


CONSERVATION SCIENCE IN MEXICO'S NORTHWEST

ECOSYSTEM STATUS AND TRENDS IN THE GULF OF CALIFORNIA




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CATTLE IMPACT ON SOIL AND VEGETATION OF THE SEASONALLY DRY TROPICAL FOREST OF BAJA CALIFORNIA SUR

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An assessment of livestock grazing pressure on the seasonally dry tropical forest (SDTF) of the lowlands of the Sierra La Laguna Biosphere Reserve is shown in this study. It was done through an experiment that excluded cattle from a study plot for 10 years. The treatments were with total exclusion and without exclusion. Each treatment included an area of 2,500 m^2 and had one repetition. Community resilience to the effect of continuous cattle grazing on the physical and chemical characteristics of soil, structural features of vegetation, and diversity were measured. Higher clay contents were obtained in the soils of the ungrazed areas. In the grazed areas, higher soil surface temperatures, higher contents of sand, nitrate, iron, and lower pHs were recorded. These results indicated differences in moisture availability and changes in biogeochemical cycles. Vegetation response in ungrazed areas showed this plant community is resilient to short periods of cattle exclusion because we obtained changes in species composition, species turnover, higher species richness and diversity, and increases in height, stem density, and crown cover of trees, shrubs, vines, and herbs. Our results showed that, even though grazing activities have occurred for centuries in the region, the SDTF had a positive response to cattle exclusion in a short recovery time. We believe that adequate management strategies could be implemented to allow natural regeneration in several areas of the SDTF of this Biosphere Reserve.

Keywords: diversity, livestock exclusion, Mexico, Sierra La Laguna Biosphere Reserve, soil recovery, structural change, tropical deciduous forest, vegetation.

1. INTRODUCTION

The seasonally dry tropical forest (SDTF) is one of the vegetation types with the greatest area in tropical and subtropical regions, covering 42% of the tropical vegetation worldwide (Murphy and Lugo 1995). It is also one of the most threatened ecosystems due to the conversion of these areas to agriculture, increasing human population density, habitat fragmentation, fire, and more recently because of climate change (Gillespie *et al.* 2000, Miles *et al.* 2006). Wood extraction for fuel and the allowed overgrazing by livestock are the most common human activities that lower biodiversity in these tropical forest communities (FAO 1986, Murphy and Lugo 1986, Janzen 1988, Stern *et al.* 2002).

In Mexico, this ecosystem covers about 10% of the country (Rzedowski 1978), but less than 27% remains undamaged, which is about 4% of the total area of the country (Trejo and Dirzo 2000). Most of the SDTFs in Mexico follow the same pattern of resource exploitation. A continuous land conversion to agriculture and induced grasslands is recorded in most of the areas covered by the SDTFs (Arriaga and Cancino 1992, Burgos and Maass 2004, Castillo *et al.* 2005, Álvarez-Yépiz *et al.* 2008, Galicia *et al.* 2008). Livestock activities prevail and local ranchers breed cattle or goats as their main commercial activity.

In the Baja California Peninsula this ecosystem grows in the southern portion (Cape Region) where it reaches its northernmost limit. This SDTF is isolated from the continent by the Gulf of California, and its contact with the northern zones of greater aridity has resulted in a high level of endemism (Lott and Atkinson 2006). In the Cape Region, resource exploitation has historically followed an extensive and extractive pattern of wildlife harvesting. The extensive use of plant resources dates from the colonial period, when activities such as agriculture, cattle raising, and wood extraction started as peripheral activities associated with mining (Amao 1997). This pattern of land use gave rise to most of the human settlements established in the Sierra La Laguna and its surrounding foothills. The SDTF currently supports a variety of human activities such as livestock production, wood gathering for fuel, tree harvesting for local use, local agriculture and hunting of native wildlife (Arriaga and Breceda 1999).

The forest communities of the low- and middle-lands of the Cape Region have been exposed to a continuous and increasing grazing pressure since the Jesuits arrived to the Peninsula more than three centuries ago (Arriaga and Cancino 1992). These areas have remained since then as the largest livestock-husbandry regions of Baja California Sur. The type of stock farming by local inhabitants is extensive, sedentary, and its production is almost all for self-sustenance. Most of the ranches occurring in the tropical dry forest raise cattle at mean densities of 0.133 individuals per hectare with little breeding management because they raise mixed-breed cattle (Arriaga and Cancino 1992). Bovines forage in pastures and on leaves, stems, and fruits of numerous herbs, shrubs, and trees. Only during the dry season do some ranchers keep livestock in stables and feed them with alfalfa, sorghum, corn, hay, or food supplements. Most of the cattle are either sold alive or are slaughtered for consumption at the ranches. Other types of livestock like goats are also raised in the area, but at lower mean densities (0.036 individuals per hectare). Pigs and poultry are also produced, but mostly for the ranchers´ own consumption (Arriaga and Cancino 1992).

