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Biological diversity in the Tehuacán-Cuicatlán Valley, Mexico

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Abstract. A general overview of the biological knowledge of the floristic province of the Tehuacán-Cuicatlán Valley in central-southern Mexico is presented. Floristic and faunistic richness and endemism, as well as uses of the flora are analyzed and discussed for this area, recently declared a biosphere reserve. The analysis shows that, in approximately 10 000 km^2, the Tehuacán-Cuicatlán Valley contains between 10 and 11.4% of the Mexican flora. In addition, the valley possesses 365 endemic species that represent 13.9% of its flora. With respect to the fauna diversity, the available information is less comprehensive than for plants. Nevertheless, the study shows that the 11 species of amphibians, 48 species of reptiles, and 91 species of birds recorded for the valley surpasses the diversity found in other dry-lands of the world. In relationship to the mammals of the region, the available data are poor for most of the groups except for bats, for which 24 species have been reported. Regarding the use of the flora, the analysis revealed that 815 species are utilized by the people in the valley. A discussion related to future research activities is also included.

Key words: arid zones, biodiversity, Mexico, Tehuacán-Cuicatlán Valley

Introduction

The Mexican territory possesses a complex geological history including the confluence of two different ancestral biotas that gave rise to a composite biogeographic zone (Flores-Villela and Geréz 1994). In addition, there is a high rate of endemic taxa, which apparently is the result of a high availability of habitats with specific biotic and abiotic features. Accordingly, the extant biota in the country are adapted to live, grow and reproduce within a variety of environments.

Within the complex biological and physical framework that constitutes the biodiversity resources of Mexico, a numerous and rich ethnic inheritance has lived, used and modified the natural habitats in different ways through time. Each ethnic

group has its own history, activities and particular requirements, in accordance with its needs and the environmental conditions under which it lives. Their activities have produced environmental alterations and in some instances positively influenced the genetic maintenance of some ecosystems.

The need for understanding the world's biological diversity has produced different criteria to evaluate and propose appropriate decisions to enable its usage, protection, and conservation. One of these criteria is the identification of centers of diversity and endemism in the world. Using this criterion, the World Conservation Union (IUCN) has identified 12 regions in the world, each of them possessing different centers of diversity that deserve special attention for the development of research and protection activities (Davies et al. 1997). The IUCN considers Mexico as part of its 'Middle America' region, along with Guatemala, Nicaragua, El Salvador, Honduras, Costa Rica, and Panama. Twelve centers of diversity were recognized for Mexico, among them the Tehuacán-Cuicatlán Valley, which was recently declared a biosphere reserve by the Mexican Government-UNESCO (February 1998).

The aim of this study is to synthesize all biological information available for the Tehuacán-Cuicatlán Valley, and to analyze within this information framework, its biodiversity, endemism and future research activities.

Methodology

Inventories

Field work for plant inventories was done from 1981 until now, visiting 780 localities in the valley and collecting specimens that were deposited in the National Herbarium of the UNAM (MEXU) and in the herbarium of ENEP-Iztacala (IZTA). Taxonomic revisions of the collected material resulted in the publication of the Flora of the Tehuacán Valley (Dávila et al. 1993) and the taxonomic revisions of some plant groups (fascicles) of the region (Fryxell 1993; Tellez and Sousa 1993; Calderón de Rzedowski and Rzedowski 1994; Dávila and Sánchez-Ken 1994; Medina 1994; Quero 1994; Rzedowski and Calderon-Rzedowski 1994; Todzia 1995; Riba and Lira 1996; Tellez 1996 a,b; Ezcurra and Medina 1997; Hernández 1997; Medina 1997a,b; Medina and Dávila 1997; Sánchez-Ken 1997; Tellez and Dávila 1997; Lomeli-Sención 1998; Rico-Arce and Rodriguez 1998; Lira and Rodriguez-Arevalo 1999) published by UNAM. In addition, on the basis of this work a database of all the herbarium specimens information (geographic coordinates and general ecological requirements) was expanded.

Field work for animal inventories, specifically for birds and mammals, was done between 1986 and 2000. During all these years, continuous work consisting of visiting, counting and trapping specimens in selected localities representing the different vegetation types in the valley was done. The collected specimens were deposited

at the Laboratorio de Ecología de Comunidades in the Ecological Institute of the UNAM. Data for amphibians, reptiles and insects was obtained from the literature, including theses and other unpublished work from the authors.

Vegetation

Field work for undertaking the description and structure of the vegetation types in the valley was done from 1981 until 1999. As a result of this work, all the different plant communities were described and mapped. In addition, a remote sensing image analysis for the valley enabled the production of a GIS referenced map for the area (Osorio et al. 1996; Valiente-Banuet et al. 2000).

Ethnobotanical data

Data on the use of plants by different ethnic groups in the area began in 1991 and continues at present. Several studies have been published regarding use, domestication and ecological traits of some plant species (Valiente-Banuet et al. 1992; Casas and Valiente-Banuet 1995; Casas et al. 1994, 1997a,b, 1998, 1999a–d, 2001).

In summary, all data gathered by the authors during almost 20 years of field work and complemented with the available literature has been integrated, in order to present an updated and synthesized view of the biological diversity of the Tehuacán-Cuicatlán Valley.

