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THE NON-VOLANT MAMMALS OF THE GALVESTON BAY REGION, TEXAS

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The Galveston Bay region is at the northernmost end of a long chain of barrier islands that stretches along the Texas coast and includes Galveston and Pelican Islands. Galveston Island, formed by natural processes, is about 4500 years old (Fisher et al., 1972), whereas man-made Pelican Island is only 40 years old.

This region of Texas has a long history of development and disturbance, beginning with the founding of the City of Galveston in 1839. Major disturbance factors have included hurricanes, loss of land due to erosion and subsidence, conversion of land for ranching, and fire control practices. All of these factors have impacted the habitats available to mammals.

The mammalian fauna of the mainland along the upper Texas coast has been well documented (Bailey, 1905; Schmidly, 1983; Davis and Schmidly, 1994), but little work has been done on Galveston Island. Bailey (1905) visited the island, but did not collect mammals there and Baker and Lay (1938) reported three species of rodents (*Sigmodon hispidus*, *Rattus norvegicus*, and *Mus musculus*). There have been no attempts to document the mammal fauna of Pelican Island.

This study was designed to document the mammals on Galveston and Pelican Islands by: (1) evaluating species diversity patterns on the islands compared to adjacent mainland regions; (2) determining the distribution of species according to major habitat types; and (3) comparing the relative distribution of non-native murid rodents with respect to native cricetid rodents in the major habitats.

Mammals were chosen as the biodiversity component to monitor for a number of reasons. Small mammals are relatively easy to capture, and they occur in high enough densities to allow a sufficiently large sample size to be obtained for virus studies done in conjunction with this study. Mammals also are good indicators of change in grassland and wetland communities. Additionally, a mixture of native and introduced rodents exists on Galveston Island, thereby presenting an opportunity to examine the dispersal patterns and impact of exotic species on the native fauna.

MATERIALS AND METHODS

Traplines were assessed from July 1995 to September 1996 in all habitats on Galveston and Pelican Islands, as well as a number of locations on the coastal mainland (Fig. 1). Individual traplines of 20 to 50 stations were set for three to five consecutive days. Each station consisted of one Sherman live trap baited with a mixture of hen scratch and oatmeal, and placed about 10 m apart (Jones et al., 1996). Traps were placed near decaying logs, shrubs, and in dense cover to attempt to maximize catch. Exact locations of traplines depended upon access to the area and habitat type. Tomahawk and Havahart live traps, baited with canned cat food, fruit, and vegetables, were placed among the Sherman traps around trails and burrows.

Although some studies have shown that snap traps are more effective for sampling small mammals than live traps (Weiner and Smith, 1972; Nagorsen and Peterson, 1980), snap traps were not used due to the destruction of captured specimens by fire ants. Additionally, the use of live traps facilitated collection of blood samples for hantavirus studies conducted in conjunction with this survey.

Pitfall traps were deployed in February 1998 in coastal prairie habitat on Galveston Island to assess shrews and fossorial mammals. The trapline, which was monitored for seven consecutive days during the sampling period, consisted of eleven 20 liter buckets placed at 5 m intervals along a continuous 50 m drift fence. Nothing was captured.

Gophers were captured using Macabee traps. Larger mammals were collected with Havahart live traps and muskrat leghold traps, as well as by shooting. In addition, the two major roads west of the City of Galveston, FM 3005 and Stewart Road, were driven weekly and road-killed animals were recorded. Long-time residents of Galveston Island, including Roland Chapman, Mr. Pines, and Frank Marullo, were interviewed concerning mammals they have observed. Bats were rarely seen and difficult to capture with mist nets. Attempts to locate bat roosting sites by observation and by distributing pamphlets were not successful, and for this reason volant mammals were excluded from this study.

DESCRIPTION OF COLLECTING SITES

Galveston and Pelican Islands are located at the northern end of a long chain of barrier islands that stretch along the Texas coast (Fig. 1). Galveston Island formed by natural proccesses from a small sand bar off the coast about 4500 years ago (LeBlanc and Hodgson, 1959). Pelican Island began as a narrow strip of marsh and sand spit off the northeastern shore of Galveston Island in 1816 (Alperin, 1977). In the 1950's, this area was filled with dredge material from the Intracoastal Waterway to form Pelican Island (Herz, 1957). The soils of the two islands are quite different because of the manner in which each was formed. The major soil type on Galveston Island is a sand and shell mixture; on Pelican Island the soil is a poorly drained, saline, clayey dredge material (Crenwelge et al., 1988).

Galveston Island is 4.8 km wide at the eastern end and gradually tapers over its 48.3 km length to a width of 0.8 km at the western end. It is, on average, 4.8 km from the mainland. It has a maximum elevation of 4.5 m at the eastern end, but most of the island is 3.0 m or less above sea level (Fisher et al., 1972).

Pelican Island is separated from Galveston Island by the Galveston Channel with an average width of 0.5 km. Pelican Island, with a diameter of 4.4 km, is roughly spherical in shape. Its maximum elevation is 4.5 m along the Galveston Channel, and gently slopes toward sea level as one proceeds northward except for the levees that criss-cross the island (Fisher et al., 1972).

Both islands are characterized by a warm, humid, subtropical climate with a mean annual air temperature of 20.9° C. The hottest month is August, with an average low temperature of 26.0° and high of 30.8°. The coldest month is January, with an average low of 8.9° and high of 15.2° . Mean annual precipitation is 1009 mm per year (Crenwelge, et al., 1988).

