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Environmental Conditions and Threatened and Endangered Species Populations near the Titan, Atlas, and Delta Launch Complexes, Cape Canaveral Air Station

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Abstract

Launches of Delta, Atlas, and Titan rockets from Cape Canaveral Air Station (CCAS) have potential environmental effects. These could occur from direct impacts of launches or indirectly from habitat alterations. This report summarizes a three-year study (1995-1998) characterizing the environment, with particular attention to threatened and endangered species, near Delta, Atlas, and Titan launch facilities.

Cape Canaveral has been modified by Air Force development and by 50 years of fire suppression. The dominant vegetation type around the Delta and Atlas launch complexes is coastal oak hammock forest. Oak scrub is the predominant upland vegetation type near the Titan launch complexes. Compositionally, these are coastal scrub communities that has been unburned for > 40 years and have developed into closed canopy, low-stature forests. Herbaceous vegetation around active and inactive facilities, coastal strand and dune vegetation near the Atlantic Ocean, and exotic vegetation in disturbed areas are common. Marsh and estuarine vegetation is most common west of the Titan complexes. Launch effects to vegetation include scorch, acid, and particulate deposition. Discernable, cumulative effects are limited to small areas near the launch complexes.

Water quality samples were collected at the Titan, Atlas, and Delta launch complexes in September 1995 (wet season) and January 1996 (dry season). Samples were analyzed for heavy metals, chloride, total organic carbon, calcium, iron, magnesium, sodium, total alkalinity, pH, and conductivity. Differences between fresh, brackish, and saline surface waters were evident. The natural buffering capacity of the environment surrounding the CCAS launch complexes is adequate for neutralizing acid deposition in rainfall and launch deposition.

Populations of the Florida Scrub-Jay (*Aphelocoma coerulescens*), a Federally-listed, threatened species, reside near the launch complexes. Thirty-seven to forty-one scrub-jay territories were located at Titan, Atlas, and Delta launch complexes between 1995 and 1997. No direct impacts to scrub-jays were observed as a result of normal launches. The explosion of the Delta rocket in January 1997 caused direct impacts to the habitat of several scrub-jays families, from fire and debris; however, no scrub-jay mortality was observed. Mortality exceeded reproductive output at all areas over the course of the study.

Populations of the southeastern beach mouse (*Peromyscus polionotus niveiventris*) populations, a Federally listed, threatened species, reside near all the launch complexes. Hurricane Erin and several other tropical storms impacted several areas at the inception of the study in 1995 causing coastal habitat alterations as a result of salt-water intrusion. Both the habitat and the beach mice populations recovered during the course of the study. No direct

impacts to southeastern beach mice were observed as a result of normal launch operations. Direct impacts were observed to the habitat as a result of the explosion of the Delta rocket in January 1997. This alteration of the habitat resulted in a shift in use with the mice moving on to the newly burned part of the site.

Waterbirds use wetlands and aquatic systems near the launch complexes. Species include the Federally-listed, endangered Wood Stork (*Mycteria americana*) and several state-listed species of special concern including the Snowy Egret (*Egretta thula thula*), Reddish Egret (*Egretta rufescens rufescens*), White Ibis (*Eudocimus albus*), Roseate Spoonbill (*Ajaia ajaja*), Tricolored Heron (*Egretta tricolor ruficolis*), and Little Blue Heron (*Egretta caerulea*). No impacts to these populations resulting from any launch operations were observed.

Gopher tortoises (*Gopherus polyphemus*) also occur around the launch complexes. Most of those observed appeared to be in good condition; however, upper respiratory tract disease is known to occur in the population.

Cape Canaveral Air Station, including areas near active launch complexes, remains important habitat for a variety of native plants and animals including threatened and endangered species. Direct negative effects of current launch systems appear limited. Additional monitoring of these populations and habitats is required to determine if subtle, long-term changes are occurring, to determine if new launch systems and facilities cause other effects, and to determine the effects of habitat restoration and management.

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Introduction

Launches of Delta, Atlas, and Titan rockets from Cape Canaveral Air Station (CCAS) have potential environmental effects. These could arise from direct impacts of the launch exhaust (e.g., blast, heat), deposition of exhaust products of the solid rocket motors (hydrogen chloride, aluminum oxide), or other effects such as noise. Monitoring has been conducted for some Titan launches (Larson et al. 1993), but less is known about both acute and long-term effects of these unmanned vehicles than is known about the Space Shuttle. Monitoring of Space Shuttle launches has been conducted since 1981 (Schmalzer et al. 1993).

A second class of impacts are indirect; these occur not from direct effects of launches but from alterations in the habitat and in ecosystem processes, such as fire, from the presence of launch structures and facilities in the environment. Indirect effects are harder to detect and often require long-term monitoring of the systems and populations of concern.

This project was initiated in 1995 with funding from the 45th Space Wing, Civil Engineering, Environmental Office, Patrick Air Force Base to develop a more comprehensive assessment of effects from Delta, Atlas, and Titan launch vehicles on the environment of CCAS. This required two coordinated approaches. One was to characterize the environment surrounding the launch complexes, with particular attention to natural resources, such as populations of threatened and endangered species, that might be sensitive to effects of launches. The second approach was characterizing the effects of launches, including the acute effects of individual launches and the cumulative effects of repeated launches, particularly the spatial distribution of launch effects; that information has been summarized in a separate report (Schmalzer et al. 1998).

In this report we:

1. Present maps of the vegetation and landcover near the Delta, Atlas, and Titan launch complexes.

2. Summarize water quality data from selected aquatic systems near the launch complexes.

3. Summarize data on Florida Scrub-Jay (*Aphelocoma coerulescens*) populations, a Federally-listed, threatened species, residing near the launch complexes.

4. Summarize data on southeastern beach mouse (*Peromyscus polionotus niveiventris*) populations, a Federally listed, threatened species, residing near the launch complexes.

5. Summarize data on waterbirds using wetlands and aquatic systems near the launch complexes. These include the Federally-listed, endangered Wood Stork (*Mycteria americana*) and several state-listed species of special concern including the Snowy Egret (*Egretta thula thula*), Reddish Egret (*Egretta rufescens rufescens*), White Ibis (*Eudocimus albus*), Roseate Spoonbill (*Ajaia ajaja*), Tricolored Heron (*Egretta tricolor ruficolis*), and Little Blue Heron (*Egretta caerulea*).

6. Present less detailed information on the gopher tortoise (*Gopherus polyphemus*) and other species of special concern near the launch complexes.

Based on our initial estimates of the expected spatial extent of launch effects, these studies concentrated within a 1 km radius of the Delta and Atlas launch complexes. For the Titan launch complexes, the study area extended from 1 km south of Launch Complex (LC) 40 to 1 km north of LC41. Most direct launch effects did occur within that distance of the launch complexes (Schmalzer et al. 1998); however, particulate and acid deposition from Titan launches sometimes extended farther.

Environmental Setting of Cape Canaveral Air Station

Cape Canaveral Air Station is located on the coast of east-central Florida and occupies most of the Cape Canaveral barrier island (Figure 1). CCAS has an area of about 6,396 ha (15,804 ac) (Johnson Controls World Services, Inc. 1991). The Air Force acquired CCAS in 1950, and it has supported a wide variety of national defense and space launch programs.

Cape Canaveral experiences a warm, humid climate. Average precipitation is greatest in the summer months due to convective storm activity, with the winter months being drier. Lightning is common in the summer months. Year-to-year variability in precipitation is high. Relative humidity is high throughout the year. Mean minimum and maximum temperatures are greatest June to September. Freezing temperatures occur one or more days many winters, but are more common on the mainland than on the barrier islands (Merritt Island, Cape Canaveral) (Mailander 1990). Severe freezes are rare, but occur and influence sensitive plants and animals (Provancha et al. 1986a).