Study area

The floristic province of the Tehuacán-Cuicatlán Valley is considered part of the Mexican xerophytic region (Rzedowski 1978) and is located in the southern part of the state of Puebla and Northern Oaxaca, between 17°39′ and 18°53′, and between 96°55′ and 97°44′ (Figure 1). The valley covers an area of almost 10 000 km^2 and represents a complex physiographic mosaic with internal valleys, separated by numerous mountain chains. It is considered a semi-arid region, with a medium annual temperature of 21 °C and a medium annual precipitation of 400 mm. The arid conditions of the valley are mainly the result of the 'orographic shadow' effect that produces the Sierra Madre Oriental (Villaseñor et al. 1990; Valiente 1991; Dávila et al. 1993).

Results

Floristic richness of the Tehuacán-Cuicatlán Valley

The plant communities found in the valley are various and complex. Twenty-nine different vegetation associations were present in the valley (Valiente-Banuet et al.

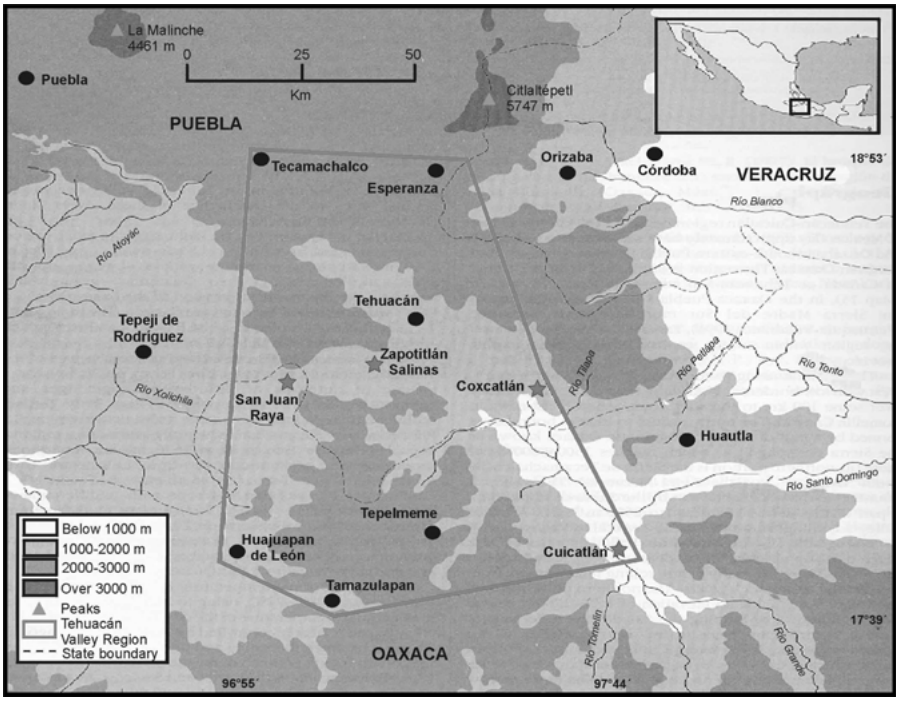

Figure 1. Study site location.

2000), including the Mezquite woodlands found in the river basins, to the complex and diverse columnar cacti widely distributed in the region, the tropical deciduous forests located in the humid parts and the temperate vegetation, such as the Mexical shubland (Chaparral) in the upper part of the valley (Valiente-Banuet et al. 1998). This small semi-isolated valley, comprising a complex mosaic of vegetation, has developed into a region with a high biotic diversity and endemism rate. The information of the floristic richness of the Tehuacán-Cuicatlán Valley will be presented for each major plant group in the following order: mosses, ferns, gymnosperms and angiosperms.

Mosses

Delgadillo and Zander (1984) found a total of 57 species in the Tehuacán-Cuicatlán Valley. The Pottiaceae, common in dry and hot habitats of the valley is the dominant moss family in the region with 39 species. There are also boreal moss elements that are restricted to places where water availability is sufficient. Among these boreal elements the following species are included: *Funaria orizabensis*, *Bryum apiculatum*, *Lindbergia mexicana*, *Cryphaea polycarpa* and *Macrocoma orthotichoides*. The moss flora of the Tehuacán-Cuicatlán Valley includes 33 species. Some of them are widely distributed, whereas a few show disjunct distribution patterns. About 20 species of mosses present in the valley occur in the Americas, including some that are

Table 1. Floristic richness of the Tehuacán-Cuicatlán Valley.

Plant group	Families	Genera	Species	Infraspecific taxa
Mosses	–	28	57	–
Ferns and allied groups	15	47	156	3
Gymnosperms	4	5	9	–
Angiosperms	161	862	2521	45
Monocotyledons	33	183	509	
Dicotyledons	128	679	2012	
Total of vascular flora	180	891	2621	48

only known from the southern part of the United States and northeastern Mexico, whereas others extend to Central and South America, and some even show an Antillean affinity. Finally, the authors reported the occurrence of four Mexican endemic species in the valley (*Didymodon incrassatolimbatus*, *Erpodium pringlei*, *F. orizabensis*, and *Gyroweisia obtusifolia*).

Vascular flora

The vascular flora of the Tehuacán-Cuicatlán Valley contains 180 families, 891 genera, and 2621 species (Dávila et al. 1993, see Table 1).

Ferns and allied groups. The ferns or Pteridophytes, as well as their allied groups, are well represented in the valley. They are mainly found in small crevices or cañadas where humidity is more or less constant throughout the year. Currently in the Tehuacán-Cuicatlán Valley the fern diversity registered is of 15 families, 47 genera and 156 species (Table 1). The most important genera are *Notholaena, Adiantum*, and *Selaginella*. Only *Pleopodium tricholepis* is endemic to the valley (Dávila et al. 1993).