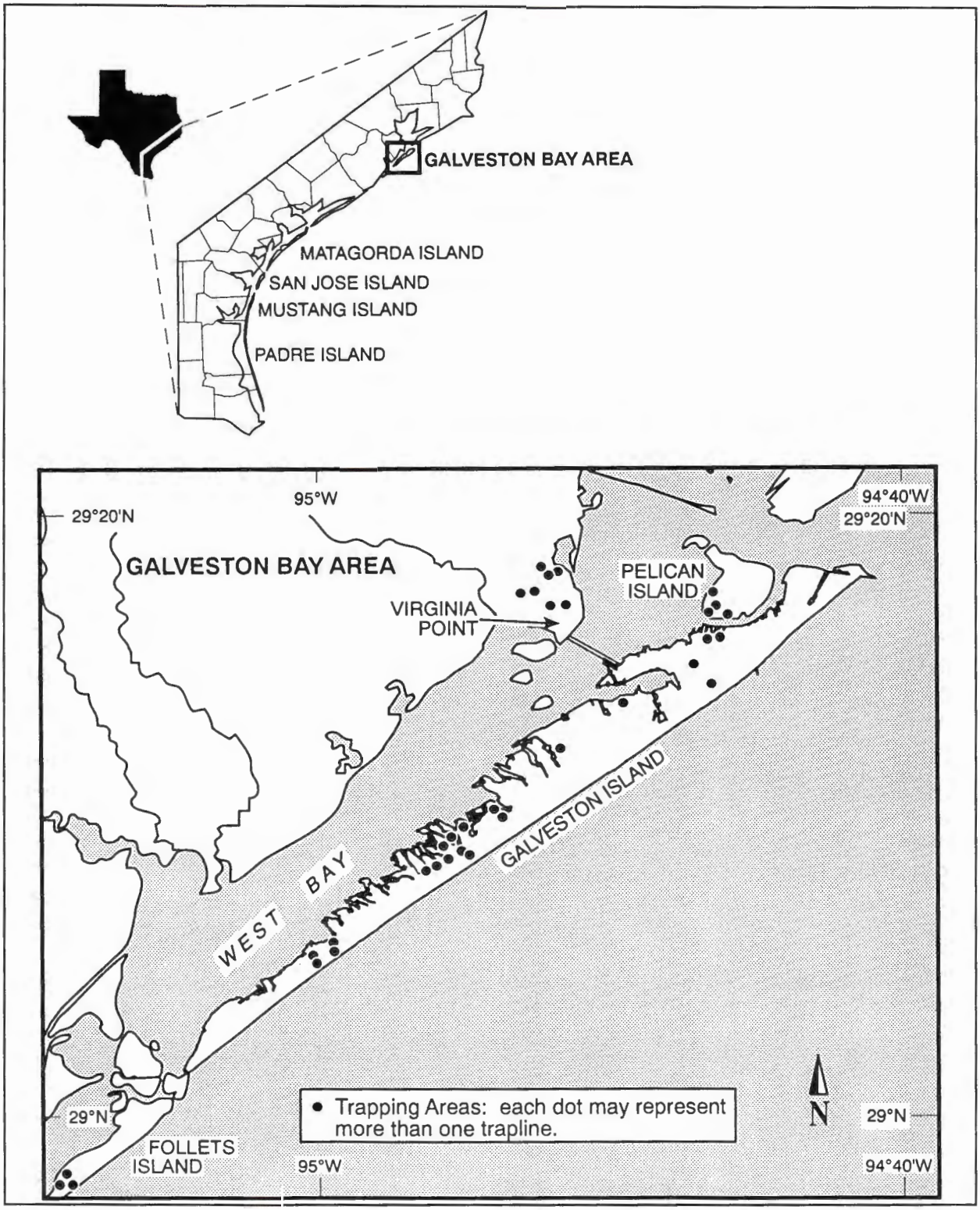

Figure 1.— Map of coastal Texas with a detailed inset of the Galveston Bay area.

Both islands are in the Basic Austral district of the Austroriparian biotic province (Dice, 1943; Blair, 1950). There are four major biotic zones on Galveston Island, each encompassing particular habitat types. From the Gulf shore to the bay side, these zones are: sandy beach; beach ridge (dunes); ridge/swale assemblage; and salt marsh (Scrudato and McCloy, 1976; Britton and Morton, 1989). These zones can be further divided into six major habitat types, including the dune ridges, fresh and brackish ponds, coastal prairie, coastal scrub, oak mottes, and salt marsh (Eubanks, 1992).

The general landscape of Galveston Island consists of abandoned beach ridges and intervening swales. These ridges become difficult to distinguish toward the bay side of the island. Some of the higher abandoned ridges harbor coastal scrub and oak motte habitats. The swales contain freshwater marshes and ponds that are surrounded by coastal prairie. The coastal prairie blends into salt marsh on the bay side of the island.

The sandy beach zone consists of a fore and back beach area, with no macrovegetation present on the fore beach. The back beach has little vegetation due to storm erosion and disturbance by people and vehicles (Britton and Morton, 1989). Although invertebrate life and bird species are diverse, there are virtually no terrestrial vertebrates present.

The beach ridge zone is comprised of a series of ridges (sand dunes). The dune habitat is limited to the primary dune ridge where the vegetation consists of plants tolerant of salt spray and sand burial (Fig. 2). Some examples of commonly found plant species include gulf croton (*Croton punctatus*), camphor daisy (*Heterotheca subaxillaris*), fiddleleaf morning-glory (*Ipomoea stolonifera*), bitter panicum (*Panicum amarum*), and sea-purslane (*Sesuvium portulacastrum*). As the dunes blend into the island uplands and marshes, they become dominated by common coastal prairie species such as seacoast bluestem (*Schizachyrium scoparium*) and gulfdune paspalum (*Paspalum monostachyum*) (Eubanks, 1992).

The ridge/swale assemblage zone is the largest of the four zones and contains four of the six habitat types. Freshwater marsh and pond habitats occur within the swales of this zone and are common within

Figure 2.—Dune habitat. This is the primary dune ridge at the east end of Galveston Island State Park.

the coastal prairie (Fig. 3). The pond edges sometimes are densely covered with stands of common cattail (*Typha domingensis*) and common reed (*Phragmites australis*), especially when freshwater marshes abut the border (Eubanks, 1992). The native rattlebush (*Sesbania drummundii*) and marsh-hay cordgrass (*Spartina patens*) also are common, but many pond shorelines are dominated by exotics, such as Chinese tallow (*Sapium sebiferum*), Japanese honeysuckle (*Lonicera japonica*), and salt cedar (*Tamarix gallica*).

The coastal prairie or grassland habitat (Fig. 4) adjoins the landward facing dune slopes and constitutes the largest portion of the ridge/swale assemblage zone. The dominant plant species are coastal prairie or fresh to brackish marsh plants, depending on elevation and tidal encroachment. Large areas of low lying prairie near salt marshes are dominated by gulf cordgrass (*Spartina spartinae*). Due to lack of burning, baccharis (*Baccharis halimifolia*) and Chinese tallow now dominate much of these upland areas (Eubanks, 1992).

The coastal scrub habitat (Fig. 5) constitutes a small portion of the ridge/swale assemblage zone and is composed mainly of wooleybucket (*Bumelia lanuginosa*), sugar hackberry (*Celtis laevigata*), red mulberry (*Morus rubra*), gulf black willow (*Salix nigra*), and tooth-ache tree (*Zanthoxylem clava-hercules*). However, a number of exotic species have invaded the scrub habitat, and a large portion of the woody plants found there now consist of chinaberry (*Melia azedarach*), Chinese tallow, and salt cedar (Eubanks, 1992). Japanese honeysuckle also is common.

A small portion of the ridge/swale assemblage zone consists of live oak mottes (Fig. 6). These upland habitats have become rare in recent years (Britton and Morton, 1989) because their higher elevation makes them preferred sites of housing developments. They are comprised mainly of live oak (*Quercus virginiana*), poison ivy (*Rhus toxicodendron*), and briar species (*Smilax* sp.) (Statler and Odum, 1993).

The salt marsh zone (Fig. 7), typically flooded by celestial tides, is comprised of saline to brackish bayous surrounded by cordgrass marsh. This habitat is nearly as common on the island as the coastal prairie habitat. The dominant species at the lower inter-

Figure 3.—Freshwater marsh and pond habitat. This pond is on the Gulf side of Galveston Island State Park and has a fairly natural transition from pond to surrounding vegetation.

Figure 4.—Coastal prairie habitat. The shrubs are baccharis and dominate much of the prairie on the island. Jamaica Beach is seen in the background.

Figure 5.—Coastal scrub habitat. This scrub is on the mainland at Virgina Point. The shrubs in the foreground are baccharis, the small tree is a tooth-ache tree, and the trees in the background are Chinese tallow and sugar hackberry.

Figure 6.—Oak motte habitat in LaFitte's Cove Nature Preserve. Trees are live oak.

Figure 7.—Salt marsh habitat. The taller plants are rushes or needlegrass, *(Juncus sp.),* the shorter grass is smooth cordgrass, *(Spartina spartinae).*

tidal zone is smooth cordgrass (*Spartina alterniflora*). Above this zone is a mixture of species whose dominance varies with elevation, including saltwort (*Batis maritima*), saltgrass (*Distichlis spicata*), marsh-hay cordgrass, glasswort species (*Salicornia* spp.), and other salt and flood tolerant species (White et al., 1993).

