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TAMAULIPAN BRUSHLAND OF THE LOWER RIO GRANDE VALLEY OF SOUTH TEXAS: DESCRIPTION, HUMAN IMPACTS, AND MANAGEMENT OPTIONS

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Tamaulipan Brushland of the Lower Rio Grande Valley of South Texas: Description, Human Impacts, and Management Options

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Summary

From June 1986 to March 1987, an extensive literature search and data synthesis were conducted on Matamoran District Tamaulipan brushland in the Lower Rio Grande Valley of south Texas, including physiographic, floral, and faunal descriptions, human impacts, and recent changes in native flora and fauna. The goal of this synthesis was to provide a single-source reference of historical review, land use planning, and management of brushland habitats and wildlife populations of the Lower Rio Grande Valley. Review of scientific journals, communication with professionals with expertise on the subject, and computer search by key words provided the majority of the material for our review. We also attempted to locate unpublished reports and other information not readily available. Our research included a trip to the area for personal observation of human impacts and discussion of current issues with U.S. Fish and Wildlife Service personnel in south Texas.

Tamaulipan brushland is a unique ecosystem, found only in south Texas and northeastern Mexico. Many plants and animals occur there that are not found elsewhere in the United States. Since the early 1900's, 95% of native Tamaulipan brushland has been cleared for agriculture, urban development, and recreation. In riparian areas, 99% of native brush has been destroyed. Clearing destroys habitat of native species of plants and animals in the Lower Rio Grande Valley, and it may cause extinction of many species. More than 100 pesticides are used on agricultural crops. These substances are incorporated into the food chain and are harmful or fatal to terrestrial and aquatic organisms. Water development on the Rio Grande has substantially reduced river flow, resulting in altered riparian habitats and additional brush clearing. Brush is destroyed in the Lower Rio Grande Valley by mechanical clearing, herbicides, and fire.

Current methods of land preservation (e.g., land purchase, easement, land lease and management agreements, and restoration of cropland to brushland) are reviewed, and constraints to each method are outlined. Fee purchase is most suitable for meeting U.S. Fish and Wildlife Service habitat and population objectives, but it cannot always be accomplished.

The resource protection and management strategy for the Lower Rio Grande Valley consists of five integrated approaches to address complex resource needs. They include: concentration of biotic community needs; maintenance of a wildlife habitat corridor; safeguarding of anchor units of large size; protection of strategically placed management units of smaller size; and the incorporation of about 20 habitat islands into the protection plan. Eighteen management suggestions that fit within this overall approach to protection and enhancement and that address the particular needs of small units of fragmented natural habitat are provided.

Interest in preservation of habitats and populations in the Lower Rio Grande Valley remains high, and development of refuges in the Valley remains a high priority of the U.S. Fish and Wildlife Service. Intense and continued local, regional, national, and international concern must be applied to implement safeguards that are needed to protect this unique and threatened habitat.

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Introduction

The U.S. Fish and Wildlife Service (USFWS) recognizes Tamaulipan brushland as a unique ecosystem that is found only in the Lower Rio Grande Valley (LRGV) of south Texas in the United States and northeastern Mexico. The LRGV is not really a valley but a delta, or a fertile plain, that slopes away from the Rio Grande (Johnston 1963; Rio Grande Valley Chamber of Commerce 1983; Lonard et al. 1988). The combination of climate, vegetation, and associated wildlife is unlike that in any other region of the United States. The vegetation is influenced by edaphic factors, and plant distribution can be correlated with geologic formations (Clover 1937). Characteristic vegetation of Tamaulipan brushland is dense and thorny. The most luxuriant brush is found on alluvial soil of the Rio Grande floodplain (Blair 1950), and large cedar elms (*Ulmus crassifolia*) dominate in some mesic areas. Vegetation in the xeric upland areas is mostly spiny shrubs and stunted trees (Clover 1937). A few characteristic plant species comprise the bulk of the brush vegetation. At present, some of the ubiquitous woody plant species are (Blair 1950): Texas ebony (*Pithecellobium flexicaule*); retama (*Parkinsonia aculeata*); granjeno (*Celtis pallida*); huisache (*Acacia smallii*); prickly pear (*Opuntia lindheimeri*); and mesquite (*Prosopis glandulosa*) – although prevalence of one mesquite may be due to human land abuse (Archer et al. 1988).

Dense brush in this unique ecosystem provides food, nest sites, and cover for many wildlife species. Neotropical genera of mammals, snakes, lizards, and salamanders reach the northern limits of their distribution in LRGV (Blair 1950). Two endangered felids, the ocelot (*Felis pardalis*) and jaguarundi (*Felis yagouaroundi*), use tracts of dense brush for cover and travel lanes (Tewes and Everett 1982). The U.S. distribution of many species of birds also is largely limited to native brushland in LRGV (USFWS 1980).

Human impacts on Tamaulipan brushland have been severe throughout this century and continue to threaten survival of this unique habitat. Since the 1920's, more than 95% of the original native brushland in LRGV has been converted to agricultural or urban use (USFWS 1980; Parvin 1988a,b). More than 90% of the riparian habitat on the United States side of the Rio Grande has been cleared (Collins 1984). It is estimated that 98% of the lush, subtropical region of the delta has been cleared in the United States (USFWS 1980), and a large percentage of similar habitat has been cleared in Mexico (Collins 1984).

Brush clearing, pesticide use, and irrigation practices associated with agriculture have had detrimental effects in LRGV. Water development, both for flood control and municipal use, has resulted in extensive clearing of brush, alteration of riparian habitats, and changes in water flow in the Rio Grande (Ramirez 1986). Population increases and associated urban expansion in LRGV have resulted in brush clearing and increased pollution (USFWS 1986). Industrialization has degraded water quality (USFWS 1986; Edwards and Contreras-Balderas, in press). Brushland habitats have been converted to rangeland with herbicides (Beasom et al. 1982), mechanical clearing (Bontrager et al. 1979), and fire (Hanselka and White, in press). Recreation, tourism, and hunting, especially for white-winged dove (*Zenaida asiatica*), net millions of dollars annually in LRGV (USFWS 1983); however, overuse can be deleterious to this brushland habitat.

Tamaulipan brushland is in need of immediate protection (USFWS 1985; Parvin 1988a,b). There are 55 plants on the list of endangered, threatened, or watch-list plants of LRGV (Table 1). Present trends suggest that the remaining LRGV brushland in private ownership will be developed within 5 yr (USFWS 1985). Most remnant tracts are small (usually < 40 ha [< 100 acres]) and scattered, such that habitat fragmentation threatens wildlife that is dependent on native brush (USFWS 1983). More than 500 vertebrate species are found regularly in LRGV, and the total could approach 700 if all marine and infrequent species are included (R. W. Schumacher, personal communication). Of these species, 67 are considered endangered or threatened by the U.S. Department of the Interior or the State of Texas (USFWS 1980). Tamaulipan brushland is a unique ecosystem found nowhere else in the United States, and urgent measures are needed to ensure preservation of unperturbed areas and restoration of previously degraded sites.

Description of Tamaulipan Brushland

Location and General Description

Blair (1950) classified the biotic provinces in Texas relative to topographic features, climate, vegetation types, and terrestrial vertebrates (excluding birds). The Tamaulipan Biotic Province of Texas is located south of the Balcones fault line (Blair 1950; Figure 1) and contains about 8 million ha (19.7 million acres) of semi-arid brushland (Lonard 1985). The boundaries of the Tamaulipan Biotic Province approximate those of the South Texas Plains vegetational area, also known as the Rio Grande Plain, which lies south of San Antonio between the Rio Grande and the Gulf Coast (Dallas Morning News 1986/87). Gould (1975a) classifies most of LRGV, which is comprised of Cameron, Hidalgo, Starr, and Willacy Counties (Figure 2), as a small part of the South Texas Plains vegetational area.

There is little moisture for plant growth in LRGV, and distribution of rainfall is often irregular (Table 2). Thus, vegetation must be drought-resistant (Crosswhite 1980). Blair (1950:103) described the area as follows:

Table 1. *Endangered, threatened, or watch-list plants of the Lower Rio Grande Valley.*

Family	Scientific name	Common name	TRPSC[a]	USDI[b]	TOES[c]	NPP[d]
Asteraceae	*Ambrosia cheiranthifolia*	Tamaulipan ragweed	E		WL	
	Dyssodia tephroleuca	ashy dogweed	E	E	E	E
	Grindelia oolepsis	plains gumweed			WL	WL
	Parthenium incanum	mariola			WL	
Euphorbiaceae	*Manihot walkerae*	Tamaulipan manihot	E		WL	
	Euphorbia antisyphylitica	candelilla			E	
	Adelia vaseyi	Vasey adelia			WL	
	Croton soliman	soliman			WL	
	Euphorbia golondrina	Boquillas spurge			WL	
Agavaceae	*Polianthes runyonii*	Runyon's huaco	E		E	
	Agave lophantha	thorn-crested agave			WL	
Liliaceae	*Anthericum chandleri*	Lila de los Llanos			WL	
Crassulaceae	*Sedum texanum*	Texas stonecrop	E		T	
Urticaceae	*Urtica chamaedryoides* var. *runyonii*	ortiguillo	E		WL	
Frankeniaceae	*Frankenia johnstonii*	Johnston's frankenia	E	E	E	E
Arecaceae	*Sabal mexicana*	Mexican palmetto			T	T
Taxodiaceae	*Taxodium mucronatum*	Montezuma baldcypress		E		E
Amaranthaceae	*Achryranthes aspera*	chaff-flower				E
	Iresine palmeri	Palmer's bloodleaf				T
Rutaceae	*Esenbeckia berlandieri*	jopoy				E
	Amyris madrensis	Sierra Madre torchwood				T
	Helietta parvifolia	Baretta				T
Sterculiaceae	*Ayenia limitaris*	Cameron ayenia				E
Violaceae	*Hybanthus verticillata* var. *platyphyllus*	Cameron green violet				E
Acanthaceae	*Justicia runyonii*	Runyon's water-willow				E
	Tetramerium platystegium	Torrey's tetramerium				T
	Dicliptera vahliana	red dicliptera				T
Cactaceae	*Echinocactus asterias*	star cactus				E
	Echinocereus reichenbachii var. *fitchii*	hair-covered hedgehog cactus				T
	Thelocactus bicolor var. *flavidispinus*	yellow-spined glory-of-Texas hedgehog cactus				T
	Coryphantha macromeris var. *runyonii*	Runyon's pincushion cactus				T

Table 1. *Continued.*

Family	Scientific name	Common name	TRPSC[a]	USDI[b]	TOES[c]	NPP[d]
Rubiaceae	*Cephalanthus salicifolius*	Mexican buttonbush				E
	Chiococca alba	David's milkberry				T
Nyctaginaceae	*Pisonia aculeata*	Devil's claw				T
Mimosaceae	*Acacia constricta*	mescat acacia				T
	Mimosa wherryana	Wherry mimosa				T
Fabaceae	*Coursetia axillaris*	Texas baby bonnets				T
Celastraceae	*Mortonia greggi*	Afinador				T
Capparidaceae	*Capparis incana*	Santa Ana capparis				T
Flacourtaceae	*Xylosma flexuosa*	brush-holly				T
Lythraceae	*Heimia salicifolia*	hachinal				T
Asclepiadaceae	*Asclepias prostrata*	prostrate milkweed				T
Verbenaceae	*Citharexylum spathulatum*	Mission fiddlewood				T
	Lantana microcephala	hammock lantana				T
	Citharexylum berlandieri	Tamaulipan fiddlewood				WL
Cyperaceae	*Eleocharis austrotexana*	Johnston's spikerush				WL
Bromeliaceae	*Tillandsia baileyi*	Bailey's ballmoss				WL
Polygonaceae	*Eriogonum greggii*	Gregg wild buckwheat				WL
Brassicaceae	*Lesquerella thamnophylla*	shrubleaf bladderpod				WL
Fabaceae	*Erythrina herbaceae*	coral bean				WL
Rosaceae	*Prunus texana*	peach bush				WL
Sapindaceae	*Cardiospermum dissectum*	Rio Grande balloon-vine				WL
Cochlospermaceae	*Amoreuxia wrightii*	yellowshow				WL
Turneraceae	*Turnera diffusa*	hierba del Veneda				WL
Boraginaceae	*Tournefortia volubilis*	twining tournefortia				WL

[a] TRPSC = Endangered (E) according to the Texas Rare Plant Study Center (1977; from USFWS 1983).
[b] USDI = Endangered (E) or threatened (T) according to the U.S. Department of the Interior (1987).
[c] TOES = Endangered (E), threatened (T), or watch-list (WL) according to the Texas Organization for Endangered Species (1983, 1987).
[d] NPP = Endangered (E), threatened (T), or watch-list (WL) according to the Native Plant Project (Everitt et al. 1986).

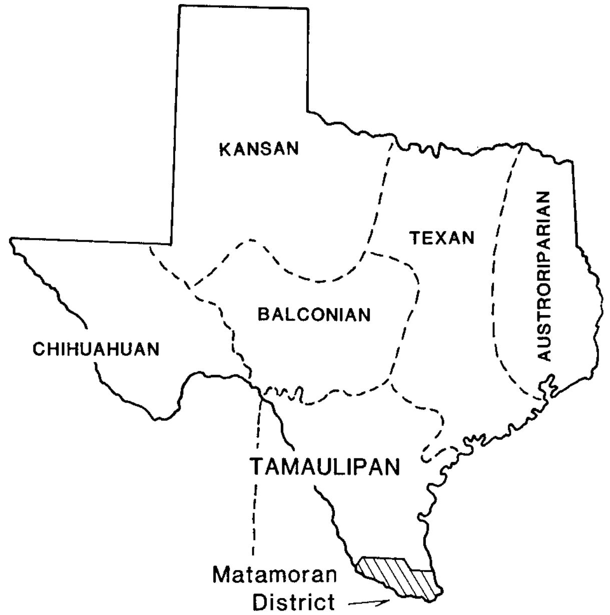

Figure 1. Boundaries of the Tamaulipan Biotic Province of southern Texas and northeastern Mexico (from Blair 1950).

Thorny brush is the predominant vegetation type of the Tamaulipan province of Texas. This brushland stretches from the Balcones fault line southward into Mexico. From the coast westward the brush thins out as available moisture declines. A few species of plants account for the bulk of brush vegetation and give it a characteristic aspect throughout the Tamaulipan of this state. The most important of these include [we have changed scientific names as revised by Correll and Johnson 1970]: mesquite (*Prosopis glandulosa*), various species of *Acacia* and *Mimosa*, granjeno (*Celtis pallida*), guayacan (*Porliera angustifolia*), cenizo (*Leucophyllum frutescens*), and white brush (*Aloysia gratissima*), prickly pear (*Opuntia lindheimeri*), tasajillo (*Opuntia leptocaulis*), and *Condalia* and *Castela*. The brush on the sandy soils differs in species and aspect from that of clay soils. Mesquite, in an open stand and mixed with various grasses, is characteristic of sandy areas. Clay soils usually have all the species listed above, including mesquite.

Blair believed that LRGV was best treated as a separate biotic district from the area of the Tamaulipan Biotic Province to the north and west (Figure 1). He designated this area the Matamoran District (named for the city of Matamoras just across the Rio Grande from Brownsville, Texas) and described it as follows:

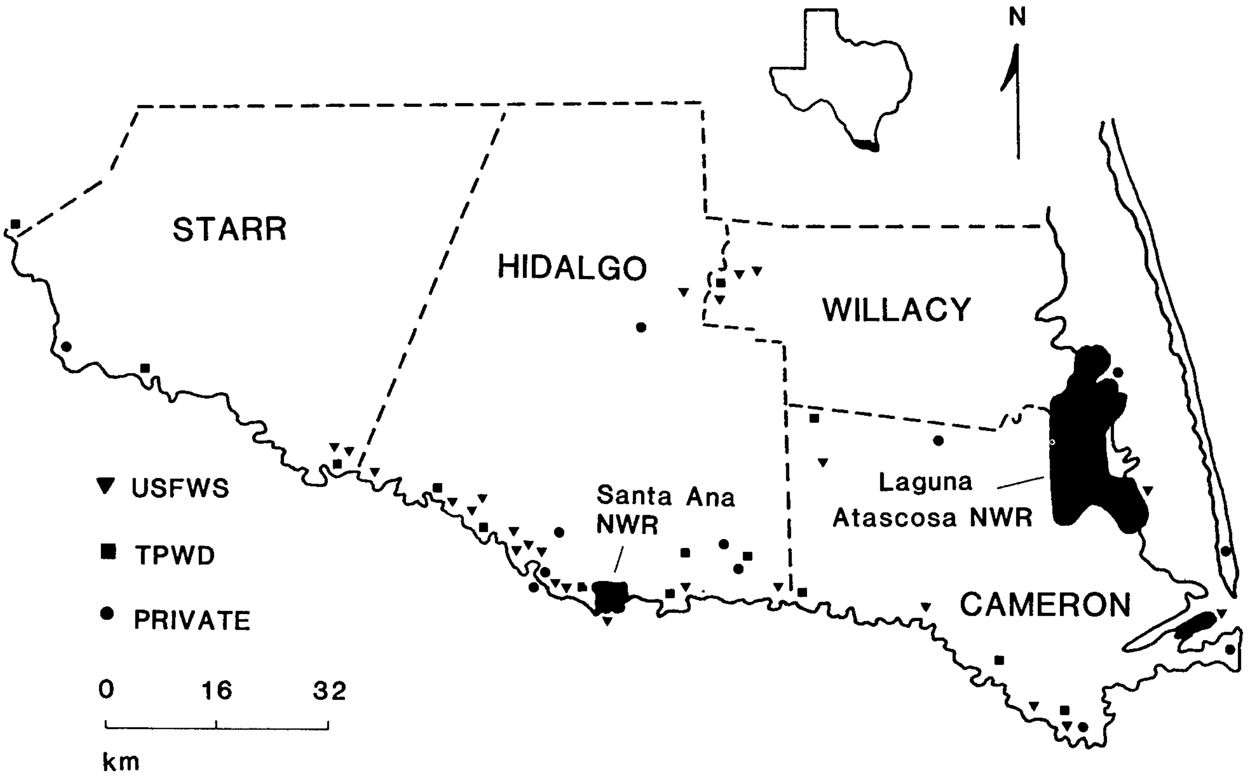

Figure 2. Counties, Federal refuges, State parks and wildlife management areas, and private sanctuaries in the Lower Rio Grande Valley, Texas.

> The southern part of the province is poorly drained....The brushlands of the Lower Rio Grande Valley, in Cameron, Willacy, Hidalgo, and Starr counties, are more luxuriant than the brushlands farther south, and they are characterized by the predominance of several species of plants that decrease in abundance northward. The most important of these species include [we have changed common and scientific names as revised by Correll and Johnson 1970]: retama (*Parkinsonia aculeata*), Texas ebony (*Pithecellobium flexicaule*), anacahuita (*Cordia boissieri*), and anacua (*Ehretia anacua*). The most luxuriant brush occurs on the immediate flood plain of the lower Rio Grande. Large elms (*Ulmus crassifolia*) dominate the flood plain in some places, and there is usually an alteration of elm dominants and brush species.

Climate in LRGV is semi-arid and subtropical (Table 2). Annual average rainfall (Crosswhite 1980) ranges from 38 to 76 cm (15 to 30 inches). In the Rio Grande plain, rainfall is highly erratic both seasonally and annually (Clover 1937). A single thunderstorm can comprise the entire monthly rainfall (Fleetwood 1973). Temperatures average about 10 °C (50 °F) in January and about 36 °C (96 °F) in July (Dallas Morning News 1986/87). Physical features vary for each county. Cameron County (Figure 2) is flat, with over 90% clay and loam soils and only 3% sandy soils, which are more typically found in coastal areas (Williams et al. 1977); Hidalgo County has 60% loamy soils, 22% sandy soils, and clayey and loamy soils in remaining areas, with flat areas near the Rio Grande and a more hilly northern region (Dallas Morning News 1986/87; Jacobs 1981); Starr County is rolling with loamy (76%), clayey and loamy (19%), and sandy (5%) soils (Dallas Morning News 1986/87; Thompson et al. 1972); Willacy County is flat, with a gradual slope to Laguna Madre, and loamy and clayey (73%) and sandy (16%) soils (Dallas Morning News 1986/87; Turner 1982).

Vegetation

Ecological characteristics of south Texas have resulted in a shrubland climax (Hanselka 1980). Mixed brush and acacia ridge associations were probably determined by climate, and species composition was modified by edaphic characteristics and past human perturbations (Hanselka 1980). In the 1700's, mesquite was present in riparian areas, canyons, and draws (Bogusch 1952). The Rio Grande was lined by a dense riparian thicket with trees as high as 21 m (66 ft) (Thornton 1977; Figure 3). Human disturbance prior to European colonization was minimal; most of the Native Americans lived in small bands on coastlines and river bottoms (Rappole et al. 1986). Spanish ships reached the coast in 1514, and the first explorers crossed LRGV in the late 17th century.

Vegetation of LRGV is unique because plants with western desert, northern, coastal, and tropical affinities are found in a relatively small area (Clover 1937). The total number of native plants found in LRGV is unknown, but estimates of native woody species range from 170 to 265 (Ideker 1985; Editor 1986). Clover (1937) divided vegetation that was designated as Tamaulipan brushland into two broad groupings: mesquital and chaparral. Crosswhite (1980) included a sacatal (grassland) element with the mesquital and chaparral. Mesquital was originally an open savannah-like bosque of large trees with a grassland understory generally comprised of curly mesquite grass (*Hilaria belangeri*). Because heavy grazing removed much of the grass, remaining dominants were cacti, brush, and stunted, bush-like mesquite. Chaparral consisted of a nearly impenetrable thicket of stiff, xerophytic, usually evergreen, brush (Crosswhite 1980) such as chaparro (*Zizyphus obtusifolius*), chaparro prieto (*Acacia rigidula*), and chaparro amargosa (*Castela texana*).

Tamaulipan brushland occurs on either side of the Rio Grande. On slightly higher, drier, and rockier sites, vegetation was originally chaparral. Flat, deep soils supported mesquite, as well as taller brush and a few drought-resistant, openly-spaced trees and associated grasses (Crosswhite 1980). Clover (1937) recognized three phases of mesquital. The mesquital-sacatal was comprised of open woods of mesquite and a pronounced understory of grasses and scattered shrubs. In the mesquital-nopalera, dense stands of prickly pear (nopal) replaced many of the shrubs and grasses. Finally, the mesquital-chaparral was comprised of mesquite and dense, thorny brush, which was often a result of heavy grazing (Clover 1937).

