Coastal Forests of the Gulf of Mexico: A Description and Some Thoughts on Their Conservation[1]

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Abstract

Millions of Nearctic-Neotropical landbirds move through the coastal forests of the Gulf of Mexico each spring and autumn as they migrate across and around the gulf. Migration routes in the gulf region are not static—they shift year to year and season to season according to prevailing wind patterns. Given the dynamic nature of migration routes, coastal forests around the Gulf of Mexico potentially can provide important stopover habitat to *en route* migrants. The coastal forests from the Florida Keys to the Yucatan Peninsula include a wide range of habitat types that we have classified as 19 broad community types. From literature reviews, we determined that the majority of these coastal habitats have been lost or degraded due to the effects of development, agriculture, livestock grazing, timber industry activities, and the spread of exotic species. The continued loss and degradation of coastal forests pose a risk to migrating birds, and thus we need to develop a conservation strategy that maximizes the suitability of the remaining forested patches around the gulf. An effective conservation strategy will require considerations at the gulf-wide, regional, landscape and habitat levels. These considerations should include migrant movement and landfall patterns, migrant use of inland versus coastal fringe stopover sites, the creation of landscape mosaics that incorporate patch size and inter-patch distance, and the availability of within-habitat resources.

Key Words: coastal forest, conservation, Gulf of Mexico, landbird, migration, Nearctic-Neotropical migrant, stopover habitat.

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Introduction

Each year millions of landbirds migrate across or near the coast of the Gulf of Mexico. During migration seasons, nearly all of the migratory landbird species of the eastern United States, as well as a strong representation of western species use the coastal plains of the western gulf (Lowery 1974, Barrow et al. 2001). The long journey that birds undergo between temperate and tropical areas is difficult, and mortality may be substantial (Wiedenfeld and Wiedenfeld 1995). Wooded vegetation situated along the gulf shores and up to distances of 100 km inland (Gauthreaux 1975) are stopover habitat that migrants use in spring to replenish energy and to sequester resources for the ensuing reproductive season. In autumn, the primary need is to store energy for continued migration and molt. Often these sites are precisely the most suitable for human development (Barrow et al. 2000). Human population growth along the coasts of the Gulf of Mexico is projected to increase rapidly over the next decade (Culliton et al. 1990).

Today, remnant forest patches are more common than intact coastal forest systems. As coastal stopover habitats are lost or degraded, there is likely to be a concomitant increase in risks posed to migrating birds (Moore et al. 1993). We should plan now to manage remaining patches of forest to maximize their suitability to migrating landbirds. Challenges to implementing a conservation strategy for migrant landbirds around the Gulf of Mexico include: 1) the large spatial scale where migration occurs, 2) the variety of habitats migrants interact with during passage, and 3) the inter- and intra-annual variation in the geographic locations where the majority of migrants stopover (e.g., coastal fringe vs. inland, western gulf vs. eastern gulf).

In this paper, we describe coastal forests around the Gulf of Mexico, discuss their status, and offer some thoughts to be considered when planning or implementing a conservation strategy for gulf coastal forests and the migratory birds that depend on them.

Coastal Forests of the Gulf of Mexico: Description and Status

Coastal forests around the Gulf of Mexico play an important role in bird migration by virtue of their position along important migration pathways. We define coastal forests as wooded communities that develop within 100 km of the coast and usually occur on barrier islands, ridges, delta splays, and along river and bayou drainages. Coastal forests around the gulf encompass a wide range of habitat types that vary from estuarine systems like the mangroves in south Florida and Mexico to arid communities like the Tamaulipan thornscrub of south Texas and northern Mexico. The plant community composition and structure of these forests vary greatly due to the influence of factors such as precipitation, soil type and moisture, proximity to a river drainage, exposure to salt spray, and disturbance events (Pessin and Burleigh 1941, Gunter and Eleuterius 1973).

In *table 1*, we describe coastal-forest vegetation as 19 broad community types found in five regions around the gulf: east, northeast, northwest, west, and south. We used major river systems to delineate the five regions (*fig. 1*). The eastern region includes the gulf coast between the Florida Keys and the Apalachicola River. The northeast region is bounded by the Apalachicola and Mississippi Rivers, and the northwest region lies between the Mississippi and Colorado rivers. The western region includes the gulf coast from the Colorado River south to the Panuco River in Mexico, and the southern region includes the coastline south of the Panuco River to the tip of the Yucatan Peninsula.

A number of human-induced factors have contributed to the loss and degradation of the coastal forest communities summarized in *table 1*. We highlight a few of these factors in the following sections and provide examples from the five regions around the gulf.

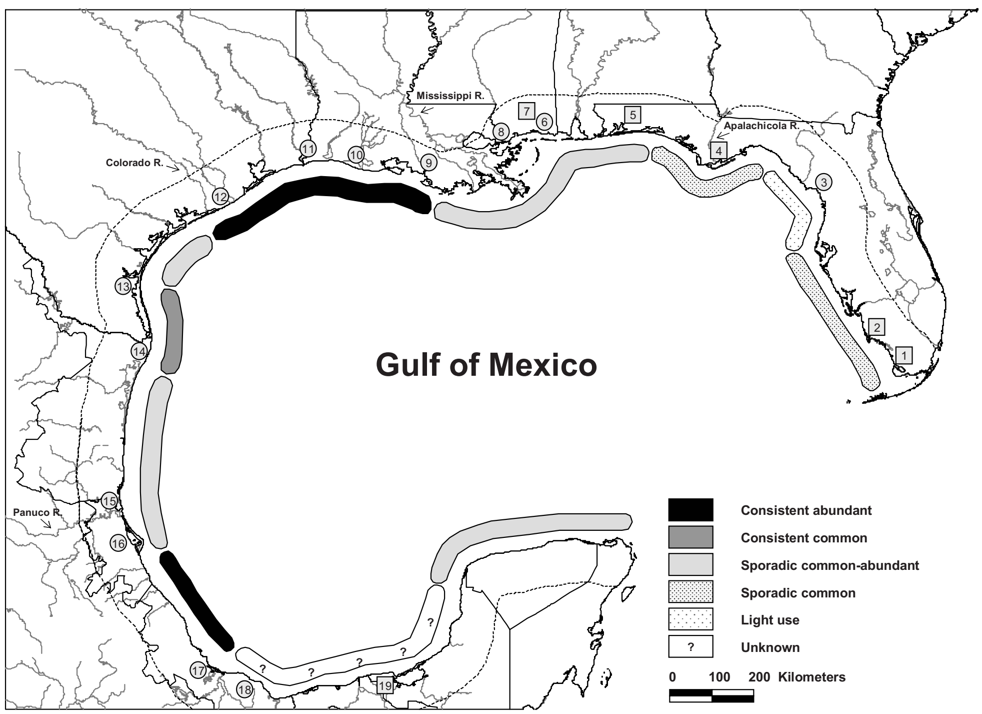

Figure 1— Geographic pattern of bird migration around the Gulf of Mexico and locations of remaining patches of extensive coastal forest. Pattern delineation is the result of literature review and the collective knowledge of authors. Migration landfalls (up to 100 km inland) are defined as: consistent abundant – area used by large numbers of migrants each year and season, consistent common – area used by a moderate number of migrants each year and season, sporadic common/abundant – prevailing winds determine if area is used by moderate to large numbers of migrants, sporadic common – prevailing winds determine if area is used by a moderate number of migrants, light use – area used by a few migrants every year or season, unknown – use is unknown to the authors. Numbered squares represent protected forest and numbered circles represent unprotected or partially protected forest. Forest locations are as follows: 1 – Everglades National Park, 2 – Big Cypress National Preserve, 3 – Gulf Hammock, 4 – Apalachicola Bay (Apalachicola National Forest and surrounding public lands), 5 – Choctawhatchee and Escambia bays (Eglin Air Force Base, Blackwater River State Forest, and surrounding public lands), 6 – Lower Pascagoula River basin 7 – DeSoto National Forest, 8 – Lower Pearl River Basin, 9 – Atchafalaya River Basin, 10 – Mermentau River Basin and chenier forests, 11 – Big Thicket National Preserve and surrounding lands, 12 – Columbia Bottomlands, 13 - Live oak woodlands, 14 – Tamaulipan thornscrub, 15 – Humedales del Sur de Tamaulipas, 16 – Laguna de Tamiahua, 17 – Humedales de Alvarado, 18 – Los Tuxtlas, 19 – Pantanos de Centla.