The habitat types on Pelican Island are more difficult to classify and delineate than those on Galveston Island. A salt marsh zone dominates the northern side of the island. The plant communities on higher ground include a mixture of prairie and scrub species, with a high proportion of opportunistic species (Fig. 8). These areas are similar to the coastal prairie on Galveston Island and the mainland, and several freshwater to brackish ponds and marshes are interspersed within this habitat. Large areas of barren ground, created by frequent use of earth-moving equipment to deposit dredge materials, are also evident on this island.

The mainland area sampled at Virginia Point is the same location that Vernon Bailey visited in 1905. At that time, a portion of it was a fig orchard owned by Mr. Lee Dick. Evidence of this land use is still visible on recent aerial photographs. Due to the series of hurricanes that occurrred in the Galveston Bay Region during the early 1900's, the fig orchard was abandoned about 1906. The remainder of the site was either coastal prairie or salt marsh.

Currently, Virginia Point is the site of three major waste disposal companies. One of these, the Texas City landfill, is closed and sealed. Malone Service Company and Gulf Coast Waste Disposal (GCWD) are still active and dispose of hazardous chemicals by ground injection. GCWD also is involved in land farming and water purification. A large portion of the prairie not used for waste disposal is owned by Texas A&M University. The habitats include extensive salt marsh and coastal prairie habitat, a small area of coastal scrub, and several freshwater to brackish ponds and marshes. The coastal prairie is less disturbed than that of Galveston Island, with fewer shrubby plants and more open grassy areas (Fig. 9). The pimple mounds described by Bailey in his field notes concerning Virginia Point are still present, but are no longer home to pocket gophers. These slightly elevated, roughly circular mounds of 3 to 10 m diameter occur in scattered groups, and are a natural feature of the coastal prairie.

Figure 8.—Coastal prairie habitat from Pelican Island. Note the patchiness of the vegetation.

Prior to human development, the habitats on Galveston Island probably were similar to conditions at Galveston Island State Park today, minus the exotic species. Matagorda Island, the next barrier island to the south of Galveston Island, is mostly undeveloped and may represent what Galveston Island habitats were like prior to human development. One of the major vegetation changes during the last part of the 20th century has been the proliferation of exotic plant species in the area. In particular, the Chinese Tallow tree from Asia has dispersed substantially along the coastal prairies of upper Texas, especially in Galveston County. In 1970, roughly 2% of Galveston County was infested by these trees. By 1990, that cover had grown to 16%, and by 2000 the infestations are expected to increase to 31%. This rapidly growing tree creates a sterile environment of dense thickets and has no value to wildlife. Chinese Tallow is common around freshwater marshes and ponds on Galveston and Pelican Islands as well as Virginia Point, but it is not as common in drier habitats, such as the coastal prairie and scrub. In drier habitats, Japanese honeysuckle is prolific, often covering native woody vegetation with dense mats of lianas, resulting in the death of the supporting plants due to lack of sunlight or collapse of the underlying shrubs and trees.

Galveston Island has a long history of development and disturbance. The city was confined mainly to the eastern one-third of the island from its founding in 1839 until the 1940's, when road construction improved access. The western two-thirds is used mainly for cattle grazing, and what is not used for this purpose is now utilized for housing developments. Housing developments, first established in 1957 at Sea Isle and Jamaica Beach, impact every habitat type on the island.

Hurricanes and other tropical storm events represent the major form of natural disturbance in the Galveston Bay Region. In 1900, a large hurricane inundated all of Galveston Island. This led to the construction of the Sea Wall beginning in 1901. Other hurricanes have been less severe, but hurricanes undoubtably have played a major role in shaping the habitat and faunal structure of the islands.

Figure 9.—Coastal prairie from Virginia Point. This is facing east from the Malone Service Company service road. Note the scarcity of baccharis and presence of pimple mounds with acacia on them.

Fire also was an important historical natural factor in maintaining the coastal grassland habitats of the region. With the advent of fire control measures, much of the coastal prairie has become choked with woody species, such as baccharis, which constituted only a minor part of the original prairie.

The upper Texas coast has suffered dramatic land losses from subsidence and erosion. Groundwater and energy resources have been drained far underground, causing the land to sink or subside. A major cause of erosion has been storm events and wind driven wave action on the bay. Wave action impacts the salt marsh especially after subsidence has lowered the elevation. Erosion and subsidence (and the loss of salt marsh habitat) are most evident on the bay side of the island.

Two protected areas are currently under management to preserve the natural habitats of Galveston Island. These areas are Lafitte's Cove Nature Preserve and Galveston Island State Park. Lafitte's Cove Nature Preserve is a 12.1 ha preserve adjacent to Eckerts Bayou, and it encompasses two freshwater ponds, a freshwater marsh, and the last remaining oak motte on Galveston Island. It is surrounded by a large housing development, Lafitte's Cove, and the adjacent bayous which have been modified into canals that access the bay. The oak motte, encompassing 2.4 ha, is intersected by three paved walking trails, but it is not large enough to create any interior habitat of value to wildlife.

Galveston Island State Park, a 809.4 ha area established in 1975, spans the width of the island from the Gulf to the West Bay and is bordered on both sides by housing developments. It is bisected about 0.5 km from the Gulf by a four lane divided highway, FM 3005. Most of the park was utilized as a ranch prior to its establishment, but the habitats now are managed for a more natural community. The inability to burn, because of the proximity of houses to the park, is the most difficult part of maintaining the habitats. Instead of burning, the habitats are mowed at intervals.

The Gulf side of the park is heavily used and consists of campsites and day use areas. The only natural habitat is the dune habitat at the eastern end. North of FM 3005, examples of four of the six habitat types can be found, with the majority of the area representing coastal prairie. Some of the freshwater ponds are stocked with fish and receive heavy use. However, many of the smaller ponds are inaccessible except by foot (as is most of the park) and enjoy a relatively natural prairie to pond transition.

RESULTS

A total of 8900 trap nights were compiled: 5384 on Galveston Island, 1140 on Pelican Island, and 2376 on the mainland. These yielded 1425 captures of 11 species of mammals (Tables 1-3) and an overall capture rate of 16.0%. Five additional species were observed, but not trapped.

Sigmodon hispidus, by far the most abundant small mammal, accounted for 80.0% of all captures, and was taken in all habitats except the oak motte and city. The second most abundant mammal, *Oryzomys palustris*, accounted for 9.5% of all captures, and was taken primarily in saltwater and freshwater wetlands (91.9% of all individuals captured). *O. palustris* was more common (66.0% of captures) than *S. hispidus* in the saltmarsh habitat, and it also accounted for 18.3% of all captures around freshwater ponds and marshes. Only a small percentage of *O. palustris* captures occurred in coastal prairie habitat.

A number of the mammalian species documented from the mainland of the upper coast of Texas were not captured or observed on Galveston or Pelican Islands (Fig. 10). The groups that demonstrated the largest discrepancies in diversity between the mainland and the islands included insectivores, native rodents, and the carnivore/marsupial group. Marsupials were grouped with carnivores because *Didelphis virginiana* has habits like the carnivores in the study area.

Differences also were noted between Galveston and Pelican Islands, although not of the magnitude seen between the mainland and island fau-

Table 1.—Number of captures of mammals within each habitat type on Galveston Island. (Habitat abbreviations: DU = dunes, FP = freshwater ponds and marshes, CP = coastal prairie, CS = coastal scrub, OM = oak motte, SM = salt marsh, CI = city.)