Presently, two general types of brush habitats exist in LRGV, riparian and scrub forests and upland thornscrub and thorn woodland. Riparian and scrub forests associated with the Rio Grande consist of several intergrading habitat types that produce taller vegetation than surrounding areas. This vegetation is important to wildlife as corridors throughout LRGV (USFWS 1984), as are "resacas," which are former streambeds now subject to repeated drying and inundation and often forming a long quiet pond or oxbow (Crosswhite 1980). Vegetation associated with resacas includes retama and huisache, which can withstand extended inundation as well as dry periods (Clover 1937). Upland sites contain the most extensive brush type remaining in LRGV, but the densest areas are limited to the western 30%–50% of Starr County. Upland areas are dissected by "arroyos," or riparian strips of dense brush known as "ramaderos." Ramaderos provide important nesting and feeding habitat for various wildlife species as well as

Table 2. *Climatic data from the four counties in the Lower Rio Grande Valley of south Texas.*[a]

	County			
Climate variable	Cameron	Hidalgo	Starr	Willacy
Temperature (F)				
Mean max. (July)	95	97	98	96
Mean min. (January)	51	49	48	50
Record high	108	110	115	107
Record low	21	18	7	19
Average date of freeze				
First in fall	12 December	8 December	7 December	11 December
Last in spring	4 February	7 February	16 February	6 February
Growing season (days)	341	327	314	331
Average monthly precipitation (inches)				
January	1.44	1.22	0.90	1.60
February	1.37	1.13	0.96	1.28
March	0.84	0.68	0.72	0.85
April	1.51	1.66	1.69	1.52
May	2.99	2.30	2.21	3.73
June	2.38	2.51	2.06	2.68
July	1.40	0.81	0.90	1.30
August	2.99	1.68	1.84	2.73
September	4.67	3.62	3.97	5.13
October	2.95	2.62	2.14	2.66
November	1.47	0.94	0.86	1.37
December	1.12	0.73	0.62	0.95
Annual precipitation (inches)	25.13	19.90	18.87	25.80

[a] Dallas Morning News (1986/87).

access routes to riparian brush along the Rio Grande (Collins 1984).

There are two plant species native to LRGV that are listed as endangered by USFWS (1987): Johnston's frankenia (*Frankenia johnstonii*) and ashy dogweed (*Dyssodia tephroleuca*). Numerous other plant species are considered either endangered or threatened by conservation organizations such as the Texas Organization for Endangered Species (Table 1). Texas ebony-anacua is recognized as an endangered habitat type (Diamond 1986); threatened habitat types include Texas ebony-snake-eyes (*Phaulothamnus spinescens*) and little bluestem-coastal live oak (*Quercus virginiana*) (Diamond 1986).

The USFWS currently recognizes 11 biotic communities in LRGV and contends that a community approach is necessary to identify and protect major wildlife/wildland resources (Figure 4). Each community is a unique component of the Matamoran District Tamaulipan biota (USFWS 1983; Collins 1984; Gilbertson 1988) and is described as follows (adapted from USFWS 1983, except where otherwise noted):

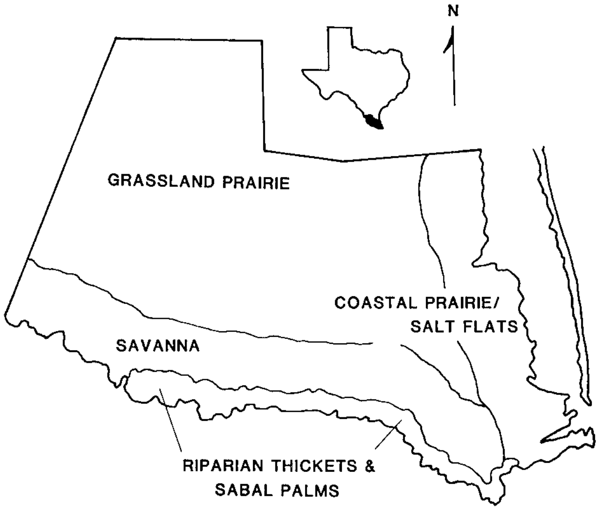

Figure 3. Historical vegetation of the Lower Rio Grande Valley (from Thornton 1977).

Chihuahuan Thorn Forest (Falcon Woodland)

This desert shrub community includes a riparian zone along the Rio Grande below Falcon Dam. The unique feature of this community is the riparian zone and its ecotone with the river on one side and desert scrub on the other. The riparian zone includes black willow (*Salix nigra*), Montezuma baldcypress (*Taxodium mucronatum*), Texas ebony, and mesquite. The upland has sotol (*Dasylirion texanum*), catclaw mimosa (*Mimosa biuncifera*), and blackbrush acacia. The brown jay (*Psilorhinus morio*), green kingfisher (*Chloroceryle americana*), ringed kingfisher (*Ceryle torquata*), belted kingfisher (*Ceryle alcyon*), and ferruginous pygmy owl (*Glacidium brasilianum*) occur in these thorn forests.

Upper Valley Flood Forest

This community consists of the small forested valleys of the Rio Grande between Falcon and Mission, Texas. Mesquite and granjeno are predominant woody species. These areas are important as traditional roosting areas for fall feeding flights of white-winged doves and are suitable habitat for many species of management concern for USFWS.

Barretal

The "barretal," or thicket, is dominated by the native citrus tree, *Helietta parvifolia*. This habitat is restricted to a narrow band of gravel and caliche (i.e., impermeable formations of calcium carbonate) ridges that form an ecotone with the floodplain (Clover 1937). The "barretal" is the only site in the United States where a native citrus occurs as a thicket. Other brush species in this community include (Crosswhite 1980) chaparro prieto, Tamaulipan Palo Verde (*Cercidium macrum*), chaparro amargosa, and junco (*Koeberlinia spinosa*). The area is important habitat for the elf owl (*Micrathene whitneyi*), the reticulate collared lizard (*Crotaphytus reticulatus*), and the Mexican burrowing toad (*Rhynophrynus dorsalis*).

Upland Thornscrub

Surrounding the Rio Grande delta and valleys within the Tamaulipan Biotic Province is the upland thornscrub. Typical woody plants are anacahuita and cenizo. The upland thornscrub is the most widespread habitat type in the province. Tracts of this habitat in proximity to the Rio Grande serve as wildland corridors connecting riparian habitats to uplands. Thornscrub is heavily used by raptors, particularly Swainson's hawks (*Buteo swainsoni*) and broad-winged hawks (*Buteo platypterus*), both of which migrate through LRGV in large numbers.

Mid-Valley Riparian Woodland

This community is essentially a bottomland hardwood site, with stands of cedar elm, Berlandier ash (*Fraxinus berlandieriana*), and sugar hackberry

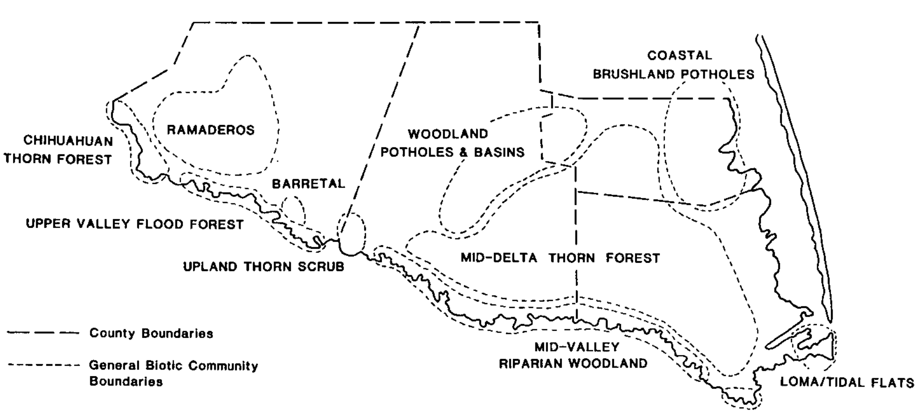

Figure 4. Biotic communities of the Lower Rio Grande Valley, classified to facilitate conservation of wildlife and floral resources (USFWS 1985).

(*Celtis laevigata*) mixed with mesquite/granjeno. The result is a dense, tall, canopied forest and greater availability of water and wildlife foods. This habitat is preferred by many rare birds; orioles (*Icterus* spp.), chachalacas (*Ortalis vetula*), and green jays (*Cyanocorax yncas*) may reach their greatest density in this habitat. Resacas in this habitat provide aquatic ecosystems that protect a unique group of Tamaulipan biota.

Sabal Palm Forest

The 149-ha (367-acre) USFWS tract in this community is known as "Boscaje de la Palma" and is located in the southmost bend of the Rio Grande near Brownsville. Remnant stands of Mexican palmettos (*Sabal mexicana*) – locally called sabal palm – found in a 1,418-ha (3,500-acre) area represent a remnant of a former 16,200-ha (40,000-acre) community. Palms were so prevalent that early Spanish explorers called the Rio Grande "Rio de las Palmas" (Crosswhite 1980). These stands are best described as palm-dominated, brush tracts with Mexican palmettos, tepeguaje (*Leucaena pulverulenta*), anacua, and Texas ebony as major woody associates. Characteristic fauna include ocelot, jaguarundi, lesser yellow bat (*Lasiurus ega*), hooded oriole (*Icterus cucullatus*), speckled racer (*Drymobius margaritiferus*), and northern cat-eyed snake (*Leptodeira septentrionalis*).

Clay Loma/Wind Tidal Flats

Three different communities form a "miniature ecosystem" of wooded islands in tidal flats that are periodically inundated by water from South Bay and the Gulf of Mexico. Lomas are formed from wind-blown silt or clay particles originally deposited in tidal flats by periodic flooding from the Rio Grande. When flats are dry and barren, prevailing winds deposit particles on dunes, which are normally covered with woody vegetation. Dunes may grow to 9 m (30 ft) above surrounding tidal flats. Rains and flooding can erode outer edges of the lomas. When wind or storm tides retreat, loma building begins again. Characteristic vegetation includes fiddlewood (*Citharexylum brachyanthum*) and Texas ebony on the lomas; borrichia (*Borrichia frutescens*) and salicornia (*Salicornia* spp.) on the flats; and black mangrove (*Avicennia nitida*) on South Bay. Representative vertebrates are the Texas tortoise (*Gopherus berlandieri*), long-billed curlews (*Numenius americanus*), and a unique hypersaline-tolerant population of oysters (*Ostrea equestris*).

Mid-Delta Thorn Forest

This community contains a mesquite and granjeno association mixed with Texas ebony, anacua, and brazil (*Condalia hookeri*) and was once an extensive thicket that covered most of the Rio Grande delta. There is < 5% of the original acreage left, mostly in fence rows, highway rights-of-way, canals, and ditch banks. Remnant tracts are small (normally < 40 ha [< 100 acres]) and scattered. Shrubs in this habitat form a tight interwoven canopy of 4-6 m (15–20 ft). The mid-delta thorn forest was used historically for nesting by white-winged doves.

Ramadero

Ramaderos are isolated riparian strips of dense brush that are associated with arroyos in upland areas of LRGV. Woody plant species that are found in ramadero habitats (e.g., granjeno, huisache, retama, brazil, and mesquite) can withstand periodic flooding (Collins 1984). Ramaderos are important nesting and feeding areas for wildlife and provide travel corridors to riparian brush along the Rio Grande for endangered felids. Common wildlife found in ramaderos includes: white-winged dove; plain chachalaca; white-tailed deer (*Odocoileus virginianus*); Harris hawk (*Parabuteo unicinctus*); reticulate collared lizard; and northern cat-eyed snake. Check dams in arroyos prevent water and nutrients from reaching ramaderos, which results in reduced height and density of plant species. It is estimated that 14,175 ha (35,000 acres) of ramaderos remain, mainly in Starr County (Collins 1984).

Wooded Potholes and Basins

This habitat includes the salt lakes of La Sal Vieja that are hypersaline due to evaporation and inflow from underground salt springs. Lakes are surrounded by brushlands that include many small freshwater wetlands or potholes. Some freshwater wetlands are resacas, but many occupy shallow basins, perhaps a result of an arid period when winds caused "blow-outs" in the sandy soil formations. During wet seasons, these wetlands are very productive; during wet winters, they function as greentree reservoirs for wintering waterfowl. Potholes are islands of wildlife habitat in an extensively cultivated region and are of high value to resident and migratory wildlife (Martin and Hehnke 1981; Guthery and Bryant 1982). Inland pothole wetlands are important for waterfowl production and overwintering, flood control, groundwater recharge, and water pollution abatement (Spiller and French 1986).

Coastal Brushland Potholes

The coastal influence separates this community from others. Wetlands in this area vary from freshwater ponds to brackish pools to saline estuaries. Vegetation also varies because of the saline influence and because of proximity to the Gulf of Mexico where microclimate is more stable than it is inland. In this biotic community, there are more days of cloud cover and precipitation and fewer extremes in temperature than in the other biotic communities. In some areas of the coastal brushlands, topography also is influenced by moving sand dunes; the leading edge buries the forest and the trailing edge uncovers dead vegetation. As these sand dunes move, depressions are sometimes formed. When these areas are wet, they receive heavy use by waterfowl and other wetland wildlife. Coastal brushland potholes may be prime habitat for the endangered ocelot and jaguarundi.

Defining the Area of Concern in LRGV

Some of the terms used herein to describe LRGV vegetational communities in earlier publications (e.g., chaparral) now have relatively unique definitions that render them inadequate to describe vegetation in south Texas. In addition, the term "Tamaulipan Biotic Province," although used extensively in the literature and colloquially to describe vegetational communities along the Texas–Mexico border, has broader application than just to the Rio Grande Delta, which is of major concern in this review. Two clarifications are therefore necessary. First, biotic communities of concern are limited to the 11 described previously. Those communities are treated herein as an inclusive list, and thus our discussion targets the communities of LRGV proper. (Detailed descriptions of plant communities throughout southern Texas can be found in Diamond et al. [1987] and Lonard et al. [1988]; Gilbertson [1988] compares historical descriptions, current USFWS community definitions, and Diamond et al.'s [1987] classification.) Second, the biogeographical area of interest is specifically the Matamoran District of the Tamaulipan Biotic Province (Figure 1; Blair 1950). In this report, the names "Matamoran District" and "Tamaulipan brushland" are given equal meaning because it is the brushland along the Rio Grande and other riparian areas that is of primary concern. The term "Tamaulipan Biotic Province" is used only when referring to the entire South Texas Plains (Rio Grande Plain) area.

Wildlife

Tamaulipan brushland provides important feeding, nesting, and cover habitats for many species. Brush clearing and other human activities thus have profound impacts on a variety of vertebrates and invertebrates in LRGV. Diversity of habitat types in LRGV results in a diverse vertebrate fauna, including species of subtropical, southwestern desert, prairie, coastal marshland, eastern forest, and marine affinities (International Boundary and Water Commission [IBWC] 1982a). About 700 vertebrate species have been found within the Matamoran District of LRGV. The USFWS considers 145 of these to be target species that require immediate protection (Table 3). Eighty-six vertebrate species in LRGV are considered endangered, threatened, or placed on a notice of review or watch-list by the U.S. Department of the Interior, the State of Texas, or the Texas Organization for Endangered Species (Table 3).

A number of vertebrate species found in LRGV are not found in any other region of the United States. The endangered ocelot and jaguarundi use extremely dense, impenetrable brush thickets for traveling and breeding (Goodwyn 1970; Davis 1974; Tewes and Everett 1982; Rappole 1988). Remnant brush tracts of this type are found only in extreme south Texas. Ocelots also are found in oak savannah habitat types in south Texas, which consist of open grassland, scattered groves, or "mottes," of live oak (*Quercus virginiana*), and a mid-story of live oak saplings and various thorn forest species (Rappole 1986). The ocelot once roamed eastern, central, and southern portions of Texas (Davis 1974), but today it exists mainly in south Texas brushland (Texas Parks and Wildlife Department [TPWD] 1986). Jaguarundi habitat in south Texas is poorly known but may be similar to ocelot habitat.

The blue spiny lizard (*Sceloporus cyanogenys*) is one of several Mexican species that reaches its northernmost distribution in LRGV (Scudday and Scudday 1976). Additionally, there are 21 bird species found in Mexico and Central America whose ranges reach their northern limits in LRGV (Winckler 1976); for example, least grebe (*Podiceps dominicus*), olivaceous cormorant (*Phalacrocorax olivaceus*), red-billed pigeon (*Columba flavirostris*), and brown jay. Other species, such as the black-bellied whistling-duck (*Dendrocygna autumnalis*), range further north, but populations that are dense enough to permit specific management reach their limits in LRGV.

The white-winged dove is the most important game bird in LRGV (Figure 5). In the early 1900's, when nesting habitat was abundant, populations of white-winged doves increased following introduction of irrigation and grain farming (George 1985). In the 1930's, extensive clearing for agriculture resulted in

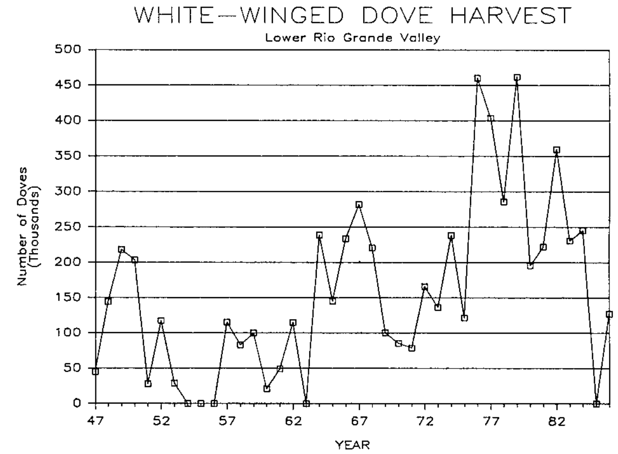

Figure 5. White-winged dove harvests from the Lower Rio Grande Valley, compiled from Cottam and Trefethen (1968) and unpublished data from the Texas Parks and Wildlife Department (pre-1976, hunter questionnaires; post-1976, mail surveys).

Table 3. *Endangered, threatened, watch-list vertebrates, and species of management concern of actual or potential occurrence in Lower Rio Grande Valley NWR (Lower Rio Grand Valley NWR 1987).*

Common name	Scientific name	USDI[a]	TOES[b]	TPWD[c]	LRGV NWR[d]
AVES					
least grebe	*Podiceps dominicus*				P
eared grebe	*Podiceps nigricollis*				W
American white pelican	*Pelecanus erythrorhynchos*				WB
brown pelican	*Pelecanus occidentalis*	E	E	E	C
olivaceous cormorant	*Phalacrocorax olivaceus*				P
anhinga	*Anhinga anhinga*				P
magnificient frigatebird	*Fregata magnificens*				C
reddish egret	*Egretta rufescens*			T	C
white ibis	*Eudocimus albus*				C
white-faced ibis	*Plegadis chihi*		T	T	
roseate spoonbill	*Ajaia ajaja*		WL		
wood stork	*Mycteria americana*	E		T	C
fulvous whistling-duck	*Dendrocygna bicolor*		T		C
black-bellied whistling-duck	*Dendrocygna autumnalis*				P
green-winged teal	*Anas crecca*				W
mottled duck	*Anas fulvigula*				P
northern pintail	*Anas acuta*				W
blue-winged teal	*Anas discors*				W
northern shoveler	*Anas clypeata*				W
canvasback	*Aythya valisineria*				W
redhead	*Aythya americana*				W
lesser scaup	*Aythya affinis*				W
ruddy duck	*Oxyura jamaicensis*				W
masked duck	*Oxyura dominica*		WL		P
osprey	*Pandion haliaetus*			T	WR
hook-billed kite	*Chondrohierax unicinatus*				P
American swallow-tailed kite	*Elanoides forficatus*		T	T	M
black-shouldered kite	*Elanus caeruleus*		WL		P
bald eagle	*Haliaeetus leucocephalus*	E	E	E	nP
common black-hawk	*Buteogallus anthracinus*		T	T	P
Harris' hawk	*Parabuteo unicinctus*				P
gray hawk	*Buteo nitidus*		T	T	P
roadside hawk	*Buteo magnirostris*				P
broad-winged hawk	*Buteo platypterus*				M

Table 3. *Continued.*

Common name	Scientific name	USDI[a]	TOES[b]	TPWD[c]	LRGV NWR[d]
Swainson's hawk	*Buteo swainsoni*				M
white-tailed hawk	*Buteo albicaudatus*		T	T	P
zone-tailed hawk	*Buteo albonotatus*		T	T	P
golden eagle	*Aquila chrysaetos*		T		nP
crested caracara	*Polyborus plancus*				P
merlin	*Falco columbarius*		T		WR
aplomado falcon	*Falco femoralis*			E	P
peregrine falcon	*Falco peregrinus*	E	E	E,T	M
prairie falcon	*Falco mexicanus*		T		nP
plain chachalaca	*Ortalis vetula*				P
northern bobwhite	*Colinus virginianus*				GS
scaled quail	*Callipepla squamata*				GS
sandhill crane	*Grus canadensis*				GS
limpkin	*Aramus guarauna*				P
piping plover	*Charadrius melodus*	E,T		T	M
northern jacana	*Jacana spinosa*		T		C
least tern	*Sterna antillarum*	E,T	E,T	E	C
black skimmer	*Rhyncops niger*		T		C
red-billed pigeon	*Columba flavirostris*		T		P
white-winged dove	*Zenaida asiatica*				P
mourning dove	*Zenaida macroura*				P
inca dove	*Columbina inca*				P
ruddy ground dove	*Columbina talpacoti*				P
white-tipped dove	*Leptotila verreauxi*				P
groove-billed ani	*Crotophaga sulcirostris*				P
ferruginous pygmy-owl	*Glaucidium brasilianum*		WL	T	P
elf owl	*Micrathene whitneyi*				P
common pauraque	*Nyctidromus albicollis*				P
buff-bellied hummingbird	*Amazila yucatanensis*				P
ringed kingfisher	*Ceryle torquata*		WL		P
green kingfisher	*Chloroceryle americana*				P
northern beardless-tyrannulet	*Camptostoma imberbe*		WL	T	P
Wied's crested flycatcher	*Myiarchus tyrannulus*				P
great kiskadee	*Pitangus sulphuratus*				P
Couch's kingbird	*Tyrannus couchii*				P
rose-throated becard	*Pachyramphus aglaiae*		WL	T	P

