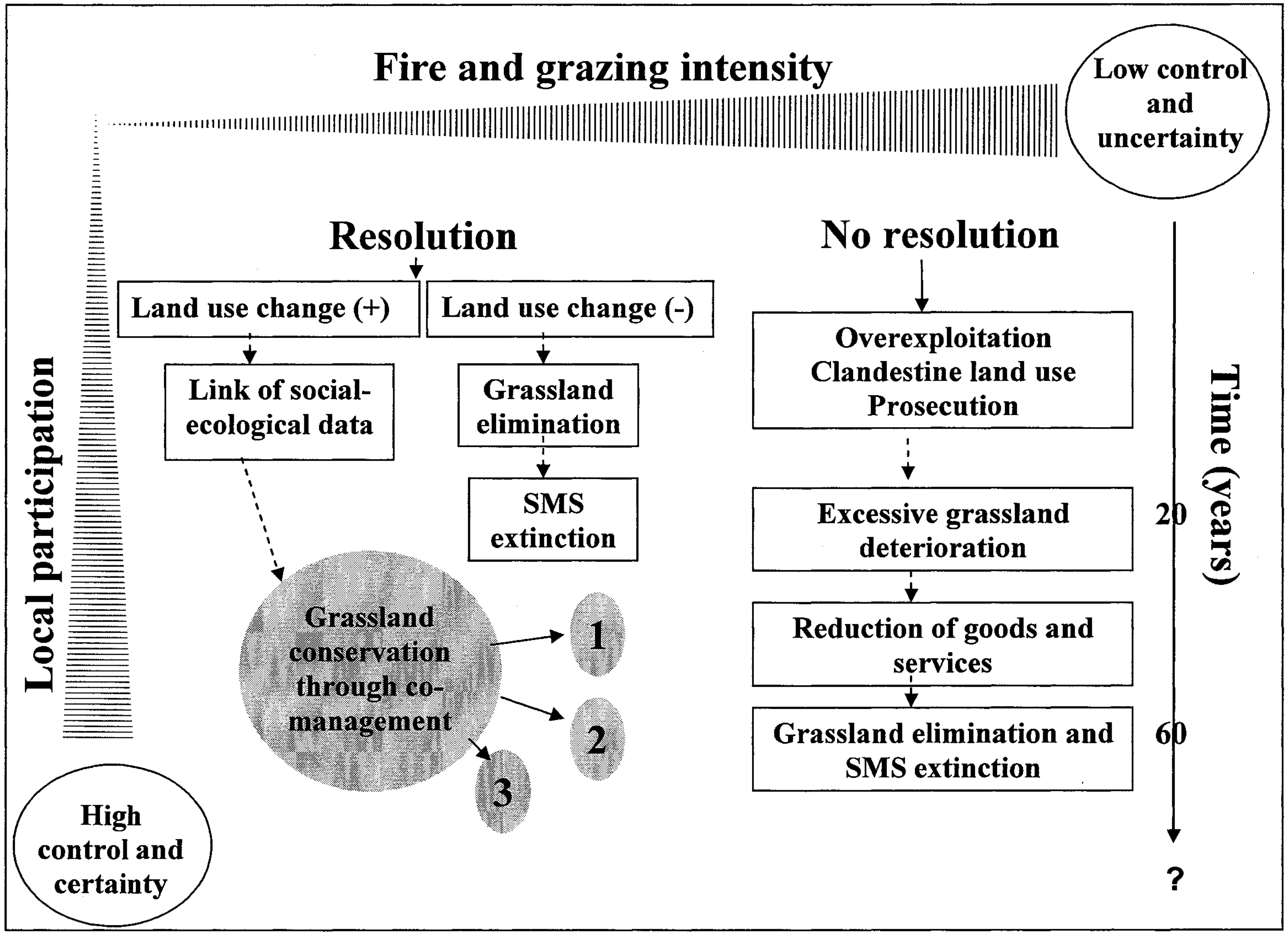
This thesis presents an alternative to how bird conservation studies are typically conducted by conceptualizing, designing and integrating diverse disciplinary studies and sources of knowledge into a common analytical framework (see Palang, 2003). As birds are amongst the most threatened taxa in the world (Birdlife International, 2000), this study brings an important example for bird conservation, with relevant methodological implications for future research.