Table 1— *Species composition and status of coastal forest community types around the Gulf of Mexico.*

Community type	Region	Common plant species	Status
Mangrove	East	black mangrove (*Avicennia germinans*) – red mangrove (*Rhizophora mangle*) – white mangrove (*Laguncularia racemosa*)	?
	Northwest	black mangrove	?
	West	black mangrove	threatened
	South	black mangrove – red mangrove – white mangrove	declining
Riparian	East	overcup oak (*Quercus lyrata*) – water hickory (*Carya aquatica*) – laurel oak (*Q. laurifolia*) – swamp chestnut oak (*Q. michauxii*) – sweetgum (*Liquidambar styraciflua*) – sweetbay (*Magnolia virginiana*)	?
	Northeast	overcup oak – water hickory – laurel oak – swamp chestnut oak – willow oak (*Q. phellos*) – green ash (*Fraxinus pennsylvanica*) – American elm (*Ulmus americana*) – sweetgum – hackberry (*Celtis laevigata*) – water oak (*Q. nigra*)	?
	Northwest	*Quercus* spp. – *Carya* spp. – american elm – winged elm (*U. alata*) – cedar elm (*U. crassifolia*) – green ash – yaupon (*Ilex vomitoria*) – deciduous holly (*Ilex decidua*) – box elder (*Acer negundo*) – dwarf palmetto (*Sabal minor*) – hackberry – red maple (*Acer rubrum*) – soapberry (*Sapindus drummondi*)	declining
	West	sweet acacia (*Acacia farnesiana*) – retama (*Parkinsonia aculeata*) – *Fraxinus* spp. – black willow (*Salix nigra*) – cedar elm – *Celtis* spp. – honey mesquite (*Prosopis glandulosa*) – Texas ebony (*Ebenopsis ebano*)	threatened
	South	guatope (*Inga* sp.) – ceibo (*Ceiba pentandra*) – Spanish cedar (*Cedrela odorata*) – capulin (*Muntingia calabura*) – maculis (*Tabebuia pentaphylla*) – Jobo (*Spondias mambin*)	?
Swamp	East	baldcypress (*Taxodium distichum*) – black gum (*Nyssa sylvatica*) – water tupelo (*Nyssa aquatica*) – *Fraxinus* spp., red maple, cabbage palm (*Sabal palmetto*)	?
	Northeast	baldcypress – black gum – water tupelo – buttonbush (*Cephalanthus occidentalis*) – black willow – red maple	?
	Northwest	baldcypress – water tupelo – black gum – red maple – black willow – dwarf palmetto – buttonbush – *Fraxinus* spp. – water-elm (*Planera aquatica*) – water locust (*Gleditsia aquatica*)	?
	South	Guiana chestnut *(Pachira aquatica)* – spiny bucida *(Bucida spinosa*) – black-olive *(Bucida buceras*) – logwood *(Haematoxylon campechianum*) – kancab'ché *(Erythroxylum confusum*) – muk *(Dalbergia glabra)* – botoncillo *(Conocarpus erecta)* - paurotis palm *(Acoelorrhaphe wrightii*)	?
Delta Splay	Northwest	black willow, three-cornered grass (*Schoenoplectus americanus*), common reed (*Phragmites communis*)	stable
Scrub-shrub	East	myrtle oak (*Q. myrtifolia*) – scrub oak (*Q. inopina*) – sand pine (*Pinus clausa*) – saw palmetto (*Serenoa repens*) – sand live oak (*Q. geminata*) – Chapman oak (*Q. chapmanii*) – rosemary (*Ceratiola ericoides*) – waxmyrtle (*Myrica cerifera*)	?

Table 1 (continued).

Community type	Region	Common plant species	Status
Scrub-shrub (contd.)	Northeast	sand pine – sand live oak – Darlington oak (*Q. hemisphaerica*) – myrtle oak - yaupon – waxmyrtle – rosemary	?
	Northwest	waxmyrtle – yaupon – sweet acacia – toothache tree (*Zanthoxylum clava-herculis*) – groundselbush (*Baccharis halimifolia*) – *Iva* spp.	?
Thornscrub	West	mesquite - *Acacia* spp. – *Mimosa* spp. – granjeno (*Celtis pallida*) – guayacan (*Guaiacum angustifolium*) – cenizo (*Leucophyllum frutescens*) –whitebrush (*Aloysia gratissima*) – Texas prickly pear (*Opuntia engelmannii*) – tasajillo (*O. leptocaulis*) – *Condalia* spp. – amargosa (*Castela erecta*)	threatened
	South	yellow-flowering tree (*Acacia pennatula*) – *Opuntia* spp.– *Cephalocereus* spp.– Jamaica dogwood (*Piscidia piscipula*) – madre cacao (*Gliricidia sepium*)	?
Hammock - maritime	East	live oak (Q. virginiana) - sand live oak – *Magnolia* spp.- sweetbay – american holly (*Ilex opaca*) – redbay (*Persea borbonia*)	threatened
- hydric		cabbage palm – live oak – sweetgum - laurel oak – southern red cedar (*Juniperus silicicola*) – American hornbeam (*Carpinus caroliniana*) – water oak – loblolly pine - swampbay (*Persea palustris*) – sweetbay – red maple	threatened
- tropical		gumbo limbo (*Bursera simaruba*) – strangler fig (*Ficus aurea*) – mastic (*Mastichodendron foetidissimum*) – pigeon plum (*Coccoloba diversifolia*) – lancewood (*Nectandra coriacea*) – poisonwood (*Metopium toxiferum*) – Spanish stopper (*Eugenia foetida*) – white stopper (*Eugenia axillaris*)	threatened
- maritime	Northeast	live oak – sand pine – loblolly pine (*Pinus taeda*) – pignut hickory (*Carya glabra*) – sand hickory (*Carya pallida*) – saw palmetto	threatened
Upland Hardwood	East	southern magnolia (*Magnolia grandiflora*) – pignut hickory– sweetgum – Florida maple (*Acer barbatum*)	?
	Northeast	southern magnolia – pignut hickory – sweetgum – *Pinus* spp. – Florida maple – American beech (*Fagus grandifolia*)	?
	Northwest	American beech – southern magnolia – *Quercus* spp. – tulip poplar (*Liriodendron tulipifera*) – sweetgum – *Carya* spp. – loblolly pine	threatened
Beach Ridge & Dunes	Northeast	Barrier Islands: Slash pine (*Pinus elliottii*), dwarf live oak (*Quercus geminata*) – waxmyrtle – yaupon - grounselbush – saw palmetto	?
	Northwest	Cheniers: live oak – hackberry – water oak – red mulberry (*Morus rubra*) – honey locust (*G. triacanthos*) – toothache tree	threatened
	West	Barrier Islands: grassland-dominated communities with patches of live oak - black willow – waxmyrtle – groundselbush – hackberry - mesquite	?
	South	black olive – *Ficus* spp. – macayo (*Andira inermis*) – maculis – gumbo limbo (*Bursea simaruba*) – palma real (*Scheelea leibmanii*)	threatened
Salt Dome	Northwest	*Carya* spp. – southern magnolia – live oak – sweetgum – water oak – hackberry	stable

Table 1 (continued)