Table 3. *Continued.*

Common name	Scientific name	USDI[a]	TOES[b]	TPWD[c]	LRGV NWR[d]
green jay	*Cyanocorax yncas*				P
brown jay	*Psilorhinus morio*		WL		P
Mexican crow	*Corvus imparatus*				P
Chihuahuan raven	*Corvus cryptoleucus*				P
clay-colored robin	*Turdus grayi*				P
long-billed thrasher	*Toxostoma longirostre*				P
black-capped vireo	*Vireo atricapillus*			T	M
red-eyed vireo	*Vireo olivaceus* (ssp. *flavoviridis*)		WL		P
tropical parula	*Parula pitiayumi*		WL	T	P
golden-cheeked warbler	*Dendroica chrysoparia*		T	T	M
olive sparrow	*Arremonops rufivirgatus*				P
white-collared seedeater	*Sporophila torqueola*				P
Botteri's sparrow	*Aimophila botterii*		T	T	P
great-tailed grackle	*Cassidix mexicanus*				P
bronzed cowbird	*Molothrus aeneus*				P
hooded oriole	*Icterus cucullatus*				P
Altamira oriole	*Icterus gularis*		WL		P
Audubon's oriole	*Icterus graduacauda*				P
MAMMALIA[e]					
lesser yellow bat	*Lasiurus ega*		WL		
Coues' rice rat	*Oryzomys couesi*		T	T	P
eastern cottontail	*Sylvilagus floridanus*				GS
collared peccary	*Dicotyles tajacu*				GS
white-tailed Deer	*Odocoileus virginianus*				GS
black bear	*Ursus americanus*		T	E	P
coati	*Nasua nasua*		WL	E	P
coyote	*Canis latrans*				PS
cougar	*Felis concolor*		T		
ocelot	*Felis pardalis*	E	E	E	P
jaguarundi	*Felis yagouaroundi*	E	E	E	P
bobcat	*Felis rufus*				PS
jaguar	*Felis onca*	E	E	E	P
pygmy killer whale	*Feresa attenuata*		T	T	A
short-finned pilot whale	*Globicephala sieboldii*			T	A
killer whale	*Orcinus orca*			T	A

Table 3. *Continued.*

Common name	Scientific name	USDI[a]	TOES[b]	TPWD[c]	LRGV NWR[d]
false killer whale	*Pseudorca crassidens*			T	A
short-snouted spinner dolphin	*Stenella longirostris*		T		A
Blainville's spotted dolphin	*Stenella pernettensis*			T	A
rough-toothed dolphin	*Steno bredanensis*			T	A
Lacepede's bottle-nosed dolphin	*Tursiops nesarnack*		T		A
pygmy sperm whale	*Kogia breviceps*		T	T	A
dwarf sperm whale	*Kogia simus*		T	T	A
sperm whale	*Physeter catodon*	E	E	E	A
Cuvier's beaked whale	*Ziphius cavirostris*			T	A
Gervais' beaked whale	*Micropteron europeaus*			T	A
blue whale	*Balaenoptera musculus*	E		E	A
fin whale	*Balaenoptera physalus*	E		E	A
northern right whale	*Balaena glacialis*	E		E	A
Caribbean manatee	*Trichechus manatus*	E	E	E	P
REPTILIA					
American alligator	*Alligator mississippiensis*	T	T		nP
Texas tortoise	*Gopherus berlandieri*		T	T	
green sea turtle	*Chelonia mydas*	T	T	T	A
hawksbill sea turtle	*Eretmochelys imbricata*	E	E	E	A
loggerhead sea turtle	*Caretta caretta*	T	T	E	A
Kemp's ridley sea turtle	*Lepidochelys kempi*	E	E	E	A
leatherback sea turtle	*Dermochelys coriacea*	E	E	E	A
reticulated collared lizard	*Crotaphytus reticulatus*		T	T	
Texas horned lizard	*Phrynosoma cornutum*		T	T	
mesquite lizard	*Sceloporus gramniens*				P
speckled racer	*Drymobius margaritiferus*		WL	E	P
Texas indigo snake	*Drymarchon corais*		WL	T	
Mexican milk snake	*Lampropeltis triangulum*		T		
Ruthven's whipsnake	*Masticophis taeniatus*				nP
black-striped snake	*Coniophanes imperialis*		WL	T	P
northern cat-eyed snake	*Leptodeira septentrionalis*		WL	E	P
black-spotted newt	*Notophthalmus meridionalis*		WL	E	P
Rio Grande lesser siren	*Siren intermedia*		T	E	P
Mexican burrowing frog	*Rhynophrynus dorsalis*		WL	T	P
giant toad	*Bufo marinus*		WL	T	P

Table 3. *Continued.*

Common name	Scientific name	USDI[a]	TOES[b]	TPWD[c]	LRGV NWR[d]
Rio Grande chirping frog	*Syrrhophus cystignathoides*		WL	T	P
white-lipped frog	*Leptodactylus fragilis*		WL	E	P
Mexican treetoad	*Smilisca baudini*		WL	T	P
sheep frog	*Hypopachus variolosus*			T	P
PISCES					
fat snook	*Centropomus parallelus*		T		
river goby	*Awaous tajasica*			T	
blackfin goby	*Gobionellus atripinnis*			E	

[a] USDI = Endangered (E) or threatened (T), according to the U.S. Department of Interior (1987).

[b] TOES = Endangered (E), threatened (T), or watch-list (WL), according to the Texas Organization for Endangered Species (1984).

[c] TPWD = Endangered (E) or threatened (T), according to Texas Parks and Wildlife Department (1978, 1984).

dUnofficial status based on examination of range maps: Marine (A), peripheral from the south (P), peripheral from the coast (C), peripheral from the north (nP), migrates through LRGV (M), winter resident (WR), predator species (PS), waterfowl (W), waterbird (WB), and game species (GS).

[e] All cetaceans that are currently on lists for Texas are included, but few records exist from LRGV to determine precisely which species should be included on this list.

population declines (Batsell 1985; George 1985). White-winged doves have adapted to nesting in citrus groves that replaced native brush (Blankinship 1970), although densities are lower in these artificial habitats (George 1985). Additionally, groves sometimes are destroyed by periodic freezes. Prior to the 1984 freeze, the LRGV population of white-winged doves had stabilized at about 530,000 breeding birds, and the autumn flight was about 1 million birds (George 1985).

Habitats in LRGV also support a unique invertebrate fauna. Many species reach their northern limits of distribution in south Texas (Santa Ana National Wildlife Refuge [NWR], unpublished data). Invertebrate populations have received little research attention, thus, their status is largely unknown. However, habitat alterations likely have been detrimental to the invertebrate fauna of LRGV.

Unique Areas

The Land Protection Plan for the Lower Rio Grande Valley National Wildlife Refuge Complex has identified for intensive management a continuous brushland corridor along the Rio Grande anchored on the west by the Falcon Woodland and on the east by South Bay estuary (Figure 6); a large management unit in the Sal del Rey–La Sal Vieja area; and about 20 forested fragments scattered throughout the delta that range in size from 80 to 810 ha (200 to 2,000 acres). Ultimately, efforts by Federal, State, and private organizations should result in acquisition and conservation of about 101,250 ha (250,000 acres) in LRGV. There are several areas that are in need of immediate protection because of their relatively large size, undisturbed status, or high wildlife value (Figure 6). These areas are privately owned and are in various states of perturbation because of indiscriminant brush clearing or other human effects.

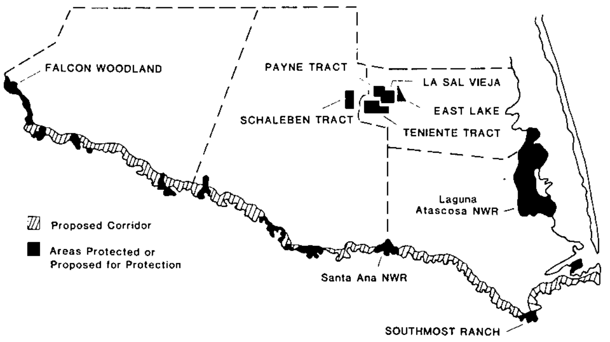

Figure 6. Unique, privately-owned areas in the Lower Rio Grande Valley, targeted for acquisition (USFWS 1983).

La Sal Vieja

La Sal Vieja is located at the northern edge of LRGV (Figure 6) and is one of the few areas in LRGV where appreciable amounts of native brush remain (Texas Nature Conservancy, undated). La Sal Vieja was ranked number 4 of the Top 100 Nationally Significant Fish and Wildlife Areas (USFWS 1983). Associated vegetation includes granjeno, brazil, prickly pear, mesquite, and Texas persimmon (*Diospyros texana*). Three large salt lakes are present, and water levels are maintained by underground salt springs and pluvial runoff. The area supports a diverse vertebrate fauna; more than 50 mammalian species are found at La Sal Vieja, including ocelot and jaguarundi, which may breed in the area (USFWS 1979). Diverse avifauna includes several peripheral Mexican species such as crested caracara (*Polyborus plancus*), groove-billed ani (*Crotophaga sulcirostris*), buff-bellied hummingbird (*Amazilia yucatanensis*), and great kiskadee (*Pitangus sulphuratus*). Wintering birds in the area include lesser scaup (*Aythya affinis*), ruddy ducks (*Oxyura jamaicensis*), black-bellied whistling-ducks, white pelicans (*Pelecanus erythrorhynchos*), and sandhill cranes (*Grus canadensis*). Approximately 6,000 pairs of white-winged doves nest on the site (USFWS 1979). An extensive amount of brush has been cleared from La Sal Vieja and immediate protection of remaining brush is critical (USFWS 1979).

Schaleben, Teniente, Payne, and East Lake Tracts

Changes in ownership of a variety of brushland tracts near La Sal Vieja (Figure 6) have occurred in the past year. The Nature Conservancy and the USFWS are actively acquiring lands in these areas, which attests to the priority placed on preserving these unique woodland pothole and basin communities. The Schaleben Tract is located in eastern Hidalgo County and encompasses 617 ha (1,526 acres), 85% of which is dominated by native brush. The Texas Nature Conservancy recently acquired 393 ha (970 acres) of the Schaleben Tract, which was conveyed to the USFWS (Nature Conservancy 1985; A. Schnapf, personal communication). The Teniente Tract, which is a combination of the Rudman, Beasley, and Ring Ranch tracts, encompasses 1,957 ha (4,835 acres) and is managed by the USFWS. The Payne (221 ha [546 acres]) and East Lake (710 ha [1,755 acres]) tracts are located in Willacy County (Figure 6).

There are numerous depressions on these tracts that fill seasonally with water. Vertebrate fauna is diverse; numerous species are threatened or protected in Texas or have restricted U.S. ranges; e.g., Rio Grande lesser siren (*Siren intermedia texana*), Texas tortoise, Texas indigo snake (*Drymarchon corais*), fulvous whistling-duck (*Dendrocygna bicolor*), and red-billed pigeon (*Columba flavirostris*). Both ocelot and jaguarundi occur on the area. All areas in the immediate vicinity of the tract have been cleared for agriculture and development (Neal 1983). Because the Schaleben and Teniente tracts are close, a protected wildlife corridor between them would increase total acreage of preserved brushland and allow movement of wildlife from one area to the other.

Falcon Woodland

The largest undisturbed remnant of tropical thorn woodland in the United States is adjacent to the Rio Grande and extends from below Falcon Dam downstream about 30 river km (19 mi) (Figure 6). Falcon Woodland contains 9,720 ha (24,000 acres) and is ranked number 5 of the Top 100 Nationally Significant Fish and Wildlife Areas (USFWS 1983). Habitat types in the area are: black willow–Berlandier ash (Rio Grande riparian), 20%; thornscrub association, 30%; and mesquite-granjeno association, 50% (USFWS 1979). The only known grove of Montezuma bald cypresses in the United States occurs in the Falcon Woodland. Three rare plants are known from the region: Gregg wild buckwheat (*Eriogonum greggi*), slashleaf heartseed (*Cardiospermum dissectum*), and *Amoreuxia wrightii* (Butterwick and Strong 1976; Smith 1976). Falcon Woodland provides habitat for > 300 species of birds, 50 species of mammals, 50 species of reptiles, and 20 species of amphibians (USFWS 1979). Many of these species are either peripheral to the United States or listed as threatened or endangered by Texas Organization for Endangered Species (USFWS 1979). Notable birds in the area include: brown jay (only nesting population in the United States); plain chachalaca; gray hawk (*Buteo nitidus*); Altamira oriole (*Icterus gularis*); and the ringed kingfisher (Smith 1976; Winckler 1976). Other uncommon wildlife species found at Falcon Woodland include (Scudday and Scudday 1976): the Mexican burrowing frog; giant toad (*Bufo marinus*); and Texas horned lizard (*Phrynosoma cornutum*). Endangered species that potentially occur in the area include: peregrine falcon (*Falco peregrinus*); ocelot; and jaguarundi. Clearing for cultivation and increased recreational development continue to threaten this area (USFWS 1979).

Southmost Ranch

Southmost Ranch, located southeast of Brownsville, Texas, on the Rio Grande (Figure 6), supports part of the remaining native Mexican palmetto community in the United States. Rio Grande thorn woodland also is present on the ranch. Southmost Ranch was ranked number 42 of the Top 100 Nationally Significant Fish and Wildlife Areas (USFWS 1983). Within the 259-ha (640-acre) ranch, 6 ha (15 acres) are dominated by Mexican palmetto, 61 ha (150 acres) have mesquite and acacia with some palmetto, and the remainder is cultivated fields and pastures (USFWS 1979). A variety of wildlife, including many peripheral species, exists in the Mexican palmetto forest community. Rare wildlife includes: the Mexican white-lipped frog (*Leptodactylus labialis*); Texas indigo snake; speckled racer; white-tipped dove (*Leptotila verreauxi*); tropical kingbird (*Tyrannus melancholicus*); white-collared seedeater (*Sporophila torqueola*); lesser yellow bat; and Mexican spiny pocket mouse (*Liomys irroratus*). The ocelot and jaguarundi may be present. Agricultural development and recreational use are primary threats to this area (USFWS 1979).

National Wildlife Refuges

There are presently three NWRs in LRGV. Santa Ana NWR and Lower Rio Grande Valley NWR form a complex, rather than two independent entities. Administrative facilities for both refuges are located in the Visitor Center at Santa Ana NWR (Figure 2). Santa Ana NWR is the centerpiece of the proposed corridor along the Rio Grande (Figure 6) and as such is located at the approximate middle of the corridor. The land base for LRGV NWR and the Land Preservation Plan for LRGV depend on and are part of the interpretive mission of the visitor center at Santa Ana NWR.

Santa Ana NWR in Hidalgo County is the smallest but most accessible refuge in LRGV (842 ha [2,080 acres]). It contains, however, one of the largest remaining tracts of subtropical riparian forest and native brushland in south Texas. The refuge is surrounded by a vast expanse of flat farmland that lacks wooded tracts (Kerlinger and Gauthreaux 1985). Santa Ana is in the Rio Grande floodplain, which was subjected to periodic overflow prior to construction of Falcon Dam in 1953 (USFWS 1986). Five National Champion trees, the largest of their species in the United States, have been found in the area: Berlandier ash, brazil, honey mesquite, guayacan, and Texas ebony (Dallas Morning News 1986/87).

Santa Ana NWR provides habitat for more endangered and threatened species than any other NWR in the U.S. Refuge System. More than 300 species of birds, 30 species of mammals, 50 species of reptiles and amphibians, and > 450 plant species occur on the refuge. The black-bellied whistling-duck, a neotropical species that reaches the northern limit of its breeding distribution in south Texas, breeds at Santa Ana (McCamant and Bolen 1979). Elms (*Ulmus* spp.) are the most important trees for nesting whistling-ducks (Delnicki and Bolen 1975). Altamira orioles also nest at Santa Ana (Pleasants 1981). Santa Ana is the most important of the few remaining roosting sites for migrant broad-winged hawks in LRGV. In 1982, 85,000 migrant broad-winged hawks were counted (Kerlinger and Gauthreaux 1985). Public facilities include a visitor center, more than 22 km (14 mi) of foot trails, photography blinds, and a 11-km (7-mi) tour road

(Dallas Morning News 1986/87). No hunting or camping is permitted.

Lower Rio Grande Valley NWR was established in 1980 and is comprised of 50 brush tracts that total approximately 11,104 ha (27,283 acres) scattered throughout Cameron, Hidalgo, Starr, and Willacy Counties (R. W. Schumacher, personal communication). Tamaulipan brushland is the typical vegetation. The primary objective of this refuge is to maintain and enhance populations of 145 vertebrate species of management concern (Table 3) through protection of Matamoran District habitat (USFWS 1986).

Laguna Atascosa NWR, the southernmost waterfowl refuge in the Central Flyway, was established in 1946. It contains 19,680 ha (48,597 acres) and is the largest refuge in LRGV. About 65,000 ducks winter on the refuge (USFWS 1986). Laguna Atascosa NWR contains coastal prairies, salt flats, and low vegetated ridges supporting thick, thorny shrubs (Fleetwood 1973). Habitat types of the refuge include: 9,720 ha (24,000 acres) of wetlands; 5,670 ha (14,000 acres) of coastal prairie; 3,280 ha (8,100 acres) of brushland; 405 ha (1,000 acres) of croplands; and 607 ha (1,500 acres) of grasslands and savannah (USFWS 1986). The refuge fauna includes 354 bird and 31 mammal species. Ocelot and jaguarundi recently have been sighted in the vicinity of Laguna Atascosa (S. Labuda, personal communication). In a 1980–81 survey of the area, 8 species of amphibians and 23 species of reptiles were collected (Scott 1982). Because of drought conditions during this period, 95% of the American alligators (*Alligator mississippiensis*) in LRGV were concentrated on the refuge (Scott 1982).

Laguna Atascosa NWR is accessible via walking trails, but parts of the bayside cannot be traversed easily. A visitor center is located in the refuge, and public refuge roads encompass much of the acreage that cannot be explored on foot. Deer hunting and fishing are allowed in designated areas, but camping is prohibited.

State and Private Lands

Tracts owned by TPWD and private conservation organizations are scattered throughout LRGV (Figure 2). The TPWD administers Las Palomas Wildlife Management Area, 13 tracts totaling 1,267 ha (3,129 acres) in Cameron, Hidalgo, Presidio, Starr, and Willacy Counties. Las Palomas provides nesting habitat for white-winged doves. Ocelot, jaguarundi, and cougar (*Felis concolor*) also have been sighted (Dallas Morning News 1986/87). Hunting for white-winged doves and plain chachalacas is allowed (Dallas Morning News 1986/87).

Bentsen–Rio Grande State Park is located southwest of McAllen adjacent to the Rio Grande. Much of the original subtropical vegetation in this 238-ha (587-acre) park has been preserved. Spanish moss (*Tillandsia usneoides*), which is important to nesting white-tipped doves (Boydstun and DeYoung 1987), grows on branches of riparian forest species (Gentry 1982). The avifauna of this park is diverse and includes many of the birds found at Santa Ana NWR. Elf owls nest in the area, and the hook-billed kite (*Chondrohierax unicinatus*) is occasionally observed (Lane 1983).

The National Audubon Society's Texas Sabal Palm Sanctuary, purchased in 1971, is south of Brownsville along the Rio Grande. The sanctuary preserves part of one of the largest remaining stands of the native Mexican palmetto. In 1940, the palm grove was > 40 ha (> 100 acres). By 1971, only about 13 ha (32 acres) remained. Currently, the sanctuary has a total of 70 ha (172 acres), including 49 ha (120 acres) of old fields that are being revegetated, and an 8-ha (20-acre) resaca (Miller 1985a). Many birds use the area (Lane 1983; Miller 1985a); for example, plain chachalaca, common ground dove (*Columbina passerina*), golden-fronted woodpecker (*Centurus aurifrons*), common pauraque (*Nyctidromus albicollis*), green jay, great kiskadee, Altamira orioles, and roseate spoonbills (*Ajaia ajaja*). Nearly 400 plant species have been identified in the palm grove. Falcon State Park, the Lower Rio Grande Valley Nature Center, Anzalduas County Park, and a few other sites further enhance the interpretive and visitation mission in LRGV.

Human Impacts

Since the early 1900's, native plants and plant communities in LRGV have faced threats from clearing for farm fields, improved range and pastures, expanding urban developments, and industrial expansion (Editor 1986). Water development projects also have resulted in clearing and inundation of native brush and alterations to the hydrology of LRGV. Since the 1920's, more than 95% of the original native brushland in LRGV has been converted to agricultural or urban use (USFWS 1978, 1980). Along the Rio Grande below Falcon Dam, 99% of the land has been cleared for agriculture and development (Miller 1985a). Rappole (1974) noted that trends in brushland clearing in south Texas were similar to clearing of tropical forests in Latin America. Significant stands of brush and woodlands in LRGV presently are found only in northern parts of Hidalgo and Willacy counties, along the Rio Grande corridor, and in the rangeland of Starr County (Collins 1984). A large percentage of similar habitat has been cleared in Mexico (Collins 1984). Gulf Coastal Plain vegetation in Mexico is rapidly being cleared, drained, and converted to farms (Judd 1985b).

Agriculture

Past and Present Trends

Crops. Agricultural clearing has had the greatest impact on native brush and thus plant communities and wildlife populations in LRGV. There were no mechanical means to remove brush in the early history of the region; brush clearing was done by hand. However, advances in land clearing and irrigation techniques in this century have increased pressure on native brush. Extensive clearing began in the late 1930's (USFWS 1980). More than 95% of the original brushland has been cleared, and approximately 2% of undisturbed brushy vegetation is being removed annually to make room for more crops.

The LRGV is one of the most intensively farmed areas in the United States (USFWS 1986). Rich delta soil of the Rio Grande and subtropical climate combine to provide some of the most productive farmland in the country (Miller 1985a). The initial surge of agriculture began in the early 1900's (Thornton 1977), but methods of operation and scale of production have intensified since the 1930's. Factors contributing to changes include: mechanization of farm operations; use of aircraft for applying seeds, fertilizers, and pesticides; and improved agricultural chemicals (Bonnen 1960). Currently, most of LRGV is in agricultural production. About 820,125 ha (2,025,000 acres) (75% of total) are used for crops, pasture, and rangeland (USFWS 1980), and about 437,400 ha (1,080,000 acres; 40% of total) of that are cultivated (Batsell 1985). Increasingly, agricultural land is being converted to other uses, including urban and rural residential development, tourism, and winter resorts.