Species	Habitat								%Trap Success
	DU	FP	CP	CS	OM	SM	CI	Total	
Didelphis virginiana	-	5	1	-	1	-	-	7	1.4*
Sylvilagus floridanus	-	-	-	-	3+	-	-	3+	na
Mus musculus	-	-	3	-	-	-	2	5	0.09
Rattus rattus	-	7	1	-	8	-	20	36	0.67
Rattus norvegicus	-	-	-	-	-	-	24	24	3.8***
Sigmodon hispidus	21	203	453	23	-	3	-	703	13.1
Oryzomys palustris	-	60	10	-	-	1	-	71	1.3
Sciurus niger	-	-	-	-	-	-	1+	1+	na
Myocastor coypus	-	4	-	-	-	-	-	4	2.4**
Procyon lotor	-	3	-	-	1	-	-	4	2.4**
TOTAL CAPTURES	21	282	468	23	10	4	46	854	
Trapnights	75	1667	1732	60	684	80	1086	5384	
% Trap Success	28.0	16.9	27.0	38.3	1.5	5.0	4.2	15.9	

* *calculated using applicable trap nights of 508 (Tomahawk, Havahart, and leghold traps).*
** *calculated using applicable trap nights of 107 (Havahart and leghold traps).*
*** *calculated using applicable trap nights of 636 (in an area only* R. norvegicus *is known to occur).*
\+ *not included in % trap success calculations due to capture method (shooting).*

Table 2.—Number of captures of mammals within each habitat type on Pelican Island. (Habitat abbreviations: FP = freshwater ponds and marshes, CP = coastal prairie).

Species	Habitat			% Trap Success
	FP	CP	Total	
Mus musculus	4	1	5	0.44
Rattus rattus	11	8	19	1.7
Oryzomys palustris	21	-	21	1.8
Myocastor coypus	1	-	1	3.3*
TOTAL CAPTURES	37	9	46	
Trapnights	520	620	1140	
% Trap Success	7.1	1.4	4.0	

**calculated using applicable trap nights of 30 (Havahart and leghold traps).*

Table 3.—Number of captures of mammals within each habitat type at Virgina Point on the mailand adjacent to Galveston and Pelican Islands. (Habitat abbreviations: DU = dunes, FP = freshwater ponds and marshes, CP = coastal prairie, CS = coastal scrub, SM = salt marsh).

Species	Habitat						% Trap Success
	DU	FP	CP	CS	SM	Total	
Sylvilagus floridanus	-	-	-	1	-	1	0.04
Sigmodon hispidus	16	154	216	36	15	437	18.4
Oryzomys palustris	-	9	-	1	34	44	1.8
Reithrodontomys fulvescens	-	8	29	-	-	37	1.6
Geomys breviceps	-	-	1+	-	-	1+	na
Procyon lotor	-	1	-	-	-	1	2.6*
TOTAL CAPTURES	16	172	245	38	46	520	
Trapnights	120	668	1183	195	210	2376	
% Trap Success	13.3	25.7	20.7	19.5	23.3	21.9	

* *calculated using applicable trap nights of 39 (Havahart and leghold traps).*
\+ *not included in % trap success calculations due to capture method (shooting).*

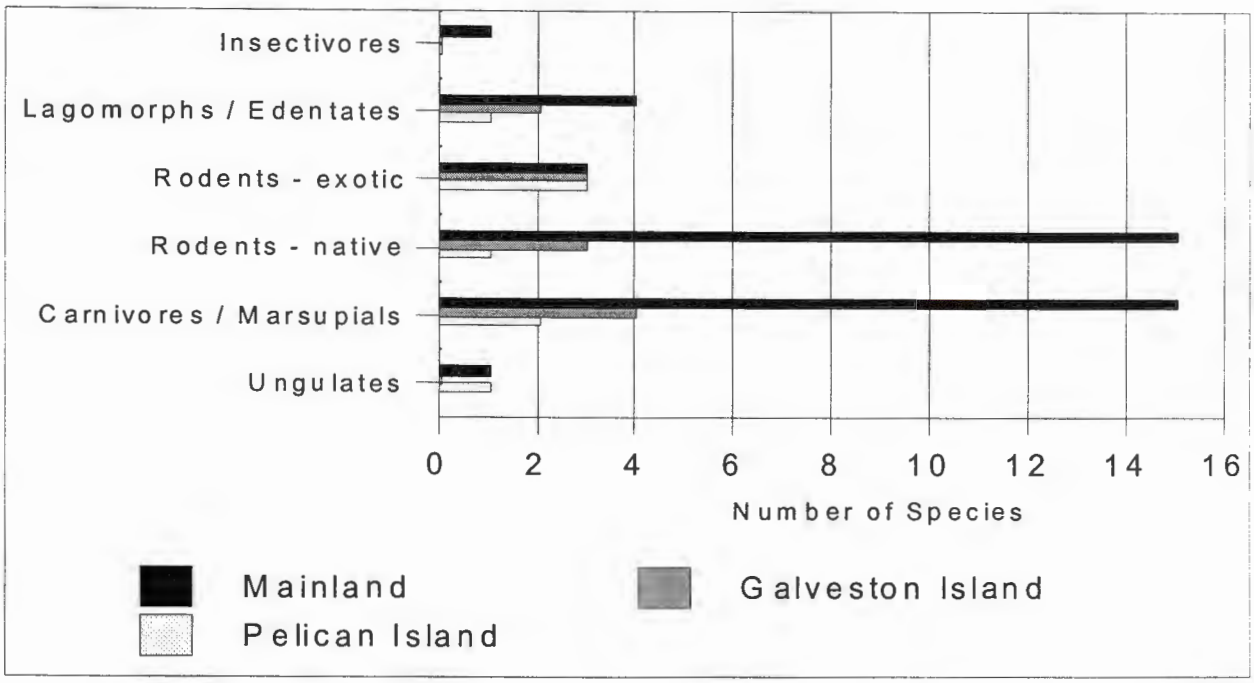

Figure 10.—Diversity patterns of major mammalian groups among areas. Capture data and observations from this study, as well as published accounts of mammals that occur in the Galveston Bay area, were used to construct this histogram.

