RESEARCH ARTICLE

•

Coastal Landscape Fragmentation by Tourism Development: Impacts and Conservation Alternatives

Claudia Leyva[1,3]
Ileana Espejel[1]
Anamaria Escofet[2]
Stephen H. Bullock[2]

[1] UABC, AP. 1880, Ensenada 22800, B.C., México

[2] CICESE, AP. 2732, Ensenada, 22800, B.C., México

•

[3] Corresponding author: cleyva@uabc.mx

Natural Areas Journal 26:117–125

ABSTRACT: Coastal succulent scrub of Baja California is being fragmented and replaced by agriculture, residential, recreational, commercial, and industrial land uses. This study evaluated fragmentation effects of a residential-recreational development. The site was a mosaic of native coastal succulent scrub (CSS) in a matrix of introduced grasslands and tourism infrastructure. Comparisons were made among extensive areas of mature or old CSS and smaller patches, which were either recently fragmented in a golf course or fragmented more than 20 years ago in a residential area. Total plant species richness was 108 species. New fragments exhibited the highest floristic richness due to invasion by opportunistic species. The number of CSS species increased with patch size. There were differences in flora among seasons due to spring annuals. In contrast, cover by native perennials was similar among all conditions and MANOVA results showed that only the variables related to origin (natives and nonnatives) were significant. This means that neither life form nor fragment type was related to the species number. Our study reflects the potential to preserve coastal sage scrub patches within an urbanized area.

Index terms: Baja California, México, coastal succulent scrub, golf course design, invasion, landscape conservation, landscape fragmentation

INTRODUCTION

Coastal succulent scrub (CSS) is a type of vegetation found along the Pacific coast from north of San Diego, California, to south of El Rosario, Baja California (Figure1). In most places, the common elements of the vegetation are shrubs (both deciduous and evergreen) up to one meter tall, cacti, agave, and other succulents (Pase and Brown 1982, Westman 1983, O'Leary et al. 1994, Peinado et al. 1994, Sawyer and Keeler-Wolf 1995, Dallman 1998, Oberbauer 1999). The region's climate is "Mediterranean," with rainy, cool winters and dry, warm summers (Di Castri 1981), and the annual precipitation is below 250 mm (INEGI 1996).

This type of vegetation has been largely fragmented and replaced by agriculture and urban development (Espejel and Ojeda 1995). In California, these perturbations have been so intense that CSS is considered an endangered plant community (Westman 1987, Alberts et al. 1993, O'Leary et al. 1994, Oberbauer 1999). The landscape in northern Baja California is a mosaic of patches of varying size, shape, and quality within a matrix of diverse land uses and disturbances. The study of the structure, function, and changes of the mosaic of the natural vegetation remnants and other landscape elements has provided basic information for regional management plans (Escofet and Espejel 1999, COCOTREN 2001, Espejel et al. 2002). Selection of high-quality fragments for preservation purposes and their incorporation into present schemes of land uses are urgently needed in order to ensure that some of this unique native landscape remains (Shafer 1990, Escofet et al. 1994, Shafer 1997). Active but generally uncoordinated efforts at conservation, with diverse motivations, have recently become apparent in the federal and municipal governments, non-governmental organizations, and heavy industry.

Our study aimed to assess the impacts of fragmentation on floristic and vegetation structure and to evaluate the possibility of preserving native elements in the context of development of recreational land use. This study corresponds to the proposal of using human-modified landscapes for research purposes (U.S. Research Council 1983; Pickett and White 1985; McDonnell and Pickett 1990; Shafer 1990, 1997), and belongs to the large class of natural experiments in which researchers do not have absolute control over conditions and events (Connell 1975, Hurlbert 1984, Diamond 1986, Eberhardt and Thomas 1991).

We had the opportunity to follow the process of fragmentation during the expansion of a golf course associated with residential areas. This property presents an impressive and naturally heterogeneous landscape with beaches, cliffs, hills, small canyons, and lowlands occupied by residential houses, hotels, agricultural fields, golf courses, and natural vegetation remnants. For this study, we measured the structure and composition of CSS in small fragments and on a large adjacent "control" area.