Cape Canaveral is a geologically recent barrier island complex; it formed after sea levels rose when the Wisconsinian glaciers retreated (Davis 1997). Cape Canaveral is mapped as Holocene in age (Brooks 1981). Brooks (1972) suggested that the formation of the Cape Canaveral peninsula began about 7,000 years ago. Cape Canaveral is part of a prograding barrier island complex, the result of southward growth of an original cape at the site of the present False Cape (White 1958, 1970). Multiple dune ridges on Cape Canaveral suggest that periods of deposition and erosion alternated (Chaki 1974).

Soils of Cape Canaveral are derived from siliceous sands that originated from erosional processes in the Appalachian and Piedmont regions and moved south by longshore drift, and carbonate shell material of local origin (Davis 1997, Scott 1997). Cape Canaveral has primarily young soils. Well-drained soils are in the Palm Beach, Canaveral, and Welaka series, and these soils cover much of the landscape (Huckle et al. 1974). Palm Beach and Canaveral soils retain shell fragments in the upper horizons and are alkaline. The older Welaka soil lacks shell fragments in the upper horizons but retains them at depth; it is acid near the surface and neutral to alkaline at depth. Shell fragments influence soil nutrient levels, particularly calcium and magnesium, as well as pH. Smaller areas of the acid, sandy Pomello sand are present. Wetland soils along the fringe of the Banana River are classified as Tidal marsh, Tidal swamp, or Submerged marsh (Huckle et al. 1974).

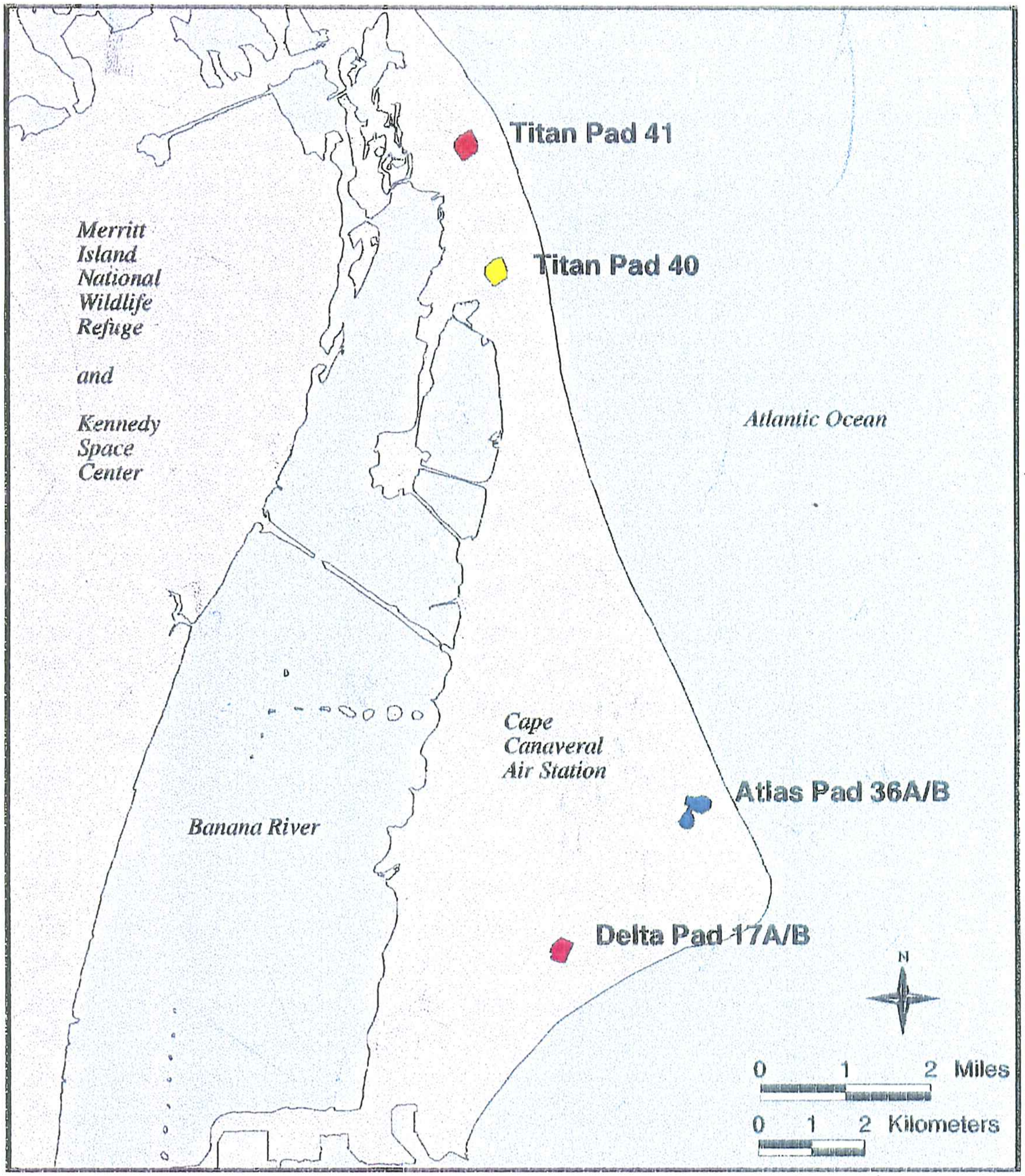
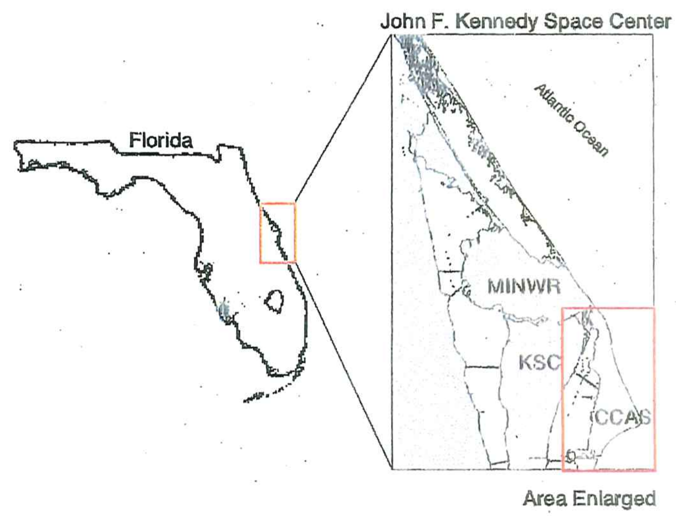


Figure 1: Location of launch complexes on Cape Canaveral Air Station (CCAS). Launch complexes include Titan 40, Titan 41, Atlas 36 A/B, and Delta 17 A/B. Cape Canaveral Air Station is located on the east coast of Florida, and is situated adjacent to Merritt Island National Wildlife Refuge (MINWR) and John F. Kennedy Space Center (KSC).