Community type	Region	Common plant species	Status
Levee and Spoilbank	Northwest	groundselbush – Chinese tallow (*Triadica sebifera*) – yaupon – wax myrtle – black willow	increasing
Live Oak Scrub	West	live oak – red bay – yaupon – wax myrtle – greenbrier (*Smilax* spp.) – mustang grape (*Vitis mustangensis*)	threatened
Live Oak Woodland	Northeast	live oak – loblolly pine – red cedar	threatened
	Northwest	live oak – water oak – american elm – hackberry – yaupon – red maple – green ash – dwarf palmetto	threatened
	West	live oak – Turk's cap (*Malvaviscus arboreus*) – granjeno – lime pricklyash (*Zanthoxylum fagara*)	stable
Palm Forest	East	cabbage palm – gumbo limbo – live oak – pigeon plum – saw palmetto	?
	West	sabal palm (*Sabal mexicana*) – tepeguaje (*Leucaena pulverulenta*) – anacua (*Ehretia anacua*) – Texas ebony	threatened
	South	Scheelea *spp*. – Sabal *spp*.	?
Tropical Evergreen	South	*Swietnia spp.* – macayo – *Nectandra spp.* – tinco (*Vatairea lundellii*) – *Ficus* spp. – magnolia (*Talauma sp.*) – rubber tree (*Castilla elastica*) – palma real – corozo (*Orbignya cohune*) – guatope – cucuá (*Poulsenia armata*)	threatened
Mesquite Grassland	West	honey mesquite – prickly pear – granjeno – lime prickly ash	stable
Tropical Savanna	South	nance (*Byrsonima crassifolia*) – sandpaper tree (*Curatella americana*) – spiny coyol palm (*Acrocomia mexicana*) – sombrero palm (*Brahea dulcis*)	increasing
Interdunal Pine	East	slash pine – cabbage palm – saw palmetto – gallberry - yaupon	threatened
	Northeast	slash pine – yaupon – wax myrtle – rosemary	threatened
Pine Savanna	East	longleaf pine (*Pinus palustris*) – slash pine – pond pine (*Pinus serotina*) – saw palmetto - gallberry	threatened
	Northeast	longleaf pine – slash pine – gallberry – turkey oak (*Q. laevis*)– shortleaf pine (*Pinus echinata*) – sand oak (*Q. incana*) – yaupon – saw palmetto – live oak	threatened
	Northwest	longleaf pine – slash pine – sweetbay – black gum – wax myrtle – live oak – blackjack oak (*Q. marilandica*) – laurel oak	threatened

Human Development

Human development (i.e., population increase, urbanization, oil and gas exploration, and pollution) is an issue that affects coastal forests in all regions of the gulf (*table 2*). The coastal population from Texas to Florida is projected to increase from 14 million in 1988 to 18 million in 2010, an increase of 22 percent. The most rapid growth has been, and will continue to be, along the Florida (27% growth rate) and Texas (22 percent) coasts (Culliton et al. 1990). In Florida, 3.9 million people lived within 25 km of the east gulf shoreline in 1990 (U.S. Census Bureau 1995) and this number is estimated to exceed 6.5 million by 2010 (Culliton et al. 1990). Harris County, Texas (Houston) is another hotspot of rapid population growth. It is projected that the county's population will increase by 900,000 between 1988 and 2010 (Culliton et al. 1990). Given these projections, it is clear that coastal forests around the gulf will be increasingly threatened by development.

In the eastern gulf region, drier sites containing maritime and tropical hammocks and scrub-shrub communities are usually the first forests displaced by development and the last to be conserved through acquisition. Commercial development removes almost all of the existing vegetation, while residential developments tend to maintain selected canopy species (e.g., live oak [*Quercus virginiana]*) but remove large areas of native shrubs and forbs that provide important fruits for many fall migrants (Parrish 1997).

Johnson et al. (1992) listed only a dozen sites along >300 km of coast in southwest Florida where upland hammock and scrub-shrub communities exist in patches >40 ha. In the Florida panhandle, Johnson et al. (1992) found maritime hammocks occupied the smallest proportion of public lands followed by scrub and mesic pine flatwood communities.

In the northeast gulf region, human impacts on coastal forests were limited during the 18th and 19th centuries, particularly on barrier islands because of their inaccessibility. Human intrusion increased significantly by the end of the 19th and the beginning of the 20th centuries (Stalter and Odum 1993). Improved transportation facilitated access to barrier islands and by 1975, over 15 percent of the barrier island area on the U.S. east and gulf coasts had become urbanized (Lins 1980).

Several authors (Boyce and Martin 1993, Grossman et al. 1994, Noss et al. 1995) have described the difficulty of finding intact coastal forest systems along coastal Alabama and Mississippi. Although no trend data are available for the loss of coastal forest in this region, barrier island development has increased by more than 300 percent in the Southeast United States in the past 50 years (Johnson and Barbour 1990). In Mississippi, the past few decades have witnessed extensive destruction of coastal habitats for residential construction, commercial sites, shipping channels, garbage disposal, and similar activities. Despite the threat of development in Alabama and Mississippi, much of the remaining maritime communities are protected through state or federal government ownership. For example, Gulf Islands National Seashore protects most of the barrier islands along the northern gulf coast in Florida and Mississippi. In Alabama, much of the remaining maritime communities are protected through Bon Secour National Wildlife Refuge. At the state level, the Mississippi Department of Marine Resources is protecting coastal lands through its active Coastal Preserves Program, an effort that includes building partnerships with other government and nongovernment agencies.

Table 2— *Factors contributing to the loss and degradation of coastal forests around the Gulf of Mexico.*

	Gulf Coast Regions				
Major factors	**East**	**Northeast**	**Northwest**	**West**	**South**
Development	X	X	X	X	X
Agriculture			X	X	X
Cattle grazing			X	X	X
Pulpwood production	X	X	X		
Pine plantations	X	X			
Logging			X		X
Exotic species	X	X	X	X	X

Development has reduced the coverage of important stopover habitats in the northwest region of the gulf. The Chenier Plain forests of Louisiana and Texas, for example, provide important stopover habitat because they are the first forests available to trans-gulf migrants in spring and the last forests available to trans-gulf migrants in autumn. Seventy-three Nearctic-Neotropical species are known to use chenier forests in the spring and 66 Nearctic-Neotropical species use them in autumn (Barrow et al. 2000). In the Chenier Plain, development has decreased the area of chenier, upland, and swamp forests while increasing urban areas and wooded spoil banks. From 1952 to 1974, native forests were reduced by 17 percent (2,890 ha) while urban areas and spoil bank habitats increased by 46 percent (10,811 ha). A 17 percent loss over a 25-year period may not seem drastic, but coastal forests were never extensive in the Chenier Plain, and they only occupied 6 percent of the total area in 1974 (Gosselink et al. 1979). In the Chenier Plain of Louisiana, the cover of forested wetlands in the Mermentau Basin was stable from 1990 to 1996 and evergreen upland forests increased at the expense of mixed upland forests. The conversion from mixed forests to evergreen forests was largely a result of activity by the timber industry (Ramsey et al. 2001).

In east Texas, bottomland hardwood forests, known as the Columbia Bottomlands, once stretched across 283,290 ha in the floodplains of the San Bernard, Brazos, and Colorado Rivers. Development, grazing, and more recently timber removal for wood chipping have reduced these forests to patches that collectively cover 71,632 ha (U.S. Fish and Wildlife Service 1997). Surveys have detected 237 species of birds in the Columbia Bottomlands, and radar data indicates that these forests host hundreds of thousands of birds during migration (U.S. Fish and Wildlife Service 1997). The effects of human population expansion and urbanization also have taken their toll in the western region of the gulf. In the Lower Rio Grande Valley of Texas, for example, Hidalgo and Cameron counties were part of the top 100 counties in the nation with the largest population increase from 2000 to 2001 (U.S. Census Bureau 2002). The main effect of urbanization in this area has been the extensive removal of native Tamaulipan thornscrub. Clearing of Tamaulipan thornscrub for agriculture and urban development began in the early 1900s and by 1988 95 percent of the existing thornscrub had been cleared (Jahrsdoerfer and Leslie 1988).