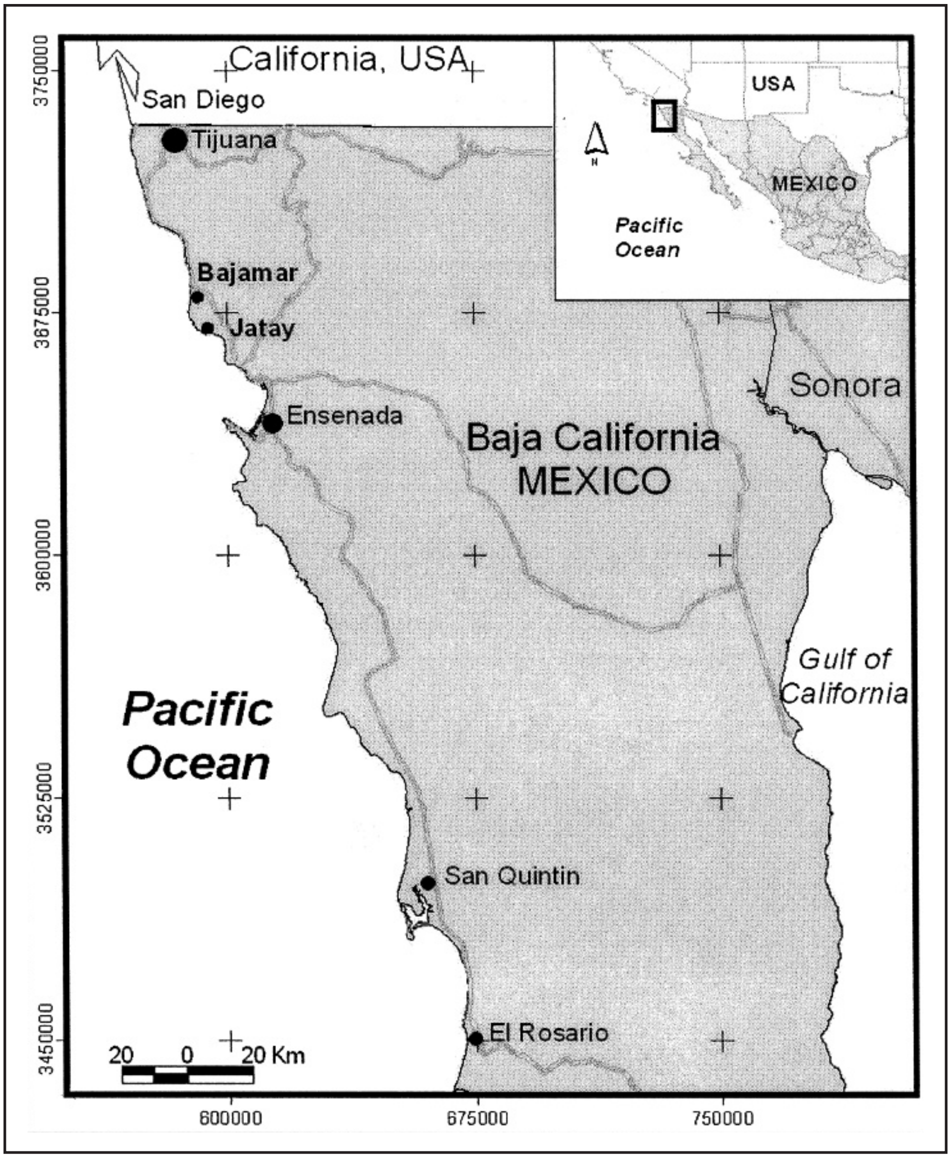

Figure 1. Geographic situation of the study area at Bajamar, Municipality of Ensenada, Baja California, México.

METHODS

The study area comprised 662 ha between the tourism development of Bajamar (where the natural experiment was placed) to the north and Jatay (the selected control area) to the south (Figures 1 and 2). This area was bordered by the Tijuana-Ensenada scenic toll road (Mexican Highway 1; at about km 78) and 5 km of Pacific Ocean shore. Development of the Bajamar property was initiated in the early 1980s, and was renewed in the 1990s. In a larger context, the property was imbedded in a mosaic of land uses that included patches of natural or old growth CSS of tens to hundreds of hectares. The golf course consisted of small sub- or near-natural patches (roughs) surrounded by intensively managed nonnative grasslands (fairways and greens). Artificial ponds, a clubhouse, a hotel, a residential area of 50 houses with nonnative gardens, and old abandoned lots (considered semi-natural patches) were also part of the landscape. The golf course had been recently expanded at the time of our study.

FIELD METHODS

We distinguished three conditions. The natural CSS was essentially non fragmented in relation to the patches in Bajamar, and, supposedly, has been without human interference for the last 40 years (owner, pers. comm.) – an assertion supported by aerial photographs from 1973, 1985, and 1999 of the Geography and Statistics National Institute (INEGI 1996, Espejel et al. 2002). This area was designated as the control site of this study. Old (20 years old) and new (one year) fragments of CSS occurred within the residential area and the golf course, respectively. The factor of increasing disturbance (control, old, and new fragments) is referred to here as "condition."

Vegetation sampling was done in the control area and the old and new fragments using 100 m^2 relevés placed in the interior of accessible fragments with low and uniform slope. This procedure was followed except in the control area (which was large enough to place samplings randomly). Each plant species was rated using a dominance scale from 1 to 9 as a rapid field assessment method. This sampling method has been used throughout the coast of Mexico (Moreno-Casasola and Espejel 1986, Moreno-Casasola et al. 1999). In this case, the nominal scale was later transformed to a percentage value where 1 included plants with cover from 0.01 to 0.75%, 2 from 0.76 to 1.5%, 3 from 1.6 to 3%, 4 from 3.1 to 6%, 5 from 6.1 to 12%, 6 from 12.1 to 25%, 7 from 25.1 to 50%, 8 from 50.1 to 75%, and 9 from 76% to 100%. For calculation purposes, the maximum value in each range was used. In 1994, we sampled the sites at Bajamar and the surroundings from February to March (n=32) and in July and August (n=44). Spring and summer samplings were carried out to detect temporal variations. Therefore, we had 76 relevés: (1) in the residential area, 11 (summer); (2) in the control area, 10 (summer) and 18 (spring); and (3) in the golf course, 23 (summer) and 14 (spring). Difficulties in obtaining permission for access limited the number of samples in the residential area and made the spring samples impossible. The golf course was sampled more often in order to include the whole range of patch sizes.