Vegetation

Historic Vegetation

Cape Canaveral has been modified by Air Force development and by 50 years of fire suppression. There were few studies before its acquisition. Aerial photography taken in 1943 (scale ca. 1:24,000) indicates that it was an open, shrubby and herbaceous landscape with forests found primarily near the Banana River. Historic records suggest that lightning induced fires were common in this coastal region (Davison and Bratton 1986). Kurz (1942) provided a detailed description of the vegetation of part of Cape Canaveral. Pioneering species on the foredunes included railroad vine (*Ipomoea pes-caprae*), beach morning-glory (*Ipomoea imperati*), inkberry (*Scaevola plumieri*), sea purslane (*Sesuvium portulacastrum*), and other herbaceous and shrubby plants. The primary dunes were dominated by sea oats (*Uniola paniculata*) with beach grass (*Panicum amarum*) and a variety of herbs and small shrubs. Inland from the coastal dunes shrub cover increased and became more continuous. Saw palmetto (*Serenoa repens*), sea grape (*Cocoloba uvifera*), wax myrtle (*Myrica cerifera*), and tough buckthorn (*Bumelia tenax*) were the dominant shrubs. Inland of this zone but still on alkaline soils, shrub vegetation predominated but the major species was a dwarf form of live oak (*Quercus virginiana*) Kurz (1942) termed Rolf's oak (*Q. rolfsii* see Small 1933) along with wax myrtle, tough buckthorn, and red bay (*Persea borbonia*). Subsequent authorities have generally included *Q. rolfsii* with *Q. virginiana* but detailed studies are lacking (Johnson and Barbour 1990). On more inland sites with older, leached but still circumneutral soils, Kurz (1942) found scrub with sand live (*Q. geminata*), myrtle (*Q. myrtifolia*), and Chapman oaks (*Q. chapmanii*), tallowwood (*Ximenia americana*), and blueberry (*Vaccinium* sp.).

Swale (freshwater) marshes are evident in the 1943 aerial photography and much reduced in the recent vegetation pattern (Provancha 1988, Larson and Swain 1991). Remaining swale marshes on Cape Canaveral are predominantly *Muhlenbergia capillaris* with some sand cordgrass (*Spartina bakeri*) and sawgrass (*Cladium jamaicense*) (Schmalzer, pers. observ.).

Salt marshes occurred historically along the shoreline of the Banana River and Cape Canaveral; these were more extensive toward the northern part of Cape Canaveral. These marshes were impounded for mosquito control and by construction of the Titan launch facilities (Trost 1964, Rey and Kain 1989). Little information exists on these marshes before impoundment, but Trost (1964) reported that black (*Avicennia germinans*) and white (*Laguncularia racemosa*) mangroves and halophytes (*Batis/Salicornia*) had been present.

Provancha (1988) and Larson and Swain (1991) have mapped the recent vegetation of Cape Canaveral. Updated maps for areas near the launch facilities are presented later.

Plant Communities

Remaining natural vegetation of Cape Canaveral includes several plant communities; these are described below.

Coastal Dunes. Coastal dunes are dominated by sea oats and other grasses including slender cordgrass (*Spartina patens*) and beach grass. Small shrubs include inkberry, varnish leaf (*Dodanaea viscosa*), elder (*Iva imbricata*), and croton (*Croton punctatus*). Common herbs include beach sunflower (*Helianthus debilis*), railroad vine, beach star (*Remirea maritima*), and camphorweed (*Heterotheca subaxillaris*) (Schmalzer and Hinkle 1985, Johnson et al. 1990, Johnson and Barbour 1990).

Coastal Grassland. The coastal grassland community is best developed south of the tip of Cape Canaveral where sand accumulation continues. It occurs between the primary dunes and predominately shrubby vegetation inland (Johnson et al. 1990, Johnson and Barbour 1990). *Muhlenbergia capillaris, Fimbristylis castanea, Andropogon* spp., and *Schizachyrium* spp. are the primary species.

Coastal Strand. Coastal strand is a shrub community on the barrier island on recent dunes inland from the coastal dunes (sea oats zone). Saw palmetto, sea grape, wax myrtle, nakedwood (*Myrcianthes fragrans*), tough buckthorn, and rapanea (*Rapanea punctata*) are typical shrubs (Schmalzer and Hinkle 1985, Johnson et al. 1990). Shrubs may be dense or sandy openings may be common. If open, herbs such as beach sunflower and camphorweed often occur. Pruning of shrubs by salt spray is common. Soils are typically the excessively well-drained Palm Beach sand or the moderately well-drained Canaveral sand (Huckle et al. 1974). In Brevard County, coastal strand is best represented on Kennedy Space Center (KSC) (Provancha et al. 1986b) and CCAS (Provancha 1988). Outside of Federal property, some remnants persist (Johnson et al. 1990, Swain et al. 1995).

Coastal Scrub. Coastal scrub is a shrub community on the barrier island inland from coastal strand where oaks become co-dominant or dominant (Johnson and Barbour 1990). The oak is often a coastal form of live oak (Kurz 1942, Johnson et al. 1990). Other shrubs include saw palmetto, wax myrtle, tough buckthorn, rapanea, and Florida privet (*Forestiera segregata*) (Schmalzer and Hinkle 1985). The soil is typically the moderately well-drained Canaveral sand (Huckle et al. 1974). Unlike soils of inland scrub, this soil is alkaline and still retains shell fragments in the upper horizons. In Brevard County, coastal scrub is best represented on CCAS and some sections of the outer barrier island part of KSC (Schmalzer et al. 1999). Outside of Federal property most has been developed, but some remnants persist (Johnson et al. 1990).

Oak Scrub. Oak scrub is a shrubland dominated by scrub oaks (*Quercus myrtifolia*, *Q. geminata*, and Q. chapmanii). Associated species may include saw palmetto, Florida rosemary (*Ceratiola ericoides*), scrub hickory (*Carya floridana*), and rusty lyonia (*Lyonia ferruginea*). Soils include the excessively-drained series that may support sand pine scrub or better drained inclusions within moderately well-drained soil series. Oak scrub occurs on the higher ridges of Merritt Island (Schmalzer and Hinkle, 1987; 1992), on the Atlantic Coastal Ridge, and on some interior sections of the barrier islands including Cape Canaveral (Schmalzer et al. 1999). Recent data on CCAS indicate that coastal scrub is associated with the Palm Beach and Canaveral soil series and oak scrub with the Welaka series (Schmalzer et al. 1999).

Sand Pine Scrub. Sand pine scrub has a closed to scattered canopy of sand pine (*Pinus clausa*) and an understory of scrub oaks (*Quercus myrtifolia, Q. geminata, Q. chapmanii*), saw palmetto, rusty lyonia, and other shrubs. Florida rosemary may occur. Sand pine scrub long has been recognized as a distinctive vegetation type (Laessle 1942, Myers 1990). In Brevard County, sand pine scrub is found primarily on the mainland on higher ridges of the Atlantic Coastal Ridge (Schmalzer et al. 1999); only minor areas occur on Cape Canaveral (Provancha 1988).

Rosemary Scrub. Rosemary scrub (rosemary bald) is typically an open shrubland dominated by Florida rosemary with numerous open, sandy areas (Myers 1990). Rosemary scrub occurs on higher ridges of the southern Lake Wales Ridge. Rosemary scrub is not well developed in Brevard County. Some small areas occur on Cape Canaveral (Stout 1980).

Scrubby Flatwoods. Scrubby flatwoods have a shrub layer of oak-saw palmetto scrub but an open canopy of pines. On Cape Canaveral, small areas occur with slash pine (*Pinus elliottii* var. *densa*) as the canopy species (Schmalzer et al. 1999).

Xeric Hammock. Xeric hammock is a low stature forest with a canopy of tree-size scrub oaks and a shrub layer of saw palmetto. Epiphytic lichens and ball moss (*Tillandsia recurvata*) may occur. Xeric hammock occurred historically where natural firebreaks limited the spread of fire (Myers 1990), but its extent has been increased by fire suppression and landscape fragmentation. Much scrub on CCAS has been unburned for 30-50 years and has developed xeric hammock features (Schmalzer and Turek, unpublished).

Freshwater Marshes. Remaining swale marshes on Cape Canaveral are predominantly *Muhlenbergia capillaris* with some sand cordgrass and sawgrass (Schmalzer, pers. observ.).