Gymnosperms. This group is represented in the valley by nine species in five genera representing four families. The pines (*Pinus* spp.) are dominant elements in the pine or pine-oak forests that are usually established above 2000 m. The genus *Juniperus* (enebro or ajenjibre) is generally present in the transitional habitats between the xerophylous vegetation and the pine or pine-oak forests. Some other genera such as *Ephedra* and *Dioon* are not dominant elements in any vegetation, but are characteristic of the region. The following three species are endemic to the valley: *Dioon califanoi*, *D. caputoi*, and *D. rzedowskii* (Dávila et al. 1993).

Angiosperms. The angiosperms are the dominant plant group in the region. They have representatives in all types of habitats, which is reflected in the tremendous diversity observed in the valley. For organization purposes, we have divided this part into two groups, the monocotyledons and the dicotyledons (Table 1).

(a) Monocotyledons: This plant group includes important floristic elements of the region, such as the following families: Poaceae, Bromeliaceae, Agavaceae, Orchidaceae. Within these families, there are dominant and very diverse genera such as *Muhlenbergia*, *Hechtia*, *Agave*, *Yucca*, *Beaucarnea*, *Nolina*, *Encyclia*, which are important elements of the scrubland vegetation. Our studies have resulted in the registration of a total of 33 families, 183 genera and 509 species of monocotyledons present in the valley. Currently we have registered 43 endemic species of monocotyledons in the valley (Dávila et al. 1993).

(b) Dicotyledons: This plant group includes many dominant and co-dominant species in the different plant communities. In this group are included some important families, such as Cactaceae, Fabaceae, Asteraceae. Within these families there are important genera such as *Opuntia*, *Neobuxbaumia*, *Acacia*, *Mimosa*, *Viguiera*, *Verbesina*. As summarized in Table 1, a total of 128 families, 679 genera and 2012 species of dicotyledons are found in the Tehuacán-Cuicatlán Valley. Currently we have identified 318 species of dicotyledons endemic to the valley, within 180 different genera (Dávila et al. 1993).

Comparison of floristic richness of the Tehuacán-Cuicatlán Valley to other floristically known areas of Mexico

The floristic richness of the Tehuacán-Cuicatlán Valley might be better understood by comparing it to other known taxonomic groups and/or regions located in Mexico. It is well documented that some of the highly diversified plant groups in the country belong to the Asteraceae (Toledo et al. 1997), Fabaceae (Sousa and Delgado 1993), Orchidaceae (Soto-Arenas 1988), Poaceae (Valdés-Renya and Cabral 1993), Cactaceae (Arias-Montes et al. 1997), and Lamiaceae (Ramamoorthy and Elliott 1993) families. The valley contains approximately 10% of the 30 000 vascular plant species found in Mexico (Toledo 1985) (Table 2). This percentage increases to 11.4% if the estimates of the floristic diversity of Mexico proposed by Rzedowski (1993) are followed, in which 22 800 taxa of vascular plants are recognized in Mexico. Invariably, these studies show that the Tehuacán-Cuicatlán Valley has between 10–11.4% of the national plant diversity in its approximately 10 000 km^2.

The floristic richness of the valley can be compared also to other floristically known regions in Mexico, which show different total areas and vegetation communities (Figure 2, Table 3). The total number of species that has been registered per km^2 helps indicate local plant diversity, as well as its overall value for comparison purposes within the country. The ratio obtained by dividing the number of plant species registered in each region by its area, can be used as a general indicator of its floristic diversity. In Table 3, the largest ratios obtained are for the Tehuacán-Cuicatlán Valley, Sierra de Manantlán, state of Querétaro and the Biological Stations of 'Los Tuxtlas' and Chamela. By comparison, the smallest ratios obtained and indicating the lowest number of species per area are found in the states of Baja California and Baja Cali-

Table 2. Comparative floristic richness of the most highly diverse families in Mexico in the Tehuacán-Cuicatlán Valley.

Family	Estimated number of species in Mexico	Number of species in the valley	Mexican species in the valley (%)	References
Asteraceae	2400	345	14.4	Dávila et al. 1993; Toledo et al. 1997
Fabaceae	1800	290	16.1	Dávila et al. 1993; Sousa and Delgado 1993
Poaceae	950	215	22.6	Dávila et al. 1993; Valdés-Reyna and Cabral 1993
Orchidaceae	920	60	6.5	Dávila et al. 1993; Soto-Arenas 1988
Cactaceae	850	81	9.5	Arias-Montes et al. 1997
Labiatae	512	95	18.6	Dávila et al. 1993; Ramamoorthy and Elliott 1993