DATA ANALYSES

The floristic database developed from the sampling was complemented with relevant biological features of the species encountered (e.g., life forms) and conservation attributes (endemic, native, nonnative, potentially useful). To have a graphic summary of the species and environmental relationships, direct gradient ordination analysis was done with binary data (presence/absence) and organized according to the perturbation gradient. The numerical data were ordered by decreasing dominance (shown in Table 1). Spring or summer occurrence was also assigned to each plant species in order to visualize seasonal differences.

These data were analyzed by multivariate statistical methods. Our indirect ordination and classification analysis used Multivariate Statistics Packages (MVSP-Plus 1993, PC-ORD 1999). The beta richness concept (Whittaker 1967, Purves and Orians 1983) was applied by the graphic method suggested by Escofet (1994).

Classification analysis grouped the 76 relevés according to plant composition. The three stages of grouping analysis were: (1) the Dissimilarity Matrix obtained by the minimum variance method applied to all samples and species, (2) the Jaccard Similarity Coefficient from binary data for control-spring, control-summer, new fragments-spring, new fragments-summer and old fragments-summer, and (3) the Sorensen Similarity Index from numerical data for groups obtained in the direct ordination gradient analysis (i.e., control-spring, control-summer, all summer, old fragment-summer, new fragment-summer and new fragment-spring). In stages two and three, various alternatives were explored: complete plant species list, annuals only, perennials only, and common plant species only.

An indirect gradient ordination analysis was used to relate plant cover to fragment age and type variables. A non-parametric multivariate analysis of variance (MANOVA, STADISTICA 6) was applied to data to confirm the indirect gradient analysis performed. Variables used were number of species, origin type (natives and nonnative), fragment type (control, new, and old) and life forms (annuals and perennials). The statistical hypotheses were: (1) differences in the species number are not related to the origin type, (2) differences in the species number are not related to the fragment type, and (3) differences in the species number are not related to life form.

Figure 2. Oblique aerial photograph of the study area (donated by the Bajamar golf course manager).

RESULTS

We recorded 108 plant species, which represented 57% of the CSS flora reported for the Tijuana-El Rosario region (Espejel et al. 2002). The species-area curve in each perturbation condition became asymptotic in the last three samples. This indicates that sample number was adequate in each condition (28 samples with 65 species for the control area, 37 samples with 80 species for new fragments, and 11 samples with 60 species for old fragments). Direct ordination showed how many species were exclusive to particular conditions: (1) in the control area, 11 species (seven annuals and four perennials); (2) in new fragments, 17 (11 annuals and six perennials); and (3) in old fragments, 14 (six annuals and eight perennials). Species shared among all conditions numbered 34 (seven annuals and 27 perennials), while control and new fragments shared an additional 20, old and new shared an additional 12, and control and old fragments shared only the 34.

Direct ordination of dominance of plant species showed that only the three most dominant species had values higher than 10% (Group I in Table 1). There was a large difference between the most dominant species (65% for the nonnative, invasive, annual grass foxtail chess, *Bromus madritensis* ssp. *rubens*) and the next two most dominant species, the native shrubs coastal agave (*Agave shawii* ssp. *shawii*, 18.7%) and buckwheat (*Eriogonium fasciculatum,* 14.5%). Foxtail chess was completely absent in the control area in summer, an especially important result for management. In contrast, it had a high cover value in the old and new fragments. The second most dominant species was a succulent characteristic of the "Bergerocacto emoryi-Agavetum shawii" association defined by Peinado et al. (1994). The natural distribution of coastal agave was in clumps due to its short-branched clonal growth. It had high cover in old fragments within the residential area because it was valued by people as an ornamental plant and thus protected. In contrast, relatively low cover of this species was found in control and new fragments because the random sampling crossed few clumps. In contrast, buckwheat had almost the same cover in the three conditions, although it showed some reduction in cover during the summer in old and new fragments – probably due to drought stress.

The rest of the species dominance values were lower than 10% in direct ordination (Groups II to IV in Table 1). All species of Group II were representative of CSS (at

Table 1. Summer dominance values of plant species in different conditions in the Bajamar property, and life form. Species dominance values are the upper limits of the rated class (see Methods). Groups were separated according to total dominance; Group V (<0.25%) is not shown. *=Native and endemic species (the liverworts are probably native but were not identified to species). Common names in USA according to Beauchamp (1986) and Dale (1986). Mexican common names are not provided since not all plants have one.