Mesic (Maritime) Hammocks. Mesic hammocks occur near the Banana River. Kurz (1942) noted that mature forest on Cape Canaveral had Rolf's oak, red bay, southern red cedar (*Juniperus silicicola*), black ironwood (*Krugiodendron ferreum*), and mastic (*Mastichodendron foetidissimum*) as canopy species. Stout (1980) reported data from one hammock on CCAS in which red bay, live oak, and cabbage palm (*Sabal palmetto*) were the dominant species, but there was a significant component of tropical species including black ironwood, marlberry (*Ardisia escallonioides*), gumbo-limbo (*Bursera simaruba*), strangler fig (*Ficus aurea*), white stopper (*Eugenia axillaris*), and Spanish stopper (*Eugenia foetida*).

Disturbed and Exotic Vegetation. Road and facility construction, ditching, line-of-sight clearing, power lines, impoundment for mosquito control, and other disturbances have created areas suitable for exotic plant establishment. Australian pine (*Casuarina equisetifolia*), Brazilian pepper (*Schinus terebinthifolius*), and Vitex (*Vitex trifolia*) have established in many disturbed areas.

Vascular Flora and Rare Plants

No flora has been compiled for CCAS. Earlier floristic surveys of KSC (Sweet 1976, Poppleton et al. 1977) included CCAS. The revised floristic list for KSC includes 1045 taxa (Schmalzer and Hinkle 1990). Chafin et al. (1996) reported 11 species of rare plants from CCAS: *Asclepias curtissii* (Curtiss' milkweed), *Chamaesyce cumulicola* (sand-dune spurge), *Cheiroglossa palmata* (hand fern), *Glandularia maritima* (coastal vervain), *Hymenocallis latifolia* (broad-leaved spider lily), *Lechea cernua* (nodding pinweed), *Pavonia spinifex* (yellow hibiscus), *Remirea maritima* (beach-star), and *Rhynchosia cinerea* (brown-haired snoutbean). *Scaevola plumieri* (inkberry) also occurs on CCAS on coastal dunes (Schmalzer and Oddy 1995).

Vegetation and Landcover Mapping

Methods

Vegetation and landcover were mapped from 1995 false color infrared imagery, the original scale of which was 1:24000. Using ARC/INFO 7.1.1, a one kilometer buffer was generated around the Atlas launch complex LC36A/B and the Delta launch complex LC17A/B. A one kilometer buffer was generated around the Titan launch complex LC40 and the Titan launch complex LC41. The area in between the two Titan launch complexes was mapped, even though it exceeded the one kilometer buffer. Ground control points (GCPs) were collected around each launch complex using Trimble Global Positioning System (GPS) (Trimble Navigation Ltd. 1991). Landcover polygons were delineated on mylar sheets overlying the photography by photo-interpretation and field ground-truthing. Polygons were labeled according to landcover, and then condensed into sixteen relevant categories: open oak scrub, oak scrub, coastal strand, dune vegetation, beach and bare sand, woody vegetation, willow and Brazilian pepper, marsh and estuarine, swale, water, coastal oak hammock forest, Australian pine, Brazilian pepper, herbaceous, roads and improved surfaces, and structures (Table 1). Map types were derived from Level III Florida Land Use, Cover and Forms Classification System (FLUCCS 1985) with certain modifications for the local environment (Larson et al. 1993). GIS coverages were created by digitizing the mylar sheets using ARC/INFO 7.1.1. The GCPs were used to register the coverages and to transform the landcover coverages to "real-world" coordinates. In order to determine vegetation and landcover impacted by launch effects, Arcview 3.0 was used to overlay landcover coverages and launch effect coverages.

Results

The dominant vegetation type around the Delta launch complex is coastal oak hammock forest (Figure 2, Table 2). Compositionally, this is a coastal scrub community that has been unburned for > 40 years and has developed into a closed canopy, low-stature forest. Herbaceous vegetation around active and inactive facilities is the second most common type. Coastal strand and dune vegetation occurs near the Atlantic Ocean.

Coastal oak hammock forest is also the dominant vegetation around the Atlas launch complex (Figure 3, Table 3) with herbaceous vegetation around facilities as the second most common type. There are significant areas of Brazilian pepper and willow-Brazilian pepper types around this complex. These occur primarily in degraded wetlands and along some roadsides.

Oak scrub is the predominant upland vegetation type near the Titan launch complexes (Figure 4, Table 4). Compositionally, this is a coastal scrub community with *Quercus virginiana* as the oak species present. Although much of this vegetation has remained unburned for decades, not as much has reached the height (> 5 m) to be considered forest as in the areas around the Atlas and Delta complexes. Coastal strand and dune vegetation occurs near the Atlantic Ocean. Substantial areas of impounded marsh and estuarine water occur west of the Titan launch complexes. Significant areas of invasive exotic vegetation, particularly Brazilian pepper and willow-Brazilian pepper types and some Australian pine occur along roads, railroads, and in other disturbed sites in this region.

Launch effects of 14 Delta launches from August 7, 1995 through November 5, 1997 were concentrated east of LC17, but single launches produced impacts north or west of the launch complex (Figure 5). Similarly, effects of twenty Atlas launches from July 31, 1995 to December 8, 1997 were concentrated east of LC36 (Figure 6), but single launches produced effects to the west. For eight Titan launches from May 14, 1995 through November 11, 1997, repeated effects occurred east of the launch complexes (Figure 7), but individual launches were more variable in direction.

Discussion

Mapped vegetation types and plant communities do not always have an exact correspondence. The mapped types of open oak scrub, oak scrub, and coastal oak hammock forest around the Delta, Atlas, and Titan launch complexes are different structural forms of the coastal scrub plant community dominated by live oak and saw palmetto with tough buckthorn and nakedwood as common associates. Time since fire and disturbance have affected vegetation height and presence of open space.

The prevalence of coastal oak hammock forest around the Delta and Atlas launch complexes (and generally on much of CCAS) is a reflection of decades of fire suppression; these areas historically were predominantly shrublands. Freshwater wetlands, particularly marshes, were common around the tip of Cape Canaveral near what now is the Atlas (LC36) launch complex. Changes in hydrology from construction and drainage along with fire suppression have allowed willow and Brazilian pepper to replace many of these marshes. Impoundment of the saline and brackish marshes along the Banana River west of the Titan launch complexes (LC40, LC41) and the construction of road and railroad causeways also facilitated the establishment of Brazilian pepper and willow-Brazilian pepper vegetation types.

Launch effects including vegetation scorching, acid and particulate deposition occurs in areas of native and disturbed vegetation. Vegetation scorching from acid and Titan launches has had some impact on small areas near the LC40, LC41, and LC36 facilities and may cause loss of shrubs with repeated defoliation

Table 1. Descriptions of types used in mapping vegetation and landcover.