The range capacity of the SDTF has been estimated to be 30 hectares per animal per year by the national rangeland office (Martínez-Balboa 1981). Arriaga and Cancino (1992) estimated a carrying capacity for the low- and middle-lands of the Sierra La Laguna Biosphere Reserve as 9.11 hectares per animal, a value that implies overgrazing in the area. This ecosystem is supporting cattle three times more than that recommended by the national rangeland office.

Overgrazing of numerous perennial forage species of the SDTF is evident by the damage on the crowns, stems, and bark of a large number of shrubs and trees. One hundred and thirteen plant species have been recorded as forage resources (Arriaga and Cancino 1992). The foraged species belong to 45 families, with Fabaceae, Poaceae, and Asteraceae as the families with the highest number of species. The Poaceae includes a large number of introduced species (Arriaga and Cancino 1992). Ranchers cultivated grasslands of the African buffel grass, *Cenchrus ciliaris* (L.) in experimental plots in the 1960s, but these were abandoned during severely dry years. However, some of these species remain in some of the abandoned plots or in the wilderness as weeds.

This chapter shows an assessment of livestock grazing pressure on the SDTF of the lowlands of the Sierra La Laguna Biosphere Reserve. It was done through an experiment that excluded cattle in a 2-ha study plot for 10 years and by addressing the following questions: How does cattle foraging influence microenvironmental conditions? To what extent are soil characteristics affected by continuous livestock grazing? How are structural features and diversity affected by grazing? Is the plant community resilient to short periods of cattle exclusion?

2. MATERIALS AND METHODS

2.1. Study site

The study was made at the Sierra La Laguna Biosphere Reserve in the southern portion of the Baja California Peninsula (23°21'-23°42' N; 109°46'-110°10' W). Here the SDTF grows from 300 to 800 m a.s.l. It covers about 170,500 ha and has the most diverse type of vegetation in the Peninsula (Arriaga and Ortega 1988). The total annual rainfall average in the area is 316 mm for a 42-y period, with a dry season from late October to July, and winter rains can occur. The mean monthly temperature is 23.6 °C (García 1981). Soils are Lithic Leptosols (formerly Lithosols) or Regosols with a sandy texture, and they are rocky, shallow, and have high organic-matter content (Maya 1991). Four hundred and fifty-seven species have been described in this plant community. The structurally important families are Fabaceae, Cactaceae, Euphorbiaceae, Asteraceae, and Acanthaceae (Arriaga and León 1989, León de la Luz and Domínguez 1989).

2.2. Sampling plots

Within the tropical dry forest, at 450-m a.s.l., a 2-ha study plot was laid out. The study plot was divided into 4 treatments to avoid grazing by bovine cattle. The treatments were 1) total exclusion, 2) exclusion during the rainy season, 3) exclusion during the dry season, and 4) without exclusion. Each treatment included an area of 2,500 m^2 and had one repetition. In this chapter we will only present the results for the total exclusion (TE) and without exclusion (WE) treatments. All perennial plants were identified *in situ* and by consulting the CIBNOR HCIB herbarium. The nomenclature follows Wiggins (1980) mostly, but updates were made with the advice of several taxonomists and by consulting online databases (Tropicos.org 2009). Perennial plants were mapped and recorded within the study site, and their height and crown cover were measured at the beginning and at the end (10-years later) of the study. Crown cover was measured as an estimate of dominance and calculated using the ellipse function: $C = \pi \cdot 0.25 \cdot D_1 \cdot D_2$; where D_1, is the largest crown diameter and D_2, the diameter perpendicular to D_1. Stem density and species richness were recorded for each condition, and species diversity and evenness were estimated using the Shannon function (Magurran 1988). Diversity indices were compared using *t*-tests (Zar 1974).

2.3. Physical environment and soil characteristics

Changes in soil surface temperatures beneath the canopy of plant clusters and in open spaces were compared in the study plot. We randomly chose plant clusters bearing the physiognomic-dominant perennial species *Lysiloma divaricatum* and *Stenocereus thurberi* as one group or *Tecoma stans* and *Jatropha vernicosa* as another group, under which to measure soil surface temperatures. Five replicates for either of these associations were measured in the WE and TE treatments. Soil surface temperatures were recorded during 11-h each day for three days at the end of the study.