Group	Species	Common Name	Life Form	Summer dominance (%)			
				Total	Control	New	Old
I	*Bromus madritensis* ssp. *rubens*	Foxtail chess	Annual grass	65	0	32.5	32.5
	**Agave shawii* ssp. *shawii*	Coastal agave	Succulent	18.75	0.5	0.75	17.5
	**Eriogonum fasciculatum* ssp. *fasciculatum*	Buckwheat	Shrub	14.5	7.5	3.5	3.5
II	**Rhus integrifolia*	Lemonade-berry	Shrub	8.5	0.25	0.75	7.5
	Liverworts	Liverworts	Liverworts	1.75	0.25	0.75	0.75
	**Artemisia california*	Coastal sagebrush	Shrub	1.5	0.75	0.25	0.5
	**Lotus scoparius* var. *scoparius*	Deerweed	Shrub	1.25	0.25	0.5	0.5
	**Viguiera laciniata*	San Diego viguiera	Shrub	1.25	0.75	0.25	0.25
	**Malosma laurina*	Laurel sumac	Shrub	1	0.25	0.5	0.25
	**Euphorbia misera*	Cliff spurge	Shrub	1	0.5	0.25	0.25
	**Simmondsia chinensis*	Jojoba	Shrub	1	0.5	0.25	0.25
III	**Dudleya lanceolata*	Coastal dudleya	Succulent	0.75	0.25	0.25	0.25
	**Malacothamnus fasciculatum*	Mesa bush-mallow	Shrub	0.75	0.25	0.25	0.25
	**Cneoridium dumosum*	Bushrue	Shrub	0.75	0.25	0.25	0.25
	**Salvia munzii*	Munz' sage	Shrub	0.75	0.5	0.25	0
	**Stephanomeria diegensis*	San Diego wreath	Annual	0.75	0.25	0.25	0.25
	**Bergerocactus emoryi*	Golden snake-cactus	Succulent	0.75	0.25	0.25	0.25
	**Gnaphalium canescens* ssp. *canescens*	Pearly everlasting	Shrub	0.75	0.25	0.25	0.25
	**Ferocactus viridescens* var. *viridescens*	Coastal barrel-cactus	Succulent	0.75	0.25	0.25	0.25
	**Rhamnus crocea*	Spiny redberry	Shrub	0.75	0.25	0.25	0.25
	**Mammillaria dioica*	Fish-hook cactus	Succulent	0.75	0.25	0.25	0.25
	**Astragalus trichopodus*	Locoweed	Perennial	0.75	0.25	0.25	0.25

continued

Table 1. Continued.

Group	Species	Common Name	Life Form	Summer dominance (%)			
				Total	Control	New	Old
IV	**Nassella pulchra*	Purple needlegrass	Perennial grass	0.5	0	0.25	0.25
	**Aesculus parryi*	Buckeye	Shrub	0.5	0	0.25	0.25
	Gastridium sp.	Nit grass	Annual grass	0.5	0	0.25	0.25
	**Navarretia hamata* ssp. *leptantha*	Skunkweed	Annual	0.5	0	0.25	0.25
	**Eriogonum wrighttii* var. *dentatum*	Wright's buckwheat	Shrub	0.5	0	0.25	0.25
	**Haplopappus venetus*	Coastal goldenbush	Shrub	0.5	0	0.25	0.25
	Avena barbata	Oat	Annual grass	0.5	0	0.25	0.25
	**Centaurium venustum*	Canchalagua	Annual	0.5	0	0.25	0.25
	Centaurea melitensis	Tocalote	Annual	0.5	0	0.25	0.25
	**Dudleya attenuata*	Orcutt's dudleya	Succulent	0.5	0	0.25	0.25
	**Galium angustifolium* ssp. *angustifolium*	Narrow-leaf bedstraw	Vine	0.5	0	0.25	0.25
	**Baccharis sarothroides*	Broom baccharis	Shrub	0.5	0	0.25	0.25
	**Encelia californica*	Bush sunflower	Shrub	0.5	0	0.25	0.25
	**Opuntia littoralis*	Coastal prickly-pear	Succulent	0.5	0	0.25	0.25
	**Senecio californicus*	Butterweed	Annual	0.5	0	0.25	0.25
	Anagallis arvensis	Scarlet pimpernel	Annual	0.5	0	0.25	0.25
	**Sisyrinchium bellum*	Blue-eyed grass	Bulb perennial	0.5	0	0.25	0.25
	Salsola kali	Tumbleweed	Annual	0.5	0	0.25	0.25
	Brassica nigra	Black mustard	Annual	0.5	0	0.25	0.25
	**Calochortus splendens*	Splendid mariposa lily	Bulb perennial	0.5	0	0.25	0.25
	**Antirrhinum cyathiferum*	Snapdragon	Annual	0.5	0	0.25	0.25
	Atriplex semibaccata	Australian saltbush	Perennial	0.5	0	0.25	0.25
	**Calystegia macrostegia* ssp. *tenuifolia*	Bindweed	Vine	0.5	0	0.25	0.25

least 82% were natives), and are considered accompanying species of the Bergerocacto emoryi-Agavetum shawii association (Peinado et al. 1994). One further group of 63 species is not shown in Table 1 due to their rarity. Seventy percent of these rare species were natives.

The classification analysis based on the Dissimilarity Matrix (minimum variance) yielded a dendrogram where summer and spring samples were grouped first and then new and old fragments were separated from the control (Figure 3). As shown by the Jaccard Similarity Coefficient (between 32% and 79%) and the Sorensen Similarity Index (between 46% and 77%) there were differences among all three conditions, as well as between the seasons. This suggested that the difference among conditions was determined by the annual species and the similarity was based on the perennial species; indeed, 90% of the perennials were common to all conditions (Figures 4 a, b, c).

MANOVA results showed that only the variables related to origin (natives and nonnatives) were significant (p=0.024). This means that neither life form (p=0.251) nor fragment type (p=0.917) was related to the species number, despite their importance in species composition.