Vegetation/Landcover Type	Description
Open Oak Scrub	Shrub vegetation of > 30% oak cover with abundant openings or bare sand
Oak Scrub	Shrub vegetation of > 30% oak cover with few openings or bare sand
Coastal Strand	Shrub vegetation of *Serenoa*, *Bumelia*, *Coccoloba*, *Myrcianthes*, and *Forestiera* with < 30% oak cover
Dune Vegetation	Herbaceous dune vegetation of grasses (*Uniola*, *Panicum*), forbs (e.g., *Helianthus*, *Ipomoea*), and small shrubs
Beach and Bare Sand	Unvegetated sand primarily of beaches
Woody Vegetation	Mixed shrub vegetation including *Myrica* and *Baccharis*
Willow and Brazilian Pepper	Shrub vegetation of *Salix caroliniana* and *Schinus terebinthifolius*
Marsh and Estuarine	Freshwater, brackish, or saline marshes
Swale	Shallow, ephemeral, freshwater marshes
Water	Open water of ponds, estuaries, or ocean
Coastal Oak Hammock Forest	Closed canopy, low stature forest primarily of *Quercus virginiana* and *Persea borbonia*
Australian Pine	Stands of *Casuarina* cf. *equisetifolia*
Brazilian Pepper	Shrub vegetation of *Schinus terebinthifolius*
Herbaceous	Herbaceous vegetation, usually mowed, around facilities and along roads
Roads and Improved Surfaces	Paved or gravel roads or lots
Structures	Facilities or other structures

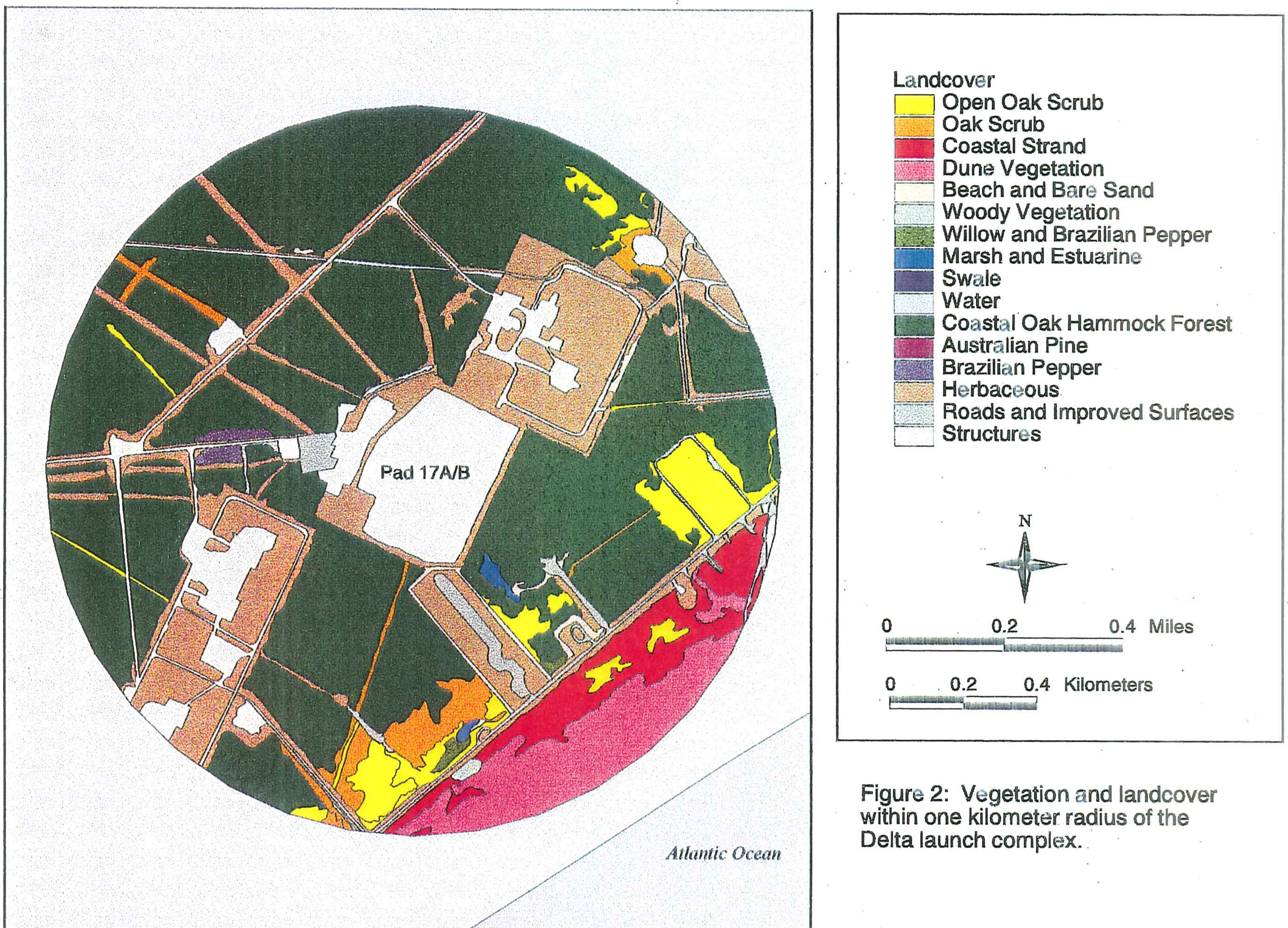


Figure 2: Vegetation and landcover within one kilometer radius of the Delta launch complex.

Table 2. Vegetation and landcover within one kilometer of the Delta launch complex, LC17.

Vegetation/Landcover Type	Area (ha)
Open Oak Scrub	14.4
Oak Scrub	7.6
Coastal Strand	11.1
Dune Vegetation	15.4
Beach and Bare Sand	2.2
Woody Vegetation	0.3
Willow and Brazilian Pepper	0.6
Marsh and Estuarine	0.7
Water	1.0
Coastal Oak Hammock Forest	158.1
Brazilian Pepper	1.1
Herbaceous	59.7
Roads and Improved Surfaces	7.2
Structures	33.1