Physical and chemical soil characteristics were also compared in the study plot at the end of the study. Each exclusion treatment was divided into ten quadrants

(20 × 25 m). In each quadrant two soil samples were taken (depths 0 to 5 cm and 5 to 15 cm). These samples were air-dried and the following physical and chemical analyses were obtained: texture (sieve and pipette, Folk 1980), pH and electric conductivity (potentiometer and conductivity bridge, Jackson 1982), organic matter content (Walkley-Black 1934), calcium, magnesium, sodium, potassium, iron (by atomic absorption spectrophotometry), carbonates and bicarbonates (Reitemeier 1946), nitrites and nitrates (Strickland and Parsons 1972), and total and assimilable nitrogen (Dahnke and Johnson 1990). Differences in soil surface temperatures and physical and chemical soil variables were tested by means of Student´s *t*-test using the Statistica software (StatSoft Inc. 2009).

3. RESULTS

3.1. Physical environment and soil characteristics

Soil temperature records beneath the canopy of the clusters and in open spaces for the physiognomic-dominant associations are shown in Figure 1. There were significant differences between soil temperatures as recorded beneath the canopy versus those recorded in open spaces in the WE treatment (t = 2.229; *d.f.* = 108; p = 0.028). A difference of almost 12.5 °C was obtained for the warmest hours of the day between shade and unshaded conditions in the WE treatment (see Figure 1a). In the TE treatment, although temperatures were higher in open spaces, no significant differences were recorded between the shade provided by the canopy and the open spaces (t = 1.705; *d.f.* = 108; p = 0.091; see Figure 1b). In this area there was a greater recovery of crown cover that decreased soil surface temperatures in open spaces.

The results for soil variables were compared for the WE and TE treatments and are shown in Table 1. In the TE treatment significantly higher clay contents were obtained in both layers, 0-5 cm (t = 2.402; *d.f.* = 18; p = 0.027) and 5-15 cm (t = 2.248; *d.f.* = 18; p = 0.037). Many other differences were found in the WE treatment but only in the 5-to 15-cm layer (see Table 1), which were higher contents of sand (t = 2.113; *d.f.* = 18; p = 0.048), nitrate (t = 2.573; *d.f.* = 18; p = 0.019), and iron (t = 3.787; *d.f.* = 18; p = 0.001), and lower values in pH (t = 2.507; *d.f.* = 18; p = 0.021). These differences are relevant because they indicate differences in moisture availability and changes in biogeochemical cycles.

3.2. Vegetation structure and diversity

Contrasting changes in structural characteristics and diversity were recorded after 10 years in the WE and TE treatments (see Table 2). Species richness, diversity, and evenness remained almost unchanged in the WE treatment. No significant differences were obtained in diversity indices in this treatment when initial conditions

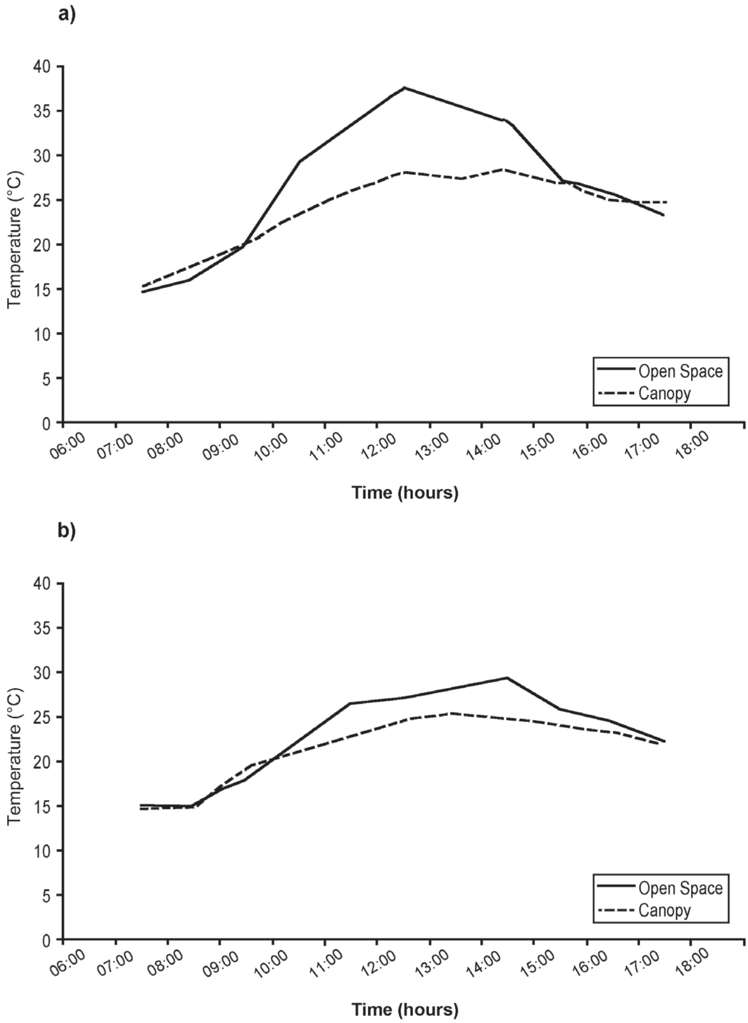

FIGURE 1. Soil surface temperatures for open spaces and shades provided by tree canopy in the 2-ha study plot of the STDF of Baja California Sur. a) without exclusion of foraging cattle; b) total exclusion treatment of foraging cattle.