The proportion of annuals and perennials is an important characteristic in landscape conservation because it is considered a structural indicator of high quality CSS. Native species were more numerous than

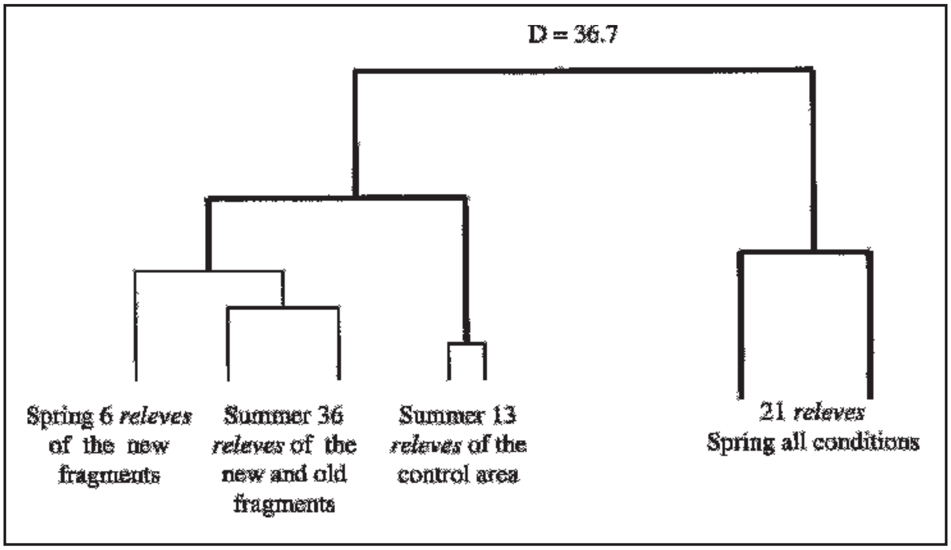

Figure 3. Cluster analysis dendrogram of samplings (simplified). D is the standard deviation.

nonnative species, and, in all conditions, perennials were more common than annuals. However, the old fragments presented higher numbers of nonnative annuals, mostly dominated by foxtail chess (Figure 4).

DISCUSSION

The idea that conservation can occur in highly fragmented landscapes has gained some attention (Schwartz 1997). This seems plausible in the present case, at least for some years, or perhaps decades, into the future. Even after intensive perturbation 20 years before our study, 77% of the native flora persisted and fewer exotic species were present than in the new fragments. The old fragments did not match the other conditions in number of native species, probably due to a combination of two effects. First, the initial clearing of native vegetation for development was apparently very extensive. Second, the suburban matrix probably limited continuing colonization of the old fragments (Hobbs 1988, McDonnell and Pickett 1990, Saunders et al. 1991, Forman 1995, Dramstad et al. 1996). With this limitation, time may become an important factor as the natural seed bank slowly becomes depleted (O'Leary 1990). On the other hand, the fragments in the golf course were not bulldozed, cut, or burned during or after fragmentation, so they may remain even better preserved. It is certainly the case that some combination of number/size of fragments could have as many native species as the control area. As