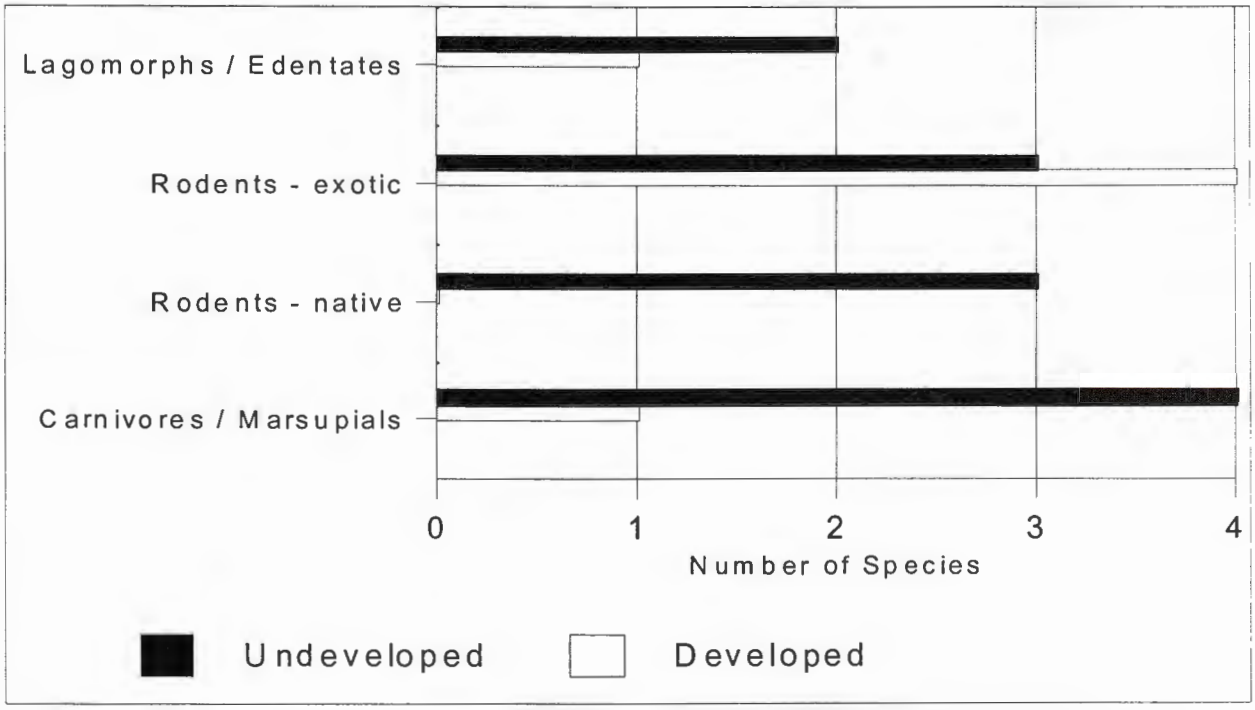

Figure 11.—Diversity patterns of mammals in developed and undeveloped areas on Galveston Island.

nas (Fig. 10). The differences between the islands are best demonstrated among species of native rodents and carnivores, each of which exhibited a lower level of diversity on Pelican compared to Galveston Island.

Faunal differences between developed and undeveloped areas on Galveston Island are also apparent (Fig. 11), particularly among the native and exotic rodents. Developed areas are those made up of houses, groomed lawns, and industrial areas; undeveloped areas include protected areas, rangeland, and areas adjacent to housing developments that are not maintained as lawns. Whereas most exotic species have successfully invaded undeveloped areas on Galveston Island, native rodents have not shown reciprocal success in developed areas.

The least diverse mammalian fauna was found in the dune habitat, with only one species, *Sigmodon hispidus*, documented there (Fig. 12). However, because of the limited number of trap types utilized in the dunes, the lack of diversity could reflect trapping bias. The freshwater ponds and marshes contained the highest level of diversity, with eight species documented.

ANNOTATED LIST OF MAMMALS OF THE GALVESTON BAY REGION

Sixteen species have been documented in the Galveston Bay area, including 13 from Galveston or Pelican Island. Twenty-seven other species have been recorded from the adjacent mainland in Galveston, Brazoria, Chambers, and Harris counties (Schmidly, 1983; Davis and Schmidly, 1994).

The following accounts include ecological and distributional records for those species that were documented during this study, as well as species that have been documented in the literature from the Galveston Bay region. Species not documented during this study have been included in the species accounts because they are the most likely mammals to eventually be found on the islands. Scientific designations and vernacular names follow Manning and Jones (1998). All measurements (mm) are in the standard sequence of total length, tail length, hind foot length, and ear length. Representative specimens are deposited in the Texas Cooperative Wildlife Collection (TCWC) at Texas A&M University.

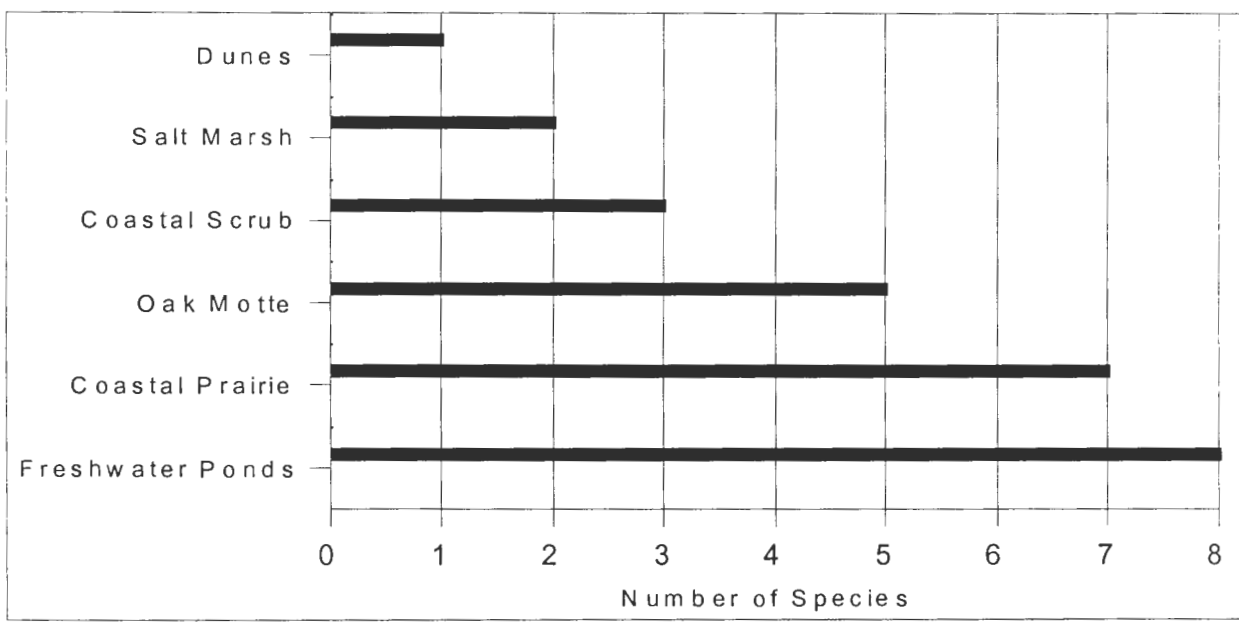

Figure 12.—Diversity patterns of mammals among habitat types.

Didelphis virginiana virginiana
Kerr, 1792
Virginia Opossum

The distribution of 65 road-killed opossums indicates this species is common in all habitat associations on Galveston Island, and it has been recorded from the mainland as well (Davis and Schmidly, 1994). No opossums were captured on Pelican Island, but local residents told one of us (C. Hice) that they have observed signs of predation by opossums on shorebird nests on the north side of the island. Seven individuals were captured. A young adult female, captured in January, weighed 1436.7 g, had measurements of 685-300-58-56, and exhibited no signs of reproductive activity.

Blarina carolinensis minima
Lowrey, 1943
Southern Short-tailed Shrew

Failure to capture this species during the study is not surprising given their preference for wooded areas and associated meadows. This type of habitat is common in Harris County, where *B. carolinensis* has been documented (Schmidly, 1983), but is uncommon in the remainder of the Galveston Bay region. For this reason, it is unlikely that *B. carolinensis* would occur on the islands.

Cryptotis parva parva
(Say, 1823)
Least Shrew

Least shrews prefer habitats with a dense cover of grasses, particularly bluestem, Johnson grass, and bermudagrass. This type of habitat is available on the islands, but no specimens were obtained in pitfall traps set during this study. Specimens have been taken from the mainland in Galveston, Brazoria, and Harris counties (Schmidly, 1983; Davis and Schmidly, 1994).