were compared with those obtained 10 years later (t = 0.045; $d.f.$ = 2338.4; p = 0.964). The recruitment of individuals was high in the WE treatment during the study period because stem density doubled, though crown cover decreased slightly from the initial conditions (-2.4%). The opposite was obtained in the TE treatment where species richness, diversity, evenness, stem density, and crown cover increased after

TABLE 1. Student's *t*—test comparisons of the physical and chemical data of the soil in the study plots. $n = 10$; *d.f.* =18. Significance level: *$p \leq 0.05$; **$p \leq 0.001$; *s.d.* = standard deviation.

	Total exclusion		Without exclusion			
Variables	Average	*s.d.*	Average	*s.d.*	*t*	*p*
0- to 5- cm depth						
Organic matter (%)	3.08	2.38	2.25	1.07	0.996	0.332
pH	6.77	0.3	6.81	0.34	-0.028	0.781
Electric conductivity (S m–1)	0.0235	98.08	0.0216	59.02	0.53	0.602
Calcium (meq 100 g soil $^{-1}$)	396.387	203.37	338.056	114.24	0.79	0.439
Magnesium (meq 100 g soil $^{-1}$)	90.713	38.35	86.934	35.23	0.229	0.821
Sodium (meq 100 g soil $^{-1}$)	0.345	0.19	0.269	0.29	0.68	0.504
Potassium (meq 100 g soil $^{-1}$)	0.072	0.04	0.122	0.15	-0.984	0.337
Iron (meq 100 g soil $^{-1}$)	77.46	52.15	60.239	46.66	0.778	0.446
Bicarbonates (meq 100 g soil $^{-1}$)	476.727	226.85	453.773	137.17	0.273	0.787
Nitrates (meq 100 g soil $^{-1}$)	0.497	0.11	0.574	0.18	-1.139	0.269
Sand (%)	83.05	5.68	86.67	2.59	-1.831	0.083
Silt (%)	8.94	3.91	7.19	2.14	0.47	0.643
Clay (%)	8	2.3	6.13	0.88	**2.402**	**0.027**
Total nitrogen (%)	0.141	0.13	0.11	0.05	0.648	0.524
Assimilable nitrogen (%)	0.002	0	0.001	0	0.935	0.362
5- to 15- cm depth						
Organic matter (%)	0.98	0.74	1.07	0.72	1.108	0.282
pH	6.84	0.28	6.58	0.16	**2.507**	**0.021***
Electric conductivity (S m^{-1})	0.0094	21.15	0.0109	60.53	-0.764	0.454
Calcium (meq 100 g soil $^{-1}$)	136.672	28.26	153.788	74.27	-0.681	0.504
Magnesium (meq 100 g soil $^{-1}$)	39.41	11.86	48.57	31.86	-0.852	0.405
Sodium (meq 100 g soil^{-1})	0.523	0.38	0.25	0.19	2.01	0.058
Potassium (meq 100 g soil $^{-1}$)	0.033	0.02	0.072	0.05	-1.948	0.067
Iron (meq 100 g soil $^{-1}$)	152.672	56	61.112	52.03	**3.787**	**0.001****
Bicarbonates (meq 100 g soil $^{-1}$)	159.581	37.15	204.052	105.25	-1.259	0.223
Nitrates (meq 100 g soil $^{-1}$)	0.416	0.115	0.561	0.136	**-2.573**	**0.019***
Sand (%)	78.24	10.31	85.41	2.93	**-2.113**	**0.048***
Silt (%)	10.66	4.72	8.01	2.51	0.636	0.532
Clay (%)	11.08	6.3	6.57	0.74	**2.248**	**0.037***
Total nitrogen (%)	0.166	0.37	0.05	0.03	0.966	0.346
Assimilable nitrogen (%)	0.0005	0	0.0005	0	-0.019	0.984

TABLE 2. Community characteristics of the study plot and cattle-exclusion experiment in the STDF of the Sierra La Laguna in Baja California Sur. Abbreviations: WE = without exclusion of grazing cattle; TE = total exclusion of grazing cattle.

Exclusion Treatment	Species Richness (S)	Diversity Index (H')	Evenness (J)	Density (ind·ha^{-1})	Crown Cover (%)
WE initial	39	2.67	0.73	1.05	85.79
WE 10-y later	37	2.63	0.73	2.04	83.41
TE initial	29	2.32	0.69	1.26	73.81
TE 10-y later	43	2.81	0.75	1.43	93.31

cattle exclusion for 10 years (see Table 2). Diversity indices were significantly different when initial and final conditions were compared. Diversity was higher in the excluded plot (t = 12.327; *d.f.* = 2685.7; p = 0.000). There was a clear increase in crown cover in the TE treatment (19.5%).