The LRGV has a very long growing season; average annual frost-free period is 300 days (Table 2). Temperatures are generally mild, although damaging frosts can occur. In some parts of LRGV, improper irrigation or a high water table may bring salt to the root zone and injure or destroy citrus trees, or affect production of other salt-sensitive crops. However, soils are highly productive if properly managed (Bonnen 1960). The LRGV ranks high among the nation's intensified fruit-and-truck farm regions, and a large variety of vegetables is grown in LRGV (e.g., broccoli, cantaloupes, carrots, green peas, lettuce, spinach, tomatoes, and watermelons). Most agricultural crops are irrigated from the Rio Grande, although dryland crops such as cotton and grain sorghum are grown (Bonnen 1960).

Hidalgo County is one of the State's leaders in farm product sales with $320 million average annual income. Approximately 90% of farm cash receipts come from crops, principally cotton, citrus, grain, vegetables, and sugarcane. In 1985, 141,750 ha (350,000 acres; 35%) of Hidalgo County were irrigated. Dairy cattle, hogs, poultry, and horses are raised in Hidalgo County (Dallas Morning News 1986/87). Cameron County is also a leader in total farm income with about $91 million annually. Important crops include citrus, vegetables, and sugarcane. More than 68,040 ha (168,000 acres) (29%) of Cameron County were irrigated in 1985. Some cattle, hogs, and goats also are raised in the county (Dallas Morning News 1986/87). Average annual agricultural income for Starr County in 1985 was $63 million. Crops, including sorghums, cotton, and vegetables, provide 66% of the total income. In 1985, 8,100 ha (20,000 acres; 3%) were irrigated for vegetables. Beef cattle, hogs, sheep, and horses are raised in Starr County (Dallas Morning News 1986/87). Willacy County receives about $44 million average yearly income from agriculture. Cotton, sorghums, sugarcane, corn, vegetables, and citrus generate 90% of the total income. About 15,390 ha (38,000 acres) (10%) were irrigated in 1985. Cattle and hog production are included in agricultural income for Willacy County (Dallas Morning News 1986/87).

Grazing. In the early 1700's, Spanish explorers established missions and introduced grazing animals to the eastern edge of south Texas. By 1748, five ranching communities had been established on the Rio Grande. Settlers brought herds of cattle and horses to the area in the early 1800's (Drawe 1980), but interior grasslands did not receive heavy grazing pressure until after the end of the Mexican War in 1848 (Lehmann 1974). During the Civil War, when many ranch owners were absent, cattle were mostly free-ranging in south Texas. After the war, wild cattle were common on ranges. War veterans and others rounded up herds, drove them north to market, and invested profits into reconstructing ranches (Crosswhite 1980). Tamaulipan brushland and associated grassland provided needed cover and food for cattle (Crosswhite 1980). Cattle used brush habitat for warmth and protection during cold winters and for calving in spring. Adaptation of cattle to brush habitat must have begun when Spaniards first grazed herds along the Rio Grande (Crosswhite 1980). Eventually, animals from LRGV were used for stocking rangelands throughout the United States (Crosswhite 1980). Thus, the seed stock, tools, and techniques of managing semi-wild cattle were transplanted from LRGV throughout the American West (Lehmann 1974).

Detrimental Effects to Native Brush and Associated Fauna

Native brushland provides vital nesting and roosting habitat for white-winged doves (USFWS 1980). After reaching a population high of 12 million birds in the early 1900's, the white-winged dove population declined to about 500,000 birds in 1939, mainly because of destruction of nesting habitat for agricultural purposes (George 1985). More than 200,000 ha (493,827 acres) of nesting habitat of the white-winged dove were destroyed by 1942. Between 1939 and 1971, an additional 30,000 ha (74,074 acres) were cleared (Batsell 1985). Extensive brush removal and changes in food supplies during the past 50 yr have had detrimental effects on both spring breeding and autumn postbreeding dove numbers. Continued brush removal is a significant factor contributing to population fluctuations in white-winged doves (USFWS 1980).

Rapid agricultural development in Tamaulipas, Mexico since the mid-1970's probably has had an adverse effect on populations of white-winged doves. In 1953–54, total agricultural production for the area was 242,800 ha (599,506 acres). By 1980–81, total production jumped to 1,310,000 ha (3,234,567 acres). Most of the land placed into agricultural production was once Tamaulipan thornscrub (USFWS 1983). Despite land clearing, Mexican populations of white-winged doves (16–19 million) are expanding due to unrestricted availability of food and water; however, declines of Mexican white-winged doves similar to that in LRGV in the 1930's will likely occur unless steps are taken to preserve nesting habitat (George 1985).

In LRGV, 32%–50% of white-winged doves nest in citrus groves that replaced native brush, but their production is only about 30% of that in native vegetation (Miller 1985b; Waggerman 1986). Dense breeding colonies of doves in citrus groves and small remnant woodland tracts are subject to nest predation (Blankinship 1966) by great-tailed grackles (*Cassidix mexicanus*) and black rats (*Rattus rattus*). White-winged doves that nest in citrus groves also are disturbed by agricultural machinery and aerial pesticide spraying (Miller 1985b). Restoration of brushland habitat is the best approach to enhance dove populations in LRGV.

Ocelot and jaguarundi prefer dense thorn forest and brushland areas. Brush clearing continues to be the major limiting factor for feline populations in LRGV (Collins 1984; Rappole 1986; TPWD 1982; USFWS 1984). These animals also depend on densely vegetated travel corridors along resacas, ramaderos, and between brush tracts (Rappole 1988). Such corridors facilitate dispersal through an otherwise cleared landscape. Vegetation removal associated with "clean farming" and water storage, delivery, and drainage has negatively affected felid populations by preventing travel between remnant brush tracts.

For the most part, plain chachalacas are confined to remnant native brush tracts and resacas close to the Rio Grande and along the Arroyo Colorado. Agricultural fields often surround these brush tracts. Lower populations of plain chachalaca in the 1950's and 1960's were probably due to massive brush clearing in the 1940's (Waggerman 1979). Plain chachalacas are vulnerable to illegal harvest, which has increased with farm-related brush clearing and human population growth.

Intensive brush clearing can have a negative impact on white-tailed deer (Collins 1984; Inglis et al. 1986); highest deer densities are found in areas with 60%–97% total brush cover (Collins 1984). Brush elimination reduces vertical cover and decreases long-term quality of deer habitats (Fulbright and Beasom 1987). In large areas lacking vertical cover, deer populations are reduced from 50% to 65% (Inglis et al. 1986). Native brush along ramaderos provides shade, cover, and food for deer and other species (Collins 1984). As sizes of clearings in brushland increase, deer densities decrease.

Brush clearing has a negative impact on threatened plant species in LRGV (Table 1). For example, the baretta tree, a native citrus, is found in the same critical habitat as the rare reticulate collared lizard and the jaguarundi, and is threatened by clearing (Collins 1984). Mexican palmetto forests originally extended about 129 km (80 mi) inland from the mouth of the Rio Grande and south along the Mexican coast. Because of agricultural clearing, only two small groves remain in Texas (Miller 1985a). Two federally endangered plants, Johnston's frankenia and ashy dogweed face possible extinction from brush clearing and grazing in LRGV (Collins 1984; USFWS 1984).

Several previously abundant tree species survive in only a few locations in LRGV (Crosswhite 1980); for example, Texas lead tree (*Leucaena pulverulenta*), Texas ebony, anacahuita, anacua, Berlandier ash, gordolobo nightshade (*Solanum verbascifolium*), and Montezuma bald cypress, the tallest tree in the region (Crosswhite 1980). Although several of these trees have viable populations outside LRGV, continued survival of remnant populations in the valley may depend on preservation and restoration of brushland.

Little or no documentation is available on long-term perturbations to native flora and fauna associated with ranching in south Texas (Lonard 1985). Data from elsewhere, however, suggest that concentrations of cattle in native brushland along the Rio Grande would have several detrimental effects. In addition to the effects of grazing, cattle trampling damages native vegetation, especially seedlings. Trampling losses of simulated avian ground nests (Hoerth et al. 1983) ranged from 9% to 15% at a nest density of 1.0/ha (0.4/acre). Predation by striped skunks (*Mephitis mephitis*), coyotes (*Canis latrans*), and raccoon (*Procyon lotor*) on dummy wild turkey (*Meleagris gallopagao)* nests increased under various grazing systems (Baker 1978).

Cattle grazing has a significant effect on wildlife diversity and density in south Texas (Teer, in press). In California, chaparral communities that were being converted to grass, both lizards and small mammals were virtually absent from heavily grazed areas (Lillywhite 1977). Overgrazing reduces habitat quality for wildlife because plants preferred by livestock disappear (Drawe 1985); regeneration of vegetation decreases due to destruction of young plants. Cattle also can degrade wildlife habitat in and around small ponds by reducing foliar cover and vegetation height of shoreline plants (Whyte and Cain 1981). Cattle trample and feed on emergent pond vegetation, and disturb nesting pairs of marsh birds (Whyte and Cain 1979).

Pesticides

Past and Present Use

Pesticide use in LRGV began in the late 1940's and has increased with agricultural activity (Thornton 1977). Some pesticides that provide good pest and weed control in other parts of the country (i.e., the herbicides Treflan and simazine and insecticide Orthene in California) are of limited utility in south Texas, because higher rainfall results in greater insect and weed diversities (Felker 1984). Nevertheless, > 100 pesticides are used on agricultural crops throughout the region (USFWS 1986; Table 4), which provides a major pathway for pesticides to enter nontarget terrestrial and aquatic habitats (Lamoreux and Newland 1977). Pesticide contamination is widespread throughout inland waters of LRGV; concentrations of DDT, dieldrin, endrin, lindane, endosulfan, Guthion, and PCBs exceed 1976 EPA criteria for propagation of fish and wildlife (U.S. Army Corps of Engineers [USACE] 1982).

Agricultural pesticides are used year-round in LRGV, and drift and overspray from aerial applications occur periodically on NWR lands. Lower Rio Grande Valley NWR is especially susceptible to pesticide contamination because most of the 50 separate, relatively small tracts have agricultural land on 3–4 sides (USFWS 1986). Laguna Atascosa NWR also is surrounded by croplands that are treated with pesticides. Several species of bats that are known to occur at Laguna Atascosa NWR were not observed during a 1980–81 survey; extensive use of pesticides in the area may be responsible (Scott 1982). In 1983, 45 Franklin's gulls (*Larus pipixcan*) were found dead in Santa Ana NWR after they ate cicadas (Cicadidae) that were contaminated with azodrin (White and Kolbe 1985).

Adequate testing is needed to document pesticide contamination and its effects on wildlife (Moore 1969; Mulla 1963). Thorough assessment of effects on invertebrates and of long-term effects on the ecosystem require costly surveys. Although existing contamination can be documented, effects on populations are often unknown (T. Custer, personal communication), but likely pernicious.

Detrimental Effects to Aquatic Ecosystems

General Effects. Pesticides that are extensively used in LRGV probably enter aquatic systems directly as a result of aerial application or indirectly as runoff from treated fields (Judd 1985a). Wetlands in the Northern Prairie Region of north-central United States that are surrounded by cropland, as they are in LRGV, are often degraded by application of agricultural chemicals (Huckins et al. 1986). The herbicides atrazine and trifluralin and the organophosphate insecticide fonofos have been used in microcosm studies to simulate edge-of-field runoff (Huckins et al. 1986). Results suggested that Northern Prairie wetlands with row-cropped watersheds receive seasonal pesticide inputs that depend largely on rainfall frequency and runoff. For the compounds tested, probability of chronic pesticide effects on wetland aquatic organisms and biomagnification of residues through waterfowl food chains appears low (Huckins et al. 1986), but acute toxicity effects of atrazine and fonofos have been observed under worst case conditions (Huckins et al. 1986).

In another microcosm study in the North Prairie region, static acute toxicity tests with water fleas (*Daphnia magna*) and midges (*Chironomus riparius*) suggested that carbofuran, fonofos, phorate, and triallate are very toxic to aquatic invertebrates (Johnson 1986). Atrazine significantly reduced gross primary productivity and inhibited algal and macrophytic growth. Impact of atrazine, fonofos, and triallate on invertebrates and plants in microcosm experiments suggested that caution should be used in application of these chemicals in or near wetland habitats (Johnson 1986). The greater need for pest control in monoculture systems and increased agricultural chemical application with no-till agriculture both increase probability of pesticide runoff into wetland habitats (Huckins et al. 1986; Johnson 1986).

Pesticides that are currently used in LRGV can be very toxic to aquatic invertebrates. Invertebrates take from several weeks to several years to recolonize an area after they have been extirpated by contamination (Brown and Hunter 1985). Insecticide applications that reduce invertebrate abundance will have a secondary effect on breeding waterfowl. Lower density of invertebrates increases the energy cost for females and ducklings to acquire essential protein from invertebrates and thereby may reduce reproductive success and survival (Brown and Hunter 1985).

Aldrin-treated rice seeds have killed waterfowl, shorebirds, passerines, avian and mammalian scavengers and predators, fish, frogs, and invertebrates on the Texas Gulf Coast, and enhanced the accumulation of residues in soils (Flickinger and King 1972). Birds that depend on invertebrates as a primary food source have been killed by secondary poisoning (Flickinger and King 1972). For example, hundreds of young white-faced ibis (*Plegadis chihi*) died after adults fed them invertebrates collected from aldrin-treated rice fields (Flickinger and Meeker 1972). Consumption of dead and dying birds from contaminated rice fields often is fatal to predators and scavengers because residues are concentrated in higher trophic levels (Flickinger and King 1972).

Table 4. *Commonly used pesticides in the Lower Rio Grande Valley, Texas.*[a]

ORGANOPHOSPHATE INSECTICIDES

- Acephate
- Azinphosmethyl (Guthion)
- Carbophenothion
- Chloropyrifos (Dursban)
- Coumaphos
- Crufomate
- Demeton
- Diazinon
- Dichlorvos (DDVP)
- Dicrotophos (Bidrin)
- Dimethoate
- Disulfoton
- EPN
- Ethion
- Ethoprop
- Famphur
- Fensulfothion
- Fenthion (Baytex)
- Fonofos
- Malathion
- Meta-Systox-R
- Methamidophos
- Methyl Parathion
- Mevinphos (Phosdrin)
- Monocrotophos (Azodrin)
- Naled (DiBrom)
- Oxydemeton-Methyl
- Parathion (Ethyl)
- Phorate
- Phosmet (Imedan)
- Phosphamidon
- Ronnel
- Sulfotepp
- TEPP
- Trichlorfon (Dylox)

N-METHYL CARBAMATE INSECTICIDES

- Aldicarb (Temik)
- Carbofuran (Furadan)
- Methiocarb
- Oxamyl (Vydate)
- Carbaryl (Sevin)
- Landrin
- Methomyl (Lannate)
- Propoxur (Baygon)

ORGANOCHLORINE INSECTICIDES[b]

- Aldrin
- Benzene Hexachloride (BHC)
- Chlordane **
- Chlorobenzilate
- DDT (DDE, DDD)
- Dicofol
- Dieldrin
- Endosulfan *
- Endrin
- Heptachlor
- Heptachlor Epoxide
- Kelthane
- Kepone (Chlordecone)
- Lindane *
- Methoxychlor *
- Mirex
- Strobane
- Toxaphene *

HERBICIDES

- 2,4-D
- 2,4-DB
- 2,4,5-T
- Ametryn
- Bromacil
- Cacodylic Acid
- Dalapon
- Dicamba
- Dichlorprop
- Diuron
- EPTC
- Erbon
- Falone
- Glyphosate
- MCPA
- MCPB
- MCPP
- Monosodium Methanearsonate
- Paraquat
- Picloram
- Silvex
- Simazine
- Tebuthiuron
- Terbacil
- Trifluralin

Table 4. *Continued.*

FUNGICIDES (citrus)

Aldicarb (Temik 15G)
Benomyl (Benlate)
Benomyl (Freshguard 113)
Biphenyl
Copper Ammonium Carbonate (Copper-Count-N)
Copper Hydroxide (Kocide 101)
Oil
Sopp
Thiabendazole (Fungicide conc. 2020)
Thiabendazole (Fungicide conc. 1020 and 6)
Thiabendazole (Mertect 260)
Tribasic Copper

[a] Adapted from: Alexander 1985; Childress 1965, 1966, 1967, 1968; Cocke et al. 1980; Cole and Jackson 1985; Mutz et al. 1978; Scifres 1980a; Smith 1987.

[b] * still used in agriculture, ** still used in structural pest control. Many organochlorines have been withdrawn or agricultural uses severely restricted due to persistence in the environment, damage to endangered species, or potential to cause chronic health problems, reproductive system damage, and cancer (Alexander 1985; Mayer and Ellersieck 1986).

In LRGV, runoff from cultivated fields may concentrate pesticides and herbicides in permanent bodies of water. High concentrations adversely affect organisms found there (Thornton 1977). Judd (1985a) observed a die-off of the Rio Grande siren that was apparently due to insecticide contamination in a farm pond. Thornton (1977) observed a 65% reduction in number of amphibian species and a 51% reduction in number of reptilian species from levels previously recorded from LRGV. He suggested that large surface area: volume ratios of small anurans may make them vulnerable to pesticides and herbicides. Aerial applications of insecticides also can reduce the food supply of insectivorous amphibians and reptiles.

Organochlorine Pesticides including DDT. Ponds, lakes, and streams can act as settling basins for contaminated sediments that contain DDT and its metabolites (Ahr 1973; Lowe 1985). The parent compound (DDT) degrades to DDE, but degradation products are not removed from the system. DDT may be retained in sediment layers in these natural sinks, or relocated by post-depositional biological or mechanical processes that result in either a large amount of DDT released over a short time or in a sustained influx (Ahr 1973).

Organochlorine insecticides negatively affect mosquitofish (*Gambusia affinis*) and bullfrog tadpoles (*Rana catesbeiana*). Toxaphene was toxic for short periods at application rates of 0.56–1.12 kg/ha (0.5–1.0 lb/acre), but fish may have acquired tolerance to this compound because of its previous wide usage (Mulla 1963). Dieldrin (0.56 kg/ha [0.5 lb/acre]) showed high toxicity for several days. For mosquitofish, endrin and isodrin were the most toxic organochlorine insecticides; each was highly toxic at 0.112 kg/ha (0.1 lb/acre), with complete kill during the first 2–3 d and moderate mortality up to one week after treatment. At 0.56 kg/ha (0.5 lb/acre), endrin and isodrin caused complete kill up to 20 d post-treatment (Mulla 1963).

Bullfrog tadpoles exhibited moderate to high mortality at 0.56 kg/ha (0.5 lb/acre) DDT (Mulla 1963). Endrin, dieldrin, aldrin, and toxaphene each caused complete initial kill at 0.56 kg/ha (0.5 lb/acre). Endrin and dieldrin resulted in appreciable mortality of young tadpoles up to 6–7 d post-treatment. Toxic hazards associated with these insecticides may be markedly reduced by using minimum application rates or making as few applications as possible (Mulla 1963). Yet, such safeguards are hard to regulate.

In 1970, a study of Texas aquatic birds revealed significant decreases in eggshell thickness in 15 of 22 species (King et al. 1978). Although environmental factors and physiological processes that result in eggshell thinning are not well understood, DDE is most frequently correlated with eggshell thinning (King et al. 1978). Mean residues of DDT compounds ranged from 0.4 ppm in white ibis (*Eudocimus albus*) to 23.2 ppm in great egrets (*Casmerodius albus*) (King et al. 1978). Shell thickness reductions of 9%–15% were found in white pelicans, brown pelicans (*Pelecanus occidentalis*), and great blue herons and correlated with residues of DDT-family compounds. Residues in marine birds were generally lower and more uniform than levels in birds feeding in fresh and brackish water (King et al. 1978). Eggshell thickness of white-faced ibis was negatively correlated with DDE residues, and reduced reproductive success was observed at 3 ppm DDE

(Henny et al. 1985). Eggshells of American kestrels (*Falco sparverius*) dosed with DDE + dieldrin were 6%–23% thinner than controls (Wiemeyer et al. 1986).

DDT residues in avian eggs from south Texas (King et al. 1978) are comparable to levels that caused reproductive failures in wild populations elsewhere. Populations of five aquatic bird species have declined in Texas (King et al. 1978): for example, brown pelican, reddish egret (*Egretta rufescens*), white-faced ibis, laughing gull (*Larus atricilla*), and Forster's tern (*Sterna forsteri*). DDE and PCB levels that are not high enough to cause chronic poisoning and reproductive problems (King and Krynitsky 1986) also have been found in carcasses and eggs of olivaceous cormorants, laughing gulls, and black skimmers (*Rhynchops niger*).

DDT and dieldrin residues were especially high in eggs from colonies near agricultural areas where these insecticides were heavily used (King et al. 1978). Consistently higher levels of DDT and the greatest amount of shell thinning were found in eggs from the lower coast near intensively cultivated LRGV. DDE and dieldrin levels detected in egg samples are often related to food habits. Adult laughing gulls are attracted to recently sprayed fields by dead and dying insects and may even key feeding flights on spray planes (White et al. 1983c). King et al. (1978) suggest that in view of the great variation in reported toxicity of dieldrin to different wildlife species, egg residues > 1 ppm must be viewed as hazardous.

Shorebirds that wintered on mudflats at outlets of agricultural drains accumulated pesticides (White et al. 1983a). In south Texas, DDE, toxaphene, and dieldrin residues were detected in 95%, 22%, and 13% of the carcasses examined, respectively (White et al. 1983a). DDE accumulation of 12–68 ppm in 40% of long-billed dowitchers (*Limnodromus scolopaceus*) that were sampled was within the range known to impair reproduction, and may be a threat to sensitive raptor species (i.e., peregrine falcon) that prey on them (White et al. 1983a).

Detrimental Effects to Terrestrial Ecosystems

Commonly used insecticides for Texas cotton production include Bidrin, methyl parathion, and Fundal (Larson et al. 1975). An estimated 1.5 million kg (4 million lb) of insecticides are used annually on cotton alone in LRGV (Larson et al. 1975). Pesticides for boll weevil control could adversely impact birds, ocelot, and jaguarundi (USFWS 1986). In addition, cotton is usually grown in the same area year after year, which leads to an accumulation of resistant pesticides (Thornton 1977). Implementation of the Integrated Pest Management Program in LRGV in 1972 has decreased insecticide applications on irrigated cotton from 15 to 20/season to 6 to 12/season (USACE 1980). Additionally, short-season cotton production can reduce insecticide use by up to 39% compared to conventional production. This approach can minimize adverse effects of insecticides because amounts of potentially harmful residues are reduced (Larson et al. 1975).