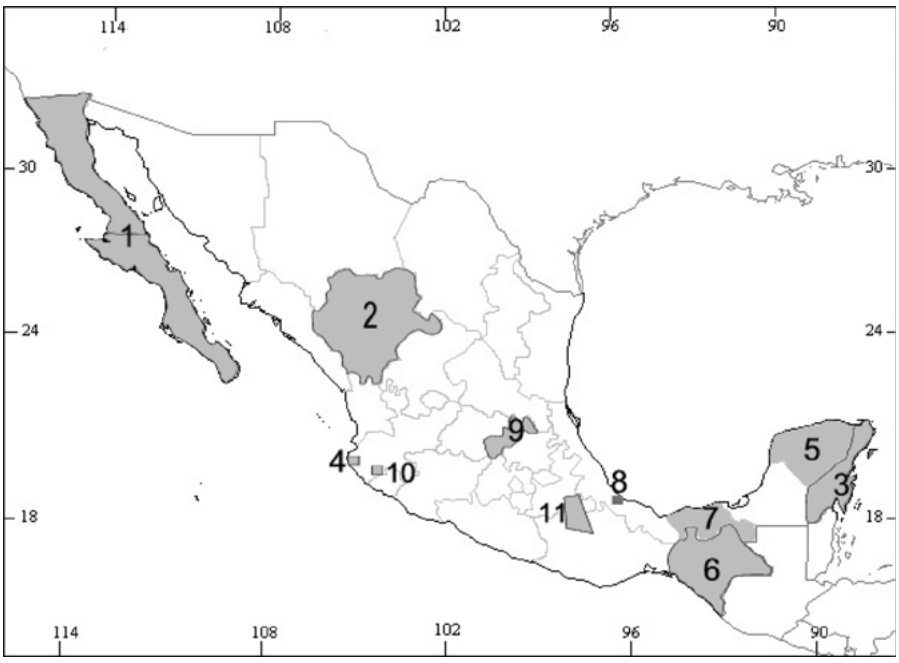

Figure 2. Geographical comparison of the floristic richness of the Tehuacan-Cuicatlan Valley with other well-studied regions in Mexico (see Table 3).

Table 3. Comparative floristic richness of some Mexican regions and in the Tehuacán-Cuicatlán Valley (see Figure 2).

	Region or state	Species	Area (km^2)	Species/km^2	References
1.	States of Baja California and Baja California Sur	2958	143 790	0.02	Wiggins 1980
2.	State of Durango	3800	119 648	0.03	González et al. 1991
3.	State of Quintana Roo	1300	50 350	0.03	Sousa and Cabrera 1983
4.	Biological Station, Chamela, Jal.	754	160	4.71	Lott 1985
5.	State of Yucatán	1936	39 340	0.05	Sosa et al. 1985
6.	State of Chiapas	7018	73 677	0.09	Breedlove 1981
7.	State of Tabasco	2147	24 661	0.09	Cowan 1983
8.	Biological Station, Los Tuxtlas, Ver.	818	70	11.68	Ibarra and Sinaca 1987
9.	State of Querétaro	2334	11 769	0.19	Argüelles et al. 1991
10.	Sierra de Manantlán, Jal.	2774	14 000	0.19	Vázquez et al. 1995
11.	Tehuacán-Cuicatlán Valley	2621	10 000	0.26	Dávila et al. 1993

fornia Sur, Quintana Roo, and Durango. Finally, a few regions present intermediate ratios values such as the flora of the Tabasco, and Yucatán. These analyses show that the plant diversity in the Tehuacán-Cuicatlán Valley is unusually high when compared to other regions of the country that are floristically well known.

Endemism

In addition to the floristic richness, the endemism rate has been used as another important biological indicator. Of the 180 families present in the valley, 76 (42.2%) have at least one endemic species in the area (Table 4A). The Polypodiaceae is the only Pteridophyte family with one endemic species inhabiting the area. In the gymnosperms the three endemic species belong to the Cycadeaceae. A total of 74 angiosperm families have at least one endemic species present in the valley (15 monocotyledons and 59 dicotyledons) (Table 4A). Among the monocotyledon families that have three or more endemic species in the valley are: Agavaceae (5 species), Cyperaceae (5 species),

Table 4. Summary of the total number of plant (A) families, (B) genera, and (C) in total which have at least one endemic species in the Tehuacán-Cuicatlán Valley.

(A) Plant group	Number of families	Number of families with at least one endemic species	Families with at least one endemic species (%)
Ferns and allied groups	15	1	6.7
Gymnosperms	4	1	25
Angiosperms	161	74	46.0
Monocotyledons	(33)	(15)	(45.5)
Dicotyledons	(128)	(59)	(46.1)
Total	180	76	42.2
(B)	Number of genera	Number of genera with at least one endemic species	Genera with at least one endemic species (%)
Ferns and allied groups	47	1	2.12
Gymnosperms	5	1	20
Angiosperms	862	203	23.5
Monocotyledons	(183)	(23)	(12.6)
Dicotyledons	(679)	(180)	(26.5)
Total	914	205	22.4
(C)	Number of plant species	Number of endemic species	Endemic species (%)
Ferns and allied groups	156	1	0.6
Gymnosperms	9	3	33.3
Angiosperms	2521	361	14.3
Monocotyledons	(509)	(43)	(8.4)
Dicotyledons	(2012)	(318)	(15.8)
Total	2686	365	13.6

Iridaceae (4 species) and Bromeliaceae (13 species). Among the dicotyledon families that have 10 or more endemic species are: Asclepiadaceae (10 species), Leguminosae (11 species), Acanthaceae (13 species), Lamiaceae (18 species), Crassulaceae (25 species), and Cactaceae (28 species).

Seven genera are endemic to the valley and most of them are monotypic: *Gypsacanthus* (Acanthaceae), *Oaxacania* (Asteraceae), *Escontria* (Cactaceae), *Mitrocereus* (Cactaceae), *Polaskia* (Cactaceae), *Fosteria* (Iridaceae), and *Gibasoides* (Commelinaceae).