Changes in structural characteristics for both treatments are shown for twenty-dominant perennial-plant species in Figures 2 and 3. Species response and recovery were contrasting in both treatments. In the WE treatment there was an important recovery in stem density of species like *Tecoma stans*, *Mimosa xanti*, *Stenocereus thurberi*, *Lysiloma divaricatum*, *Coursetia glandulosa*, *Viguiera* sp., *Senna villosa*, *Bursera microphylla*, and *Euphorbia lagunensis* (see Figure 2a). Species that increased in stem density did not necessarily increase their crown cover compared to initial conditions. *Lysiloma divaricatum* had the greatest loss in crown cover in the grazed area. This species decreased 2.4 times in crown cover compared to initial conditions (see Figure 2b). This result was surely caused by cattle grazing pressure because this species is the most palatable of the legumes growing in the study plot. The spiny legumes *Mimosa xanti* and *Haematoxylum brasiletto* increased their crown cover as did *Bursera microphylla*, a species with an aromatic sap not palatable to cattle (see Figure 2b).

In the TE treatment the species with the greatest recruitment in stem density were *Lysiloma divaricatum*, *Stenocereus thurberi*, *Mimosa xanti*, *Senna villosa*, and *Bursera microphylla* (see Figure 3a). We also recorded 21 species that were not recorded during initial conditions (see Table 2). In this treatment legumes like *L. divaricatum*, *Haematoxylum brasiletto*, *Chloroleucon mangense*, *Mimosa xanti*, *S. villosa*, *Erythrina*

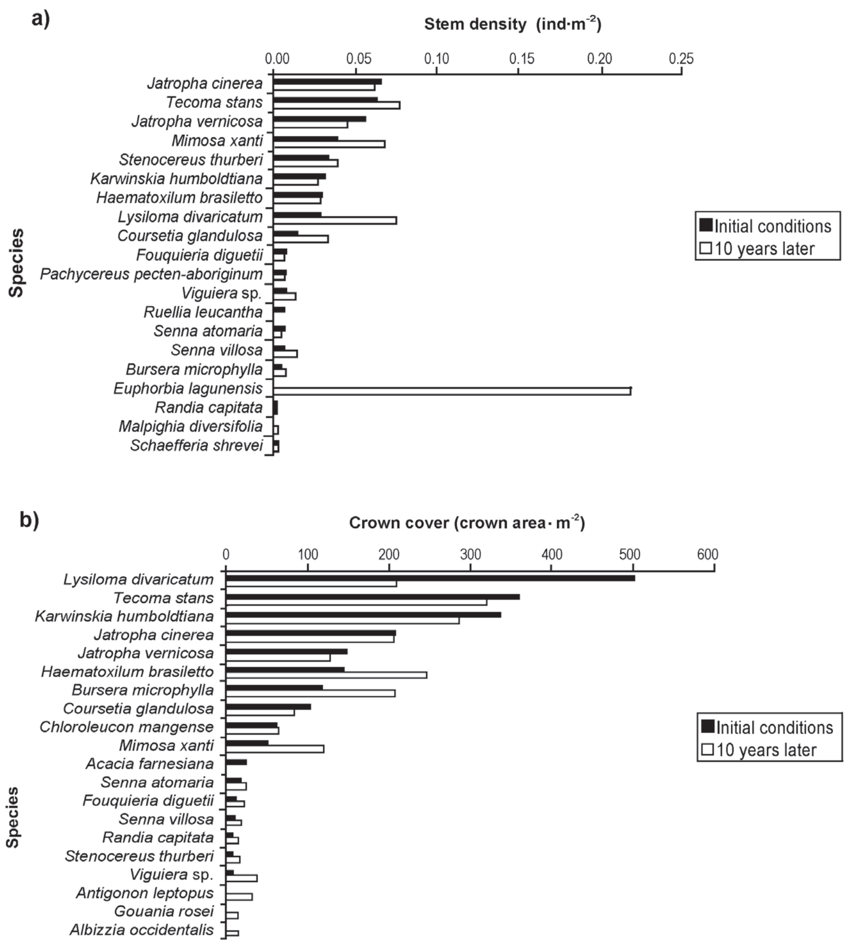

FIGURE 2. Changes in structural characteristics for 20 dominant perennial plant species in the Without Exclusion (WE) treatment of the STDF of the Sierra La Laguna Biosphere Reserve. a) stem density, and b) crown cover.

flabelliformis, and *Albizzia occidentalis* had the highest recovery in crown cover (see Figure 3b). Particularly *L. divaricatum* had the most striking differences, by increasing 1.3 times in stem density and 2.1 times in crown cover compared to initial conditions in the ungrazed area. On the contrary, unpalatable species like *Tecoma stans*, *Jatropha cinerea*, and *Karwinskia humboldtiana*, that have also been described as characteristic of disturbed habitats, reduced their crown cover by the end of the study (see Figure 3b).