Scalopus aquaticus cryptus
Davis, 1942
Eastern Mole

No signs of moles were observed on the islands or the mainland. Moles have been documented in the northern portion of the Galveston Bay area in Harris County (Davis and Schmidly, 1994), but some distribution maps exclude the entire coastal prairie habitat of East Texas from their range (Schmidly, 1983).

Dasypus novemcinctus mexicanus
Peters, 1864
Nine-banded Armadillo

One live armadillo was observed in an upper salt marsh on Galveston Island, and the distribution of 10 road-killed individuals indicates these mammals are common in the dune, freshwater marsh and pond, and coastal prairie habitats. No armadillos were observed on Pelican Island or on the mainland, although they have been documented in Chambers County (Davis and Schmidly, 1994).

Sylvilagus aquaticus
(Bachman, 1837)
Swamp Rabbit

The swamp rabbit is common in the Galveston Bay area and has been documented in all four counties surrounding the bay (Davis and Schmidly, 1994). Although numerous evenings were spent searching for these rabbits, none were observed on the islands. Local residents (some with 50 years residency) who have observed swamp rabbits on the mainland claim they have never seen one on Galveston Island.

Sylvilagus floridanus alacer
(Bangs, 1896)
Eastern Cottontail

The documentation of 44 road-killed rabbits indicates that cottontails are common in all habitat associations on Galveston Island and the mainland, but they are especially abundant in the oak motte of Galveston Island, where dozens of individuals can be observed in a few minutes. The skull of a very young rabbit was found on Pelican Island, but we did not observe any cottontails or other sign of rabbits on this island. Three female cottontails were shot on Galveston Island in May. None of them were pregnant. Average measurements were 331-44-83-49 and the average weight was 737.0 g.

Lepus californicus merriami
Mearns, 1896
Black-tailed Jackrabbit

No evidence of black-tailed jackrabbits was found on Galveston or Pelican Island. Bailey (1905) reported jackrabbits from a coastal prairie at Virginia Point on the mainland, and, more recently, one hunter claimed to have seen a *L. californicus* in the same area three or four years ago. James Webb (pers. comm.) also indicated that jackrabbits are common elsewhere on the mainland in prairie habitat near marshes.

Sciurus carolinensis carolinensis
Gmelin, 1788
Eastern Gray Squirrel

No gray squirrels were observed in the study area, although they have been documented from Brazoria and Harris counties (Davis and Schmidly, 1994). Gray squirrels prefer bottomland forest and are seldom found in upland forests or cities in this part of their range, which undoubtably explains their absence from Galveston Island.

Sciurus niger ludovicianus
Custis, 1806
Eastern Fox Squirrel

A number of fox squirrels were observed in the City of Galveston, and one road-killed, male specimen was collected and prepared. Due to the paucity of trees, squirrels do not occur elsewhere on the island. According to some tree trimmers, squirrel density has varied a great deal over the last 15 years in Galveston. Squirrels were common during the year of this study. Fox squirrels prefer upland forest areas and seem to adapt well to city life. The squirrels in Galveston may have been introduced by people who kept them as pets and subsequently released them. The collected animal weighed 472.3 g and had measurements of 450-202-63-24. It was smaller and grayer than the fox squirrels observed on the mainland.

Glaucomys volans texensis
Howell, 1915
Southern Flying Squirrel

No flying squirrels were observed in the Galveston Bay area, probably due to lack of suitable habitat. The record from Brazoria County (Schmidly, 1983) was obtained from a forested area and no such areas exist on Galveston Island.

Geomys breviceps sagittalis
Merriam, 1895
Baird's Pocket Gopher

No evidence of gopher activity was documented on Galveston Island. One female was captured near Hitchcock on the mainland of Galveston County and gopher mounds were plentiful on pimple mounds that are part of the landscape of the coastal prairies in this area. Bailey (1905) reported high densities of gophers at Virginia Point, but he did not observe sign of gophers on Galveston Island. We found evidence of

approximately 12 old gopher mounds at Virginia Point, although none of it appeared to be recent activity. Numerous fire ant nests were noticed on the pimple mounds at Virginia Point, but not at Hitchcock. The invasion of fire ants, coupled with a reduction of habitat at Virginia Point, may explain why gophers are no longer active there. The specimen weighed 110.8 g and measured 199-50-24-2.

Chaetodipus hispidus hispidus
(Baird, 1858)
Hispid Pocket Mouse

The hispid pocket mouse reaches the southeasternmost limit of its range in the Galveston Bay area where it has been documented in Harris County (Davis and Schmidly, 1994). *C. hispidus* is uncommon in coastal prairie habitat due to the lack of suitable soils. No individuals were captured during this study, and it is unlikely this species occurs on the islands.

Castor canadensis texensis
Bailey, 1905
American Beaver

To our knowledge, beaver are no longer present in the Galveston Bay area. Historically, they were present along the entire Texas Coast, but trapping pressure virtually eliminated them. Beaver were reintroduced to a number of river systems in East Texas (Schmidly, 1983), but the Trinity River system, which feeds into the Galveston Bay area, was not among them because of the high level of development along much of the southern end of the Trinity River, which flows through the greater Houston area.

Oryzomys palustris texensis
J. A. Allen, 1894
Marsh Rice Rat

Rice rats were common on Galveston and Pelican Islands and on the mainland. They were noticeably more abundant around ponds and in salt marshes and were rarely captured far from wet areas. More than 90% of adult males were in reproductive condition in every month except January, when only 67% had descended testes. The average testicular length was 13 mm. Pregnant females were captured in November, March, and April. These data suggest that rice rats breed year-round in the Galveston Bay area, with a possible peak in the spring. Weights varied widely, but males tended to be heavier than females.

Reithrodontomys fulvescens aurantius
J. A. Allen, 1895
Fulvous Harvest Mouse

The fulvous harvest mouse was common on the mainland in the coastal prairie at Virginia Point where it demonstrated a definite propensity for densely shrubby prairie as opposed to open grasslands. Howard McCarley (pers. comm.) also reported fulvous harvest mice on Bolivar Peninsula in 1973. No harvest mice were captured on Galveston or Pelican Island, even in habitat associations identical to those on the mainland where these mice were common. Reasons for this absence are not apparent, but it appears that *R. fulvescens* has not yet successfully colonized either island. Individuals were taken in March and April, and all but one of 16 males was in reproductive condition. However, of 21 females obtained, none was pregnant. The average weight was 11.3 g and measurements were 161-90-19-13. Average testicular length was 9 mm.

Reithrodontomys humulis merriami
J. A. Allen, 1895
Eastern Harvest Mouse

The eastern harvest mouse has been documented in Brazoria County (Schmidly, 1983), where it reaches the westernmost limit of its range. It is uncommon in eastern Texas, and prefers habitats in early successional stages. No individuals of this species were captured during this study, and this species is not thought to occur on either Galveston or Pelican Island.

Peromyscus gossypinus megacephalis
(Rhoads, 1894)
Cotton Mouse

Peromyscus gossypinus reaches the westernmost limit of its range in the Galveston Bay area and has been documented in Harris County (Davis and Schmidly, 1994). The cotton mouse prefers forested habitats and no such habitat is present on Galveston or Pelican Island.