In addition, there are 205 genera (23% of the total number of genera present in the area) that have at least one endemic species (Table 4B). In the ferns, the only genus that has an endemic species is *Pleopodium*. In the gymnosperms, the genus *Dioon* has three endemic species, whereas in the angiosperms, 74 genera have at least one endemic species (15 genera in the monocotyledons and 59 in dicotyledons). Within the monocotyledons, the genera that have three or more endemic species are: *Tillandsia* (3), *Schoencaulon* (4), *Agave* (5), *Hechtia* (10). In the angiosperms the genera that have three or more endemic species are: *Phoradendron* (3 species), *Acacia* (3 species), *Polygala* (3 species) *Matelea* (5 species), *Acourtia* (5 species), *Perymenium* (5 species), *Verbesina* (5 species), *Euphorbia* (5 species), *Jatropha* (5 species), *Dalea* (6 species), *Viguiera* (6 species), *Sedum* (8 species), *Quercus* (9 species), *Mamillaria* (11 species), *Salvia* (13 species), and *Echeveria* (14 species).

At the species level, registered so far, 365 species of vascular plants are endemic to the Tehuacán-Cuicatlán Valley. In other words, approximately 13.9% of the known vascular flora of the valley is endemic. From the total endemic species, one is a fern, three are gymnosperms and 361 are angiosperms (43 monocotyledons and 318 dicotyledons) (Table 4C). The endemism rate can be better appreciated if compared with other floristically known areas, where the endemism rates have been documented. The regions with the highest number of endemic species are the Baja California Peninsula (23.1% of endemic species) and the Tehuacán-Cuicatlán Valley (14.2% of endemic species), whereas Manantlán (1.08%) and Los Tuxtlas (1.22%) show very low rates of endemism (Table 5). Interestingly, the first two regions are located in dry areas, whereas Manantlán is mostly included in a tropical montane region, and Los Tuxtlas is located in a humid, hot lowland area. Accordingly, the results obtained and shown in Table 4C agree with those obtained by Rzedowski (1993), who states that in the arid and semi-arid regions of Mexico, the endemism rate is higher than in other temperate (excluding the Cloud Forest) and lowland humid zones.

Uses of the flora

In the Tehuacán-Cuicatlán Valley there are six different ethnic groups (Table 6) inhabiting different areas and using the existent natural resources. Even though a comprehensive record of the uses of the natural resources by the communities has not been accomplished, there is some evidence that highlights the importance and the

Table 5. Summary of species endemism rates for some floristically well-known regions of Mexico.

Region	Species	Endemics	Endemism (%)
Sierra de Manantlán	2774	30	1.1
Baja California Peninsula	2958	686	23.2
Biological Station of Los Tuxtlas	818	10	1.2
Tehuacán-Cuicatlán Valley	2564	365	14.2

Table 6. Ethnic groups represented in the Tehuacán-Cuicatlán Valley

Ethnic groups	Principal settlements
Nahuas	Tehuacán, Coxcatlán and Sta. María Coapan
Popolocas	Tlacotepec de Benito Juárez, Tepanco de López, San Gabriel Chila and Zapotitlán Salinas
Mazatecos	Teotitlán del Camino and Cuicatlán
Chinantecos–Cuicatecos	Cuicatlán
Ixcatecos	Sta. María Ixcatlán
Mixtecos	Teotitlán del Camino, Sta. María Ixcatlán, Teposcolula and Huajuapan de León

relationship of these resources to the subsistence of the human groups in the region. A total of 815 useful plant species were identified by Casas et al. (2001). Most of these species are native (nearly 90%), 42 of which are endemic to the region. A total of 685 are wild species and 117 are weeds and ruderal plants foraged by both humans and domestic animals where they occur, but 59 of them are also managed *in situ*, whereas 167 species are cultivated.

Faunistic richness of the Tehuacán-Cuicatlán Valley

In general terms, the fauna of the Tehuacán-Cuicatlán Valley is known relatively less than its vascular flora. An insect inventory of the Coreids (Hemiptera–Heteroptera) native to the valley by Brailovsky et al. (1994, 1995) found 24 species. Incidental observations show that there is a high diversity of ants and termites, as well as other arthropods such as scorpions and spiders. Nothing yet has been systematically documented.

With respect to the vertebrates, the situation is quite similar. The only revision that has been accomplished in the valley includes some animal groups that are directly related to human history in the valley (Byers 1967). Recently some specific groups, such as amphibians and reptiles have been studied (Canseco 1996). In addition, an inventory of the bats mainly inhabiting the Zapotitlán Valley has been undertaken by Rojas-Martínez and Valiente-Banuet (1996) and Arizmendi and Espinosa de Los Monteros (1996) have finished the faunistic checklist of the birds that inhabit the valley.

Faunistic richness assessment

A summary of the faunistic richness of the Tehuacán-Cuicatlán Valley in each major animal group is presented below.

Insects

Relatively little is known about the distribution and diversity of insects of the valley even though some authors have recognized this group as very diverse in the deserts of the world (MacKay 1991; Crawford 1981, among others). For the Tehuacán Valley two studies have focused on the relationships of seven species of Coreidae (Brailovsky et al. 1994, 1995). A total of 24 species of Coreidae has been documented, as needing specific plants for their survival or to complete certain parts of their life cycle (*Opuntia*, *Prosopis* and *Acacia*). Interestingly, three species (e.g., *Celinidea staffilesi*, *C. tabulata*, and *Narnia femorata*) are strongly associated to *Opuntia pilifera* on which they feed and reproduce. The remaining four species (*Mozena lunata*, *Pachylis hector*, *Savius jurgiosu*, and *Thasus gigas*) feed on either *Acacia farnesiana* or *Prosopis laevigata*.