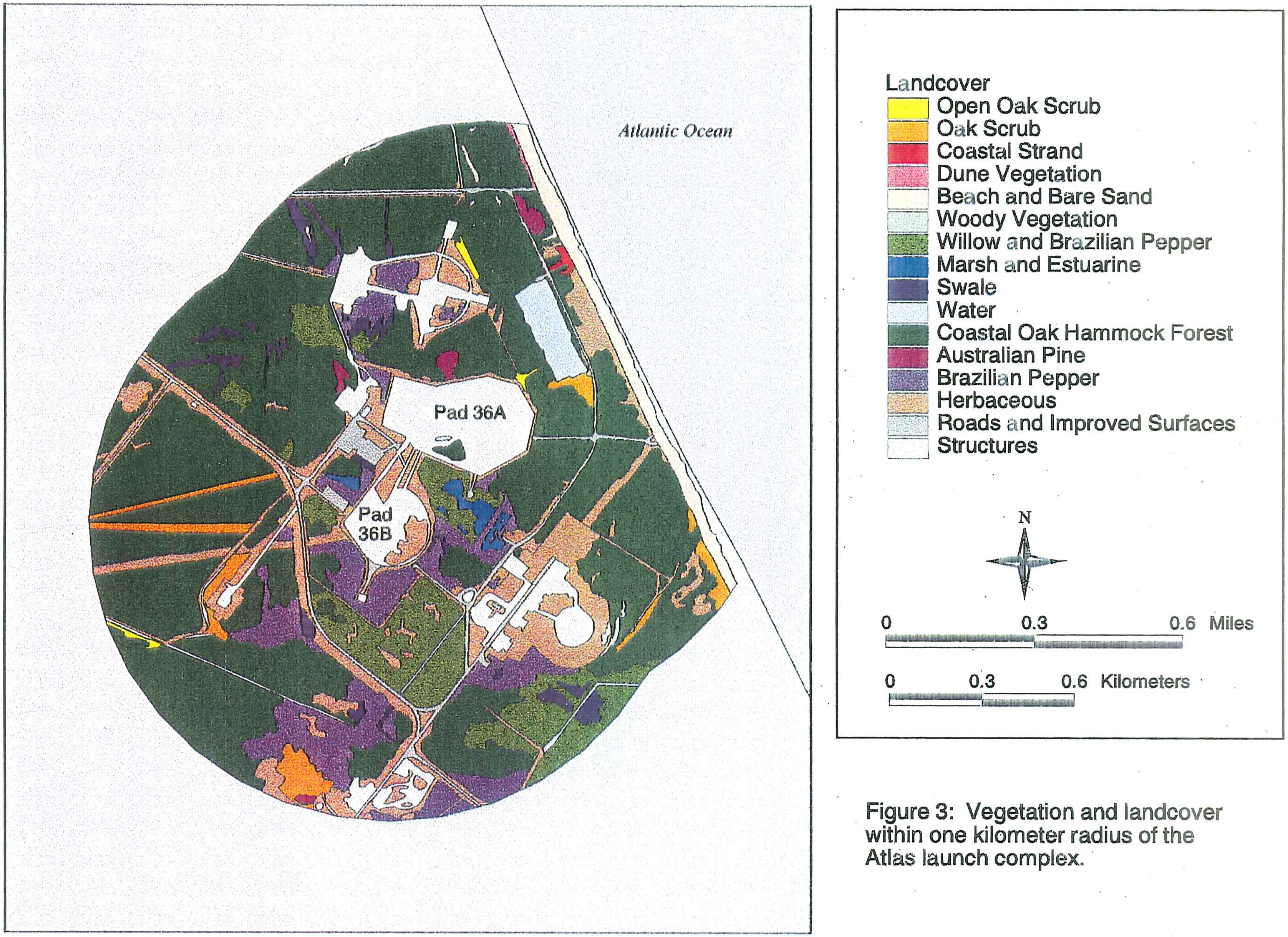


Figure 3: Vegetation and landcover within one kilometer radius of the Atlas launch complex.

Table 3. Vegetation and landcover within one kilometer of the Atlas launch complex, LC36.

Vegetation/Landcover Type	Area (ha)
Open Oak Scrub	0.8
Oak Scrub	7.7
Coastal Strand	0.4
Dune Vegetation	0.3
Beach and Bare Sand	7.4
Woody Vegetation	0.06
Willow and Brazilian Pepper	26.5
Marsh and Estuarine	1.9
Swale	6.6
Water	6.5
Coastal Oak Hammock Forest	160.2
Australian Pine	1.7
Brazilian Pepper	27.1
Herbaceous	47.4
Roads and Improved Surfaces	10.1
Structures	30.2

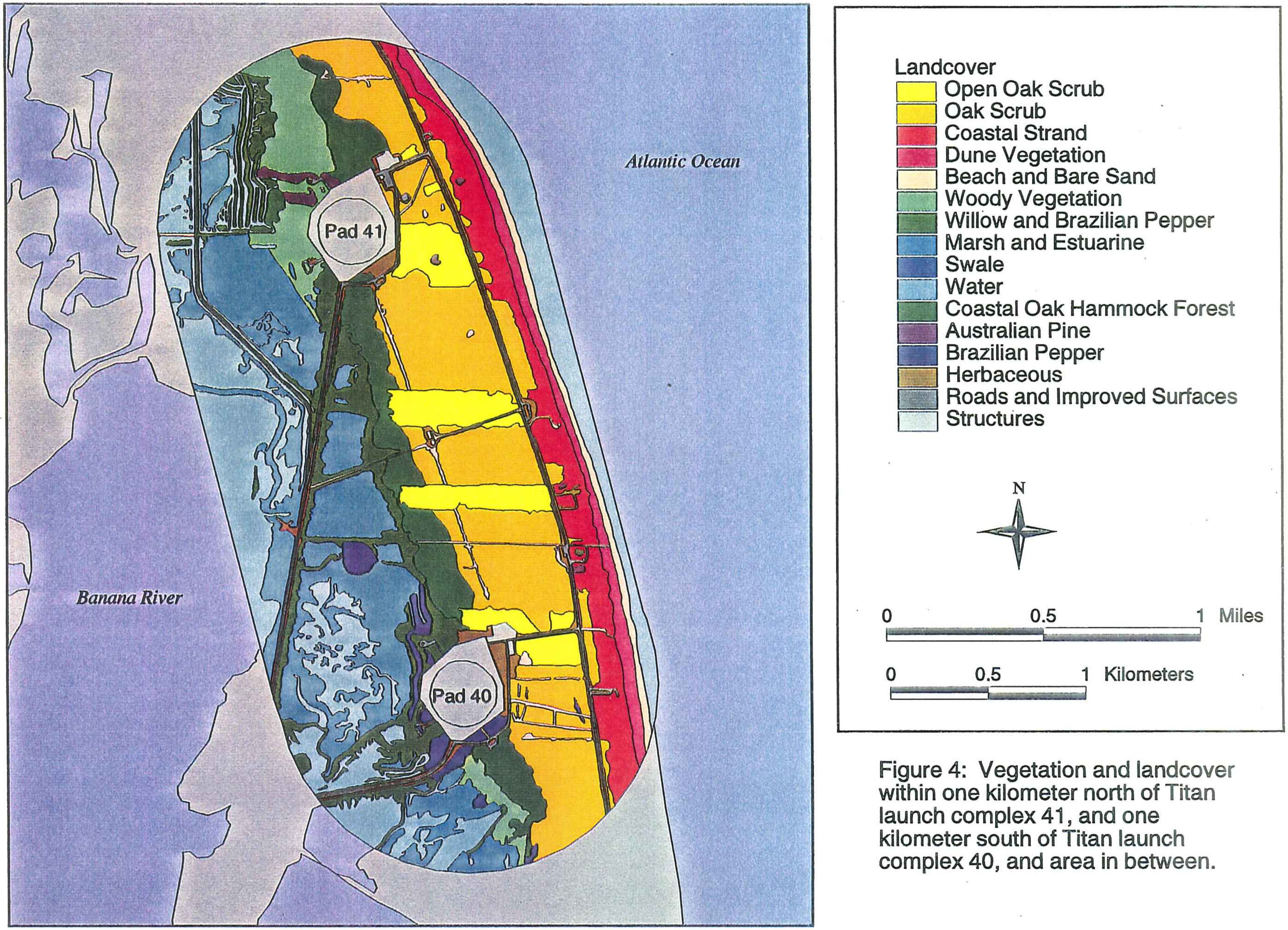
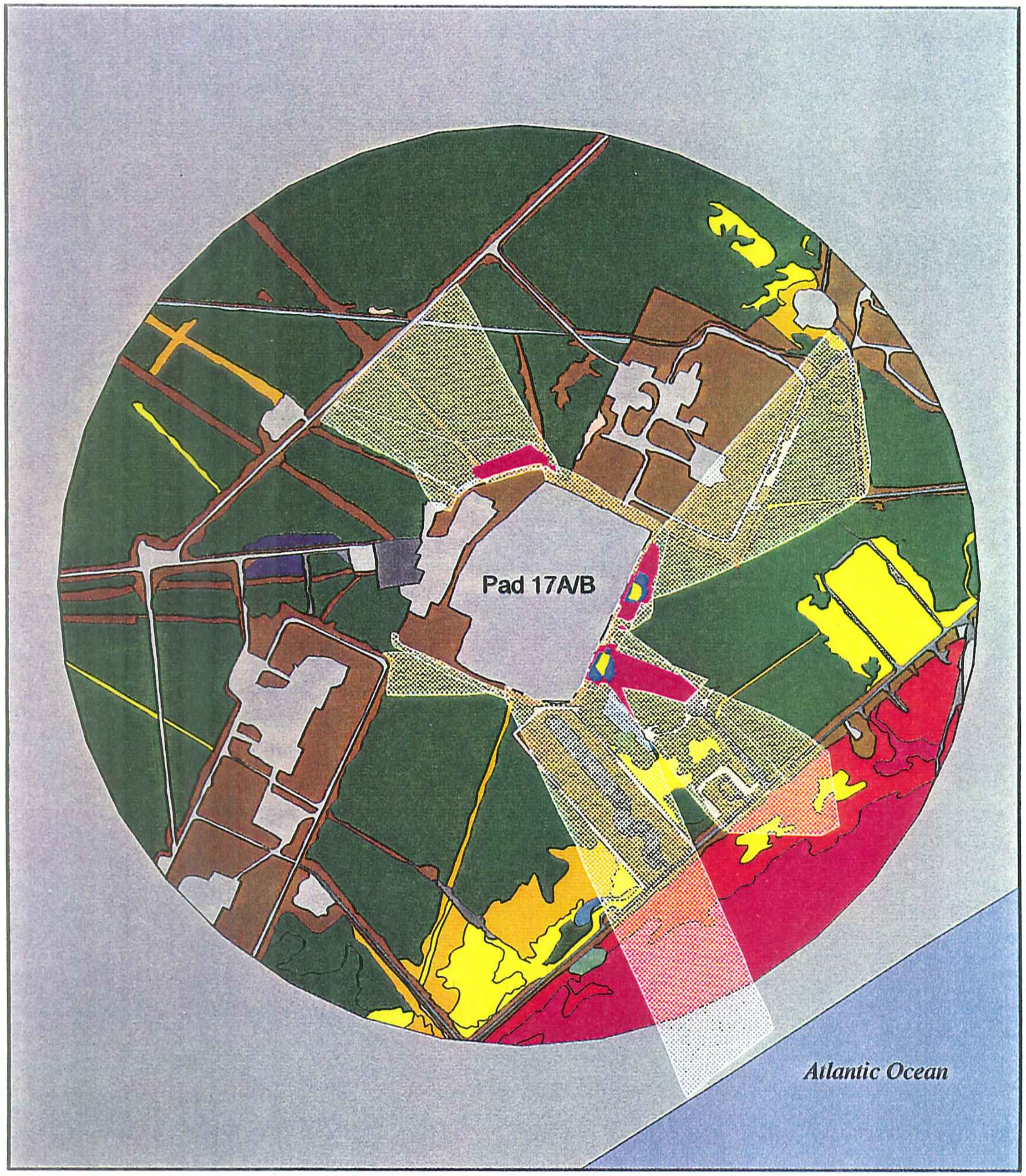