Lease hunting is also popular in this area, and thornscrub is removed in strips to increase edge habitat for game species. Vega and Rappole (1994) determined the effect of this style of thornscrub removal (i.e., cleared in strips) on avian communities by comparing avian use of partially cleared thornscrub habitat to the use of undisturbed thornscrub habitat. Overall, the authors found that the partially cleared thornscrub habitat supported fewer species.

The coastal forests of the Mexican states of Tabasco and Campeche (south gulf region) include mangroves and swamps that are a part of the Biosphere Reserve of Pantanos de Centla, a Ramsar wetland of international importance and an Area of Importance for Conservation of Aves (AICAS) (Arizmendi and Marquez 2000). These forests are also at the heart of Mexico's oil and gas industry. As a result of this industry, the forested wetlands of the region have been altered through drainage, pollution, and salinization. It has been estimated that 33 percent of the migrants that use the Mississippi flyway also use the mangroves that surround the Laguna de Terminos in Campeche for stopover and wintering habitat (Secretariat of Environment, Natural Resources, and Fisheries 1997).

Agriculture, Livestock Grazing, and Related Activities

Agriculture, livestock grazing, and their associated effects have transformed coastal forests in three of the five regions of the gulf (*table 2*). In the Chenier Plain, for example, many of the coastal forests have been cleared for agricultural uses (Gosselink et al. 1979). Often, agricultural lands are then converted to urban areas and are rarely returned to their natural state.

Grazing is also an issue in the Chenier Plain of Louisiana and the Columbia Bottomlands of Texas where virtually all of the remaining coastal forests have been grazed by livestock or over-browsed by white-tailed deer (*Odocoileus virginianus*) (Barrow et al. 2000). Grazing alters the structure of chenier forests by changing species composition and by reducing the understory. Barrow et al. (2000) investigated how these structural changes may affect Nearctic-Neotropical migrants by comparing migrant use of grazed forests to migrant use of undisturbed forests. Overall, the authors found that most *en route* forest-dwelling migrants can tolerate some degradation of chenier forests. Select groups, such as early migrants, dead-leaf foragers, frugivores, and nectarivores used grazed forests significantly less than undisturbed forests (Barrow et al. 2000).

As discussed above, the majority of Tamaulipan thornscrub in south Texas and northern Mexico has been cleared for agriculture and urban development (Jahrsdoerfer and Leslie 1988). Similarly, citrus, sugar cane, and vegetable agriculture in the Lower Rio Grande Valley have resulted in extensive fragmentation of native riparian habitats and over 90 percent have been cleared from the United States side of the border (Collins 1984). Sabal Palm Forest, which once covered 16,188 ha in the Lower Rio Grande Valley is now restricted to less than 40 ha in Cameron County, Texas (Bezanson 2002, Tunnell and Judd 2002). The remaining coastal forests of the Lower Rio Grande Valley and of south Texas in general are important stopover habitat (Gauthreaux 1999). It is known that the region supports many circum- and trans-gulf migrants in spring and autumn, as well as, provides habitat for migrants needing to make landfall during storm events (Forsyth and James 1971, Langschied 1994, Tunnell and Judd 2002).

Maritime habitats are reduced to marginal extents in the southern Gulf of Mexico and little information is currently available on the trend of coastal forests. It is known that central Veracruz was once comprised of 19 vegetation types that extended over a wide elevation gradient. Today, over 75 percent of these habitats have been converted into sugar cane plantations and cattle pastures (Ruelas 2000). Conversion of forest for agriculture and livestock grazing is also a concern in southern Veracruz. Dirzo and Garcia (1992) mapped the coverage of tropical forest in the Sierra Los Tuxtlas for 1967, 1976, and 1986. By comparing these maps, the authors determined that deforestation for development, agriculture, and livestock grazing had reduced forest coverage to 13,600 ha or 16 percent of the original area (85,000 ha) by 1986.

Though fragmented, the remaining tracts of forest in Veracruz are crucial because of the resources they provide to millions of migrating birds. The area is unique in that a geographic bottleneck is created by the intersection of the eastern slope of the Sierra Madre Oriental and the Central Volcanic Belt. This geographic feature sets the stage for the largest raptor migration site in the world. Approximately 4.3 million raptors migrate through the area each fall. Millions of non-raptors funnel through the bottleneck as well. For example, at least 7 million swallows were counted during the 1999 fall migration, and on a peak day in the season Yellow Warblers (*Dendroica petechia*) passed through the area at a rate of just under 500 individuals per hour (Ruelas 2000). Four hundred sixty-five species (raptors and non-raptors) have been identified in the area, 220 of which are Neotropical migrants (Ruelas 2000). From fat deposition data we know that forests in this region provide important resources for some species during autumn migration (Winker 1995).

The coastal forests of Campeche and Yucatan provide yet another example of fragmented habitat. The distribution of these forests, which may be important staging or stopover habitat for many trans-gulf migrants, has been decreased in the last century by the conversion of forests to pastures (Olmsted and Garcia 1998).

Pine Plantations, Pulpwood Production and Logging

Coastal forests have been altered by timber-related activity in four of the five regions of the gulf (*table 2*).

In the eastern gulf region, many hydric hammocks and forested wetlands have been converted to pine plantations (Simons et al. 1989). Deciduous trees are removed, the ground is bedded, and pine seedlings (typically loblolly pine [*Pinus taeda*]) are planted at densities of 1,110/ha (Simons et al. 1989). Gulf Hammock, one of the largest hydric hammocks remaining in the Big Bend region of Florida (40,470 ha), has experienced large-scale losses (approximately 80 percent removed between 1970 and 1989) through such practices (Simons et al. 1989), and these trends likely will continue.

In 1992, Simons et al. (2000) studied migrant use of bottomland forest versus pine forest along the Mississippi coast. The authors determined that a greater number of migrant individuals and of migrant species were detected in bottomland forest. Surveys were conducted on a finer scale the following year by comparing migrant use of three habitat types: bottomland forest, pine forest with an understory, and pine forest without an understory. A greater number of migrant individuals and migrant species were found in bottomland forest and in pine forest with an understory (Simons et al. 2000). These findings suggest that the observed habitat preference was the result of differences in habitat quality (Simons et al. 2000).

The United States produces 28.5 percent of the world's industrial timber products with the majority of the exports coming from the southern states. As consumer demands have changed, production has shifted from solid wood (i.e., lumber) to composite (i.e., pulpwood) products (Prestemon and Abt 2002). In the past decade, chipping for pulpwood production has become more common as is evident in the construction of over 100 new chip mills across the South (Forest Ethics 2002). From 1989 to 1999 hardwood chip exports increased by 369 percent and softwood chip exports increased by 373 percent. Chipping encourages clearcutting because there is no need to discriminate between tree species and tree size, and native forests have declined as a result of this harvest method.

Lumber was once an important economic resource in the south region of the gulf. In Tabasco, lumber is no longer an important commodity because the resource was overly exploited and few mature mahogany trees remain (West et al. 1969). The coastal forests of Yucatan also experienced a period of intensive logging that extended from 1600-1900 (Olmsted and Garcia 1998). Today, the mangrove forests of this region are gradually declining because the local human population exploits them for timber and fuel (World Wildlife Fund 2002).

Exotic Species

A threat posed to many coastal forests stems from invasion of exotic species (Johnson and Barbour 1990, Barrow et al. 2000). We will discuss just a few examples here. In the east gulf, the threat of exotic species is most common south of 28° latitude where freezing temperatures are rare. Three species, Australian pine (*Casuarina equisetifolia*), Brazilian pepper (*Schinus terebinthifolius*), and sisal (*Agave sisalana*), create the greatest problems (Johnson and Barbour 1990). Australian pines invade newly exposed sands where dredge spoils are dumped or storm over-wash occurs. Once established, Australian pines form a dense canopy and thick litter layer that inhibit germination of native species. Restoration of sites dominated by Australian pine has proven difficult.