The ants are well represented and are abundant in the valley. They forage for columnar cacti seeds contained in the soil and produce high depredation (Valiente-Banuet and Ezcurra 1991b). However, the ant diversity in the valley is almost unknown, a fact that is also true for most other areas of the world (MacKay 1991).

Termites are also very common in the valley, but very little is known about their life histories and diversity.

The social and solitary bees have been identified as primary pollinators of some cacti species, especially the barrel shape or the globose-type, such as *Echinocactus* spp. and *Ferocactus* spp., and some important shrubs, such as *Acacia* spp. and *Prosopis* spp. Some bee species are considered secondary pollinators or 'nectar thieves' of some cacti, especially the columnar taxa (Valiente-Banuet et al. 1996a,b, 1997a,b). The taxonomy and behavior of this group of species is currently being studied at the Instituto de Biología, UNAM and the Universidad de Las Américas in the state of Puebla.

Amphibians and reptiles

These groups are well represented in the valley, but again not well known. The first studies of amphibians and reptiles of the valley are by Byers (1967), who gave a description of those species that are useful to people. Flannery (1967) documents the use of five species of reptiles: (1) *Kinosternon integrum* (turtle), which is still present in the region, even though it is scarcely seen nowadays; (2) *Gopherus berlandieri* (Pleistocene turtle), which is apparently extinct; (3) *Iguana iguana*, (green Iguana), now restricted to the humid parts of the valley and probably more common in the past; (4) *Ctenosaura pectinata*, which represents a common species of the region, and (5) *Ameiva undulata*, which is also common, especially during the summer.

Table 7. Amphibians, reptiles (according to Canseco 1996) and birds (this work) endemic to the Tehuacán-Cuicatlán Valley.

Name	Classification	Common name	Habitat
Barisia imbricata planifrons	Reptilia: Squamata, Sauria	Scorpion	Pine–oak forests
Mesaspis juaresi	Reptilia: Squamata, Sauria	Scorpion	Pine–oak forests
Sceloporus siniferus cupresus	Reptilia: Squamata, Phrynostomatidae		Oak forests
Urosaurus bicarinatus Nelson	Reptilia: Squamata, Phrynostomatidae		Tropical deciduous forest
Geophis duellmani	Reptilia: Serpentes, Colubridae		Pine-oak forest
Crotalus intermedius gloydi	Reptilia: Serpentes, Viperidae	Snake	Pine–oak forest
Pseudoeurycea juarezi	Amphibia: Caudata, Plethodontidae	Salamander	Pine–oak forest
Thorius sp. G de Hanken (1983)	Amphibia: Caudata, Plethodontidae	Frog	Pine–oak forest
Cynanthus sordidus	Apodiformes: Trochilidae	Dusky Hummingbird	Cosmopolite
Calothorax pulcher	Apodiformes: Trochilidae	Beautiful Hummingbird	Cosmopolite
Melanerpes hypopolius	Piciformes: Picidae	Gray-breasted Woodpecker	Columnar cacti forests
Campylorhynchus jocosus	Passeriformes: Troglodytidae	Boucard's Wren	Columnar cacti forests
Toxostoma ocellatum	Passeriformes: Mimidae	Ocellated Thrasher	Columnar cacti forests
Vireo brevipennis	Passeriformes: Vireonidae	Slaty Vireo	Columnar cacti forests
V. nelsoni	Passeriformes: Vireonidae	Dwarf Vireo	Columnar cacti forests
Pipilo albicollis	Passeriformes: Emberizidae	White-throated Towhee	Riparian forests
Aimophila mystacallis	Passeriformes: Emberizidae	Bridled Sparrow	Riparian forests
A. notosticta	Passeriformes: Emberizidae	Oaxaca Sparrow	Columnar cacti forests

Recently, Canseco (1996) has undertaken an inventory of the Cañada de Cuicatlán region located in the southern part of the valley. His report includes all the species reported by Flannery (1967), except *Ameiva undulata*. He registered 11 amphibian species and 48 reptiles, including 8 endemic species of Oaxaca. The high elevations of Cuicatlán are dominated by pine–oak forest, whereas tropical deciduous forests and scrubland vegetation are common in the lowlands. The highest diversity of amphibians and reptiles (50% of the local herpetofauna) in this area is concentrated in the lowlands, where the dominant plant elements are the columnar cacti and some elements of the tropical deciduous forest, such as *Bursera*, *Conzattia*, and *Lysiloma*. The eight endemic species are described in Table 7 along with their habitat in the region.

In contrast, in some other deserts of the world, it is common that only a few amphibian species are present. In fact, Vit (1991) and Woodward and Mitchell (1991) stated that usually there are no more than 10 species of this group in some arid regions. Within the reptiles, there are some species that have specialized in inhabiting dry areas, but again their regional diversity is also low. In the North American temperate deserts (Chihuahuan, Sonoran, Mohave and Great Canyon), a total of 4–11 species of lizards, iguanas and turtles, as well as an average of 4.5 snake species, have been registered. In contrast, in Australia there are 15–42 species of lizards, iguanas and turtles and an average of 3.6 snake species per site (Woodward and Mitchell 1991). Compared to the data obtained from the deserts of North America and Australia, the valley shows a higher diversity by having 27 species of lizards, iguanas and turtles and 21 species of snakes (Canseco 1996).