This research illustrated the value of integrative and systemic approaches to biodiversity conservation, with special attention given to the participation of local people and traditional ecological knowledge for cultural landscapes' conservation (Farina, 2000; Davidson-Hunt, 2003; Berkes, 2004; Gilchrist, et al., 2005). By adopting such perspective, ornithologists and conservationists can recognize that "bird paradises" or endangered habitats are more than "precious untouchable habitats" to preserve, but rather, are often complex landscapes shaped by human actions and cultural values, maintained by traditional practices and local social institutions (Bonta, 2003; p. 154) and sometimes by complex socio-political processes..

The study of traditional ecological knowledge of birds is in its early stages (see Bonta, 2003 and Gilchrist, et al., 2005; Gosford, 2005). From this study, I highly recommend that traditional ecological knowledge is researched as often as possible because it can provide historical and current information on birds' habitat dynamics, distributional patterns, population status and uses, and also it can reveal main threats the ecosystem or species are facing, and can contribute to understanding conservation possibilities that may or may not be compatible with local situations.

This thesis does not suggest, naively, that local management will always be consistent with conservation objectives, nor does it imply that current land use practices that are consistent, will always be retained as local economies and expectations change. It does, however, provide strong evidence to support the growing literature that argues that at least where landscapes are anthropogenic, and where they provide important resource pools for local populations, conservation initiatives will be more likely successful if they recognize the human role in landscape evolution, and if they win the support of local populations for the conservation objectives. This may mean finding local benefits that arise from, and are consistent with, the conservation agenda, or, at the very least, it will mean identifying the points within the socio-ecological system where conservation actions will clash with local economic or subsistence activities. By acknowledging this, ethical dilemmas will emerge that will make conservation initiatives appear more complex than if local land users had been ignored. But where conservation solutions are reached through more realistic, respectful and collaborative efforts that benefit all the parties involved, the solutions will be more enduring (Alcorn, 1995; Velázquez et al., 2000a; Bonta, 2003; Berkes et al., 2005).

Figure 7.1. Conceptual model for the Sierra Madre sparrow's conservation based on the relevant factors documented in this study. At the top and right the model indicates lack of control of the land because of the land tenure conflict and a dominance of official perspectives over land management. Under these conditions grassland may degrade and eventually disappear. At the left and below of the model, grassland conservation may occur when no dispute exist over the land and people's participation increases and be included into co-management scenarios. This scenario would imply the continuation of traditional pastoral practices where SMS' habitat management recommendation can be implemented more effectively.


Fire and grazing intensity
Low control and uncertainty
Local participation
Resolution
No resolution
Land use change (+)
Land use change (-)
Link of social-ecological data
Grassland elimination
SMS extinction
Grassland conservation through co-management
1
2
3
Overexploitation
Clandestine land use
Prosecution
Excessive grassland deterioration
Reduction of goods and services
Grassland elimination and SMS extinction
Time (years)
20
60
?
High control and certainty

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APPENDIX 1

Semi-structured questionnaire guide[1]

Knowledge on grassland management

Where do you live?
Since when?
What do you do for living? (to know if they are shepherds and or if they do another activity, i.e. farming)
Since when do you use to grow cows and or sheep here?
How did you learn to do it?
How do you handle your animals in a typical day of grazing?
How long does it take to come to the grazing areas?
Do you have a particular pathway to come over here?
Do you use to do it alone or with someone else (i.e. family members, friends, other shepherds).

Knowledge on fire use

How do you manage the *zacatonal* (the pasture)?
-open question-----

when *the use of fire comes out*:

How do you light the fire?
In which season of the year do you use to burn the grassland?
How do you know when to burn?
How often do you burn?
Which areas are burned?
Are they always the same?
What size are the burns?
How did you learn to use the fire?
Do you know if there are some risks when burning? Or do you consider the fire might be a dangerous element?
How do you know it? Do you remember some special event concerning a fire (a *chamuzquina*)?
Do you consider some preventive measurements when using the fire?