Organophosphate and Carbamate Insecticides. Organophosphate insecticides, such as ethyl parathion and methyl parathion, and carbamate insecticides, such as Furadan, can be toxic to fish and wildlife (Custer et al. 1985; Flickinger 1986; USFWS 1986; Smith 1987). Negative effects are especially dangerous where wildlife congregate. Areas such as refuges may be the only remaining suitable habitat for wildlife in intensively agricultural areas like LRGV (White and Kolbe 1985).

Furadan 3G (3% carbofuran) is the only formulation that is registered by the EPA for control of the rice water weevil (*Lissorhoptrus oryzophilus*) in Texas rice fields. Furadan 3G in Texas rice fields has caused mortality to birds, fish, frogs, crayfish, earthworms, and nontarget insects (Flickinger et al. 1980). Rice seed also may be commercially treated with malathion insecticide, Difolatan 4 flowable fungicide, and Kocide-zinc (zinc-oxide) fertilizer, or malathion and Vitavax-R fungicide (Flickinger et al. 1986). Ethyl and methyl parathion also are commonly used on Texas rice fields (Custer et al. 1985). In south Texas, parathion application killed >70 geese (White et al. 1982), including 60 Canada geese (*Branta canadensis*).

Kills of 11 avian species (primarily migrant dickcissels [*Spiza americana*] and savannah sparrows [*Passerculus sandwichensis*]) have resulted from misuses of Furadan (e.g., applying more than the registered rate), but also from applications at registered rates (Flickinger et al. 1986). Compared with controls, brain cholinesterase (ChE) activity in 44% of the birds killed by Furadan in a Texas rice field was depressed 32%–85%, and Furadan residues in contents of alimentary tracts averaged 3.4 ppm (Flickinger et al. 1986). Although rice seeds had been treated with malathion prior to planting, they contained both malathion and Furadan upon collection from the study field, which suggested that the field was illegally treated with Furadan during planting. Flickinger et al. (1986) recommended that use and distribution of Furadan formulations 4F and 10G should be restricted to prevent recurring wildlife losses from legal, illegal, or careless treatments.

Ethyl and methyl parathion are used in Texas rice fields to control tadpole shrimp (*Triops longicaudatus*). In a study by Custer et al. (1985), no sick or dead vertebrates were found in or near treated fields. However, significant inhibition of brain ChE activity associated with methyl parathion exposure was demonstrated in at least one bird and one mammal species that used the area. Compared with controls, mean ChE activities of 43% of ring-necked pheasants

(*Phasianus colchicus*) and 37% of house mice (*Mus musculus*) were significantly inhibited. Neither treatment was acutely hazardous to wildlife in or near fields, but there was enough potential hazard to warrant caution in use of chemicals in rice fields, especially methyl parathion (Custer et al. 1985).

In a recent study of effects of organophosphate insecticides on brushland wildlife, no wildlife deaths were reported, and there were no overt effects on most of the animals studied. However, brain anticholinesterase (AChE) activity of great-tailed grackles and mourning doves were significantly lower than controls after application of azodrin, sulprofos + EPN-methyl parathion (Custer and Mitchell 1987). Effects of sub-lethal exposure to these insecticides were not evaluated. Future research on effects of organophosphate insecticides should investigate reproductive success and survival of brushland wildlife (Custer and Mitchell 1987).

Azodrin was implicated in a severe die-off from secondary poisoning in Israel (Mendelssohn and Paz 1977). Following azodrin application to control voles (*Microtus guenthera*) in alfalfa fields, 145 raptors were found dead. An estimated 300–400 birds of prey were destroyed on 8 km^2 (3.1 mi^2) within 3 mo. Other mortality included songbirds and mammals including jungle cats (*Felis chaus*) and feral pigs that died from direct contact with the pesticide or by eating contaminated foods. In LRGV, ocelot and jaguarundi could have been exposed to azodrin poisoning, because several poisoned Franklin's gulls were partially eaten by predators or scavengers (White and Kolbe 1985). Restriction or close regulation of such pesticides is needed in LRGV.

Organochlorine Insecticides including DDT. Although the EPA banned DDT in 1972, DDT family compounds persist in the biota (Saiki and Schmitt 1986). DDT has a half-life up to 17 yr and is concentrated exponentially in higher trophic levels (Ahr 1973). DDD and DDE are the two principal metabolites of DDT (Henny et al. 1982, 1985; Lowe 1985; Saiki and Schmitt 1986; White and Krynitsky 1986; White et al. 1983a; Wiemeyer et al. 1986). Studies suggest that insectivorous animals living in areas subjected to one DDT application retain a significant proportion of DDT for several months up to about 2 yr. Following this period, DDE constitutes nearly all residues (DeWeese et al. 1986). Presently, contamination comes from both legal and possibly illegal uses. DDT, dieldrin, and other persistent pesticides are still legally used in Latin America (King et al. 1978; White et al. 1981). DDE concentration in second year peregrine falcons returning from Latin America was significantly higher than DDE concentration in hatchling year birds enroute to Latin America (Henny et al. 1982).

Continued illegal use of DDT may be suspected if high levels of DDT contamination are found in animals (Lowe 1985). Recent but unpublished surveys of passerine birds, waterfowl, and reptiles in the Rio Grande and Pecos River drainages have shown high DDE concentrations. Because DDE concentrations have decreased in other parts of the country, and because some of the passerine species are year-round residents of south Texas, it is possible that clandestine use of DDT maintains high DDE concentrations in area wildlife (Lowe 1985). Western kingbirds (*Tyrannus verticalis*) that winter in Latin America accumulated significantly higher levels of DDE over a 2-mo period in both Texas and Mexico than was present upon arrival (White 1984). Some whiptail lizards (*Cnemidophorus* spp.) also had high DDE levels. These animals are nonmigratory and were collected near agricultural fields, which suggests that lizards were exposed to elevated DDE levels (White 1984; White and Krynitsky 1986). Whether contamination was recent or residual is presently unknown (White and Krynitsky 1986).

A study of organochlorine contaminants in 38 species of passeriformes in the western United States suggested that potentially harmful organochlorine concentrations are present in some western migrants. These contaminants pose an even greater hazard to avian predators, such as the peregrine falcon (DeWeese et al. 1986). Chemicals detected ($>$ 0.05 ppm) in order of frequency were DDE, polychlorinated biphenyls (PCBs), hexachlorocyclohexane (HCH), heptachlor epoxide, oxychlordane, dieldrin, and toxaphene. DDE comprised 72% of total organochlorine concentration. Migrant insectivorous species contained higher DDE, PCB, and total organochlorine residues than omnivores or granivores. Thirteen species contained DDE concentrations ($>$ 3 ppm) that were considered sufficient to inhibit normal reproduction of avian predators that feed on them (DeWeese et al. 1986).

DeWeese et al. (1986) found dieldrin, hexachlorobenzene, Mirex, and beta-nonachlor only in avian migrants. Species with higher DDE concentrations were contaminated with more kinds of organochlorines. Among migrants, insectivores were $>$ 4 times more contaminated with DDE than omnivores. Among omnivores, migrants were $>$ 6 times more contaminated with DDE than non-migrants. Differences in DDE residues among different migrants may be due to exposure while migrating or wintering in contaminated areas, or differences in metabolism and excretion of contaminants. Limited evidence in this study suggested that migrant birds acquire significant accumulation of DDE both in the southwestern United States and in parts of Latin America (King et al. 1978; DeWeese et al. 1986).

Fifteen of 38 Californian songbird species had at least one composite sample with $>$ 3.0 ppm DDE, although there was not evidence of regional decline in any species (DeWeese et al. 1986). Many migratory species were as contaminated with DDE in 1980 as were starlings (*Sturnus vulgaris*) during the period when DDT was used regularly in the United States (1967–68). Wild populations of sensitive raptors may suffer reduced reproductive success from consuming DDE-contaminated food (DeWeese et al. 1986). DDE concentrations are considered a serious threat to peregrine falcons and other affected bird species (DeWeese et al. 1986).

Conclusion

Past pesticide use, both the types of chemical compounds and application rates, has been extensive and heavy in LRGV. Despite some legislative controls, present use continues to threaten native flora and fauna. As a result, pesticide accumulation in the biota remains a major concern in management of the Tamaulipan brushland.

Water Development

Present stream discharge characteristics of the lower Rio Grande are a result of both natural fluvial processes and anthropogenic activities. Because of the connectivity of fluvial systems, human-induced changes at any location can impact a wide area, especially downstream locations (Brooks 1986). Human modifications of the Rio Grande include: dams and reservoirs for flood control and hydroelectric power; floodway systems that remove water from the stream channel during peak flows; water diversions for irrigation, municipal, and industrial usage; and channel rectification and canalization (Shideler 1985; Judd 1985b; Figure 7). The existing United States interior floodway system in LRGV has a total length of 212 km (132 mi); Hackney Floodway below Anzalduas Dam and Mission Floodway above Anzalduas Dam join to form Main Floodway (IBWC 1973). In its delta, the Rio Grande is well entrenched in a comparatively narrow, meandering channel with generally steep banks (6–11 m [20–35 ft]) of silt and sand. Channel width ranges from 60–150 m (200–500 ft; IBWC 1983). Before flood control works were undertaken from 1900 to 1923 (Figure 7), the Rio Grande overflowed 23 times (Ramirez 1986). Peak flows caused flooding in Hidalgo and Cameron counties, and then collected in natural overflow channels and discharged into Laguna Madre and the Gulf of Mexico (IBWC 1983).

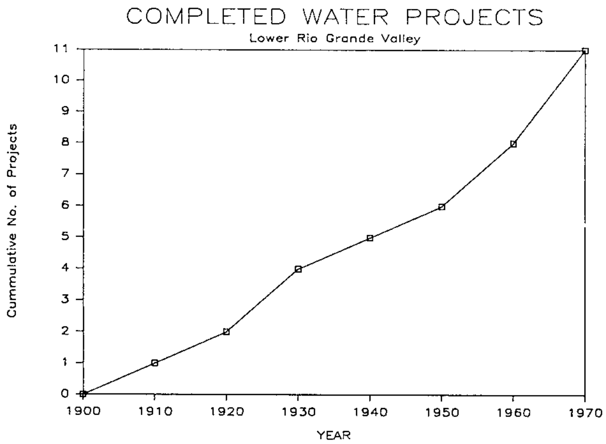

Figure 7. Completed water projects in the Lower Rio Grande Valley (adapted from Ramirez 1986).

The 1970's were a "water-rich" decade in LRGV (Edwards and Contreras-Balderas, in press). However, upstream impoundments on the Rio Grande in Texas and New Mexico, floodway systems that remove water from the stream channel during peak flows, and development of irrigated agriculture and municipal growth have reduced yearly average flow of the lower part of the river by 30%–50% (Edwards and Contreras-Balderas, in press). As a result, serious regional urban water shortages are predicted for 1985–90 (Texas Department of Water Resources [TDWR] 1981). Flow of the Rio Grande consists mainly of runoff from local rains, field runoff and water too salty for irrigation, and municipal effluent from Texas and Mexico (Breuer 1970).

Past Development

The first flood control structures in LRGV were build in the 1920's. Construction of Main Floodway extended to a point near Mercedes, TX, where the floodway naturally divided into two branches: North Floodway and Arroyo Colorado (IBWC 1973). In 1923, counties in LRGV initiated plans for construction of flood control levees. Inlets through levees allowed water to pass into floodways and the Gulf of Mexico. The LRGV Flood Control Project began in 1932 and was designed to protect against a 187,000 cubic feet per second (cfs) flood; however, a severe flood in 1932 demonstrated that the project was inadequate (Ramirez 1986). Since 1932, dams, floodways, and levees have been constructed to provide additional water storage and flood control in LRGV.

Falcon Dam, which has a capacity of 3,978,000 acre-ft (2,677,000 acre-ft for conservation storage and 1,311,000 acre-ft for flood control storage) was completed in 1953. In 1960, Anzalduas Dam was completed; the project included alteration of the floodway system along the Rio Grande. At Anzalduas Dam, > 80% of the United States share of floodwaters below Falcon Dam is diverted into Hackney Floodway, and the Mexico share of irrigation water is diverted into the main irrigation canal. Sixteen major pumping stations between Anzalduas Dam and Brownsville, TX, lift water from the Rio Grande into conveyance canals that serve irrigation districts and municipal-industrial water users in Cameron, Hidalgo, and Willacy Counties.

Retamal Dam, a diversion dam without flood storage capabilities, was built in the early 1970's. It diverts flood flows that exceed 20,000 cfs to the Retamal Floodway in Mexico. Several weirs in the Rio Grande below Retamal Dam and the Brownsville gaging station raise the water level and facilitate pumping into conveyance canals. Saline water from the San Juan irrigation district in Mexico enters the Morillo Drain above the point where 80% of U.S. diversions are made. The Morillo Drain Water Quality Improvement Project, completed in 1969, reduced salinity levels, but salinity from unknown source(s) between Falcon and Anzalduas dams continues to be a problem (Ramirez 1986).

Proposed Development

Since the early 1970's, a number of water projects have been proposed by the International Boundary and Water Commission and U.S. Army Corps of Engineers (Figure 7). These include: (1) extending and enlarging Hackney Floodway from Anzalduas Dam to Main Floodway and abandonment of the existing Mission Floodway (IBWC 1971); (2) increasing levee heights along existing North and Main Floodways (IBWC 1973); (3) altering new and existing drainage systems and increasing on-farm productivity in LRGV (e.g., the Lower Rio Grande Basin Flood Control and Major Drainage Project by the U.S. Army Corps of Engineers in cooperation with U.S. Soil Conservation Service) (Spiller 1981); (4) construction of a dike to increase diversion of first flows in Main Floodway to the Arroyo Colorado Floodway by 500 cfs before flows begin down North Floodway (IBWC 1982b); and (5) construction of channel storage dams on the Rio Grande downstream from Falcon Dam to conserve water for municipal and irrigation use in LRGV (IBWC 1983). Many of the proposals have been approved and implemented, although construction of channel storage dams remains a matter of debate.

Presently, the Rio Grande can safely carry 20,000 cfs water past Brownsville, TX, and Matamoros, Mexico (IBWC 1982a). However, two channel dams proposed by the Rio Grande Valley Municipal Water Authority could reduce water flow past these areas to 25 cfs (Ramirez 1986), which is the minimum flow required by the Texas Water Commission to dilute wastewater effluent discharged below the proposed dam site (Ramirez 1986). The project includes construction of a concrete dam (similar to Retamal Dam) at river kilometer 76.9 (mile 47.8) near Brownsville and modification of Retamal Dam from a floodwater diversion into a water storage structure. The dams would impound water to 8–22 m (26–72 ft) above mean sea level, respectively. Each dam would impound an additional 48 km (30 mi) of the Rio Grande. Resulting reservoirs would frequently empty and fill based on water demand (Ramirez 1986).

The Lower Rio Grande Basin Flood Control and Major Drainage Project is a 3-phase project that is designed to improve floodwater removal capabilities and agricultural drainage. The Army Corps of Engineers granted a permit (#11374) to Hidalgo County Drainage District #1 to conduct this project (USFWS 1981b). The Water Resources Development Act of 1974 authorized advanced engineering and design for Phase I. A feasibility report is complete, and the Army Corps of Engineers has recommended that Congress authorize construction (TDWR 1984).

Phase I of the project is a system of channels to remove floodwater from Hidalgo and Willacy counties; a large ditch will divert water into Laguna Madre. Phase II includes a lateral system of multipurpose channels and water-control structures in Hidalgo and Willacy counties. Phase III is an accelerated land-treatment program for Cameron, Hidalgo, and Willacy Counties that includes on-farm alterations such as subsurface tile drains (TDWR 1984; Perez 1986). The proposed project includes construction of 84 km (53 mi) of new earthen channels, 17 pumping stations, and alterations of 229 km (142 mi) of existing channels (USFWS 1981b).

Originally, the Army Corps of Engineers was planning Phase I; the Hidalgo County Drainage District #1, Army Corps of Engineers, and Soil Conservation Service were planning Phase II; and Soil Conservation Service was planning Phase III. Although the project consisted of 3 phases, the Army Corps of Engineers was only going to mitigate Phase I. The USFWS Ecological Services Office found this unacceptable. The Army Corps of Engineers has discontinued plans for the project; however, the Drainage District obtained a permit for the project in 1980. The Drainage District began digging from Laguna Madre inland but ceased because of lack of funds. Currently, an extension is in progress, and all 3 phases are covered by the permit granted to the Drainage District (K. Collins, personal communication).

The Army Corps of Engineers has granted two permits recently that necessitated review under the National Environmental Policy Act because of brush clearing (J. French, personal communication). Permit #11374 involved clearing 81 ha (200 acres) of brush, and mitigation only involved allowing the banks of the ditch to revegetate naturally between maintenance. However, "spill" will be dumped onto new growth of brush during ditch maintenance (J. French, personal communication). This action will inhibit brush regeneration. The Brownsville Navigation District was granted Permit #13942 to dredge and deepen the harbor. An oil terminal on an upland site affected 32 ha (80 acres) of brush that was part of the unique loma community. Mitigation for this impact was 1,873 ha (4,627 acres) of wetlands and lomas transferred to the LRGV NWR on a 40-yr lease (J. French, personal communication).

The Playa del Rio project, proposed for the Rio Grande delta, represents one of the largest potential threats to the ecological integrity of LRGV (Turner 1988). This project would degrade 4,858 ha (12,000 acres) of coastal habitat but also has the potential to impact upland areas, 66% of which are wetlands. The integrity of all natural areas adjacent to this project including South Padre Island, Redhead Ridge, the Loma Preserve, Brazos Island, Laguna Madre, South Bay, Boca Chica, and the last 32 km (20 mi) of the Rio Grande is threatened by the proposed Playa del Rio development. This project has the potential to negatively affect several endangered species; jaguarundi have been documented near the area, and ocelot may occur in suitable dense brush. Brown pelican and peregrine falcon also may be affected by the project. Several plants in the area are proposed for listing as threatened or endangered by USFWS. The Corpus Christi Ecological Services Office (USFWS) is presently gathering information for the biological assessment (J. French, personal communication).

Detrimental Effects of Development

Periodic flooding is a critical physical factor required to maintain natural conditions in subtropical, floodplain forests (Gehlbach 1981). Proposed channel dam construction and concomitant reduced flow could result in accelerated environmental degradation (Ramirez 1986). Some plants and unique communities along the Rio Grande already suffer from loss of annual or semi-annual floods that follow spring snow melt and autumn hurricanes (Editor 1986). Controlled release of water prevents normal flooding cycles of the river and contributes to replacement of mesic riparian woodland species (e.g., granjeno, cedar elm, and Montezuma baldcypress) with more xeric species (e.g., mesquite) (Ramirez 1986; Judd 1985b). Changes in the plant community can affect stability of natural channels, flood behavior, wildlife, and aesthetic resource values (Harris 1986). Roots of riparian trees help create the characteristic riffle and pool morphology of a stream, and irregularities in roots increase the roughness factor of the channel. This reduces bank erosion (Mason et al. 1984). Absence of floods also slows normal succession from grasses to palm woodlands in old farmland adjacent to Mexican palmetto forests (Miller 1985a).

In eastern Starr County, ramaderos contain the only significant brush stands left in LRGV; such areas are comprised of plant species that can withstand periodic flooding. Check dams on arroyos prevent significant amounts of water and nutrients from reaching ramaderos downstream, which reduces vegetational structure and density (Collins 1984). In an area where few native brush stands remain, ramaderos provide critical habitat to ocelot, jaguarundi, and other wildlife, and access to riparian brushland along the Rio Grande (Collins 1984). Destruction of ramaderos would have a negative impact on remnant felid populations.

Impoundments upstream from proposed channel dams would inundate riparian brush found only within the river channel. These narrow brush strips inside the channel connect with patches of more extensive riparian woodlands on top of the banks. Riparian brushland is critical for animals that travel the riparian corridor (Ramirez 1986).

Intermittent resacas depend on river flows, runoff, and precipitation for flushing and nutrient recharge. Flood control structures eliminate periodic floods and restrict recharge to rainfall and runoff (Perez 1986; Ramirez 1986). Cessation of flooding in LRGV has resulted in fewer resacas, ponds, and sloughs, which are excellent wildlife habitats (Judd 1985a).

Further reduction in flow of the Rio Grande would intensify negative impacts already associated with low river flow. Previously, large floods in LRGV periodically scoured the river bed and probably prevented silt deposits in the channel. Upstream dams may cause local increases in siltation due to moderated peak flows and restricted stream gradients (Edwards and Contreras-Balderas, in press).

Water that flows through natural stream channels is important habitat for fish and wildlife. Dam construction for water storage, diversion of water for irrigation, and municipal and industrial uses increase demands on available water resources and deplete natural stream flows (Orth and Maughan 1981a,b). Channelization destroys the natural stream community and speeds runoff. Regional water plans rarely quantify water needs for instream uses such as propagation of fish and wildlife, and flows are not reserved for these purposes (Orth and Maughan 1981b). Quantification of the effects of altered stream flow regimes on fish habitat is greatly needed (Orth and Maughan 1982). Presently, a major limitation of habitat assessment techniques is lack of quantitative information on microhabitat preferences of target species (Orth and Maughan 1982).

Changes in the aquatic fauna of the lower Rio Grande may be correlated with decreased stream flow, increased chemical pollution, or increased salinity (Edwards and Contreras-Balderas, in press). Two major fish communities have existed in the river over the past 130 yr. These consisted of an upstream, mostly freshwater community, and a downstream community with a mixture of abundant elements of upstream fauna and estuarine species (Edwards and Contreras-Balderas, in press). Recently, characteristic freshwater components of the upstream community have been replaced by exotic (i.e., nonnative) and estuarine forms. Reduced abundance of freshwater species may have been caused by an increased abundance of killifishes (Cyprinodontidae). These changes have been correlated with an apparent change in salinity regimes in upstream segments of the river. The presence of large numbers of young marine species indicates that the lower Rio Grande is being used as a nursery or spawning ground. Faunal changes ultimately have resulted in fewer fishes and less diverse aquatic faunal assemblages.

South Texas is particularly susceptible to the introduction of exotic fishes (Contreras-Balderas and Escalante-C. 1984) because of its subtropical climate and significant environmental perturbations and alteration of waterways (Courtenay et al. 1984). Exotics negatively affect native fauna and flora and reclamation of the preexisting ichthyofauna is usually impossible (Elton 1958; McDowall 1968; Zale 1984). Falcon Reservoir limits downstream penetration of longear sunfish (*Lepomis megalotis*) and redbreast sunfish (*L. auritus*) into lower Rio Grande environments, but they are common in upstream areas (Edwards and Contreras-Balderas, in press). Exotic blue tilapia (*Sarotherodon aureus*), which were first found above Falcon Reservoir in 1975, are now the dominant perciform and often the dominant taxon upstream from the Brownsville area. Tilapia populations are growing exponentially in the area and colonizing habitats in a more generalized fashion than nearly any other species (Edwards and Contreras-Balderas, in press).