Birds

The bird assemblage that inhabits deserts has been poorly studied, with respect to species richness and endemism (Serventy 1971). However, some important contributions to these aspects have been published, for example, the ornithological study of the American deserts (Mojave and Great Canyon) by Uvardy (1958), where he found 39 bird species. In studies undertaken in the Sahara desert, Moureau (1966) registered 25 bird species, while McMohan (1990) reported 31 bird species for the same area. In Australia, a total of 40 bird species from its dry zones have been reported (Williams and Calaby 1985), and finally, in Mexico, Thiollay (1981) pointed out the existence of 47 resident bird species located in the Bolsón de Mapimi region of the state of Durango, in north-central Mexico.

The characteristics and distribution of the bird fauna of the valley were formerly presented by Flannery (1967), who reported a total of 10 bird species that were commonly eaten by man in the prehistory of the Tehuacan Valley. These species are: *Anas cyanoptera* (pato canela), *Colinus virginianus* (partridge), *Meleagris gallopavo* (wild turkey), *Charadius vociferus* (chichicuilote), *Zenaida asiatica* and *Columbina passerina* (doves), *Tyto alba* (owl), *Caprimulgus ridgwayi* and *Chordeiles acutipennis* (chotacabras), and *Corvus corax* (raven).

In a recent study, Arizmendi and Espinosa de los Monteros (1996) studied five localities within the valley dominated by giant columnar cacti with different floristic composition and tropical deciduous forests. They found 91 bird species, belonging to 13 orders and 27 families. From these species, 10 are endemic (Table 7) to the physiographic province denominated 'Cuenca del Balsas' and Tehuacán-Cuicatlán Valley (Rzedowski 1978). Interestingly, four of the birds species mentioned by Flannery (1967) (*A. cyanoptera*, *C. virginianus*, *M. gallopavo* and *C. acutipennis*) were not found in the sampled localities. Due to the fact that these four species are associated with more humid habitats than those found at present, it is probable that they have disappeared locally under the drier conditions. An additional species, mentioned by Flannery (1967), *T. alba*, was also not found by Arizmendi and Espinosa de los Monteros (1996). However, based on the local reports, as well as incidental findings of feathers, bones and muscle remains in the southern region of the valley, it is probable that they still exist in the area although with a low density value.

Additional records made from 1996 until now by the authors increased the number of species cited to 141. When the complete bird checklist of the valley is compared to other North American deserts, where information is already available, the pattern observed highlights the higher bird diversity in the Tehuacán Valley. This valley shows one-third more species than the Sonoran and the Chihuahuan deserts, and it almost doubles the total number of species from the Mohave and Great Canyon deserts, even though these areas are much larger than the Tehuacán Valley.

Bird fauna of the Tehuacán Valley shares only 30% of its species with the North American deserts. In contrast, when tropical bird species are excluded, the results show that the Tehuacán-Cuicatlán Valley and other North American deserts share about 80% of their species. The difference in the species shared by all these deserts, is probably due to the fact that the bird fauna of the Tehuacán-Cuicatlán Valley shares more species with those typical of the southern tropical deciduous forests of Jalisco, Michoacán, Guerrero, and Oaxaca.

The birds in the valley play an important role in mutualistic relationships with several species of plants. It is believed that mutualistic relationships enhance plant reproduction. For example, some hummingbirds are important pollinators of *Fouquieria* spp. (ocotillos) and act as occasional pollinators for some columnar cacti (*Pachycereus*, *Neobuxbaumia*, *Cephalocereus*, etc., Valiente-Banuet et al. 1996a). Other birds as orioles, mockingbirds and woodpeckers are also seed dispersers for some plant species (Valiente-Banuet et al. 1991a,b, 1996a,b).

Mammals

Arid zones have traditionally been characterized as simple ecosystems, where vertebrate diversity is low. However, there are some mammal groups that are specialized in living in arid and semi-arid regions and their diversity can be very high locally, as it is in other types of ecosystems (Reichman 1991). In the Tehuacán-Cuicatlán Valley, a study summarizing all the mammal information has not yet been

Table 8. Total number of bird species registered in the North American deserts.

Arid zone	Area (km^2)	Bird species	Bird species/km^2	Bat species	Bat species/km^2	Reference
Sonoran desert	275 000	60	0.0002	26	0.000094	McMahon 1990
Chihuahuan desert	281 627	55	0.00019	25	0.000088	McMahon 1990
Mojave desert	54 000	45	0.0008	9	0.00016	McMahon 1990
Great Canyon	254 269	44	0.00017	9	0.000035	McMahon 1990
Tehuacán-Cuicatlán Valley	10 000	141	0.0141	34	0.0034	This work

finished. However, some partial contributions show the diversity of this animal group in the area. Flannery (1967) reported that the human community diet in the valley included 38 mammal species, the most important being *Didelphis marsupialis* (opossum), which is still very common in the region, *Artibeus jamaicensis* and *Eptesicus fuscus* (bats), *Lepus callotis* and *Sylvilagus* spp. (hare and rabbits), *Spermophilus* spp. (squirrel), *Heterogeomys* sp., *Cratogeomys* sp., *Dipodomys* spp., *Lyomis* spp., *Peromiscus* spp. (mice), *Neotoma* spp. (rats), *Canis* sp. (coyote), *Urocyon* sp. (fox), *Bassariscus astutus* (cacomixtle), *Procyon lotor* (racoon), *Spilogale* spp. and *Conepatus* spp. (skwks), including some wild cats, such as *Felis concolor* (mountain lion) and *Lynx rufus* (gato montés), as well as *Pecari tajacu* (wild boar), and *Odoicoleucus virginianus* (deer). Some of these species are still very common in the valley, whereas others, such as mountain lions, bears, and deer, are practically locally extinct.