What kind of animals do (have) you have (had)?
Do you have or know about better areas for grazing?
How do you recognize them?

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[1] Some questions are adapted from Mistry, J. (1998). The information obtained was complemented, supported and followed-up by using additional social methods and techniques (Hay, 2000; Kull, 2000) applied in the workshops.

Do you always take care of the animals? Or is there other persons taking care of them? (sharing the job between other herders)
From where do you bring your animals?
Is there some particular species of grasses preferred by the animals?
Do you recognize them?
How do you call them?
Where are they?
Are there other uses given to the *zacatonal*? Or do you know if the *zacatonal* is used for other purposes (collect food, handicrafts, etc).

Knowledge on landscape change and historical facts

Since when do you graze in these lands?
Have you notice "changes" in the *zacatonal*? (mentioning to the respondent for example in grasslands size, species, abundance)
If yes...ask how or on what
How many shepherds do you know graze these lands too?
Is pastoraslism a popular activity practiced in your town?
Since you remember, how these lands looked?
How old are these grasslands?
Who and or how many people are (were) working as shepherds?

Knowledge on local problematic

Are there some problems with your *zacatonal* or your activities as herder? (i.e. conversion from one this cover to another?)...
Since when is this occurring?
Do you think being herder is a convenient activity for you?
What do you think is happening with the agricultural fields expanding in the grasslands?
Does this represent a problem for you?
What do you think is necessary to do?
Who should do it?

APPENDIX 2. List of key informants interviewed in this thesis. Some of them were not necessarily quoted.

Interview/ number	Acronym of informants	Sex	Age	Occupation/ status in community	Town/ Organization
1	VCH	M	Late 40s	Comunero and local environmental activitst	MA
2	JF	M	Late 70s	Comunero and communal authority	MA
3	RAP	M	Late 40s	Official environmental authority	CORENA
4	Christian Kull	M	30's	Professor	MCGILL
5	Mike Edges	M	30s	Fire Ecologist	Parks Canada
6	HUCO	M	Early 20s	Comunero	MA
7	PAHE	M	Early 30s	Comunero	MA
8	AGSP	M	Early 40s	Comunero and communal authority	MA
9	RT	M	Early 50s	Comunero and communal authority	MA
10	FCH	M	Late 40s	Comunero and communal authority	MA
11	PCH	M	Early 70s	Comunero	MA
36	SN	M	Middle 70s	Comunero	MA
39	MAES	M	Middle 40s	Comunero/artisan	MA
40	MAAG	F	Late 70s	Comunera/farmer	MA
12	BR	M	Late 60s	Comunero/herder	SJT
13	SC	M	Late 40s	Comunero/herder	SJT
14-15	GR	M	Middle 40s	Comunero/herder	SJT
16	JO	M	Late 70s	Comunero/herder	SJT
17	MARE	M	Late 40s	Comunero/	SJT
18-21	RA	M	Early 50s	Comunero/herder	SJT
22-23	AA	M	Middle 50s	Comunero and communal authority	SJT
24	FERI	M	Middle 40s	Comunero/Herder	SJT
25	SRLU	M	Early 50s	Comunero/herder	SJT
26	AC	M	Early 30s	Comunero and communal authority	SJT
27	SRAL	M	40s	Comunero	SJT
28	RP	M	Early 40s	Comunero/herder	SJT
29	SCR	M	40s	Comunero	SJT
30	ALCU	M	50s	Comunero/herder	SJT
31	ARRO	M	40	Comunero/herder	SJT
32	J	M	Middle 40s	Comunero/ worker in the government	SJT
33	SRTI	M	Early 40s	Comunero/personal business	SJT
34	PAJA	M	Late 70s	Comunero/Retired herder	SJT
35	JGR	M	Late 70s	Comunero/profesor	SJT
36	BORI	F	Late 60s	Comunera	SJT
38	SRPA	M	Middle 40s	Comunero	SJT
39	LMF	F	Middle 20s	Comunero	MA
40	MAA	M	Middle 50s	Official environmental authority	CORENA

APPENDIX III. McGill University Ethics Letter of Approval