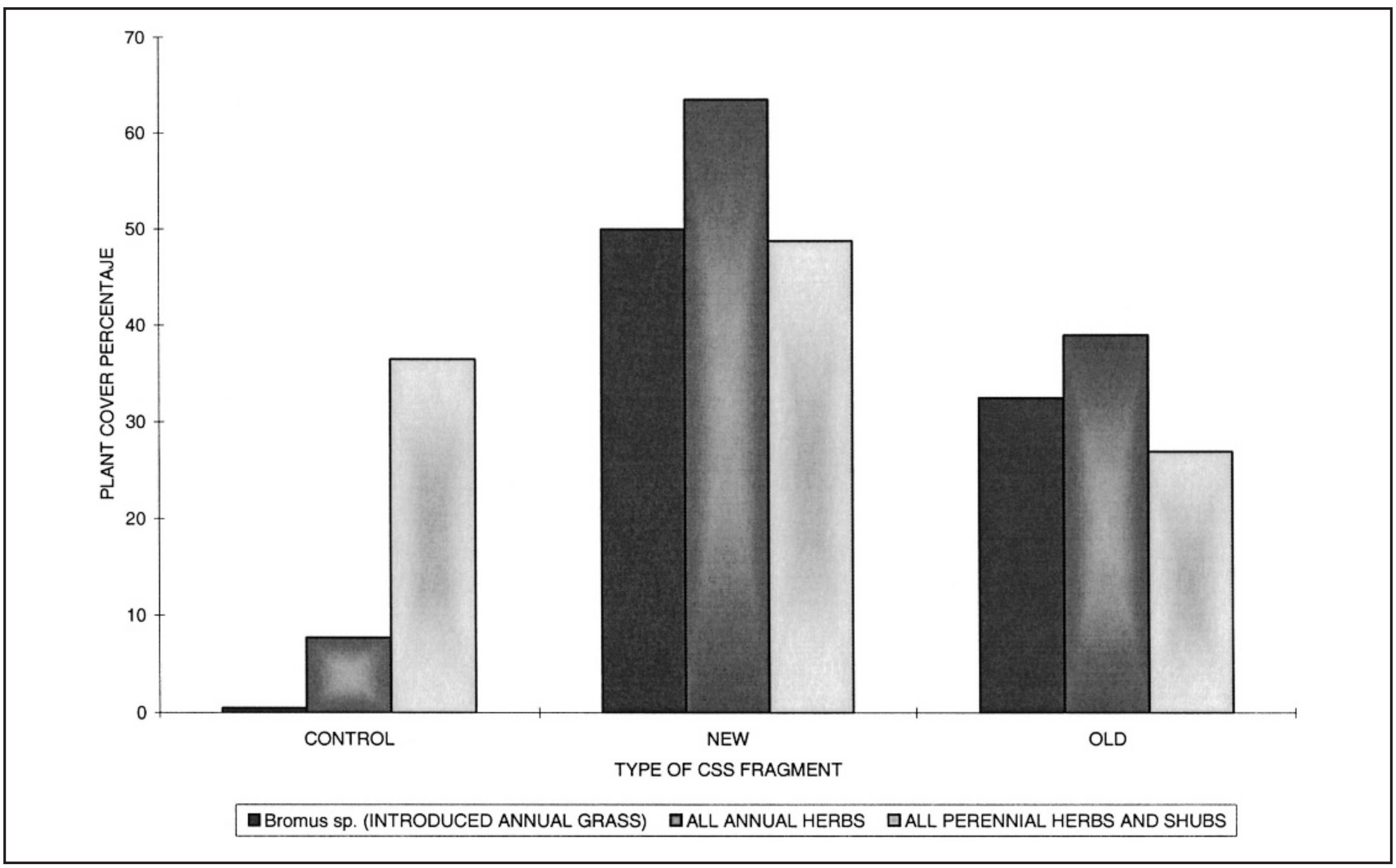

Figure 4. Cover values for foxtail chess (*Bromus madritensis* ssp. *rubens*) compared to native herbaceous plants in Bajamar.

for urban forest fragments (Hobbs 1988) and other "islands," smaller fragments will generally have smaller floras (MacArthur 1972, Saunders et al. 1991). Altogether, the total sample of new fragments in our case had a richness of native species similar to the control. New and old fragments had higher numbers of nonnative species than the control. Because the greatest number of nonnatives was not in old or control but in new fragments, some species were apparently introduced during the construction of the golf course. In addition, the effect of continuing traffic in the residential area has not matched the "construction effect," and the possibility exists of a slight decline of exotics in the recreation fragments if they are not further disturbed. Certainly, work is needed on construction practices that may decrease invasions and on management that may foster extraction of exotics.

The invasion process should be monitored because some changes in species are more important than richness itself. Foxtail chess, a nonnative and extremely invasive grass, has replaced large areas of coastal sage scrub vegetation in southern California (O'Leary and Westman 1988, Alberts et al. 1993, Minnich and Bahre 1995), and we found it to be an important element in both old and new fragments. There are two possibilities for the future development of fragments in the residential landscapes: (1) the abundance of foxtail chess in new patches could reflect a transitory stage, to be followed by a decline because of less perturbation and immigration; or (2) the invader may expand simply by dispersal on local fauna or even increasing its dominance by facilitating fires (Minnich and Bahre 1995). On the other hand, with careful management of fire, weeds, and water, the fragments might keep the desired intrinsic conditions (Alberts et al. 1993, Davis 1994, Minnich and Bahre 1995).

The most striking result obtained by cluster analysis was that the cover of the species common to all conditions, higher than 70%, was very similar among conditions. Thus, the control CSS vegetation composition and structure persisted through time and across types of perturbation at Bajamar. This suggests that CSS has resilience importance for landscape conservation purposes. Over the entire mosaic, most of the shared species were native shrubs and succulents (e.g., buckwheat, lemonade berry *Rhus integrifolia*, coastal sagebrush *Artemisia californica*, jojoba *Simmondsia chinensis*, coastal agave, golden snake cactus *Bergerocactus emoryi*, fish hook cactus *Mammillaria dioica,* and coastal barrel cactus *Ferocactus viridiscens* var. *viridiscens*) (Westman 1983, Beauchamp 1986, Delgadillo 1995, Oberbauer 1999). However, native herbaceous species were rather poorly represented in the old fragments (11%) although being an important compound of the regional CSS flora (41%) (Leyva 1995).

In urban landscapes of southern California, Soulé et al. (1988) studied the chaparral fragments as a source for wildlife refuges, and Alberts et al. (1993) studied the coastal scrub. Their results do not coincide with ours in the proportion of natives and exotic species. They present a higher number of introduced plant species, because the area they studied was mostly urban and was influenced by other sources of disturbance, such as non-natural water supplies and disruption of the fire regime – factors not occurring in the Bajamar area.

CONCLUSIONS

The Bajamar resort property and surrounding areas are representative of the modification processes of the natural landscape in the coastal zone of northern Baja California. Recreational and residential land uses have fragmented CSS and have opened new habitats. Our research suggests that CSS structure can be largely preserved in small "islands," and floristic composition can be preserved in the "archipelago" within residential and recreational developments. This may be a better alternative (rather than the traditional scheme of massive replacement of the natural landscape), not only for conservation purposes but also to improve the economics of the development, by lowering both construction and maintenance costs. The fragments also benefit the resort by significantly adding to the recreational experience (determined in interviews by Leyva 1995 and Cervantes-Rosas 2001). Initial impacts are apparently very important in determining the balance between natives and invaders. The principle management problem may be the need to limit the invasion of nonnative plants. Nonnatives compete extremely well and often increase certain hazards, such as fire potential and animal pest problems.

With these ecological and social arguments, we consider that leaving fragments of native vegetation within "developing" landscapes can benefit both the economics of use and the conservation of biodiversity.