Impoundments and reduced flow affect more than just fishes. For example, the rare green and ringed kingfishers are frequently observed with the more common belted kingfisher along a 20-km (12-mi) section of the Rio Grande below Falcon Dam (Lane 1983). Green kingfisher prefer shallow (< 15 cm [< 6.9 inches]) water for foraging; ringed kingfisher feed most often where water is deep (> 40 cm [> 16.7 inches]); and belted kingfishers actively feed in all water depths (Passmore and Thompson 1981). Downstream impoundments would reduce kingfisher habitat by decreasing water fluctuations.

A proposed flow of 25 cfs past Brownsville, which would result if the two channel dams were built, is 3% or less of average seasonal flow (Ramirez 1986). That flow is probably inadequate to sustain current levels of fisheries in the estuarine reach of the Rio Grande. Estuarine finfish and shellfish use the river mouth as a nursery area and depend on cyclic highs and lows of riverine flows (Ramirez 1986). White shrimp (*Penaeus setiferus*) is the most important commercial invertebrate in the tidal parts of the Rio Grande (Breuer 1970). White shrimp and brown shrimp (*P. aztecus*) need freshwater flows in the estuarine portion of the Rio Grande for postlarval and juvenile development (Breuer 1970). Brackish conditions that are caused by freshwater inflow exclude predatory adult finfish that prefer higher salinities. Freshwater inflows also transport nutrients and detritus into the lower river, which are necessary for development of juvenile shrimp (Breuer 1970).

Atlantic croaker (*Micropogon undulatus*) is the most important commercial marine fish off south Texas and uses the tidal Rio Grande as a nursery. Other species that form the basis for local sport and commercial fisheries include: spotted sea trout (*Cynoscion nebulosus*); black drum (*Pogonias cromis*); redfish (*Sciaenops ocellatus*); and snook (*Centropomus* spp.) (Breuer 1970). Bay anchovies (*Anchoa mitchelli*) and blue crab (*Callinectes sapidus*) are other important species that use the Rio Grande. Important freshwater game fishes that are affected by change in amount, timing, and quality of streamflows include (Ramirez 1986) channel catfish (*Ictalurus punctatus*), blue catfish (*I. furcatus*), and green sunfish (*Lepomis cyanellus*). Impact of channel dams on estuarine finfish and shellfish at the mouth of the Rio Grande would be especially critical during droughts, which occur about once every 5 yr (Ramirez 1986).

Increased deterioration and habitat loss would be expected with enlargement of existing drainage facilities and establishment of new ones. Although existing endangered species in LRGV would not be initially affected by the Lower Rio Grande Basin Flood Control and Major Drainage Project (USFWS 1981a,b), other negative impacts would occur. Surface waters redirected to channels would not flow into wetlands. Water levels would be reduced along with the amount of waterfowl habitat. In addition to direct effects of habitat loss, reduction of wetland areas also may increase potential for disease such as fowl cholera (Bolen and Guthery 1982). Concentrations of large numbers of waterfowl on relatively small areas of surface water probably enhances disease transmission; infected migrants may reintroduce disease each winter (Bolen and Guthery 1982). Connecting wetlands that are filled by land leveling would be permanently lost. Mitigation proposed by the Army Corps of Engineers, such as dredging remaining wetlands and stocking with game fish, are inadequate to offset wetland losses. These procedures would lower primary productivity and reduce value of wetlands as wildlife feeding areas (Spiller 1981). Wetlands also slow agricultural runoff and allow agricultural pollutants (e.g., pesticides and fertilizers) to break down before entering Laguna Madre (Spiller and French 1986). Future losses of areas with such high ecological values must be avoided.

Projects that involve construction or modification of canals also result in water quality deterioration (Espey, Huston, and Associates 1977, 1979; USACE 1980). Sediments and contaminants are released whenever the bed and banks of a channel are disturbed by machinery used in flowing water (Brooks 1986). Redistribution of contaminants increases exposure to the biota because pesticide-laden sediments are resuspended by dredging and increased flows within canals (Perez 1986). Dredged sediments that are disposed of along canal borders also expose terrestrial species to contaminants (Perez 1986).

Irrigation

Most irrigation systems in LRGV were developed by private capital and initiative (Ramirez 1986). In the early 1900's, land developers in LRGV purchased large tracts of land along the Rio Grande. Construction and operation costs of irrigation systems were paid by developers through land sales and water delivery charges to customers. In the early 1920's, irrigation districts were organized in LRGV, and farmers bought irrigation systems from developers (Perez 1986; Ramirez 1986). Old districts were reorganized into water improvement, irrigation, and drainage districts. Currently, there are 33 local water management institutions in LRGV.

More than 70% of total water consumption in LRGV is for irrigation (TDWR 1984; Figure 8). Irrigation systems require construction of ditches, canals, and weirs to provide controlled flooding (Rappole et al. 1986). The primary source of irrigation water is surface water from the Rio Grande. Water removed for irrigation does not reenter the river as "return flow" but rather flows into floodways and irrigation systems and eventually into Laguna Madre, or evaporates (Edwards and Contreras-Balderas, in press).

Flat topography and inadequate inland drainage lead to water-logged soils and salinity problems in most of LRGV (Spiller 1981; TDWR 1984). The high water table allows dissolved salts to rise through the soil and enter the crop root zone. If water with dissolved salts reaches the surface, it evaporates and leaves a salt deposit (Box and Bennett 1959) that can reduce agricultural productivity (Spiller 1981). Application of saline irrigation water from the Rio Grande can cause soil to become critically saline (Perez 1986) and render it unsuitable for agricultural crops. Cultivated fields that are not allowed fallow periods of a few years have an effective production life of only 15–30 yr. Natural plant communities are adapted to local edaphic and climate regimes and do not suffer from salt build-ups (Rappole et al. 1986) because of deep root systems, soil integrity, and protection of soil from direct exposure to sun (i.e., baking, destruction of microflora), rain (i.e., leaching, runoff), and wind (i.e., loss of topsoil).

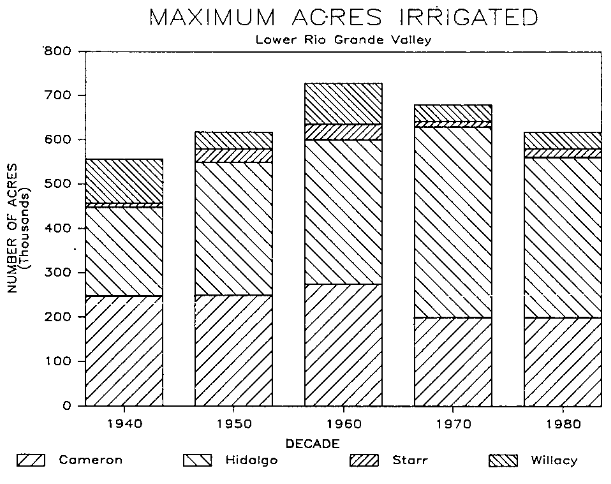

Figure 8. Maximum acres irrigated/decade in each county of the Lower Rio Grande Valley.

Detrimental Effects of Irrigation

Contaminants are distributed throughout LRGV by existing irrigation systems (Black and Veatch Consulting Engineers 1981b). In a study pertinent to the concerns in LRGV, Saiki and Schmitt (1986) investigated organochlorine residues in bluegills (*Lepomis macrochirus*) and common carp in California to determine if pesticide contamination was more prevalent in downstream sites exposed to irrigated agriculture than nonirrigated upstream sites. Samples of both species from the two areas contained p,p'-DDE residues, and chlordane, p,p'-DDD, p,p'-DDT, and dieldrin were present in both species at one or more sites. However, concentrations of most organochlorines in fishes increased from upstream to downstream. Water quality variables influenced by irrigation return flows (e.g., conductivity, turbidity, and total alkalinity) also increased from upstream to downstream and were significantly correlated with organochlorine residue levels in fishes (Saiki and Schmitt 1986).

Subsurface tile drainage systems have been proposed as mitigative techniques to offset increases in contaminant levels in surface waters (USACE 1982). However, turbidity from suspended sediments in drainage systems would reduce water quality. Additionally, such sediments can be laden with contaminants that are associated with agricultural pesticide application and urban runoff (Spiller 1981). In California, subsurface tile drainage systems were installed in parts of the San Joaquin Valley to remove excess groundwater and allow application of fresh water to leach salts from the soils (Saiki 1985a,b). Tile drainage water contained heavy metals, boron, selenium, and other organic elements that are toxic to fish and wildlife at high concentrations (Saiki 1985a).

Sediment samples from Laguna Atascosa NWR in LRGV have shown elevated selenium levels (USFWS 1986). Selenium is an essential element for growth and proper functions of organisms, but it is toxic to animals at 0.1 mg/kg–10 mg/kg in food (Black and Veatch Consulting Engineers 1981a; Saiki 1985b). Animals can accumulate toxic levels of selenium by eating contaminated foods (Saiki 1985b). In California, forage organisms exposed to subsurface tile drainage water contained high concentrations of selenium; mosquitofish and various aquatic plants had up to 370–390 μg/g dry weight, respectively (Saiki 1985a).

Selenium concentrations increased to toxic levels from water to plants to animals (Saiki 1985a). Selenium can be transferred from female bluegills to offspring and is known to cause reductions of fish populations in selenium-enriched reservoirs (Gillespie and Baumann 1986).

Severe reproductive impacts have been found in aquatic birds nesting on irrigation drainwater ponds in the San Joaquin Valley, CA (Ohlendorf et al. 1986). Of 347 nests studied through late incubation or hatching, 40.6% had at least one dead embryo and 19.6% had at least one embryo or chick with obvious external abnormalities. Deformities were often multiple and included missing or abnormal eyes, beaks, wings, legs, and feet. Brain, heart, liver, and skeletal anomalies also were present. Mean selenium concentrations in plants, invertebrates, and fish from drainwater ponds were 12–130 times those at a nearby control area. Bird eggs and livers also contained elevated levels of selenium. Aquatic birds may experience similar problems in areas where selenium occurs at elevated levels in soil or water (Ohlendorf et al. 1986). Selenium levels > 11 ppm were found in 6 out of 10 samples from laughing gulls in Galveston Bay, TX; reproduction may be impaired at this contaminant level (King and Cromartie 1986).

Floodway Systems into Laguna Madre

Originally, Arroyo Colorado was an arm of the Rio Grande that branched from the river below Mission, TX. Now, North Floodway and Arroyo Colorado are the primary source of fresh water to lower Laguna Madre. Arroyo Colorado also receives much of the municipal, agricultural, and industrial wastes of LRGV (Espey, Huston, and Associates 1977) and serves as an inland waterway and a recreational area for boating and fishing (Bryan 1971). In a 2-yr period, every organism analyzed (107) from Arroyo Colorado contained DDT, and 84 contained either dieldrin or endrin or both (Bryan 1971). DDT and its metabolites also were found in water and sediments. Oyster tissue samples averaged 0.294 ppm DDT; menhaden (*Brevoortia* spp.) averaged 0.977 ppm DDT at kilometer 11 (mile 7) and 3.82 ppm DDT at kilometer 40 (mile 25); and spotted seatrout ovaries and eggs averaged 4.17 ppm DDT and 2.93 ppm DDT, respectively. White et al. (1983b) found that freshwater fishes in Arroyo Colorado were highly contaminated with DDE and toxaphene residues compared with fishes from other areas in LRGV. Both DDE and toxaphene ranged up to 31.5 ppm wet weight in whole fish (White et al. 1983b). Observed DDT levels may be high enough to affect reproduction of fishes and invertebrates in lower Laguna Madre and may have contributed to low blue crab numbers (Bryan 1971). Overall, water quality of Arroyo Colorado is poor, and a large portion of the waterway suffers from pollution-induced oxygen depletion (Bryan 1971).

Laguna Madre is a major hypersaline lagoon that is unique as a physical, chemical, and biological system (Bach and Cofer 1981). Lower Laguna Madre and its associated coastal bays, estuaries, and wetlands represent the largest contiguous habitat type in LRGV (USFWS 1986). Wind-blown tidal flats of Laguna Madre typically comprise the entire intertidal zone because the arid climate and low freshwater runoff prevent development of estuarine salt marshes (Pulich et al., in press). The area has an abbreviated food chain that goes from plant detritus to forage fishes and shrimp to top carnivores (Bach and Cofer 1981). Fish and shellfish harvests are important to the local economy (Perez 1986).

Pesticides that are carried in irrigation water to Arroyo Colorado flow through Laguna Atascosa NWR into Laguna Madre estuary. Pesticide contamination is therefore magnified in Lower Laguna Madre, and increases in pesticides could cause mortality, reproductive failure, or physiological disturbances in local animal and plant populations (Bach and Cofer 1981). In a survey of Texas bays, Lower Laguna Madre oysters (*Crassostrea virginica*) had higher pesticide levels (e.g., up to 0.583 ppm DDT, 0.17 ppm DDE, 0.52 ppm DDD, 0.046 ppm dieldrin, and 0.032 ppm endrin) than oysters from other areas; the associated watershed had the highest rate of pesticide application/ha of cropland in LRGV (Childress 1965, 1966, 1967, 1968). DDT residue in fish tissue reached 7.2–8.1 ppm (Childress 1967, 1968). Elevated concentrations of DDE and toxaphene also have been found in a fish and migratory birds in the Lower Laguna Madre (USFWS 1986).

Water project construction has and will result in increased levels of silt, nutrients, pesticides, and turbidity entering Laguna Madre. Negative impacts from herbicides include reduced oxygen, increased carbon dioxide, lower pH, increased bacterial populations, change in nutrient status of water, and changes in plant and animal communities. Most herbicides cause serious declines of both fauna and flora over a short period (Newbold 1975). Herbicides from agricultural drainwater inflows and decreased light levels associated with turbid water have an adverse impact on seagrass (submergent marine flowering plants) production. Seagrass functions in carbon fixation, sediment stabilization, nutrient cycling, as a critical food resource for redheads (*Aythya americana*) and other wintering waterfowl, (P. J. Zwank, personal communication), and as nursery and rearing areas for fish and shellfish (Perez 1986; USFWS 1986). Elimination of seagrass could increase erosion and reduce associated biota that use seagrass for food, shelter, and reproduction (Bach and Cofer 1981).

Conclusion

Construction of irrigation and floodway systems destroys native brush, degrades water quality, and facilitates transport of pesticide-laden sediments throughout LRGV. Reduced river flow results in many detrimental effects on native plants and wildlife. Other values lost by damming and diverting rivers and using water in flowing streams include aesthetic, recreational, scientific, and environmental quality (Hamilton 1971). According to Ramirez (1986), additional river impoundments on the lower Rio Grande should be avoided and less damaging alternatives (e.g., water conservation and desalinization) to solve water problems in LRGV should be encouraged. To prevent further degradation of the Rio Grande, Judd (1985a) suggested use of legislation to preclude construction of new dams or floodways, and establishment of incentives for municipal, industrial, and agricultural users to conserve water.

Historical and present water developments in LRGV have affected negatively the Matamoran District Tamaulipan brushland ecosystem. Proposed developments may involve even more severe impacts because of the already reduced natural habitat, its isolation in corridors and small tracts, and the seriously perturbed hydrological system of LRGV.

Brush Eradication

Preservation and enhancement of existing brushland in LRGV, restoration of previously cleared and disturbed areas, and acquisition of additional acreages are primary management concerns of the USFWS. Estimates of remaining native brush range from 1% to 5% of original vegetation, so protection of remnant brush tracts is imperative. There are now Federal and State agencies and conservation groups that concur with the goals of the USFWS, but that has not always been the case. Since the early 1900's, a prevalent local philosophy among developers and ranchers in LRGV has been that native brush was worthless and should be eradicated (Gilbertson 1988).

Past and Present Approaches to Brush Clearing

Mechanical. In the early 1900's, land managers began large-scale removal of brush (Inglis et al. 1986). In a brush removal survey, Davis and Spicer (1965) classified 89% of the Rio Grande Plain as rangelands where forage production depended on native plants or introduced perennials that did not require repeated cultivation. Of that, 28% had experienced some brush eradication in the past 30 yr. In the late 1920's, individual shrubs and trees were killed with kerosene (Inglis et al. 1986). Extensive mechanized brush removal began in the early 1930's and developed through phases of large tractors pulling steel cables, heavy anchor chains, large rolling choppers, root plows, brush mowers, and tree grubbers (Inglis 1964; Inglis et al. 1986).

Until 1955, extensive areas of brush were destroyed by chaining or chopping. From 1956 to 1960, root-plowing and seeding of small blocks of rangelands comprised about 25% of all brush removal (Davis and Spicer 1965). Throughout the Rio Grande Plain, about 3,240 ha (8,000 acres) of brush/year were destroyed from 1930 to 1948; about 21,460 ha/year (53,000 acres/year) were destroyed from 1949 to 1954; and about 19,430 ha/year (47,992 acres/year) were destroyed from 1955 to 1959 (Davis and Spicer 1965).

Up to the early 1970's, most brush removal in south Texas was done mechanically with heavy equipment. During that time, energy was relatively inexpensive, and herbicides did not effectively eradicate many of the species in the mixed brush complex (Mutz et al. 1978). From 1940 to 1981, Texas landowners treated an average 600,000 ha (1,482,000 acres) annually to remove thorn forest (Welch 1982). Most brush management efforts led to a control-regrowth cycle of 5–10 yr (Davis and Spicer 1965).

Chemical. Until the late 1940's and early 1950's, most herbicide application attempted to target individual plants, but available herbicides were not selective (Scifres 1977). In the early 1960's, chemical growth stimulants and poisons were used to destroy brush (Inglis et al. 1986). In the early 1970's, herbicides that could destroy many of the common woody species in Texan mixed brush communities were developed (Beasom and Scifres 1977; Mutz et al. 1978). The phenoxy herbicide 2,4,5–T destroyed honey mesquite, but it released herbicide-tolerant species. New herbicides, such as dicamba, destroyed most species. When picloram became commercially available, it was combined with 2,4,5–T for brush spraying in south Texas. Tebuthiuron is a new compound that destroys some herbicide-resistant woody species (Mutz et al. 1978). Recovery is inhibited for at least 8 yr post-treatment (Rappole et al. 1986). Nevertheless, chemicals are still not selective enough to prevent damage to non-target species (Teer, in press).

Aerial spraying with selected herbicides takes about a month to reduce brush cover (Beasom et al. 1982; Scifres 1980b). Aerial spraying of liquid herbicides proved to be damaging to adjacent susceptible crops (Bontrager et al. 1979; Mutz et al. 1979). Pelleted herbicides can reduce drift to nontarget areas, essentially eliminate volatility hazards, extend the period for effective herbicide application, and can be applied with ground or aerial equipment (Mutz et al. 1979); however, surface runoff and thus damage to adjacent areas remains a problem.

Fire. Naturally occurring wildfires are not common in LRGV. Most of the vegetative associations now present are not fire dependent, but shrubs in LRGV exhibit fire-tolerant adaptations. On Welder Wildlife Refuge (Sinton, TX), 95% of the upland shrubs sprout from the root crown when the top is removed by fire; other species such as live oak can root sprout and form large colonies (Hanselka 1980). None of the 95 fires in Santa Ana and LRGV NWRs reported to date began in or penetrated into what is considered "climax" Tamaulipan brushland (N. M Gilbertson, personal communication).

Detrimental Effects to Fauna and Flora

Mechanized brush removal methods can be categorized in two broad groups based on type of action on woody plants. The first method is designed to simply remove above ground growth and includes roller chopping and shredding. Top removal kills woody species that are incapable of resprouting from basal stem segments, roots, or rhizomes (Mutz et al. 1978). The second brush removal method involves destruction of the entire woody plant by grubbing, chaining, or root plowing (Mutz et al. 1978).

The most drastic reductions in brush cover are achieved with methods that disturb soil and remove roots of brush plants (Drawe 1977). These methods have particularly adverse effects on fossorial species (e.g., Texas tortoise). Removal of brush results in loss of shade cover, physical damage, and rough terrain with deep furrows and mounds (Rose and Judd 1982). Root plowing causes maximum surface soil disturbance and usually results in comparatively long-term (ca. 20 yr) brush suppression. It also eliminates brush cover and seriously reduces browse availability for an extended period (Mutz et al. 1978). Reduced browse has a negative impact on white-tailed deer and other species that depend on woody plants for forage and cover (Guthery 1980; Fulbright and Beasom 1987). In the early stages of conversion from thornscrub to grass, mechanical brush clearing causes greater initial reductions in lizard and small mammal populations than selective herbicides. Large areas that are completely and permanently cleared have significant wildlife losses (Lillywhite 1977).

Grass production benefits from brush reduction are short-lived and seem to be largely the result of release of nutrients from the dead brush stems and roots (Gilbert, in press). Retreatment is necessary within 15 yr after root-plowing and within 2 yr after chaining (Rappole et al. 1986). Additionally, detrimental effects of brush control practices may last longer than temporary benefits gained for livestock production. Density of mesquite was 3–4 times greater in root plowed areas 25 yr after treatment than in untreated areas (Fulbright and Beasom 1987).

Community species richness is much lower in treated than untreated brushland; many plant species that are valuable to wildlife are rare or absent (Fulbright and Beasom 1987). Recent studies of succession in Texas brushlands (Bush and Van Auken 1986a,b, 1987; Van Auken and Bush 1985; Van Auken et al. 1985) have shown that brush species change soil quality during succession and that both edaphic and light requirements affect species order during successional stages. Brush acts as a soil enhancer, especially for nitrogen, which is often limiting in arid soils (Gilbert, in press). Altering succession to graminoid stages thus reduces productivity of the entire community.

Treatment by spraying causes less initial physical disturbance than mechanical clearing (Beasom and Scifres 1977; Inglis et al. 1986). Nevertheless, in a mature honey mesquite brushland that was completely sprayed with 2,4,5–T + picloram (1:1), populations of white-tailed deer, wild turkeys, and feral hogs were reduced; collared peccary were reduced because of reduction of prickly pear cactus, their major food (Beasom and Scifres 1977). Chamrad et al. (1979) found that herbicide use was initially detrimental to forbs and thus temporarily lowered habitat quality for deer. Clearing shrubs by spraying with 2,4,5–T or cutting can result in a 30% reduction in number of bird territories by the following spring (Slagsvold 1977).