Peromyscus leucopus leucopus
(Rafinesque, 1818)
White-footed Mouse

The white-footed mouse has been documented in all of the counties surrounding the Galveston Bay area (Davis and Schmidly, 1994), but not in coastal prairie habitat. White-footed mice occur in timbered areas, and the one oak motte on Galveston Island is small and contained only roof rats.

Baiomys taylori subater
(Bailey, 1905)
Northern Pygmy Mouse

Bailey (1905) reported that pygmy mice were common at Virginia Point, and Howard McCarley (pers. comm.) captured two individuals in Anahuac National Wildlife Refuge in Chambers County in 1973. These small rodents appear to be uncommon in the Galveston Bay area, possibly because of the high densities of cotton rats in this region (Schmidly, 1983). It is possible that they occur on Galveston Island, although no individuals were captured during this study.

Sigmodon hispidus texianus
(Audubon and Bachman, 1853)
Hispid Cotton Rat

Except for the oak motte habitat, cotton rats were abundant in all habitat associations on Galveston Island, and on the mainland. However, no cotton rats were captured on Pelican Island, suggesting this rat has not yet colonized Pelican Island. *Rattus rattus,* which is very abundant on Pelican Island, may be aggressive enough to prevent a successful invasion by *S. hispidus.*

Cotton rats are reproductively active throughout the year, with a large peak in the spring coinciding with the emergence and growth of grasses, which is their main food source. More than 50% of the males were in reproductive condition from February to November. The reproductive high was in April, with 88% having descended testes. In December and January, less than 25% of the males were in reproductive condition. Typical testes lengths were 25 mm. Pregnant females were taken in every month, but pregnancy rates varied from as low as 1.3% in January to 44% in May. Each pregnant female carried three to six embryos, with an average of four. Males tended to be larger than females, but a large range of sizes of both sexes was obtained in our sample. The heaviest cotton rat captured was a male that weighed 235.0 g.

Neotoma floridana rubida
Bangs, 1898
Eastern Woodrat

No woodrats were captured during this study, but this species has been documented in Harris County (Davis and Schmidly, 1994). The one possible area of suitable woodrat habitat on Galveston Island was overrun with roof rats. Howard McCarley (pers. comm.) captured two woodrats at Smith Point (25 km north of eastern Galveston Island) in Chambers County in 1974.

Rattus norvegicus
(Berkenhout, 1769)
Norway Rat

Norway rats were captured only around the grain elevator in the city of Galveston. They may occur around the piers on Pelican Island, but we were unable to trap at those locations. There was no evidence of Norway rats invading surrounding habitat. Individuals were captured in June, July, and August and, during this time, all of the males captured had descended testes with an average length of 40 mm. No pregnant females were captured, but signs of nursing and recent births were observed. Sizes varied greatly. The heaviest individual was a male that weighed 400.5 g.

Rattus rattus
(Linnaeus, 1758)
Roof Rat

Roof rats were present in all habitat associations on Galveston and Pelican Islands. They were more common on Pelican Island, which may partially explain the absence of cotton rats there. Roof rats were captured throughout Galveston Island State Park, although according to the park superintendent, they are much less common than they were five years ago. Roof rats also were the only small rodents present in the single oak motte on Galveston Island. Roof rats were taken in 23% of all traplines set in relatively undisturbed habitat. Five different color morphs were observed, ranging from light hispid brown to dark charcoal gray. These represent the gradations among the three subspecies that occur in eastern Texas (Schmidly, 1983). Individuals were captured yearround, and males evinced signs of reproductive activity during all months. One pregnant female, captured in February, contained nine fetuses.

Mus musculus
Linnaeus, 1766
House Mouse

House mice were captured occasionally on Galveston and Pelican Islands. Howard McCarley (pers. comm.) captured one individual in 1973 on Bolivar Peninsula. These mice were most commonly found in disturbed areas, although a few were taken in coastal prairie habitat. Males were in breeding condition yearround with testes averaging 5 mm in length. Pregnant females were taken in August and February. Weights varied from 12.5 g to 25.3 g.

Ondatra zibethicus rivalicius
(Bangs, 1895)
Common Muskrat

Bailey (1905) did not report muskrats from the upper Texas Coast at the turn of the century, and there is little documentation of them prior to this time (Geiser, 1930; Weniger, 1997). Their apparent absence at the turn of the century is an enigma, especially since they had become abundant in the area by the 1930's. In 1936, they accounted for 54% of the total dollar value of furs from Jefferson, Chambers, and Orange counties (Lay, 1939). Several investigations of their natural history were conducted in Chambers County in the 1940's (Lay and O'Neil, 1942; Lay, 1945), and the species also was documented from Harris County (Davis and Schmidly, 1994).

Audubon reported muskrats on Galveston Island in 1824 (Geiser, 1930) and, according to longtime residents, muskrats were once present there, although it has been many years since they were last seen. Muskrats are still present, though uncommon, in Anahuac National Wildlife Refuge in Chambers County to the north of Galveston Island (Andrew Shiro, pers. comm.).

Myocastor coypus
(Molina, 1782)
Nutria

The nutria is an exotic species that was introduced in the United States in 1938. Since that time, they have spread rapidly throughout Texas wherever suitable habitat is available. Nutria were trapped or sighted in ponds and bayous on both Galveston and Pelican Islands, and burrows were located in the middle of the oak motte on Galveston Island. Three juveniles were captured with leghold traps, but adults avoided or escaped from such traps. Average measurements were 609-279-106-24. Road-killed animals were generally observed near standing water.

Canis latrans frustror
Woodhouse, 1851
Coyote

Canid tracks were seen several times on Galveston Island and on the mainland, although we could not determine whether they were made by coyotes or feral dogs. No coyotes were observed in the study area, although residents claim to have seen coyotes and feral dogs on Galveston Island. Coyotes are common on the mainland, having been recorded from Galveston, Brazoria, and Harris counties (Davis and Schmidly, 1994), as well as from Chambers County (McCarley and Carley, 1979).

Canis rufus gregoryi
Goldman, 1937
Red Wolf

Historically, red wolves occurred on Galveston Island, although not in large numbers. They have been documented in all counties surrounding the Galveston Bay area (Davis and Schmidly, 1994), as well as from Chambers County as recently as 1977 (McCarley and Carley, 1979). With the increase in abundance of coyotes and subsequent dilution of the red wolf gene pool because of coyote/red wolf hybridization, it is unlikely there are any pure red wolves left in Texas and this species is now thought to be extinct in the state (McCarley and Carley, 1979).

Vulpes vulpes fulva
(Dermarest, 1820)
Red Fox

Red foxes are not native to Texas and seem to be uncommon in the Galveston Bay region. No red foxes were observed or documented during this study, but they have been documented on the mainland in Galveston, Brazoria, and Harris counties (Davis and Schmidly, 1994).

Urocyon cinereoargentius floridanus
Rhoads, 1895
Common Gray Fox

A family of gray foxes was captured in mid-May by the Galveston County Health Department under a house near Virginia Point on the mainland. One of us (C. Hice) observed and photographed the animals at a local animal rehabilitation facility. Gray foxes have been documented in all counties surrounding the Galveston Bay area (Davis and Schmidly, 1994), so it is possible that they could occur on Galveston Island.

Bassariscus astutus flavus
Rhoads, 1894
Ringtail

Trapper records indicate ringtails have been captured in Brazoria and Harris counties. There was no evidence of ringtails in the study area, which is not surprising because ringtails prefer rocky, brushy areas (Schmidly, 1983) which are not found on Galveston Island.