Figure 4: Vegetation and landcover within one kilometer north of Titan launch complex 41, and one kilometer south of Titan launch complex 40, and area in between.

Table 4. Vegetation and landcover from one kilometer north of Titan launch complex LC41 to one kilometer south of Titan launch complex LC40.

Vegetation/Landcover Type	Area (ha)
Open Oak Scrub	40.8
Oak Scrub	144.7
Coastal Strand	47.5
Dune Vegetation	19.2
Beach and Bare Sand	21.0
Woody Vegetation	33.4
Willow and Brazilian Pepper	57.7
Marsh and Estuarine	127.9
Swale	0.2
Water	146.0
Coastal Oak Hammock Forest	47.6
Australian Pine	3.2
Brazilian Pepper	10.8
Herbaceous	25.0
Roads and Improved Surfaces	13.0
Structures	35.5

(Schmalzer et al. 1998). Particulate deposition has no known (Figure 5) discernable negative effects on vegetation (Schmalzer et al. 1986, 1998). The acid deposition from most Titan and Delta launches is not sufficient to damage vegetation significantly; however, launches from the modified LC17B complex have produced a local acid impact zone that may become devoid of tree and shrub vegetation over time (Schmalzer et al. 1998) similar to the near-field impact zone of Space Shuttle (Schmalzer et al. 1985, 1993) although of a much smaller spatial scale.



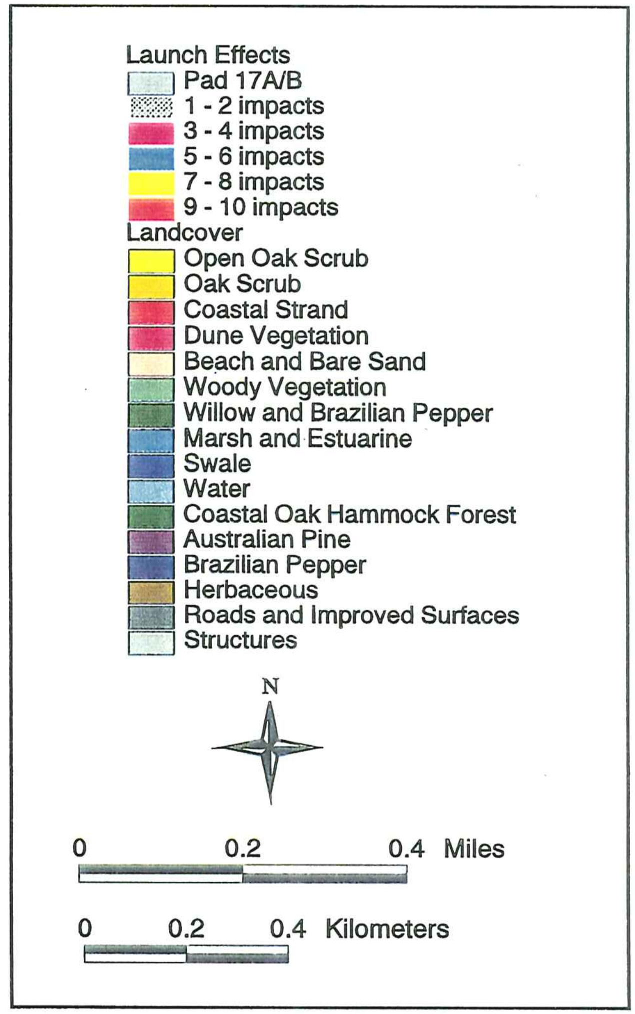


Figure 5: Vegetation and landcover impacted by Delta Rocket launch effects within one kilometer of Delta launch complex.