Relatively cool fires (i.e., maintenance burns) applied within 2–4 yr after mechanical top removal usually destroy woody resprouts and invading seedlings (Mutz et al. 1978). Fall burning of shrubs significantly reduces brush canopy in both untreated areas and areas treated by roller chopping, shredding, or scalping (Box et al. 1967). Huisache is an important species in the mixed brush (i.e., *Prosopis-Acacia*) complex of south Texas (Bontrager et al. 1979) that is used by wildlife for browse, mast, and cover (Scrifes et al. 1982a). Exposure of huisache to fire usually killed canopies of > 90% of the plants; however, all burned huisache plants sprouted after treatment, regardless of season or intensity of burning (Rasmussen et al. 1983).

In areas of extensive farmland where wild plant cover is scarce, burning reduces wildlife use (Guthery and Stormer 1984). Loss of protective cover by fire may increase raptor predation on small mammals (Tewes 1984). Following prescribed fire, it may take 2–3 yr to return to pre-burn species composition and density (Drawe 1980). Fire is not used as a management tool in LRGV, and until there is evidence that fire is needed, it is not a necessary tool for enhancement or maintenance of the present system. Fire in other areas tends to favor grasses over woody vegetation, an undesired outcome in LRGV.

Brush Management for Native Flora and Fauna. General prescriptions exist for brush reduction and removal (U.S. Department of Agriculture [USDA] 1970; Scifres 1980a); however, native flora and fauna will benefit most when brush eradication programs are eliminated in LRGV. Brush should always be left along drainages, on steep slopes, near watering and roosting places, and on other areas that are most attractive to wildlife in LRGV. Other preferred wildlife areas such as along rivers, creeks, resacas, and playas also should not be perturbed with mechanical brush removal, herbicides or fire.

Introduced Grasses. Buffelgrass (*Cenchrus ciliaris*) is an introduced grass that has spread to thousands of hectares in south Texas. This highly competitive plant spreads into native plant communities, but it is of little value to wildlife. Monocultures are prone to die-offs during cold spells, and buffelgrass provides few nutrients during drought (Rappole et al. 1986). Widespread clearing to plant buffelgrass pastures destroys ocelot habitat (Tewes and Everett 1982). Populations of reticulate collared lizard are reduced by land clearing practices, conversion of native grazing lands to farms and improved pastures, and spread of buffelgrass (Judd 1985a). Buffelgrass presently is invading the only known population of endangered ashy dogweed. Dense stands of this exotic grass prevent survival of most other plant species, including the endangered Johnston's frankenia (Editor 1987). Additionally, densities of cotton rats (*Sigmodon hispidus*) were four times greater on areas planted to exotic grasses than on native rangeland (Guthery et al. 1979), which likely decreased endemic populations of small mammals. Native flora and fauna would benefit from the eradication of buffelgrass and other exotic plant species from LRGV.

Urbanization

Along with water projects and agricultural development, urbanization is a threat to the unique flora and fauna of LRGV. Human population in the area has increased steadily since the early 1900's (Figure 9). A 40% region-wide population growth from 1980 to 1990 is projected, compared to the State average of 27% (TPWD 1985). Census figures from 1982 show a population of 230,500 in Cameron County. Brownsville, the county seat, is the largest city (84,997). Hidalgo County had a 1982 population of 315,000. McAllen (66,281) is the largest city in the county, and Edinburg (24,075) is the county seat. The population of Starr County was 30,000 in 1982, and Rio Grande City (5,720), the county seat, is the largest city. Willacy County had the smallest (18,200) 1982 population in LRGV; the county seat and largest city is Raymondville (9,493) (Dallas Morning News 1986/87).

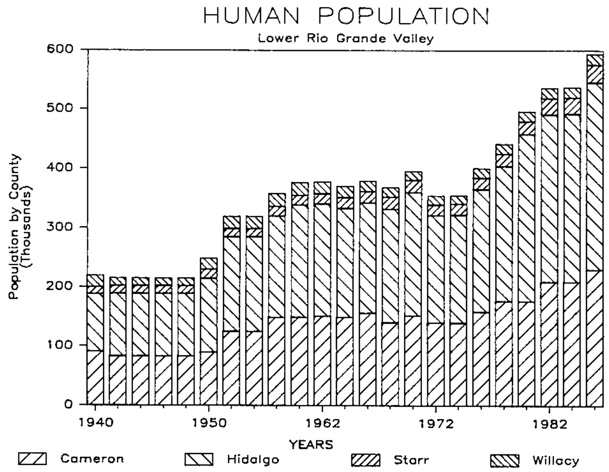

Figure 9. Human population size by county in the Lower Rio Grande Valley, 1940–86.

Brush Clearing

Clearing of native brush is the primary effect associated with urbanization. For example, waterfront housing subdivisions have been built on many resacas near Brownsville, which has resulted in loss of unique native riparian woodlands and critical wildlife habitats (Ramirez 1986).

Sewage

An additional impact associated with urbanization is dumping of untreated municipal sewage into the Rio Grande from Mexico and possibly some U.S. cities (USFWS 1986). Quantitative data on effects of untreated sewage on associated faunal and floral species in the Rio Grande are not available; however, degradation of water quality is likely. Sewage dumping contributes to eutrophication of waterways because nutrient levels in the water, especially nitrogen and phosphorus, increase. These nutrients enhance algal production, which results in increased turbidity. Rooted macrophytes may become shaded and eventually killed if growths of epiphytic algae are excessive (Liddle and Scorgie 1980). Loss of macrophytes results in a loss of fauna dependent on them; for example, waterfowl.

Specific responses of wetland ecosystems to sewage disposal are difficult to predict (Guntenspergen and Stearns 1985). Wastewater disposal can result in the addition of nutrients, suspended and dissolved solids, chlorine, heavy metals, and disease organisms to wetland systems (Brennan 1985). Inadequate treatment may cause reduced dissolved oxygen levels and increased presence of toxic substances, which can result in fish kills, decreased species richness, and increased occurrence of diseases (U.S. Environmental Protection Agency [USEPA] 1983). Changes in flow rate and periodicity, water levels, and vegetation structure and composition as a result of sewage inputs likely cause a wide range of changes in invertebrates, fish, amphibians, reptiles, birds, and mammals that depend on wetland areas (USEPA 1983; Brennan 1985).

Effects of sewage wastewater disposal in wetlands are not available for LRGV, but they have been investigated elsewhere. Wetlands that receive large amounts of agricultural and industrial waste are most likely to contain pathogens transmissible to wildlife (Friend 1982). Additionally, chemicals from sewage effluent that reach wetlands are health concerns (Friend 1982). Outbreaks of *Clostridium botulinum* type C frequently occur in California wetlands and occasionally elsewhere in the United States (Friend 1982). Wastes from domestic sources are less likely to contain wildlife pathogens if they have received at least secondary treatment. Migratory waterfowl and shorebirds are at greatest risk from sewage effluent discharges in wetlands because they are attracted in large numbers to sites that could be contaminated (Friend 1982).

Road Construction

Road building is positively correlated with human population growth. The number of roads, and brushlands lost to road construction, increases each year in south Texas and northeastern Mexico. On the United States side of the border, communities form an almost continuous chain of urban development along U.S. Highway 83, which parallels the Rio Grande within a 5- to 13-km (3- to 8-mi) belt. A network of State, farm-to-market, and county roads interconnect communities with farm and orchard lands (IBWC 1973). Roads are particularly abundant in Hidalgo and Cameron Counties, where there is a paved road virtually every 1.6 km (1.0 mi) (Judd 1985a).

Roads have direct and indirect impacts on wildlife. Road building can result in drainage of ponds and low areas that temporarily hold water, thus altering the hydrology of an area (Van der Zande et al. 1980). Vehicle traffic kills a large number of wildlife each year; populations of black-spotted newt (*Notophthalmus meridionalis*) may be reduced due to traffic mortality (Judd 1985a). The ocelot population in LRGV is significantly affected by road mortality (M. E. Tewes, personal communication). Demand for caliche, which is used locally in road construction, also threatens critical habitats of some species such as the reticulate collared lizard. Road construction isolates parts of habitat and can affect artificially disjunct animal communities by interfering with natural exchange of dispersing animals (Van der Zande et al. 1980; Mader 1984). Other disturbances associated with roads include noise, dust, headlight illuminations, and lead, cadmium, and sulfur dioxide emissions from automobile exhaust (Mader 1984).

Industry

A wide variety of businesses, mostly light industries, exist in the LRGV (Dallas Morning News 1986/87). Cameron County businesses include fruit, vegetable, and seafood processing; fishing; shipping; tourism; agribusiness; manufacturing; and natural gas and oil production. Businesses in Hidalgo County include food processing, shipping, other agribusinesses, tourism, and mineral operations. Mineral production includes oil, gas, sand, gravel, and stone. Businesses found in Starr County are vegetable packing, shipping, other agribusinesses, oil processing, and tourism. Oil, gas, sand, and gravel production also occur in this county. Mineral production, agribusiness, tourism, and shipping occur in Willacy County. Mineral production centers on oil and gas (Dallas Morning News 1986/87).

A variety of industries in the LRGV discharge wastes into the Rio Grande and into Sal Vieja and Arroyo Colorado drainage canals. The combination of contaminant sources is potentially detrimental to all associated refuge habitats (USFWS 1986). In absence of floods, industrial runoff contributes to contamination and siltation in resacas. As of 1981, stormwater runoff from urban areas was not a significant nonpoint source pollution problem (Black and Veatch Consulting Engineers 1981a). However, more recent studies indicate that runoff degrades water quality in resacas as a nonpoint source for fecal coliform bacteria, oil and grease, chlorides, phosphates, and nitrates (Ramirez 1986). Higher PCB residues found in Texas aquatic bird eggs were consistently associated with industrial and urban areas (King et al. 1978).

Recreation

General

Mild climate in LRGV in conducive to outdoor activities during all seasons and attracts many winter tourists (Fleetwood 1973). The area also is important as a gateway to Mexico (Dallas Morning News 1986/87). In 1975, the winter visitor population in Cameron, Hidalgo, and Willacy counties was 126,151 (IBWC 1982b). More recently, more than 500,000 visitors from northern states arrive each year to winter in LRGV (Schumacher et al. 1988). The yearly influx of winter visitors results in economic benefits to LRGV but can result in heavy use of existing recreation resources (TPWD 1985).

The three National Wildlife Refuges, several state parks, and private sanctuaries in LRGV serve as greenbelts and open spaces—locations for passive activities, preservation areas for unique natural features, and interpretive sites that highlight or explain ecosystem processes (TPWD 1985). Santa Ana NWR (Figure 10), Laguna Atascosa NWR, and Bentsen–Rio Grande State Park attract about 300,000 visitors annually. Falcon Reservoir also provides many recreational opportunities. Total visitation to the 4 counties generates nearly $500 million/yr for the local economy (USFWS 1988).

Visitors who are interested in the natural resources of LRGV generally go to refuges or parks that have visitor centers, established trails, picnic areas, campgrounds, or other public facilities (Figure 2). Visitors can have a direct impact on undisturbed brush when their activities are uncontrolled. However, private development associated with recreation, especially along the Rio Grande, has even more serious impacts. Private RV parks adjacent to the river include boat

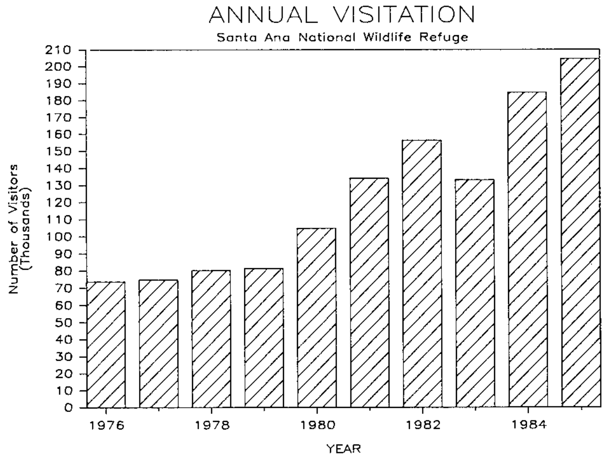

Figure 10. Annual visitation to Santa Ana National Wildlife Refuge, 1976–85.

ramps, docking facilities, and vehicle sites; such development requires clearing of riparian brush. Intensive recreational activity and disruption of the riparian corridor anywhere along the Rio Grande is detrimental to wildlife, especially endangered felids (Ramirez 1986).

Boating

Negative impacts caused by boating include: turbulence, turbidity, cutting of vegetation by propellers, direct contact with river banks and riparian vegetation, visual and auditory disturbance to animals, pollution from motors, and sewage. Shore-based recreation such as fishing and swimming results in trampling of vegetation, erosion, sewage, and other chemical impacts (Liddle and Scorgie 1980). Human disturbance also affects nesting success of birds by causing inter- and intraspecific behavioral imbalances. Brown pelican and Heermann's gull (*Larus heermanni*) colonies in California have been damaged significantly by recreationists (Anderson and Keith 1980).

Fishing and Hunting

Freshwater and saltwater fishing and hunting are major consumptive recreational activities in LRGV (USFWS 1983). Hunting alone is a multi-million dollar "industry." White-winged doves (Figure 6) and white-tailed deer are the most important game species; others include collared peccary, northern bobwhite (*Colinus virginianus*), mourning dove, scaled quail (*Callipepla squamata*), and plain chachalaca (Collins 1984).

Game species can be managed as a sustained yield for profit and recreation (Kiel 1980). Access to wildlife for hunting purposes is controlled by most Texas landowners under a lease system whereby the hunter pays a certain fee/ha for the lease or per animal shot (Rappole et al. 1986). Each year, more than 15,000 landowners in Texas make lands available for hunting on a fee basis (USDA 1970). In agricultural areas, economic return from a hunting lease program may exceed any potential increased production from land clearing activities (Collins 1984). Economic value of hunting leases equals or exceeds net income from livestock production on many ranches; such financial incentives should stimulate preservation of high quality wildlife habitat (USDA 1970).

Rangeland that is managed to produce both wildlife and livestock can net the landowner $10–$15/ha ($4–$6/acre) or more annually through lease hunting in addition to income from livestock production (Kiel 1980). If a deer herd is properly managed and harvested, quail and dove hunting also can be profitable on the same land (USDA 1970). Although collared peccary hunting is not popular with Texas hunters, out-of-state hunters pay $50–$200/head (Carl and Brown 1980).

As income from leases to hunt white-tailed deer has increased in south Texas, ranchers have come to appreciate the value of managing their lands for both cattle and deer (Meyer et al. 1984). Woody cover provides shaded bedding areas for deer, cattle, and collared peccaries (Drawe and Higginbotham 1980). Bobwhites use low, densely branched clumps of woody vegetation for loafing cover (Lehmann 1974). Diverse vegetation, particularly of herbaceous species, may be best in the long run for cattle (Kiel 1980).

White-winged dove hunting generates $20 million annually for the local economy in LRGV (USFWS 1983). Habitat acquisition for white-winged doves was a low priority for Texas until 1971, when the legislature authorized the sale of dove stamps. Revenue from stamps can only be spent for white-winged dove research and management, and acquisition, lease, or development of habitat. Stamp sales generate more than $250,000 annually (George 1985). Previously, excessive hunting pressure occurred on specific segments of the white-winged dove population when areas were open to hunting for consecutive seasons. Establishment of six small sanctuaries along the Rio Grande (rather than two large ones) that are open on alternate years now distributes hunting pressure more evenly. This system ensures some protection of white-winged doves and provides optimum hunter and landowner opportunity (Dunks 1978).

Demand for waterfowl hunting in LRGV is not as great as for other types of hunting, but in a survey of bird use of wetlands in the middle Rio Grande Valley, Chaney (1981) found heavy hunting pressure in several areas. Additionally, the recent establishment of two Ducks Unlimited chapters in LRGV has lead to increased demand for waterfowl hunting opportunities. Ponds are important stopover sites for migrating birds and spring and summer nesting areas for many species. Laguna Atacosa NWR is a primary wintering area for redheads (USFWS 1986), and South Bay, part of the

Lower Rio Grande Valley NWR, is also important. Draining and filling of many potholes and wetland areas has resulted in reduced waterfowl habitat in LRGV.

Because of the money generated by white-winged dove stamps for habitat preservation and because management practices favoring wildlife have been adopted by some Texas landowners, hunting has provided impetus for conservation of native brush and associated wildlife. These activities probably will provide increased incentive for management practices that benefit native flora and fauna.

Current Management: An Evaluation

Numerous human activities threaten native brushland in LRGV and make protection of remnant brushland tracts imperative. The USFWS uses several protection methods, including land purchase, easement, and land lease to acquire management rights to these tracts (USFWS 1980, 1983, 1985). In some areas where Tamaulipan brushland has been cleared completely for cropland, Federal and State agencies, and private conservation organizations have developed methods to restore brush species. Investigations continue on ways to increase cost-effectiveness and survival of restored vegetation.

Land Purchase

Fee acquisition of lands in LRGV by USFWS results in preservation of riparian and upland brushland habitat and associated wildlife. Soil conservation, brushland, and water quality improve after acquisition. The local county receives refuge revenue sharing funds for any lands acquired in fee by USFWS (USFWS 1983). Land purchase offers a permanent conservation alternative and affords the most unrestricted management option to USFWS.

Easement

When properly designed, conservation easements can be a valuable and viable preservation initiative in LRGV, but primary resource protection must be accomplished. Easements may have potential to aid establishment of a wildlife corridor along the Rio Grande floodplain by protecting those key tracts where the present owners cannot or will not sell or transfer full rights. Perpetual easements meet objectives best when they assure future preservation of brushland habitat. Typical easements grant USFWS wildlife management rights on the property with the owner retaining all other uses. Easements in LRGV therefore must be tailored to the individual tract of land. Easement terms must be variable between biotic communities and can approach full initial cost of fee acquisition. The USFWS must have the right to fence and post easement areas and prohibit clearing of brushland or uses that would impact wildlife habitat, for example, overgrazing and excessive public use (USFWS 1983).

Land Lease and Land Management Agreements

Use of mutually-beneficial, no-cost leases and agreements, especially on brushland owned by public entities, is a viable conservation tool. For example, the Brownsville Navigation District has leased 1,873 ha (4,627 acres) to USFWS for 40 yr at no cost as mitigation (USFWS 1983). Leases of property for a specified number of years have been used by USFWS on several refuges when critical habitat preservation needs must be met.

These options do not give as much freedom in management programs as fee title or easement. Costs associated with preparation of appraisal reports and other overhead are the same as in a fee or easement. A second problem with leases is that Federal procurement regulations proscribe payment for leases until wildlife management rights are actually received by the government. Leasing may result in future uncertainty to landowners and USFWS because either party may terminate the agreement at the end of any lease period (USFWS 1980).

Restoration of Cropland

Native brush has been reduced so severely that a key to preserving wildlife in LRGV is restoration of habitat through reforestation (Miller 1985b). For this reason, remnants of farms and pasture land are often included in purchases of natural areas (Gilbertson et al., in press).

Habitat restoration research began in the late 1950's on the Longoria Unit of Las Palomas WMA (TPWD). Five important woody species were used in this research: Texas ebony, anacua, huisache, granjeno, and brazil. Seedlings were dug by hand from existing native brush stands and transplanted into cultivated test plots (George 1985). Maximum area planted was 2.5 ha/d (6.2 acres/d) (Miller 1985b). Restoration of native brush was feasible with these methods, but because of the extensive amount of hand labor involved, it was very costly ($2,500/ha [$1,012/acre]). White-winged doves nested in revegetated ares within 3 yr, and nesting densities reached 100 pairs/ha (40 pairs/acre) 25 yr post-planting (George 1985). Under favorable conditions, white- winged doves can nest in huisache 18 mo after planting (USFWS 1978).

With current technology, revegetation can be made less labor-intensive. Seeds can be germinated and reared in a greenhouse and later planted at a restoration site with a chisel-type planter pulled by a 4-wheel driven drive tractor (George 1985; Miller 1985b). The combination of mechanized planting and greenhouse seedlings makes revegetation of cropland to native brushland economically feasible ($400/ha [$162/acre]). Under some agreements, farmers care for revegetated fields and plant food crops for doves on other cleared land nearby (Miller 1985b). About 25 ha (62 acres) of native brush were planted in LRGV in 1984, 300 ha (741 acres) in 1985, 350 ha (865 acres) in 1986, 520 ha (1,285 acres) in 1987, and 600 ha (1,482 acres) will be planted in 1988 for a total of 1,795 ha (4,435 acres) (N. M. Gilbertson, personal communication). Current studies involving use of plant-growth hormones (i.e., gibberellic acid) and light-control devices indicate that brush restoration may be even more cost effective in the future (George 1985).

As part of revegetation research, several studies have been conducted on seed germination requirements of woody species. Texas ebony germination is usually low because of the hard seed coat. Soaking seeds in H_2SO_4 for scarification increased germination of Texas ebony seeds (Alaniz and Everitt 1978). Salts apparently have little effect on seed germination and seedling growth. Emergence was optimal when seeds were planted 1 cm (0.4 inch) deep (Alaniz and Everitt 1978). Germination of huisache seeds also is constrained by a seed coat that appears to be impervious to water; however, after the seed coat is broken, germination occurs rapidly (Scifres et al. 1982a).

Anacua germination also is restricted by an impermeable seed coat (Alaniz and Everitt 1988). Germination was not enhanced by chemical scarification or rinsing with water. Gibberellic acid increased germination from 35% to 61%. Mechanical scarification and dry heat only enhanced germination of highly dormant seeds (Fulbright et al. 1986). Emergence is optimal when seeds are exposed on the soil surface (Alaniz and Everitt 1988).

Many woody species in LRGV produce few seeds at irregular intervals. Asexual propagation methods need to be developed for these species. Seeds are not easy to obtain from species such as brush holly (*Xylosma flexuosa*) and devil's claw (*Pisonia aculeata*); however, these species are easily propagated by stem cuttings. No root promoting substances are necessary. In fact, results showed decreased rooting success when synthetic root-promoting substances or nutrient solution were used (Heep and Vora 1986).

More basic research is needed on native species of trees, shrubs and grasses that provide habitat and food for wildlife in LRGV. Little is known about riparian communities along the Rio Grande, and cedar elm and baretta communities are especially in need of study. The arboretum at Santa Ana NWR should be expanded to serve as a source area for nursery stocks of native plant species in LRGV. Although revegetation projects are important, preservation of existing habitat is preferable and less expensive than acquisition and restoration of cleared land (George 1985).