ACKNOWLEDGMENTS

We thank Yrma Cruz and Salvador González for help with the fieldwork, Alejandro Espinoza for drawing the map, and the residents and staff of Bajamar for access. We also thank Janet Franklin and anonymous reviewers for comments on manuscript. CONACyT 3579-N9311 and FMCN A98/51 funded the project.

Claudia Leyva is a biologist from the Escuela Nacional de Ciencias Biológicas for the National Polytechnic Institute (ENCB-IPN) in Mexico City. She got her masters degree in Ecosystem Management in 1995 from the Universidad de Baja California (UABC), and has been the coordinator of the ecosystems management masters program in the same school since 1997.

Ileana Espejel is a biologist from the Mexican National University (UNAM). She got her PhD at Uppsala's University in Sweden in 1986. Since 1989, she has worked as a researcher in the Sciences School – University of Baja California (UABC).

Anamaria Escofet is an ecologist from the University of La Plata, Argentina. She got her masters degree from Washington University and got her PhD at the University of Baja California (UABC). She is a researcher at Centro de Investigación Científica y Estudios Superiores de Ensenada (CICESE).

Stephen H. Bullock is an ecologist from the University of California. Since 1991, he has been a researcher at the Centro

de Investigación Científica y Estudios Superiores de Ensenada (CICESE). He is also an Honorary Fellow of the California Academy of Sciences and an adjunct faculty of San Diego State University.

LITERATURE CITED

Alberts, A.C., A.D. Richman, D. Tran, R. Sauvajot, C. McCalvin, and D.T. Bolge. 1993. Effects of Habitat Fragmentation on Native and Exotic Plants in Southern California Coastal Scrub. Pp. 103-110 *in* J.E. Keeley, ed., Interface Between Ecology and Land Development in California. Southern California Academy of Sciences, Los Angeles.

Beauchamp, R.M. 1986. A Flora of San Diego County, California. Sweetwater River Press, National City, Calif.

Cervantes-Rosas, O.D. 2001. Aplicación de técnicas econométricas, como una aportación a la estimación del valor de ecosistemas costeros en Baja California, caso de estudio: Bajamar, Baja California. M.S. thesis, Marine Sciences School, University of Baja California, Baja California, México.

COCOTREN. 2001. Gobierno del Estado de Baja California. Ordenamiento urbano, turístico y ecológico del Corredor Costero Tijuana Rosarito Ensenada. Technical report. Secretaría de Obras Públicas. Baja California, México.

Connell, J.H. 1975. Some mechanisms producing structure in natural communities: a model and evidence from Field Experiments. Pp. 460-490 *in* M.L. Cody and J.M. Diamond, eds., Ecology and Evolution of Communities. Harvard University Press, Cambridge, Mass.

Dale, N. 1986. Flowering Plants. The Santa Monica Mountains, Coastal and Chaparral Regions of Southern California. Capra Press, Santa Barbara, Calif.

Dallman R.P. 1998. Plant life in the World's Mediterranean Climates. California Native Plant Society and University of California Press, Berkeley.

Davis, C. 1994. Successional changes in California shrub communities after mechanical anthropogenic disturbance. M.S. thesis, San Diego State University, San Diego, Calif.

Delgadillo, R.J. 1995. Introducción al conocimiento bioclimático, fitogeográfico y fitosociológico del suroeste de Norteamérica (Estados Unidos y México). Tesis doctoral, Henares University, Spain.

Di Castri, F. 1981. Mediterranean-type shrublands of the world. Pp 1-52 *in* Di Castri, D.W. Goodall, and R.C. Specht, eds., Mediterranean-type Shrublands. Elsevier, Amsterdam, Netherlands.

Diamond, J.M., 1986. Overview: laboratory experiments, field experiments, and natural experiments. Pp. 3-22 *in* J. Diamond and T.J. Case, eds., Community Ecology. Harper and Row, New York.

Dramstad, W.E., J.D. Olson, and R.T.T. Forman. 1996. Landscape ecology: principles in landscape architecture and land-use planning. Harvard University Graduate School of Design, Island Press, and American Society of Landscape Architects, Washington D.C.

Eberhardt, L.L., and J.M. Thomas, 1991. Designing environmental field studies. Ecological Monographs 61:53-73.

Escofet, A., 1994. Evaluación de hábitat y fuentes de disturbio. Pp. 497-525 *in* G. de la Lanza-Espino and C. Cáceres-Martínez, eds., Lagunas Costeras y el litoral mexicano. Universidad Autónoma de Baja California Sur, La Paz, México.

Escofet, A., I. Espejel, J.L. Fermán, L. Gómez-Morin, and G. Torres-Moya, 1994. El manejo de Fragmentos naturales e inducidos en la zona costera: alternativas para la conservación. Pp 182-193 *in* S.I. Salazar-Vallejo and N.E. González, eds., Biodiversidad Marina y Costera de México. Comisión Nacional de la Biodiversidad and CIQRO, México, D.F., México.

Escofet, A., and I. Espejel. 1999. Conservation and management-oriented research in the coastal zone of Baja California, México. Journal of Coastal Conservation 5:43-50.

Espejel, I., and L. Ojeda, 1995. Coastal plants for recreation in México. Restoration and Management Notes 13:84-89.