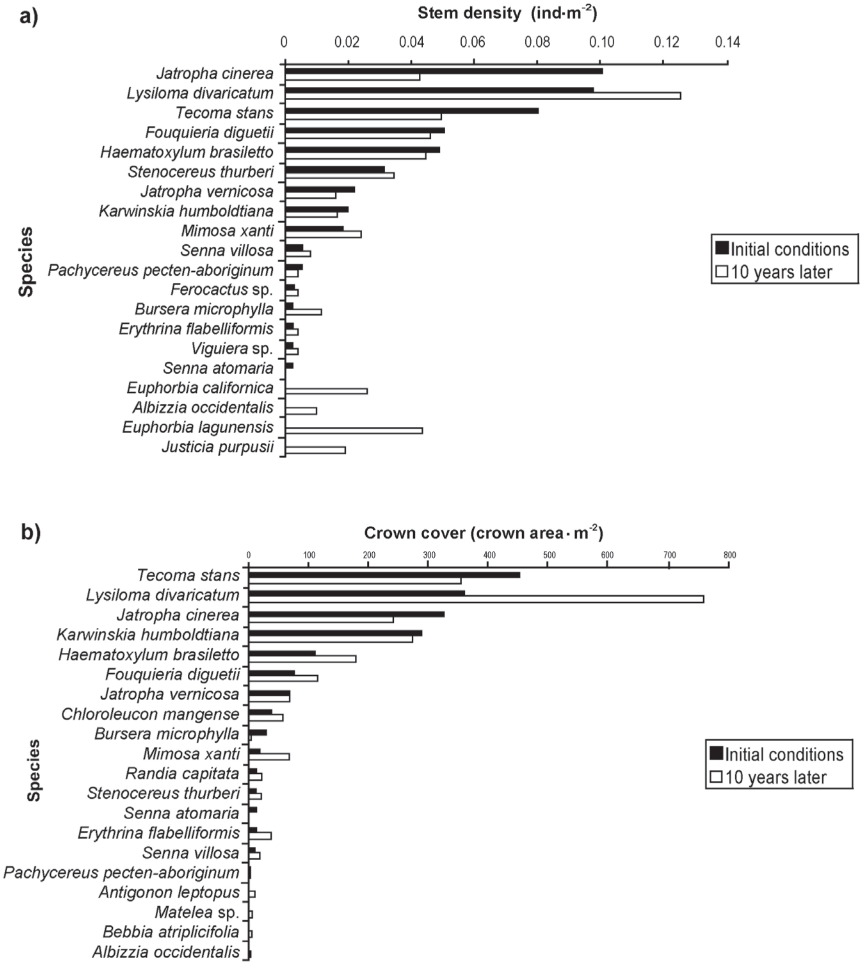

FIGURE 3. Changes in structural characteristics for 20 dominant perennial plant species in the Total Exclusion (TE) treatment of the STDF of the Sierra La Laguna Biosphere Reserve. a) stem density, and b) crown cover.

4. DISCUSSION

4.1. Physical environment and soil characteristics

After 10 years of cattle exclusion, our study showed that grazing changed the physical environment and soil characteristics of the SDTF. Significant differences in soil surface temperatures between shade and unshaded areas in the WE treatment were obtained (see Figure 1a). The differences in soil surface temperatures in this study plot (12.5 °C less at the warmest hours of the day) can be explained as the result of a decrease in crown cover (2.4%; see Table 2). In the ungrazed plot (TE), crown recovery provided more shade, decreasing soil surface temperatures and leaving less unshaded areas (see Figure 1b). An increase of 19.5% in crown cover was obtained in this treatment (see Table 2). These results indicate that protection against radiation by the dominant plants appears to be an important factor in the pattern of species establishment. Several studies have documented that safe sites are needed for seed germination and seedling establishment, and their occurrence is associated with cattle exclusion and soil conditions in the SDTF (Arriaga *et al.* 1993; Dalling and Hubbell 2002, Griscom *et al.* 2007).

Based on the results obtained for structure and diversity between the TE and WE treatments, we expected a significantly lower quantity of organic matter in the soil of the WE treatment. However, organic-matter content was not significantly different from that obtained in the TE treatment (see Table 1), which suggests that dung is quickly integrated into soil rapidly enough to nearly match the level of the TE treatment. As mentioned earlier, most of the livestock diet is composed of tree species (Arriaga and Cancino 1992), whose biomass would take longer to incorporate into soil organic matter in the TE treatment.