Chinese tallow tree (*Sapium sebiferum*) is a widespread, invasive species that was introduced to the United States in 1784 and currently has naturalized populations from North Carolina to south Texas (Bruce et al. 1997). The species is very prolific and in Galveston County, Texas, for example, Chinese tallow woodlands have increased from 2 to 12,141 ha since 1970 (Barrow and Renne 2001). Chinese tallow tree affects native communities by altering species composition and structure and thus, affects the resources available to migrating birds. To determine the use of tallow woodlands by migrating landbirds, Barrow and Renne (2001) compared migrant use of riparian forests to their use of tallow woodlands during spring migration. The study confirmed that some migrants were more common in tallow woodlands, but species richness was not significantly different between the two habitat types. The authors also compared the insect load of Chinese tallow to that of native species and found that not only was the insect load lower in tallow, but that important food resources like Lepidopteran larvae were absent (Barrow and Renne 2001). Thus, it is possible that tallow woodlands provide the cover needed during stopover, but lack the food resources needed for continued migration.

Climate Change

Increasing storm severity resulting from the warmer conditions of global climate change (Emanuel 1987) may alter coastal landscapes or entire regions through shifts in structure and composition of plant communities (for example, Doyle and Girod 1997). The areal extent of altered habitat due to strong storms like hurricanes can be vast. Hurricane Hugo, for example, affected 23 counties and damaged 1.8 million ha of wooded lands in South Carolina (Sheffield and Thompson 1992); more than 90 percent of the forested landscape of 6 counties was damaged. No one has assessed the consequences that landscape-level vegetation changes would have on migrating landbirds.

From a geologic perspective, coastal communities are in a constant state of flux because of the accretion and loss of sandy substrates in response to the constant force of wind and wave (Johnson and Barbour 1990). Changes of this type may occur quickly when catastrophic storms strike the coast, or they may occur gradually over a period of several decades (Johnson and Barbour 1990). Two hurricanes striking Grayton Beach State Park in the Florida Panhandle in the 1970's sent foredune sand into scrub and hammock vegetation behind the dune. If not stabilized, migrating sand banks such as this can engulf forest vegetation over a very large area (Johnson and Barbour 1990). Upland areas of Anclote Key, on the other hand, appear to be moving gradually northward in response to changes in nearby seagrass beds (Hine et al. 1987). Accreting sands to the north are colonized quickly by Australian pines (Johnson et al. 1992), while the maritime hammock on the southern end of the island is eroding.

Sea-level rise is another result of global climate change. The effects of rising sea-levels become amplified in areas like the Mississippi River delta where natural subsidence occurs. In the Mississippi Deltaic Plain, subsidence combined with eustatic sea-level rise results in a relative sea-level rise that is as high as 1.2 cm/yr (Baumann et al. 1984). This increase in water level triggers a chain of events that can be devastating to coastal forests. Coastal forests in this region follow a seasonal cycle of flooding and drying, but increased flooding duration brought on by sea-level rise can lead to waterlogging stress. Bottomland hardwood species would eventually die from waterlogging stress, while the regeneration of swamp species would eventually cease due to permanent flooding (Conner and Day 1998).

Remaining Tracts of Extensive Coastal Forest

Not all coastal forests are in dire straits. Whereas the live oak scrub of central Texas (between Baffin Bay and Matagorda Bay) is threatened by development (Collins 1987), the live oak woodlands of south Texas are relatively stable. This forest type occurs in the Coastal Sand Plain of Kennedy County, an area that is vast and sparsely populated (*fig. 1*). Historically, this habitat consisted of small groves of trees (or mottes), but in some areas they have expanded and coalesced to form large contiguous forests (Tharp 1939, Johnston 1963, Fall 1973). Live oak woodlands now occupy well over 29,000 ha within the South Texas Brushlands physiographic area (Proudfoot and Beasom 1997).

There are other coastal forest systems around the gulf that are still extensive (*fig. 1*), but are threatened by the pressures of human activities. The Columbia Bottomlands of east Texas (71,632 ha) represent the largest expanse of forest along the Texas coast even though development, logging and chipping, drainage, and clearing for agriculture have reduced forest coverage by 75 percent (U.S. Fish and Wildlife Service 1997).

Other extensive tracts of forests (*fig. 1*) can be found in Everglades National Park (park extends over 610,684 ha) and Big Cypress National Preserve (621,600 ha), both in southern Florida. In the northeast region of the gulf, large tracts of forest occur around Apalachicola Bay (Apalachicola National Forest and surrounding public lands totaling >273,000 ha), the Blackwater River State Forest (76,729 ha), Eglin Air Force Base and surrounding public lands (>302,000 ha), the Lower Pascagoula River basin (431,753 ha south of the confluence of the Leaf and Chickasawhay Rivers) (Woodrey et al. 2001), the DeSoto National Forest (202,755 ha), the lower Pearl River Basin (42,898 ha) (Watson 1988), and the Pontchartrain Basin (including Lakes Maurepas and Borgne, ca. 87,253 ha). In the northwest region, extensive bottomland hardwoods, swamps and adjacent forests are present in the Atchafalalaya (337,601 ha) (U.S. Fish and Wildlife Service 1978), Sabine and Mermentau (>209,937 ha) (Ramsey et al. 2001) River basins of Louisiana, and in the Big Thicket National Preserve (39,256 ha) in Texas.

In Mexico, important wooded areas (*fig. 1*) include the remnant thornscrub and mesquite woodlands of Tamaulipas (12,141 ha present at Rancho Rincon de Anacahuitas); mangroves and swamps around the Humedales del Sur de Tamaulipas, the Laguna de Tamiahua, and the Laguna La Mancha (48 ha); tropical evergreen forests (13,600 ha) near Los Tuxtlas, Veracruz; and mangroves, swamps, palm stands and thornscrub of the Humedales de Alvarado in Veracruz (279,890 ha of wetlands), and of the Pantanos de Centla in Tabasco (302,706 ha of wetlands).

Most of the large forested systems remaining along the coasts of the Gulf of Mexico are associated with river basins and deltas. We offer here a caveat on seasonally-flooded, floodplain forests as stopover habitat. These productive forests provide excellent habitat for migrating birds, but not for all species of migrant landbirds. Those species that specialize on searching for food in the leaf litter of the forest floor, like Swainson's Warbler (*Limnothlypis swainsonii*) and others, must find alternate sites. Other specialists may also have fewer opportunities to find suitable microhabitats within floodplain forests. The hydrology of these systems precludes a well-developed understory. Several species specialize in foraging amongst thickets beneath the canopy: Worm-eating Warbler (*Helmitheros vermivora*) and *Vermivora* spp., for example, search for clumps of dead leaves on branchlets that become suspended in vine tangles and thickets of the understory. Often floodplain forests are dominated by one or two tree species, like bald cypress (*Taxodium distichum*) and/or tupelo-gum (*Nyssa* spp.) (*table 1*), and do not provide an abundance or diversity of fruiting and flowering plants that provide food items useful in meeting the energetic demands of *en route* migrants.

Thoughts on Conservation Strategies for Coastal Forests

Planning for the effective conservation of gulf coastal habitats for forest-dwelling birds during their annual migrations will not be a simple task. We know that most eastern migrant landbirds migrate over or near the shore of the Gulf of Mexico, but this is a vast area and conservation funds for targeting stopover habitats is limited. We offer here a few thoughts to consider when developing a conservation strategy for the coastal forests of the Gulf of Mexico.