Constraints

Land Title Problems

Spanish land grants in the floodplain of the Rio Grande date back to the early 1500's (USFWS 1983). When Hispanic settlements became part of the United States territory, Spanish land grants were respected and private ownership was affirmed by the new government. Land grants were generally large acreages, and the tendency for large ranches continues to the present (Crosswhite 1980).

Ownership of much of the lands designated as Falcon Woodland (Figure 6), approximately 9,700 ha (24,000 acres) in LRGV, requires curative title actions to clear long-standing land claims (USFWS 1985). In this area, title problems have discouraged USFWS from purchasing lands. Meanwhile, this brushland continues to be converted into cropland, pasturelands, or homes and recreational outlets. This conversion has a negative impact on ecological integrity in the area and adds curative costs to acquisition and management plans. Habitat must be protected until some means can be found to provide permanent protection (R. W. Schumacher et al., in press).

Habitat Fragmentation

Many remnant brush tracts in LRGV are small (< 40 ha [< 100 acres]) and scattered (USFWS 1983). Isolated native brush tracts in extensively cleared areas may serve as "islands" of wildlife habitat (Blake and Karr 1984). The size of natural areas, or the degree of fragmentation, and their proximity to each other influence recruitment and extinction relationships (Diamond 1975). Larger areas, or small areas with close neighbors, provide increased diversity, dispersal potential, and lower extinction rates (Harris 1984).

On an island, population size and probability of extinction for a species are greatly affected by body size, trophic level, and habitat specialization (Brown 1971). On montane islands, small mammals are found on more islands than large mammals, herbivores more than carnivores, and herbivores that are generalists inhabit more islands than herbivores that are specialists. Species that occur on only a few montane islands usually are found only on large islands. In cases where environmental changes (e.g., the result of human activity) have caused massive extinctions, numbers of species on an island will be less than the equilibrium number (Brown 1971). Such relationships may be operative in LRGV, and their potential effects are incorporated into the resource protection and management strategy for LRGV.

Island Biogeography

The theory of island biogeography includes ideas such as: the number of species on an island is positively related to its area; when immigration and extinction rates are equal, the area will reach a biotic equilibrium; and island area is correlated with environmental diversity, which has a more direct effect on species number than area alone (MacArthur and Wilson 1967). This theory has stimulated much theoretical and empirical discussion.

The theory of island biogeography has been extended to include continental areas. A biological island is an area of at least marginal habitat surrounded by areas of unacceptable quality (Picton 1979; Picton and Mackie 1980). Most nature reserves are natural landscape "islands" surrounded by expanses of culturally modified habitat (Pickett and Thompson 1978). Direct or indirect human influence is the greatest threat to preservation goals of nature reserves (White and Bratton 1980). A major effect of human perturbations such as agriculture, roads, and grazing has been habitat fragmentation (Middleton and Merriam 1985). Probability of extinction may be high if available habitat in and around the area has decreased because of habitat destruction and disturbance (Soule and Simberloff 1986). Such disturbance and its associated habitat fragmentation are prevalent in the LRGV, but local extinction rates are unknown.

Effect of Size

The relative merits of one large versus several small refuges in maintaining species richness have been debated in the ecological literature. Diamond (1975) believed that large reserves that are close to other reserves contained more species than small, isolated reserves because of the higher extinction rate in small reserves. However, archipelagos of small islands may have more plant species among them than a single large island of equal area (Simberloff and Gotelli 1984). Several reserves with occasional inter-reserve migration may be the optimum design strategy for genetic conservation (Boecklen 1986). On the other hand, large reserves likely are needed to maintain ecological processes, with additional reserves necessary for perpetuation of particular endangered species (Kushlan 1979).

Although some argue that the theory of island biogeography is unsubstantiated (Margules et al. 1982; Reed 1983), many studies indicate that size, alone or with other factors, influences number of species found in an area and ecological health (Moore and Hooper 1975; Kitchener et al. 1982; Blake and Karr 1984; Opdam et al. 1985; Soule and Simberloff 1986). There is substantial evidence that the probability of loss of rare species is related to reserve size and isolation, species natural history, and population size and isolation (White and Bratton 1980). Habitat diversity, in combination with size, has a significant effect on species richness (Picton 1979; Kitchener et al. 1982; Reed 1983; Freemark and Merriam 1986). Additionally, reserve shape determines effective protection and management (Schonewald-Cox and Bayless 1986). Generally, nature reserves should be as large and numerous as possible (Soule and Simberloff 1986).

Current models may be insufficient to determine minimum area requirements of species. To achieve accurate area specifications, detailed natural history observations are necessary (McCoy 1983). Predictions of the equilibrium model are useless without autecological information on target species to be preserved (McCoy 1982; Boecklen and Gotelli 1984). Unfortunately, such information is lacking for most species in LRGV.

Effect of Isolation

There is evidence that isolated reserves may experience species depletion due to isolation from contiguous gene pools in surrounding natural habitat (Miller and Harris 1977). Lack of recolonization sources leads to decreased immigration, followed by increased extinction (Pickett and Thompson 1978; Wilson and Johns 1982). Agricultural activities cause habitat isolation and interfere with natural exchange of individuals via emigration or immigration (Mader 1984).

Isolation of reserves may result in ecosystem degradation (Kushlan 1979). In Maryland, forest isolation and plant diversity were the best predictors of local abundance of individual bird species. Red-eyed vireo (*Vireo olivaceus*) and wood thrush (*Hylocichla mustelina*) experienced declines of about 2% in local density with each 100 m (328 ft) of isolation (Lynch and Whigham 1984). Degree of isolation affects the number of bird species restricted to mature woods (Opdam et al. 1985).

The major reason for decline of tropical bird species in cleared forests in Mexico was isolation of forest remnants from larger tracts (Rappole and Morton 1985). Isolation and small size of remnants apparently made forest patches unsuitable for use by multispecies foraging flocks. Mature forests supported higher, more stable populations of forest-dwelling migrants and residents than disturbed forest, ecotones, and second growth sites (Rappole and Morton 1985).

Brushland tracts in LRGV are isolated. Movement rates and distances moved between tracts by various species in LRGV are unknown. Similarly, recolonization ability and optimum distances between brushland patches that would afford maximum species interchange are unknown. Considerable refuge research is directed toward clarifying these relations in LRGV.

Effects of Corridors

Use of corridors is becoming prevalent in reserve design (Noss 1987). The original landscape in many reserve areas, as in LRGV, was once a series of interconnected natural habitats. Thus, corridors are an attempt to maintain or restore natural landscape connectivity. Increased connectivity, along with increased effective habitat area, counteract habitat fragmentation (Noss 1987).

Corridors facilitate gene flow and dispersal of individual animals (Soule and Simberloff 1986). Life histories of wide-ranging animals suggest that maintenance or restoration of landscape connectivity is a good management strategy (Noss 1987). Corridors alleviate threats from inbreeding depression, and a network of refuges connected by corridors may allow persistence of species that need more resources than are found in one refuge. A corridor (e.g., riparian forests along the Rio Grande) is an important habitat in its own right (Simberloff and Cox 1987).

There may be costs associated with corridors, such as transmittal of contagious diseases or fire, and increased exposure of animals to predators, domestic animals, and poachers (Noss 1987; Simberloff and Cox 1987). However, potential disadvantages of corridors can be avoided by enlarging corridor width (Noss 1987). Because of probable human and associated disturbances, the best corridors are as wide as possible. Necessary width depends on habitat structure and quality within the corridor, the nature of surrounding habitat, human use patterns, and particular species that are expected to use it (Noss 1987). The ideal corridor width along the Rio Grande would be wide enough for target species to access sufficient food, water, and cover. In this way, genetic exchange could occur along the corridor, and populations could be maintained even though density at any particular place in the corridor might be low.

For the eastern chipmunk (*Tamias striatus*), fencerows were critical connections between woods separated by farmland. Minimum area for population survival was several woods and interconnecting fencerows. Small breeding populations were established in fencerows only 3-m (9.8-ft) wide (Henderson et al. 1985). On power-line corridors, bird density was correlated with corridor width, length of forest edge, and number of years after cutting of vegetation (Kroodsma 1982).

Application to the Lower Rio Grande Valley

Howe et al. (1986) investigated fragmentation of thornscrub habitats along the lower Rio Grande and its effect on local extinction or loss of numbers in populations of resident amphibians, reptiles, birds, and mammals. (Their survey only applied to the number of species present at a particular time. They did not address long-term persistence of species on these sites, nor did they examine reproductive success and survival.) Preliminary results did not demonstrate significant correlation between species abundance or frequency of occurrence of a selected group of species and tract size or shape, but larger mammals that require extensive tracts of undisturbed habitat were not addressed in the study. Total abundance of peripheral or rare species was significantly higher in the interior of large tracts than in small tracts. An isolated small strip had very low bird species richness, which suggested that distance from large tracts may be an important determinant of species richness (Howe et al. 1986). Vegetation density also may be an important component of faunal diversity and abundance. More small mammals were trapped in dense thorny vegetation in Laguna Atascosa NWR than in other habitat types (Scott 1982).

Rappole (1986) surveyed a 6.9 km^2 (2.6 mi^2) area of the Schalaben Tract (Figure 6) for ocelot and jaguarundi. The area was small, isolated, and degraded from overgrazing. No evidence of either species was found. If all of the habitat on the ranch were suitable for ocelots, it could support only 1–2 males and 3–4 females. Areas of this size may be too small to maintain viable populations of ocelots without the presence of neighboring thorn forest of similar or larger size. Normal fluctuations in population size due to drought or disease would likely cause complete elimination of small populations (4–5) in restricted and isolated habitats (Rappole 1986).

Tewes and Everett (1982) set the arbitrary minimum area for a unit of potential ocelot habitat as a contiguous dense brush stand of 40 ha (100 acres) or 2 proximate 30-ha (75-acre) tracts. Several small acreages of suitable brush were considered potential ocelot habitat if they totalled 40 ha (100 acres), were in close proximity (ca. 0.8 km [0.5 mi]), and if some type of brushy travel lanes were available. Nevertheless, home ranges were considerably larger than the minimum area suggested. A male ocelot had a 334-ha (825-acre) home range, and a female had a 269-ha (664-acre) home range. This highlights the importance of travel corridors between brushland tracts.

Resource Protection and Management Strategy of the LRGV Refuge Complex

The major issue facing the USFWS in LRGV is the continued loss of wildlife species, populations, and habitats in the Matamoran District of the Tamaulipan Biotic Province. The mission of USFWS is to preserve those species, populations, and habitats in perpetuity throughout the Matamoran District. Authority exists to identify and acquire important lands in the four southernmost counties of Texas that are critical to this mission.

The strategy applied to the resource protection efforts is dynamic in that it addresses both long-term and current needs of wildlife and its habitat. It also is pragmatic in that it recognizes that some opportunities to meet USFWS goals have only a narrow window in which action may be effectively initiated and that priorities often must change to meet current circumstances. Discussion in previous sections on various aspects of habitat alteration that affect all plant and animal populations have particular applicability to LRGV because isolation of habitats, fragmentation of remaining habitats, and needs of substantial numbers of species with low population numbers require special efforts to not only maintain populations but augment their numbers over time. Accordingly, USFWS has developed a five-part integrated approach to resource protection and management in the Matamoran District:

1. **Community Approach** – Because the project area is large and heterogeneous, communities under particular threat are given a high priority in acquisition and preservation planning. As additional communities become threatened by development, they will be included in this approach – hence the dynamic nature of the resource protection and management strategy.

2. **Corridor Approach** – The Matamoran District is essentially the riparian and deltaic reaches of the lower Rio Grande. The Rio Grande is the major corridor for movement of flora and fauna within the District because of the destruction of native habitats in surrounding areas. Most communities of concern to USFWS are within practical reach of the Rio Grande. Thus, this approach is intended to maintain and repair the riparian link between important biotic communities.

3. **Anchor Approach** – La Sal Vieja, Falcon Woodland, and the estuary of the Rio Grande are large enough to maintain in perpetuity most of the species now found within them. These units maintain the biological material needed to safeguard gene pools and replenish populations throughout the corridor. This approach recognizes the value of maintaining large units on the edges of the project area that augment the smaller units throughout LRGV.

4. **Management Unit Approach** – Management Units are strategically placed habitats that are sufficient in size to provide food, water, and cover for selected target populations. They are valuable as sites that can maintain numbers and genetic material during periods of stress including the development stages of LRGV resource protection and management efforts. They are valuable as "stepping stones" for movements of species throughout the Valley. Santa Ana, Santa Maria, and Anzalduas are examples of Management Units.

5. **Island Approach** – Some individual fragments or "islands" of habitat left largely untouched when the Rio Grande delta was cleared contain important wildlife values not found elsewhere in LRGV. Historic sites of white-winged dove nesting and wetlands used by black-spotted newts are examples. The Thompson Road and Goodfields tracts are examples of such "islands."

The integration of the five approaches above recognizes the equal value of intrinsic attributes and synergistic and complementary aspects of communities, corridors, anchors, management units, and islands. Daily management, long-range planning, and habitat acquisition and protection efforts of the LRGV Refuge Complex use the combination of these five approaches to guide their efforts. However, it is important to note that management in LRGV is evolving in response to new environmental threats and conflicts. Although unforeseen crises may require additional efforts and perhaps a redirection of strategy, for the present, a combination of the five approaches is the optimal means to meet LRGV resource protection and management needs (N. M. Fuller and R. W. Schumacher, personal communication).

Management Suggestions

Current and future management of Tamaulipan brushland in LRGV is a portion of the overall USFWS resource protection and management strategy. These efforts focus on two primary goals: acquisition and preservation of remaining native brush tracts, and acquisition and revegetation of previously altered brush habitats. Attainment of these goals will require cooperative effort between Federal and State agencies, conservation organizations, and private individuals. Public education and support are integral parts of achieving management goals.

We suggest the following management recommendations in support of current USFWS management efforts in LRGV. Not all of the following recommendations are novel, but in total they address a broad range of management alternatives that will enhance preservation of the unique and important Tamaulipan brushland of LRGV. These recommendations were synthesized from material reviewed for this report.

1. Acquire and preserve as many examples as possible of threatened biotic communities throughout LRGV. These reserves should be as large as possible.

2. Preserve remnants of the Rio Grande's deltaic forest.

3. Provide buffer zones to insulate refuges from detrimental effects of human activity.

4. Augment and encourage current international and conservation community interest in establishing a wildlife-wildland corridor on both sides of the Rio Grande between the levee system and the river.

5. Establish connecting corridors between the riparian corridor and isolated tracts near the river.

6. Make corridors as wide as possible to ensure that they encompass enough of each biotic community to guarantee preservation. Species such as large carnivores may require wide corridors to travel safely among reserves, but corridors facilitate dispersal and gene flow even if insufficient for residency.

7. Preserve as many secondary corridors on resacas, arroyos, canals, ditches, and other rights-of-way as possible.

8. Maintain and enhance cooperative conservation efforts of private, State, Federal, and international groups.

9. Use interpretation, extension, education, and individual contact to involve the LRGV community in resource protection.

10. Use public education to emphasize importance of brushland as wildlife habitat; educational efforts can help offset anti-environmental attitudes.

11. Encourage the public to fully understand the intrinsic value of the region's nature preserves.

12. If lands cannot be protected in other ways, propose to landowners that they manage their land as wildlife habitat for lease hunting, rather than clearing additional brushland.

13. Encourage users of agricultural chemicals to reevaluate current programs and to select the least ecologically damaging alternatives.

14. Determine feasibility of a settling basin system within conveyance canals to minimize input of additional sediment and contaminants into Lower Laguna Madre.

15. Plug old channels rapidly at the site of channel realignment to minimize impact of sedimentation on the downstream environment. This procedure will reduce the duration of contact between water and easily eroded, loose sediment used as backfill.

16. Substitute managed flooding for natural flooding to ensure preservation of riparian forests. Controlled floods should be scheduled during the summer and fall hurricane season to coincide with remaining natural cycles of vegetative growth and faunal reproduction.

17. Investigate potential use of misunderstood species of the region such as prickly pear and mesquite for forage, fodder, and even crop plants as a means to gain support for maintenance of natural vegetation.

18. Develop strong arguments for conservation of this unique habitat on its own merits, regardless of specific wildlife considerations.

Conclusions

The USFWS administers three National Wildlife Refuges in LRGV of south Texas. Each conserves dense Matamoran District Tamaulipan brushland, which is characteristic of the area under natural conditions. Current efforts to protect native brush include preservation of existing tracts owned by USFWS, acquisition of additional tracts, and restoration and revegetation of altered habitat. Other organizations that are deeply involved in preservation of Tamaulipan brushland include: Texas Parks and Wildlife Department; Frontera Audubon Society; Texas Organization for Endangered Species; Native Plant Project; Texas Nature Conservancy; Lonestar Chapter of the Sierra Club; The Valley Nature Center; the cities of Brownsville, McAllen, and Weslaco; Methodist Retreat; and the Boy Scouts and Girl Scouts of America.

There are several biological criteria that should be considered when nature reserve location is discussed. A particular site should be surveyed to see if it has optimal habitat for one or more species of special concern. Areas with maximum habitat and species richness should be sought. Sites of maximum endemicity are of great value, especially for retention of biotic diversity (Soule and Simberloff 1986). Tamaulipan brushland habitat satisfies all of these criteria, and therefore acquisition of the few remaining native brush tracts in LRGV is appropriate.

Conservation of biological diversity is accomplished best by management of a variety of habitats (Moore 1969). Matamoran District Tamaulipan brushland habitat contains riparian forest, upland thornscrub, wooded potholes, and other diverse biotic communities. Natural areas such as these, with minimal human disturbance, are valuable for purposes other than economic exploitation. They serve as outdoor classrooms and provide living models of how complex organisms interact in biotic communities (Gehlbach 1975; Janzen 1986). Additional knowledge of undisturbed ecosystems is needed as a baseline against which to measure effects of human modifications (Jenkins and Bedford 1975). Natural areas also serve as living banks of genetic diversity (Gehlbach 1975; Janzen 1986) and provide aesthetic, historical, therapeutic, and intrinsic values associated with wildlands (Rolston 1981, 1985).

Most land developments are pernicious to native flora and fauna and largely irreversible. Such developments often undergo depreciation of benefits with time, whereas environmental assets are enhanced with time (Dearden 1978). For example, in LRGV, developers may be uncritically accepting the philosophy that the only "good" stream is a "harnessed" stream (Hamilton 1971). For example—there has been discussion of water in the Rio Grande that flows "wasted" into the Gulf of Mexico. Ecologically speaking, this idea has no basis, because in nature things are recycled, not "wasted."

Some species in LRGV are in danger of becoming "orphan species" (i.e., those on the brink of extinction because their natural habitats are destroyed; Temple 1981). These animals and plants can serve as indicators of larger environmental problems that may have major adverse effects on humans (Pister 1979). Preservation of plants and animals ensures protection of any anthropocentric values that they possess but that research has not yet revealed (Pister 1979). Thus, it is in our best interests to preserve natural habitats such as Tamaulipan brushland of LRGV not only because of current ecological and aesthetic benefits, which would be lost if remnants were not conserved and human perturbations not restricted, but also because of inevitable future benefits.

Current concern for preservation, acquisition, and appropriate management of the resources of the Tamaulipan brushland of LRGV is illustrated by the broad range of support provided by local organizations. This support also is reflected in the concerted efforts of conservation organizations to provide funding for land acquisition in LRGV. For example, 13 national and international conservation organizations prepared a report on potential use of Land and Water Conservation Fund monies in Fiscal Year 1989 that listed purchase of 5,062 ha (12,500 acres) in LRGV as a major conservation need (American Hiking Society et al. 1988). At present, the LRGV NWR is the number one priority project for the USFWS with regard to use of Land and Water Conservation funding. To date, insufficient funding has limited acquisition to less than 25% of the projected need for land protection.

The exceptional concentration of wildlife in native brushland in LRGV, the presence of numerous endangered species and many species at the northern limits of their range, and the limited extent of brushland in both the United States and Mexico emphasize the value of remaining natural habitat. Losses of this habitat to date, approximately 95%, and continued destruction through conversion of brushland to agricultural, urban, and recreational lands further emphasize the need for acquisition, preservation, enhancement, and reestablishment of native vegetation and wildlife communities. There is almost unanimous agreement on the uniqueness and value of the biological diversity and natural communities remaining in LRGV, but no other Refuge acquisition program has to cope with an area in which so little of the original habitat remains. Plant and animal communities of LRGV are unique in the United States, and worthy of intensive conservation efforts. The need for preservation is imperative and the extreme value of all tangible results is clear.

References

Each citation below is followed by one or more acronyms (the list of acronyms is arranged as presented in the text) to indicate its major subject matter; references followed by an asterisk (*) are cited in the text. Acronyms are defined as follows:

AG = Agriculture
BC = Brush Control – General
BCFI = Brush Control – Fire
BCHB = Brush Control – Herbicides
BCMC = Mechanical Brush Clearing
E = Environmental Ethics
GR = Grazing
LD = Location and Description
PM = Present Management
PT = Pesticides
UR = Urbanization
VE = Vegetation – General Ecology
VI = Vegetation – Impacts
WD = Water Development
WE = Wildlife – General Ecology
WI = Wildlife – Impacts

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16. Abstract (Limit: 200 words)

An extensive literature search and data synthesis were conducted on Matamoran District Tamaulipan Brushland in the Lower Rio Grande Valley of South Texas. The goal of the synthesis was to provide a single-source reference of historical review, land use planning, and management of brushland habitats and wildlife populations of the Lower Rio Grande Valley.

Tamaulipan brushland is a unique exosystem, found only in south Texas and northeastern Mexico. Since the early 1900's, 95% of native Tamaulipan brushland has been cleared for agriculture, urban development, and recreation. In riparian areas, 99% of native brush has been destroyed. Clearing destroys habitat of native species of plants and animals in the Lower Rio Grande Valley, and it may cause extinction of many species. Water development on the Rio Grande has substantially reduced river flow, resulting in altered riparian habitats and additional brush clearing.

The resource protection and management strategy for the Lower Rio Grande Valley consists of five integrated approaches: concentration of biotic community needs; maintenance of a wildlife habitat corridor; safeguarding of anchor untis of large size; protection of smaller management units; and the incorporation of 20 habitat islands into the management plan.

17. Document Analysis a. Descriptors
Tamaulipan brushland, south Texas, Tamaulipas, land clearing, pesticides, herbicides, corridor, endangered species, water development, Rio Grande, riparian habitat; resource protection, island biogeography, Matamoran District

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