The diversity of mammals in the Tehuacán-Cuicatlán Valley can be partially understood by means of the high number of bat species that has been registered. Rojas-Martínez and Valiente-Banuet (1996) have been able to find 34 species of bats in the valley. This number of species is high when compared to the information available for other North American deserts, as shown in Table 8. The faunistic composition of bats in the valley is more related again to the deciduous forests in Western Mexico than to the Northern deserts.

The mammals, and especially bats, seem to play an important role in the maintenance of the structure, composition, and diversity of the plant communities of the valley. Recently it has been found that bats represent the only animal group that is capable of enhancing seed production among columnar Cactaceae, which are in many sites the dominant elements of the valley (Valiente-Banuet et al. 1996a,b). Accordingly, many of the columnar Cactaceae in the valley are unable to produce viable seeds when bats are not present.

Discussion

The biodiversity of the Tehuacán-Cuicatlán Valley is very remarkable. In approximately 10 000 km^2, this area contains 10–11.4% of the Mexican flora. In addition, the

valley possesses 365 endemic species that represent 13.9% of its flora. It is partially documented that more than 25% of the vascular flora of the valley is used by the different human communities inhabiting the region. However, the total number of useful plant species might be higher, due to the fact that a comprehensive survey has not yet been done. Consequently, a complete documentation of the useful plants of the valley and an estimation of the total amount of biomass that is extracted from the different plant communities during the year should be the focus of future studies.

With respect to the faunal diversity, it is documented that the valley has 11 species of amphibians, 48 species of reptiles, and 91 species of birds. As discussed above, for all these groups the number of species registered in the valley surpasses the diversity found in other dry-lands of the world. With regard to the mammals of the region, the available data are poor for most groups except for bats, for which 24 species have been reported. Thus, well-organized efforts have to be undertaken to obtain a representative list and distribution patterns for most of the animal groups in the region.

The faunistic diversity observed in the Tehuacán-Cuicatlán Valley and its taxonomic and ecological similarity to some adjacent humid areas reveals that aridity by itself does not determine the impoverishment of the fauna (Rojas-Martínez and Valiente-Banuet 1996), as has been suggested before (Wiens 1991). Consequently, studies focusing on the documentation of the biotic and abiotic interactions of the dominant fauna should also be supported, in order to understand the accelerated impoverishment of some animal populations and/or species.

The valley possess climatic peculiarities, which makes it different from other extra-tropical deserts, such as thermic stability (García 1981) and weather predictability (Valiente 1991). These factors surely enable environmental dynamics that favor the structural complexity and the vegetation diversity that the valley has (Dávila 1983; Dávila et al. 1991, 1993). In addition, the valley remains adjacent to some humid areas in the states of Puebla, Oaxaca, Morelos, and Guerrero, which might represent, at least for the birds and probably for some other vertebrates, a seasonal and altitudinal corridor by means of which they can move to other areas in search of resources. The understanding of this flow and its consequences are important for conservation purposes.

In particular, the high levels of diversity and endemism in the valley are the result of many factors, including a complex physiographic framework, diverse altitudinal ranges, as well as remarkable differences in substrate geological origin and soil types. From a physiographic point of view, the valley represents a complex mosaic. It is part of the Mixteca-Oaxaqueña Province (Tamayo 1962), where the upper basins of the Papaloapan and Balsas rivers are the main components. Some of the major mountain chains occur in the zone, such as the Oriental Sierra Madre (locally called Sierra de Zongolica and Sierra de Juárez) and the Occidental Sierra Madre (locally called Sierra Mixteca). With respect to the altitudinal range, the valley has an average altitude of 1500 m above sea level; however, some sites have ca. 545 m above sea level (e.g. Cuicatlán), whereas in some localities they can reach 2460 m above sea level (e.g.

Esperanza). From a geological point of view, the region is also diverse in nature and age (López 1981). The northern-central part of the valley has a Cretaceous origin, whereas the central-southern region corresponds to a mixture of Precambric and lower Jurassic sediments, In addition, the Sierra de Juárez is mainly formed by metamorphic rocks. As a consequence of this geological mosaic, many soil types can be found in the area, including calcareous, saline and those with high levels of gypsum. These soils host very unique and successful plant communities, such as some kinds of scrub land vegetation, deciduous forests, chaparral and grasslands. As a result of the valley complexity, important evolutionary processes, such as biota diversification and speciation, seem to have been taken place in different epochs and directions. Consequently, at present the valley has a remarkable autochthonous biota that needs to be understood and protected.

Unfortunately, all this rich, peculiar and autochthonous biological inheritance that is present in the Tehuacán-Cuicatlán Valley has been negatively affected in its composition and functionality by diverse human activities, such as deforestation, agriculture, cattle grazing, and illegal extraction of endemic species, amongst others. The human activities in the valley are not controlled whatsoever and some areas that are still in good condition from an ecological point of view, are currently menaced by the new accessibility, which resulted from the recent construction of a highway that crosses the valley from north to south; in February 1998, this region was officially declared a biosphere reserve. Given the threat of more habitat conversion, higher population, and more roads, a management program has to be developed to strike a balance between human needs and demands and the ecosystem.

Currently, there is an important regulatory framework that should be used by the federal and state governments for planning both economic development and the implementation of conservation strategies in a particular area. It is important to understand present human activities and needs to implement programs in the region that might enable the conservation, restoration and sustainability of the natural resources of the area, as well as to define new alternatives of income for the people involved.

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