Gulf-Wide Considerations

Broad frontal passages and consequently pathways and densities of migrating birds shift from year to year and sometimes within a given migration season. Migration pathways over or around the Gulf of Mexico are affected, in large part, by the major wind patterns over the gulf when birds are aloft (Gauthreaux 1991). Wind patterns also affect the origination of long-range migratory movements of birds prepared to migrate. Interestingly, the ways that prevailing wind patterns influence migration passages around and over the gulf are interpreted differently by some researchers (see Rappole and Ramos 1994, Gauthreaux 1999). The precise interpretation is not necessary for our analysis because we base it on the actual position and density of migrating birds. Results from our meta-analysis of patterns of migration movements and landfalls are summarized in *Figure 1*. The map is based on a synthesis of both field and radar studies. We present this map in the hope that others will work to improve it and its usefulness to conservation efforts. The heavily shaded areas are those that are used consistently year to year (even with the acknowledged shifting nature of wind patterns and the corresponding migratory bird density) and in both seasons (Gauthreaux 1999, Gauthreaux and Belser 1999).

In the eastern United States, there are several migratory pathways. To the east, these go through Florida and the Caribbean. Some species even migrate through the western Atlantic. To the west of Florida there are two main migratory strategies: 1) trans-gulf migrants cross the Gulf of Mexico in primarily a north-south direction; and 2) circum-gulf migrants fly around the western border of the gulf, but much of the movement may be over water. It is movements across and around the gulf that we are interested in here. Due to prevailing southerly winds, the majority of migration movement in autumn is around the western gulf coast (Able 1972). Many birds are known to migrate along the Texas coast but off shore over gulf waters in both spring and autumn (Forsyth and James 1971, Gauthreaux 1999). Thus the western gulf coast becomes important during days of inclement weather (head winds and rain). Some trans-gulf flights cut across the waters of the northwest gulf (Forsyth and James 1971) and depart and/or make landfall along the United States-Mexico borderlands and the upper Texas and southwest Louisiana coasts (Gauthreaux 1999, Gauthreaux and Belser 1999). The southwestern coast of the gulf is shaded dark because of the geographic bottleneck created by two mountain ranges on the west and the gulf to the east forcing birds to concentrate in a narrow coastal plain. Fewer individuals use the lighter-shaded areas, but the areas are important because of the dynamic nature of pathway zones. In some years, the greatest concentrations of migrants within a migration season will occur in some of these lightly-shaded zones. We know much less about patterns of use along the southern coast of the gulf, but there is evidence of migrant landfall along the Yucatan Peninsula in autumn (Paynter 1953, Buskirk 1980).

Regional Planning

Within a region, should planners target coastal forests that lie inland (25-100 km from the shoreline) or coastal fringe sites? We believe an approach that incorporates both areas is required. The importance of inland sites will vary depending on whether the coast is parallel to the predominant direction of movement or not. Wooded habitats along the gulf shoreline may be used by concentrations of migrants that encounter stormy weather near the coast or by individuals that must cease migratory flight at the first opportunity due to physiological demands (e.g., dehydration, lipid depletion, or exhaustion). Wooded vegetation near the coast may serve as habitat for staging migrants waiting for favorable weather conditions before embarking on gulf-wide flights; this is especially true where the coast is perpendicular to the predominant flight direction. Inland sites may function as resting and feeding areas for birds ready to depart on their nocturnal flights (again the extent of this depends on the orientation of the coast with respect to predominant flight direction). In autumn, all sites may provide cover and food for molting birds. Throughout each region, we recommend designing landscape mosaics that provide adequate habitat configurations. The amount of habitat required will depend on the expected density of use by birds (migrant and resident). Boundaries for landscape mosaics could be delineated by natural landforms or they could follow the boundaries of habitats identified in existing regional conservation/management plans (e.g., joint ventures, Partner's in Flight plans, The Nature Conservancy ecoregional plans, wildlife refuges or parks, etc.). In *Figure 1*, we have identified the locations of known wooded tracts that remain as extensive intact systems. Habitats within these systems may be important to migrating birds. Large distances between these wooded systems appear to occur in the western, southern, and eastern regions. We know much less about the location and status of smaller forest patches. The importance of distance is related to the likelihood of encounter by migrating birds; this depends on the predominant direction of flight. Mapping the dispersion and type of wooded patches within each region should be one goal of conservation planners. The predominant flight direction needs to be considered.

Landscape Mosaics

Delineation of migrant-landscape relations with predictive models (e.g., Simons et al. 2000, Gutzwiller and Barrow 2002) can be an effective approach to incorporate broad-scale habitat associations into conservation decision processes (Gutzwiller and Barrow 2001). Consideration should be made of how migrants find suitable or likely suitable habitats near the Gulf of Mexico. The altitude of trans-gulf migration ranges from about 600-2,500 m (Gauthreaux 1991). How far can migrants see habitat patches from these heights? Once this is determined, we should be able to estimate a useful range of interpatch distances required within a landscape mosaic. Again the probable direction of flight must be considered. At least, we can suggest what maximum distance may be allowed between any two habitat patches along the expected flight path and perpendicular to it. Conservationists may be able to manipulate the landscape structure as to maximize the interception of migrating birds by restoring or creating patches of habitat perpendicular to their north-south movements (Gutzwiller and Anderson 1992). We, of course, would like to know what constitutes a suitable patch size. Patch sizes need to be larger where expected use is greatest; this can be determined from *Figure 1*. Migration routes are not completely deterministic for most species.

The approach we advocate here is a general one and will serve the needs for most species. If any particular species has more precise routes; they must be determined and habitat must be provided—especially for rare and endangered species. For instance, nearshore habitats in Florida may be particularly important for Cape May Warbler (*D. tigrina*), Black-throated Blue Warbler (*D. caerulescens*), Kirtland's Warbler (*D. kirklandii*), and Connecticut Warbler (*Oporornis agilis*) (Hunter et al. 1993). The Mexico and Texas coastlines appear to be important for Nashville Warbler (*Vermivora ruficapilla*). Enough habitat patches have to be present to allow the successful completion of migration for each species. The "programmed" routes may change to accommodate current landscapes, but habitats must be suitable in any reasonable alternative routes.

Concentrations at particular places do not necessarily mean that the habitats at these locations are particularly good. It may only mean that these were the only habitats available. We should be careful to look at landscape context of all stopover areas. In many cases, the landscape may concentrate the birds; suitability may be a separate issue.

Suitability of Wooded Habitats

In the vicinity of the Gulf of Mexico, individual migrants do not seem to return to the same stopover areas from year to year (Barrow et al. 2000). Apparently birds are programmed to take their chances at a variety of locations. This makes us doubt that a too-detailed accounting of what they do is relevant. Apparently they can do a variety of things. Emphasis should be made of habitat structure and complexity. We believe that in all cases (but especially during migration) that the availability of resource concentrations is constantly changing. Residents have daily exposure to the habitat and are able to track these changes; migrants do not. What they seem to do instead is move through the habitat and continuously sample it (Moore et al. 1990). They congregate where there are more resources because it is not necessary to move as often or as far as they need to move when resources are scarcer. Thus the concentration of resources themselves results in higher densities in the most suitable places. The location of hot spots will continuously change because the food resources will vary in time and space, and the competitive environment is in constant flux. In more complex habitats, resource patches should be scattered and diverse so as to accommodate a variety of species. In many cases, it may not be necessary to manage for a particular situation; managing for complexity should be enough. The loss of complexity and heterogeneity where exotics predominate may be one of the main problems with their introduction (Barrow and Renne 2001).

Coastal habitats are used throughout the year and are important for residents as well as migrants (especially in the neotropics). Fortunately, the same rules for habitat suitability apply to both. Landscape considerations would be different for the two groups, however.

On the Diets of *En Route* Migrants

Nearctic-Neotropical migrant landbirds tend to be insectivorous, frugivorous, nectarivorous, or omnivorous. Therefore, insects, fruits, and flowers are especially important habitat components at stopover sites. A more thorough study of requirements of stopover areas should be made. It is uncertain that energy content is the only important consideration for food. We do know that water is often required (Leberg et al. 1996). We do not know how much energy is needed to complete flight; this would vary by species. In the spring, energy may also be needed to accommodate changes in the reproductive systems of both males and females; energetic needs may be especially important in females. It is likely that specific metabolic requirements may also be needed to bring about these changes, and particular foods may be required in the diets of migrants, especially females where morphological and physiological changes are greatest. It needs to be determined if specific substances are needed. If they are required, the availability of them needs to be evaluated. In autumn, requirements for molt may need to be determined. Of course, molt can be rescheduled more easily than reproduction.