Procyon lotor fuscipes
Mearns, 1914
Common Raccoon

Raccoons were most frequently captured near ponds on Galveston Island and the mainland. No raccoons were captured on Pelican Island, but local residents told one of us (C. Hice) that they have observed signs of predation by raccoons on shorebird nests along the north side of the island. The small number (six) of road-killed animals suggests that either they are much less common than other mammals of their size or that they are adept at avoiding roads or cars. A young, adult male captured in January had measurements of 845-243-107-60 and testes that measured 35 mm in length.

Mustella frenata arthuri
Hall, 1927
Long-tailed Weasel

Weasels are extremely rare in eastern Texas. Literature records exist from Chambers and Harris counties (Schmidly, 1983). Weasels are very secretive and difficult to capture, so it is possible that they occur on Galveston Island.

Mustella vison mink
Peale and Palisot de Beauvois, 1796
Mink

Trapping records indicate that mink once occurred in all counties surrounding the Galveston Bay area (Schmidly, 1983). They still occur in Chambers County (Jake Dameron, pers. comm.), but probably are no longer present on Galveston Island due to the advent of housing and industrial developments on most of the bayous.

Spilogale putorius interrupta
(Rafinesque, 1820)
Eastern Spotted Skunk

No evidence of spotted skunks was found in the study area, but they have been documented on the mainland in Galveston, Brazoria, and Harris counties (Schmidly, 1983). Bailey (1905) reported taking spotted skunks at Virginia Point on the mainland, but we did not observe or obtain any specimens there.

Mephitis mephitis mesomelas
Lichtenstein, 1832
Striped Skunk

Striped skunks have been documented in all counties surrounding the Galveston Bay area (Davis and Schmidly, 1994), and Bailey (1905) reported taking them at Virginia Point. One resident of Galveston Island, Mr. Roland Chapman, indicated that he infrequently observed road-killed striped skunks on the island, but we were unable to confirm the presence of *M. mephitis* during this study.

Conepatus mesoleucus telmalestes
Bailey, 1905
Common Hog-nosed Skunk

Hog-nosed skunks have been documented in Harris County and the Big Thicket, but they are now thought to be extinct throughout their range in east Texas (Schmidly, 1983). It is unlikely that they ever occurred on the island complex.

Lontra canadensis lataxina
(F. Cuvier, 1823)
River Otter

River otters have been documented throughout the Galveston Bay area (Davis and Schmidly, 1994), and they are seen sporadically in the Galveston Ship Channel and in canals at Jamaica Beach (Jackson et al., 1998). Four road-killed otters have been documented on Galveston Island, including three near Offatts Bayou in an industrialized area and one near a pond in a cow pasture about 4 km east of Galveston Island State Park (Jackson et al., 1998). Otters also have been sighted off Bolivar Peninsula.

Leopardus pardalis albescens
(Pucheran, 1855)
Ocelot

There are historical records of the ocelot from Brazoria County, but this small, spotted cat is now confined to exteme south Texas. The species is listed as endangered, and it is unlikely that extant populations remain along the upper Texas coast.

Lynx rufus texensis
J. A. Allen, 1895
Bobcat

Bobcats have been documented in all counties surrounding the Galveston Bay area (Davis and Schmidly, 1994). The Galveston Island State Park superintendent informed one of us (C. Hice) that bobcats are sighted occasionally at night in the state park, but we found no evidence of them during this study.

Sus scrofa
Linnaeus, 1758
Feral Pig

There is a large population of feral pigs on Pelican Island. While one of us (C. Hice) was setting traps in August, two juveniles approached to within 5 m. Footprints and trampled vegetation were found frequently on Pelican Island. There was no evidence of feral pigs on Galveston Island or in the mainland areas sampled.

Odocoileus virginianus mcilhennyi
(F. W. Miller, 1928)
White-tailed Deer

No evidence of deer was found on Galveston or Pelican Island during our study, although they have been documented in Brazoria County (Schmidly, 1983). Individual deer may periodically wander onto Galveston Island, but a resident population is unlikely. The subspecies *mcilhennyi* occupied the upper Texas coast until the 1920's, by which time it was hunted to extinction. To reestablish populations, individuals of another subspecies, *O. v. texana,* were introduced into the region from central and southern Texas.

DISCUSSION AND SUMMARY

Our assessment of non-volant mammals reveals the mammalian fauna of Galveston and Pelican Islands is depauperate compared to the mainland fauna of the upper Texas coast. This same conclusion has been reached for all the barrier islands of Texas (Shew et al., 1981), as well as for the barrier islands of Virginia (Duesser et al., 1979). Island biogeography studies indicate that oceanic (Brown and Gibson, 1983), landbridge (Lawlor, 1986), and mountaintop (Brown, 1971) islands normally are characterized by a depauperate fauna that is colonization limited for non-volant species. Barrier islands would be expected to fall somewhere between oceanic and landbridge islands as far as species diversity is concerned because of their proximity to the mainland, and the fact they usually do not share a connection with the mainland during their formation (LeBlanc and Hodgson, 1959).

The patterns of mammalian diversity documented on Galveston and Pelican Islands are due to a number of factors. The primary limiting factor is the poor colonization ability of non-volant mammals on islands (Brown, 1971; Brown and Gibson, 1983). A second major influence is the frequent storm events that occur in the Galveston Bay area. In 1900, a major hurricane inundated Galveston Island, covering the entire island with at least 2 m of water (Crenwelge et al., 1988). Storm events such as this have probably caused recent extinctions of some species of mammals on the island. Such extinction events have been documented on other barrier islands of Texas (McAlister and McAlister, 1993). Re-colonization would occur via a sweepstakes route, which is a chance event, so the length of time since the last major storm would be an important factor in determining island diversity. This is illustrated by the lower level of species diversity on Pelican Island, which has had only 40 years to be colonized since its formation.

Once an island colonization event occurs, its success depends upon the adaptability of the colonizing species and the availability of suitable habitat. In the case of Galveston and Pelican Islands, an additional factor may limit successful colonization by small mammals. Feral populations of *Rattus rattus* inhabit many areas of both islands, and there is good evidence these commensal rats can cause native rodent extinctions on islands (Elton, 1958). In fact, *R. rattus* is so abundant on Pelican Island that it may be preventing successful invasion attempts by other rodent species, specifically *Sigmodon hispidus*.

A number of management practices would help maintain the native mammalian species on the islands. Since it is unlikely that development will cease in the near future, management of currently protected areas is most important. The freshwater marshes and ponds and adjacent areas contain the highest level of species diversity, so maintenance of these areas should take priority. One way to maintain this habitat, as well as other habitats within the park, would be to allow natural processes, such as fire, to proceed at historical rates. A regime of controlled burns should be implemented at Galveston Island State Park to promote further recovery toward the natural condition, given that there is still a viable seed bank present there. If not, other recovery and management procedures may be neccessary, such a reseeding and replanting of areas with native species.

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Publications of the Museum of Texas Tech University

It was through the efforts of Horn Professor J Knox Jones, as director of Academic Publications, that Texas Tech University initiated several publications series including the Occasional Papers of the Museum. This and future editions in the series are a memorial to his dedication to excellence in academic publications. Professor Jones enjoyed editing scientific publications and served the scientific community as an editor for the Journal of Mammalogy, Evolution, The Texas Journal of Science, Occasional Papers of the Museum, and Special Publications of the Museum. It is with special fondness that we remember Dr. J Knox Jones.

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