Espejel, I., G. Aramburo, C. Leyva, Y. Cruz, L.C. Bravo, and W. Zuñiga. 2002. Coastal vegetation of northwest Baja California: Conservation options. Bight Bulletin. Summer/Fall 5:1-5.

Forman, T.R., 1995. Land Mosaics: the Ecology of Landscapes and Regions. Cambridge University Press, Cambridge, U.K.

Hobbs, E.R., 1988. Species richness of urban forest patches and implications for urban landscape diversity. Landscape Ecology 1:141-152.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54:187-211.

INEGI. 1996. Anuario Estadístico del Estado de Baja California. Edición 1996. Instituto Nacional de Estadística, Geografía e Historia, Aguascalientes, México.

Leyva C. 1995. Dinámica de parches en el matorral costero de Bajamar, Baja California. M.S. thesis, Sciences School, University of Baja California, Baja California, México.

MacArthur, R.H. 1972. Geographical Ecology: Patterns in the Distribution of Species. Harper and Row, New York.

McDonnell, M.J., and S.T.A. Pickett. 1990. Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. Ecology 7:1232-1237.

Minnich, R.A., and C.J. Bahre. 1995. Wildland fire and chaparral succession along the California-Baja-California boundary. International Journal of Wildland Fires 5:13-24.

Moreno-Casasola, P., and I. Espejel. 1986. Clasification: an ordination of coastal sand dune vegetation along the Gulf and Caribbean Sea of México. Vegetatio 66:147-182 .

Moreno-Casasola, P., I. Espejel, S. Castillo, G. Castillo-Campos, R. Durán, J.J. Pérez-Navarro, J.J. León, I. Olmsted, and J. Trejo-Torres. 1999. Flora de los Ambientes Arenosos y Rocosos de las Costas de México. Pp. 177-258 *in* G. Halffter, comp., La Diversidad Biológica de Iberoamérica, Vol. II. New Series, Special Volume. Acta Zoologica Mexicana, Xalapa, México.

MVSP-Plus. 1993. Multi Variate Statistics Package for IBM PC and compatibles. Ver. 2.1.a. Warren L. Kovach. Wales, U.K.

O'Leary, J.F. 1990. Postfire diversity patters in two subassociations of California coastal sage-scrub. Journal of Vegetation Science 1:172-180.

O'Leary, J.F., and W.E. Westman. 1988. Regional disturbance effects on herb succession patterns in coastal sage scrub. Journal of Biogeography 15:775-786.

O'Leary, J.F., S.A. DeSimone, D.D. Murphy, P.F. Brussard, M.S. Gilpin, and R.F. Noss. 1994. Bibliographies on Coastal Sage Scrub and Related Malacophyllous Shrublands of other Mediterranean-type Climates. California Wildlife Conservation Bulletin 10:1-51.

Oberbauer, T.A., 1999. La vegetación del noroeste de Baja California. Fremontia Edición Especial 16-22.

PC-ORD. 1999. Multivariate Analysis of Ecological Data, Ver 4 for Windows. MjM Software Design.

Pase C.P., and D.E. Brown. 1982. Warm-temperate scrublands. Pp. 85-93 in D.E. Brown, ed., Biotic communities of American Southwest United States and Mexico Desert Plants. University of Arizona, for the Boyle Thompson Southwest Arboretum, Tucson.

Peinado, M., C. Bartolomé, J. Delgadillo, and I. Aguado. 1994. Pisos de vegetación de la

Sierra de San Pedro Mártir, Baja California, México. Acta Botanica Mexicana 29:1-30.

Pickett, S.T.A., and P.S. White. 1985. The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, London, U.K.

Purves, W.K., and G.H. Orians. 1983. Life: the Science of Biology. Sinauer Associates, Sunderland, Mass.

Saunders, D., R. Hobbs, and C. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5:18-32.

Sawyer J.O., and T. Keeler-Wolf. 1995. A Manual of California Vegetation. California Native Plants Society, Sacramento.

Schwartz, M.W. (ed.). 1997. Conservation in Highly Fragmented Landscapes. Chapman and Hall, New York.

Shafer, L.C. 1990. Nature reserves: island theory and conservation practice. Smithsonian Institution, Washington, D.C.

Shafer, L.C. 1997. Terrestrial nature reserve design at the urban/rural interface. Pp. 345-378 in M. Schwartz, ed., Conservation in Highly Fragmented Landscapes. Chapman and Hall, New York.

Soulé, M.E., D.T. Bolger, A.C. Alberts, R. Sauvajot, J. Wright, M. Sorice, and S. Hill. 1988. Reconstructed dynamics of rapid extinctions of chaparral-requiring bird in urban habitat islands. Conservation Biology 2:75-92.

STADISTICA 6. 1984-2002. Ver 6.1, Stat Soft, Inc.

U.S. Research Council. 1983. Ecological knowledge and environmental problem solving. National Academic Press, Washington, D.C.

Westman, W.E. 1983. Xeric Mediterranean type shrub land associations of Alta and Baja California and the community / continuum debate. Vegetatio 53:3-19.

Westman, W.E. 1987. Implications of ecological theory for rare plant conservation in coastal sage scrub. Pp. 133-140 in T.S. Elias, ed., Conservation and management of rare and endangered plants: proceedings of a California conference in the conservation and management of rare and endangered plants. California Native Plant Society, Sacramento.

Whittaker, R.H, 1967. Gradient analysis of vegetation. Biological Reviews 49:207-264.