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Literature Cited

Able, K. P. 1972. **Fall migration in coastal Louisiana and the evolution of migration patterns in the gulf region**. Wilson Bulletin 84(3): 231-242.

Arizmendi, M. Del C. and L. Marquez V., editors. 2000. **Areas de importancia para la conservacion de las Aves en**

Mexico. Consejo Internacional para la Preservación de las Aves en México (CIPAMEX), D. F.

Barrow, W. C., Jr., C. Chen, R. B. Hamilton, K. Ouchley, and T. J. Spengler. 2000. **Disruption and restoration of en route habitat, a case study: The Chenier Plain**. In: F. R. Moore, editor. Stopover ecology of nearctic-neotropical landbird migrants: Habitat relations and conservation implications. Studies in Avian Biology 20: 71-87.

Barrow, W. C., Jr., R. B. Hamilton, M. A. Powell, and K. Ouchley. 2001. **Contribution of landbird migration to the biological diversity of the Northwest Gulf Coastal Plain**. Texas Journal of Science 52(4) Supplement: 151-172.

Barrow, W. C., Jr., and I. Renne. 2001. **Interactions between migrant landbirds and an invasive exotic plant: The Chinese tallow tree**. Flyway 8:11.

Baumann, R. H., J. W. Day Jr., and C. A. Miller. 1984. **Mississippi deltaic wetland survival: Sedimentation vs. coastal submergence**. Science 224: 1093-1095.

Bezanson, D. 2002. **Natural vegetation types of Texas and their representation in conservation areas**. http://tconr.home.texas.net/vegetation. Last accessed 6/05/2002.

Boyce, S. G. and W. H. Martin. 1993**. The future of terrestrial communities of the southeastern United States.** In: H. G. Martin, S. G. Boyce, and A. C. Echternacht, editors. Biodiversity of the Southeastern United States: Upland terrestrial communities. New York, NY: John Wiley & Sons, Inc.; 339-366.

Bruce, K. A., G. N. Cameron, P. A. Harcombe, and G. Jubinsky. 1997. **Introduction, impact on native habitats, and management of a woody invader, the Chinese tallow tree, *Sapium sebiferum* (L.) Roxb.** Natural Areas Journal 17(3): 255-260.

Buskirk, W. H. 1980. **Influence of meteorological patterns and trans-gulf migration on the calendars of latitudinal migrants**. In: A. Keast and E. S. Morton, editors. Migrant birds in the neotropics. Washington, DC: Smithsonian Institution Press; 485-491.

Collins, K. 1984. **Status and management of native south Texas brushlands**. Corpus Christi, TX: Ecological Services, Fish and Wildlife Service, U.S. Department of the Interior.

Collins, K. D. 1987. **The distribution, status and ecological value of inland pothole wetlands associated with the live oak brush community in south Texas**. Corpus Christi, TX: Ecological Services, Fish and Wildlife Service, U.S. Department of the Interior.

Conner, W. H., and J. W. Day, Jr. 1998. **The effect of sea level rise on coastal wetland forests.** In: A. D. Laderman editor. Coastally restricted forests. New York, NY: Oxford University Press; 278-292.

Culliton, T. J., M. A. Warren, T. R. Goodspeed, D. G. Remer, C. M. Blackwell, and J. J. Mcdonouogh, III. 1990. **Fifty years of population change along the nation's coast: 1960-2010**. Rockville, MD: Strategic Assessment Branch, Ocean Assessments Division, National Oceanographic and Atmospheric Administration.

Dirzo, R. and M. C. Garcia. 1992. **Rates of deforestation in Los Tuxtlas, a Neotropical area in southeast Mexico**. Conservation Biology 6(1): 84-90.

Doyle, T. W. and G. F. Girod. 1997. **The frequency and severity of Atlantic hurricanes and their influence on the structure of south Florida mangrove communities**. In: H. F. Diaz and R. S. Pulwarty, editors. Hurricanes, climate and socioeconomic impacts. New York, NY: Springer-Verlag; 110-120.

Emanuel, K. A. 1987. **The dependence of hurricane intensity on climate**. Nature 326: 483-485.

Fall, B. A. 1973. **Noteworthy bird records from South Texas (Kenedy County)**. Southwestern Naturalist 18: 244-247.

Forest Ethics. 2002. **Southeast U.S. forests**. http://www.forestethics.org/forests/seus.html. Last accessed December 9, 2002.

Forsyth, B. J. and D. James. 1971. **Springtime movements of transient nocturnally migrating landbirds in the gulf coastal bend region of Texas**. The Condor 73: 193-207.

Gauthreaux, S. A. 1975. **Coastal hiatus of spring trans-gulf bird migration.** In: W. G. McIntire, M. J. Hershman, R. D. Adams, K. D. Midboe, and B. B. Barrett, editors. A rationale for determining Louisiana's coastal zone. Report No. 1, Coastal Zone Management Series. Baton Rouge, LA: Center for Wetland Resources, Louisiana State University; 85-91.

Gauthreaux, S. A., Jr. 1991. **The flight behavior of migrating birds in changing wind fields: Radar and visual analyses**. American Zoologist 31: 187-204.

Gauthreaux, S. A., Jr. 1999. **Neotropical migrants and the Gulf of Mexico: the view from aloft**. In: K. P. Able editor. Gatherings of angels: Migrating birds and their ecology. Ithaca, NY: Cornell University Press; 27-49.

Gauthreaux, S. A. Jr. and C. G. Belser. 1999. **Bird migration in the region of the Gulf of Mexico**. In: N. J. Adams and R. H. Slotow, editors. Proceedings of the 22nd International Ornithological Congress. 1998. August 16-22. Durban, South Africa; 1931-1947.

Gosselink, J. G., C. L. Cordes, and J. W. Parsons. 1979. **An ecological characterization study of the Chenier Plain ecosystem of Louisiana and Texas**. FWS/OBS-78/9 through 78/11. Washington, DC, Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior.

Grossman, D. H., K. L. Goodin, and C. L. Reuss, eds. 1994. **Rare plant communities of the coterminous United States**. Arlington,VA: The Nature Conservancy.

Gunter, G. and L. N. Eleuterius. 1973. **Some effects of hurricanes on the terrestrial biota with special reference to Camile**. Gulf Research Report 4: 174-185.

Gutzwiller, K. J. and S. H. Anderson. 1992. **Interception of moving organisms: Influences of patch shape, size, and**

orientation on community structure. Landscape Ecology 6(4): 293-303.

Gutzwiller, K. J. and W. C. Barrow, Jr. 2001. **Bird-landscape relations in the Chihuahuan Desert: Coping with uncertainties about predictive models**. Ecological Applications 11(5): 1517-1532.

Gutzwiller, K. J. and W. C. Barrow, Jr. 2002. **Does bird community structure vary with landscape patchiness? A Chihuahuan Desert perspective**. Oikos 98(2): 284-298.

Hine, A. C., M. W. Evans, R. A. Davis, Jr., and D. F. Belknap. 1987. **Depositional response to seagrass mortality along a low-energy, barrier island coast: West-central Florida**. Journal of Sedimentary Petrology 57: 431-439.

Hunter, W. C., D. N. Pashley, and R. E. F. Escano. 1993. **Neotropical migratory landbird species and their habitats of special concern within the southeast region**. In: D. M. Finch and P. W. Stangel, editors. Status and management of Neotropical migratory birds. Gen. Tech. Rep. RM-229. Ft. Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 159-169.