The significantly higher nitrate content obtained in the WE treatment (see Table 1) indicates that cattle provide feces and urine that can be converted to nitrates by soil microorganisms. In the TE treatment, where a normal nitrogen cycle was occurring, many stages of vegetative decomposition were required before nitrogen was liberated from organic litter on the soil. Additionally, higher nitrification rates produce lower pH values, which explained the significantly lower pH in the WE treatment (see Table 1). The greater biomass in the TE treatment suggests a greater consumption of nitric forms of nitrogen by plants, which contributes to increases in pH (Duchaufour 1995).

Iron content was significantly higher in the TE treatment (see Table 1). A higher pH can explain this result because iron solubility decreases inversely to pH, reducing its lixiviation and use by plants (Duchaufour 1995). Some studies indicate that land subjected to long periods of intensive cattle grazing show declines in total nitrogen, cation-exchange capacity, and interchangeable calcium and magnesium (Turner 1998, Ayuba 2001). Higher values of these variables were found in the TE treatment (see Table 1), which suggests this phenomenon has taken place in the grazed areas.

The herbaceous layer increases soil infiltration rates and shades the soil, leading to lower soil surface temperatures and evaporation rates (see Figure 1 and Table 1). It is indirectly confirmed by the higher clay content in both sampled layers (0–5 and 5–15 cm) of the TE treatment (see Table 1) because clay formation requires humid conditions, which are not present in the WE treatment where the cattle have removed the herbaceous layer. Moreover, the results suggest that eluviated clay particles from the soil surface were added to the clay that was already in the subsurface. Clay promotes particle aggregation, improves soil stability, and increases moisture-retention and cationic-interchange capacity; all of these would contribute to decrease soil degradation in the TE treatment. Conversely, in the WE treatment, cattle grazing would cause mechanical soil degradation processes, such as compaction and destruction of soil aggregates (Parizek *et al.* 2002). Our results also support the argument that cattle grazing removed protective cover, increasing the surface area of bare soil that is then exposed to direct radiation, which triggers the mineralization of humic compounds (Salmon *et al.* 2008), increasing degradation. Based on all the previous information, we confirm that continuous livestock grazing affects soil characteristics and that overgrazing is a threat to the stability of the ecosystem.

4.2. Vegetation structure and diversity

The floristic composition of the SDTF also changed after 10 years of cattle exclusion, and the structural complexity of vegetation decreased with grazing. The analyses of floristic composition and diversity demonstrated that significantly lower species diversity was obtained in the WE treatment (see Table 2) compared with the ungrazed area. The TE treatment had a higher species richness and diversity (see Table 2) and also contributed more to overall species diversity with 21 species unique to this habitat (5 were vines, 13 were shrubs, and 3 were trees). Our results agree with those obtained for other SDTFs of Mexico and Central America. Álvarez-Yépiz *et al.* (2008) found that species density was lower in secondary forests (20 to 30 years of recovery) when these were compared with old-growth, tropical dry forests in Sonora, Mexico. Stern *et al.* (2002) found that intermittent grazing had a negative impact on the structure and diversity of the SDTF compared to an ungrazed area in northwestern Costa Rica.

Species that were abundant in both treatments included *Jatropha cinerea* and *Tecoma stans* (see Figures 2a and 3a). Some authors have reported that the main physiognomic trait of this SDTF is the abundance of *T. stans*, whose occurrence indicates a high disturbance of the overall ecosystem (González-Medrano, pers. comm.). The most abundant species in the WE treatment was *Euphorbia lagunensis* (see Figure 2a). This species was not recorded during initial conditions but had the highest recruitment in the grazed area. Its occurrence was not expected because it has been recorded at higher elevations of the Sierra La Laguna and as part of the seed bank of the oak-pine forest (Huft 1984, Arriaga and Mercado 2004). In contrast, several species in the TE treatment included species that are characteristic of more mature conditions, such as *Albizzia occidentalis* and *Erythrina flabelliformis* (see Figure 3a) although these were found at low densities. The lack of regeneration of *Senna atomaria* was evident in both areas. This is a dominant canopy species of the SDTF, but it had been completely extracted by local inhabitants in the study plots. The distinctive canopy species *Lysiloma divaricatum* had the highest response to the exclusion of cattle. It increased significantly in stem density and in crown cover in the ungrazed area (see Figures 3a and 3b). This species is the most affected by cattle grazing; it is a palatable legume that changed its small, pruned appearance to vigorous branched trees after 10 years of cattle exclusion. The average height in the grazed plot for this species was 0.56 ± 1.2 m, whereas in the ungrazed plot the average was 2.0 ± 1.3 m. The maximum height recorded for this species in the grazed plot was 7.5 m, whereas it was 12.2 m in the ungrazed plot.

Plant structure analyses (see Figures 2 and 3) between grazed and ungrazed areas emphasized the impact that cattle have on the SDTF structure. The vegetation response indicated this plant community is resilient to short periods of cattle exclusion and that a 10-year period is enough time to see changes in species composition, diversity recovery, species turnover, and increases in height, stem density, and crown cover of trees, shrubs, vines, and herbs. Griscom *et al.* (2007) obtained similar results in a forest regeneration plot in the dry tropical forest of Panama. They found that basal area, stem density, and species richness of trees, shrubs, vines, and herbs were significantly and positively affected by cattle exclusion. Rapid increases in height and crown cover have also been reported by some authors in neotropical secondary forests (Guariguata and Ostertag 2001). Other authors have found that certain features (canopy height, plant density, crown cover) recovered rapidly (in less than 20 years), whereas other features (including basal area and species richness) had not recovered after 40 years in the SDTF of Oaxaca, Mexico (Lebrija-Trejos *et al.* 2008). Vegetation response depends on the intensity of disturbance that a specific area has had and its previous changes in land use. Our results showed that, even though grazing activities have occurred for centuries in the region, the SDTF had a positive response to cattle exclusion in a short time. These results suggest rapid vegetation responses could be obtained if adequate management strategies to exclude cattle were implemented to recover and restore some areas of the SDTF.

Current management practices in the Sierra La Laguna Biosphere Reserve do not allow the regeneration of the tree species in grazed pastures by excluding cattle grazing. Some federal programs have been implemented by the National Commission on Natural Protected Areas to restore degraded areas of the SDTF within the reserve. However, these programs have been oriented to regenerate some locations with introduced species of *Agave*, or with shrub species that are already abundant, characteristic of disturbed habitats that arrest succession and that are not useful for local inhabitants (*i.e. Jatropha vernicosa, Tecoma stans*). On a smaller scale, some legumes (*i.e. Senna atomaria, Lysiloma divaricatum, Erythrina flabelliformis)* are being cultivated by local inhabitants on their own ranches. Seeds are germinated under shade, but there is a lack of assessment as to where to plant the legume saplings, without the monitoring of plant survival after planting. The regeneration of species that show limited regeneration, such as *Plumeria acutifolia, Bursera microphylla*, *Albizzia occidentalis* is not being enhanced at all. The great touristic development of the lowlands and coastal zone that surrounds this Biosphere Reserve has caused a massive removal of *B. microphylla*, and nothing is being done to limit these illegal activities, particularly outside of the Biosphere Reserve limits. We think several management strategies are necessary to allow the regeneration of the SDTF in this region. These should include temporary grazing cattle exclusion in different areas of the Biosphere Reserve. For the dominant species of the SDTF, the retention of adult trees, protection of saplings and seedlings from grazing, and the use of plant nurseries and larger plantings would be necessary to enhance further reforestation.

5. CONCLUSIONS

The SDTF has been exploited by man for more than three centuries, though exploitation of this ecosystem has not been planned or based on adequate management strategies. Our study shows that, even though grazing activities have occurred for centuries in the region, the SDTF will have a positive response to cattle exclusion in a short time.

Continuous livestock grazing deeply affects many soil characteristics, such as soil surface temperatures, infiltration, particle aggregation, and fertility. Even if the effect on soil is derived from direct modifications to the vegetation cover, it is cumulative and can overcome the resilient capacity of the soil.

Vegetation response has shown this plant community is resilient to short periods of cattle exclusion. The 10-year exclusion allowed us to see changes in species composition, diversity recovery, species turnover, and increases in height, stem density, and crown cover of trees, shrubs, vines, and herbs.

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Exploring Mexico's northwest, the Baja California Peninsula, its surrounding oceans, its islands, its rugged mountains, and rich seamounds, one feels diminished by the vastness and the greatness of the landscape while consumed by a sense of curiosity and awe. In a great natural paradox, we see the region's harsh arid nature molded by water through deep time, and we feel that its unique lifeforms have been linked to this desert and sea for thousands of years, as they are now.

These landscapes of fantasy and adventure, this territory of surprising, often bizarre growth-forms and of immense natural beauty, has inspired a wide array of research for over two centuries and continues to inspire the search for a deeper knowledge on the functioning, trends, and conservation status of these ecosystems in both land and ocean.

This book offers a compilation of research efforts aimed at understanding this extraordinary region and preserving its complex richness. It is a synthesis of work done by some exceptional researchers, mostly from Mexico, who indefatigably explore, record, and analyze these deserts and these seas to understand their ecological processes and the role of humans in their ever-changing dynamics.

Elisabet V. Wehncke

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