Jahrsdoerfer, S. E. and D. M. Leslie, Jr. 1988. **Tamaulipan brushland of the lower Rio Grande valley of south Texas: Description, human impacts, and management options**. Biological Report 88(36). Washington, DC: Fish and Wildlife Service, U.S. Department of the Interior.

Johnson, A. and M. G. Barbour. 1990. **Dunes and maritime forests.** In: R. L. Myers and J. Ewel, editors. Ecosystems of Florida. Orlando, FL: University of Florida Press; 429-480.

Johnson, A. F., J. W. Muller, and K. A. Bettinger. 1992. **An assessment of Florida's remaining coastal upland natural communities: Panhandle**. Tallahassee, FL: Florida Natural Areas Inventory.

Johnston, M. C. 1963. **Past and present grasslands of southern Texas and northeastern Mexico**. Ecology 44(3): 456-466.

Langschied, T. M. 1994. **Temporal variation in avian communties in southern Texas**. Kingsville, TX: Texas A & M University. M. S. Thesis.

Leberg, P. L., T. J. Spengler, and W. C. Barrow, Jr. 1996. **Lipid and water depletion in migrating passerines following passage over the Gulf of Mexico**. Oecologia 106: 1-7.

Lins, H. F. 1980. **Patterns and trends of land use and land cover on Atlantic and Gulf coast barrier islands**. Geological Survey Professional Paper 1156. Washington, DC: U.S. Government Printing Office.

Lowery, G. H. 1974. **Louisiana birds**. Baton Rouge, LA: Louisiana State University Press.

Moore, F. R., S. A. Gauthreaux, Jr., P. Kerlinger, and T. R. Simons. 1993. **Stopover habitat: Management implications and guidelines**. In: D. M. Finch and P. W. Stangel, editors. Status and management of Neotropical migratory birds. Gen. Tech. Rep. RM-229. Ft. Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 58-69.

Moore, F. R., P. Kerlinger, and T. R. Simons. 1990. **Stopover on a gulf coast barrier island by spring trans-gulf migrants**. Wilson Bulletin 102: 487-500.

Noss, R. F., E. T. Laroe, and J. M. Scott. 1995. **Endangered ecosystems of the United States: A preliminary assessment of loss and degradation**. Biological Report No. 28, Washington, DC: National Biological Survey, U.S. Department of the Interior.

Olmsted, I. and R. D. Garcia. 1998. **Distribution and ecology of low freshwater coastal forests of the Yucatan Peninsula, Mexico**. In: A. D. Laderman, editor. Coastally restricted forests. New York, NY: Oxford University Press; 237-256.

Parrish, J. D. 1997. **Patterns of frugivory and energetic condition in Nearctic landbird migrants during autumn migration**. Condor 99: 681-697.

Paynter, R. A., Jr. 1953. **Autumnal migrants on the Campeche Bank**. Auk 70: 338-349.

Pessin, L. J. and T. D. Burleigh. 1941. **Notes on the forest biology of Horn Island, Mississippi**. Ecology 22: 70-78.

Prestemon, J. P. and R. C. Abt. 2002. **Chapter 13: Timber products supply and demand**. In: D. Wear and J. G. Greis, editors. Southern forest resource assessment. General Technical Report SRS-53. Asheville, NC: Southern Research Station, Forest Service, U.S. Department of Agriculture; 299-326.

Proudfoot, G. A. and S. L. Beasom. 1997. **Food habits of nesting Ferruginous Pygmy-Owls in southern Texas**. Wilson Bulletin 109: 741-748.

Ramsey III, E. W., G. A. Nelson, and S. K. Sapkota. 2001. **Coastal change analysis program implemented in Louisiana**. Journal of Coastal Research 17(1): 53-71.

Rappole, J. H. and M. A. Ramos. 1994. **Factors affecting migratory bird routes over the Gulf of Mexico**. Bird Conservation International 4: 251-262.

Ruelas I., E. 2000. **Veracruz river of raptors III: towards a self-sustaining, long term strategy for the conservation of migratory raptors, wading birds, and their habitats in eastern Mexico**. Technical report for the National Fish and Wildlife Foundation. Pronatura Veracruz, Xalapa, Veracruz, Mexico.

Secretariat of Environment, Natural Resources and Fisheries. 1997. **Programa de manejo del area de proteccion de flora y fauna Laguna de Terminos**. Mexico: Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP); 167 p.

Sheffield, R. M. and M. T. Thompson. 1992. **Hurricane Hugo, effects on South Carolina's forest resource**. Research Paper SE-284. Forest Service, U.S. Department of Agriculture.

Simons, R. W., S. W. Vince, and S. R. Humphrey. 1989. **Hydric hammocks: A guide to management**. Biological Report 85(7.26 Supplement). Washington DC: Fish and Wildlife Service, U.S. Department of the Interior.

Simons, T. R., S. M. Pearson, and F. R. Moore. 2000. **Application of spatial models to the stopover ecology of trans-gulf migrants**. Studies in Avian Biology 20: 4-14.

Stalter, R. and W. E. Odum. 1993. **Maritime communities**. In: H. G. Martin, S. G. Boyce, and A. C. Echternacht, editors. Biodiversity of the Southeastern United States: Lowland terrestrial communities. New York, NY: John Wiley & Sons, Inc.; 117-163.

Tharp, B. C. 1939. **The vegetation of Texas**. Houston, TX: Anson Jones Press.

Tunnell, J. W., Jr. and F. W. Judd. Editors. 2002. **The Laguna Madre of Texas and Tamaulipas**. College Station, TX: Texas A & M University Press.

U.S. Census Bureau. 1995. **Topologically integrated geographic encoding and referencing system**. Washington, DC. http://www.census.gov/geo/www/tiger/. Last accessed December 10, 2002.

U.S. Census Bureau. 2002. **Population estimates - 100 largest gaining counties**. http://eire.census.gov/popest/data/counties/tables/CO-EST2001-10.php. Last accessed July 9, 2002.

U.S. Fish and Wildlife Service. 1978. **The Atchafalaya Basin land and water resources, Louisiana study**. National Space Technology Laboratories Station, MS: Fish and Wildlife Service, U. S. Department of the Interior.

U.S. Fish and Wildlife Service. 1997. **Final proposed Austin's woods conservation plan, land protection compliance document and conceptual management plan: Austin's woods units of the Brazoria National Wildlife Refuge complex**. Albuquerque, NM: Fish and Wildlife Service, U. S. Department of the Interior.

Vega, J. H. and J. H. Rappole. 1994. **Effects of scrub mechanical treatment on the nongame bird community in the Rio Grande plain of Texas**. Wildlife Society Bulletin 22: 165-171.

Watson, R. C. 1988. **Planning aid report on Pearl River basin, Mississippi and Louisiana lower Pearl River low flow allocation study**. Vicksburg, MS: Fish and Wildlife Service, U. S. Department of the Interior.

West, R. C., N. P. Psuty, and B. G. Thom. 1969. **The Tabasco lowlands of southeastern Mexico**. Technical Report No. 70. Baton Rouge, LA: Coastal Studies Institute, Louisiana State University.

Wiedenfeld, D. A. and M. G. Wiedenfeld. 1995. **Large kill of Neotropical migrants by tornado and storm in Louisiana, April 1993**. Journal of Field Ornithology 66(1): 70-80.

Winker, K. 1995. **Autumn stopover on the Isthmus of Tehuantepec by woodland Nearctic-neotropic migrants**. The Auk 112(3): 690-700.

Woodrey, M. S., B. Reid, F. R. Moore, S. Woltmann, J. Clark, and J. J. Buler. 2001. **Birds of the Pascagoula River**. In: M. S. Woodrey, B. Reid, and C. Ramseur, editors. Proceedings of the Singing River Symposium: A focus on conservation of the Pascagoula River System. 2001 September 21-22. Moss Point, MS.

World Wildlife Fund. 2002. **Usumacinta mangroves (NT1437)**. http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt1437_full.html. Last accessed July 9, 2002.