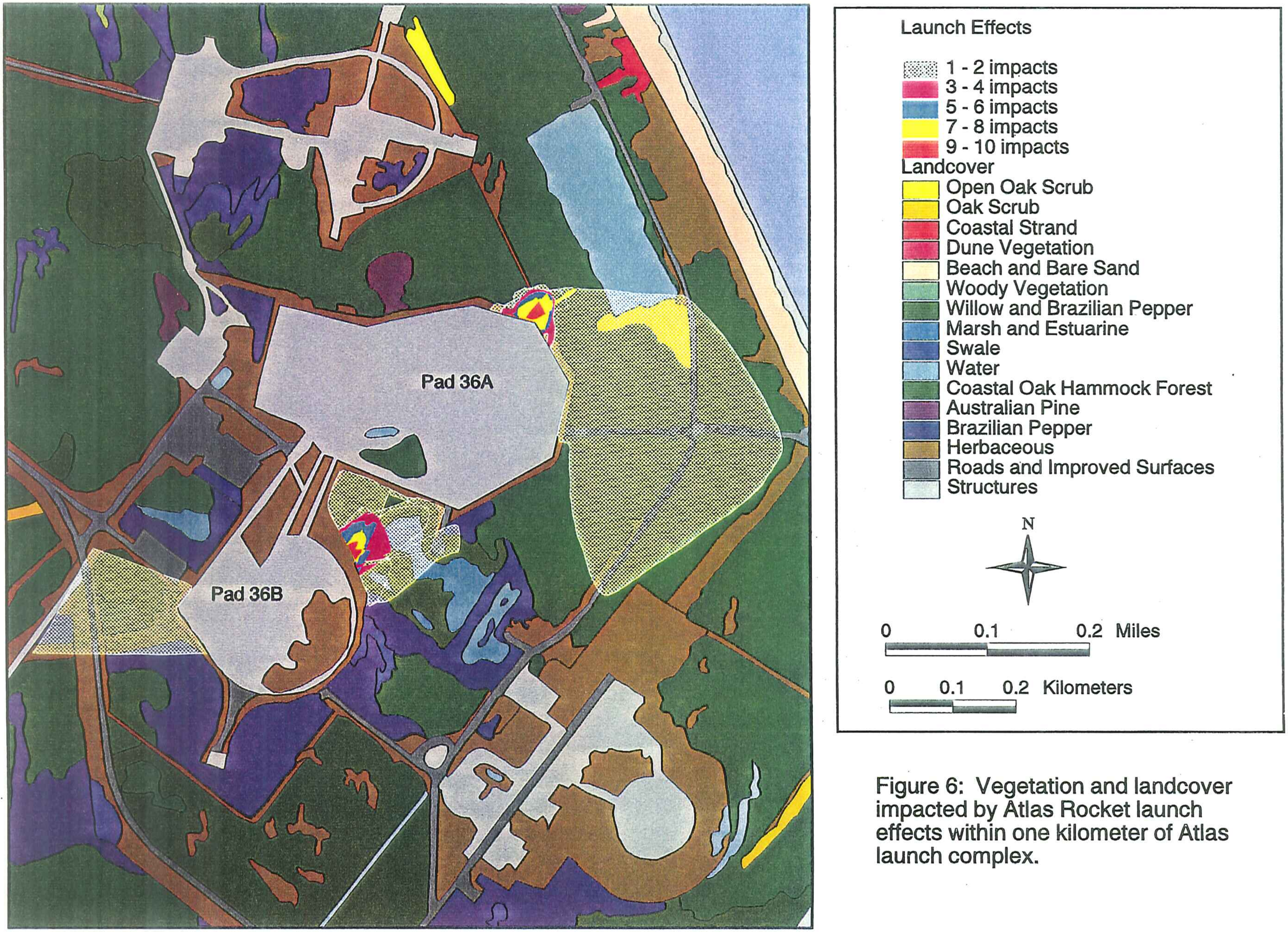


Figure 6: Vegetation and landcover impacted by Atlas Rocket launch effects within one kilometer of Atlas launch complex.

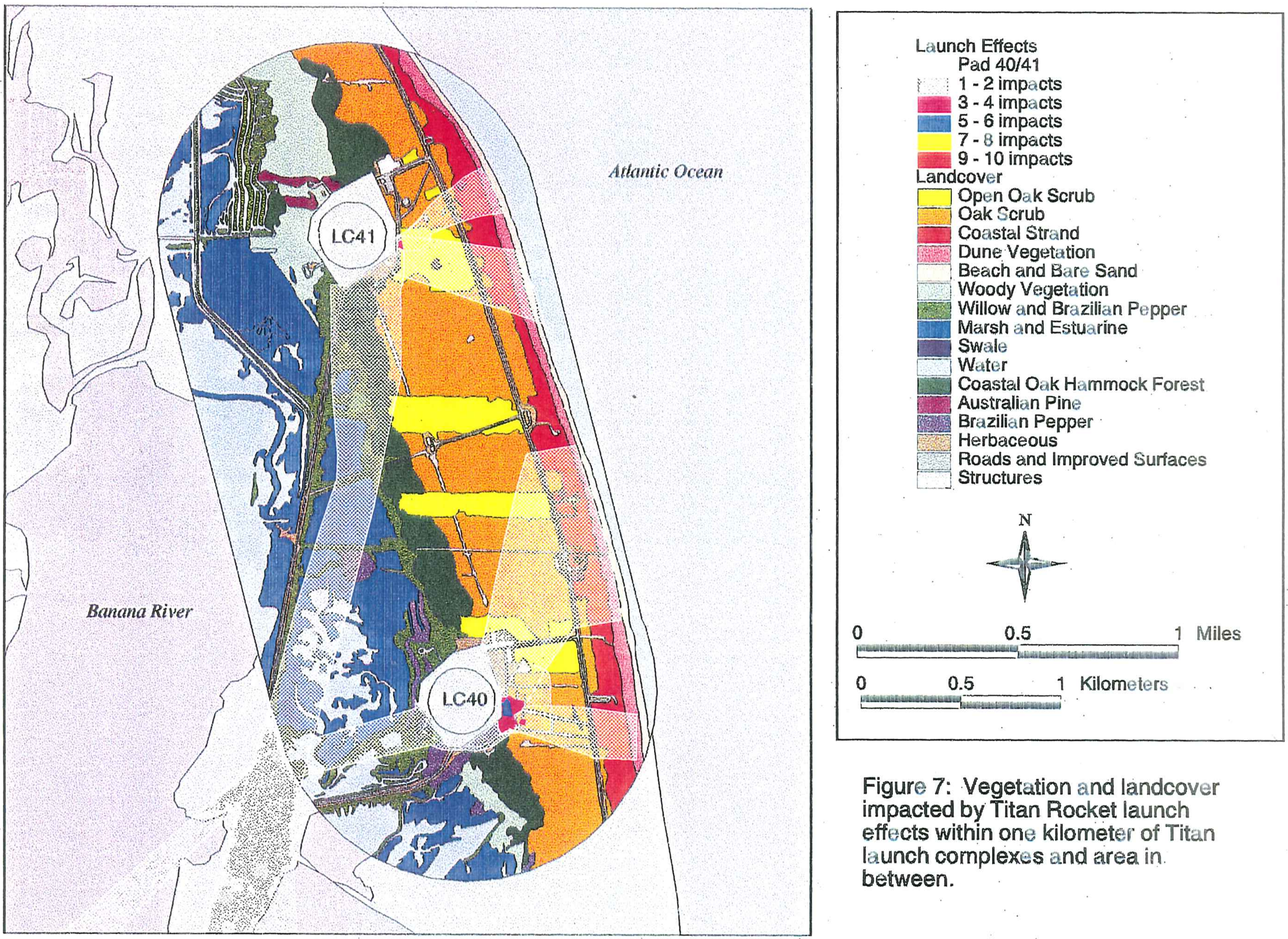


Figure 7: Vegetation and landcover impacted by Titan Rocket launch effects within one kilometer of Titan launch complexes and area in between.

Water Quality

Methods

Water quality sampling was conducted during both the wet (September 1995) and dry (January 1996) seasons to determine existing conditions and a range of buffering capacity for waters surrounding the Titan, Atlas, and Delta launch complexes. This information will be used to determine potential chemical impacts of acid deposition resulting from launch activities. There were a total of ten sampling stations at the three launch complexes:

- LC41
  - T41OC - ocean at end of the dirt road across from the LC41 entrance
  - T41IMPW - Banana River southwest of the Pad
  - T41IMPS - impoundment west of ITL Road, southernmost station
  - T41IMPN - impoundment west of ITL Road, northernmost station
- LC40
  - T40IMPW - ditch southwest of the Pad
  - T40IMPS - impoundment east of ITL Road, south of bypass road
  - T40IMPN - impoundment east of ITL Road, north of bypass road
- LC36
  - LC36A - north end of borrow pit, east of Pad A
  - LC36B - impoundment east of Pad B
- LC17
  - LC17OC - ocean at end of Camera Road A

Three replicate samples were taken at each station. In addition, three spiked samples were taken to test the accuracy of the analytical laboratory, Post, Buckley, Schuh and Jernigan, Inc. (PBS&J). Locations of all water quality stations were permanently recorded with a GPS (Trimble Navigation LTD. 1991). These locations are depicted in Figure 8.

Results

A water quality data summary giving the minimum, maximum, and mean values for each parameter at each sampling station is provided in Table 5.

Aluminum (Al)
Aluminum values ranged from below detection (0.05 mg/l) to 1.93 mg/l. LC17OC and T41IMPN had higher Al concentrations than the other sampling sites. Al was below detection for both sampling periods at T40IMPN and T41IMPS. The mean Al concentration for both sampling periods at all stations was 0.30 mg/l. Two samples collected from LC17OC on 1/8/96 were above the state water quality standard of 1.5 mg/l. All other samples were below the state standard.

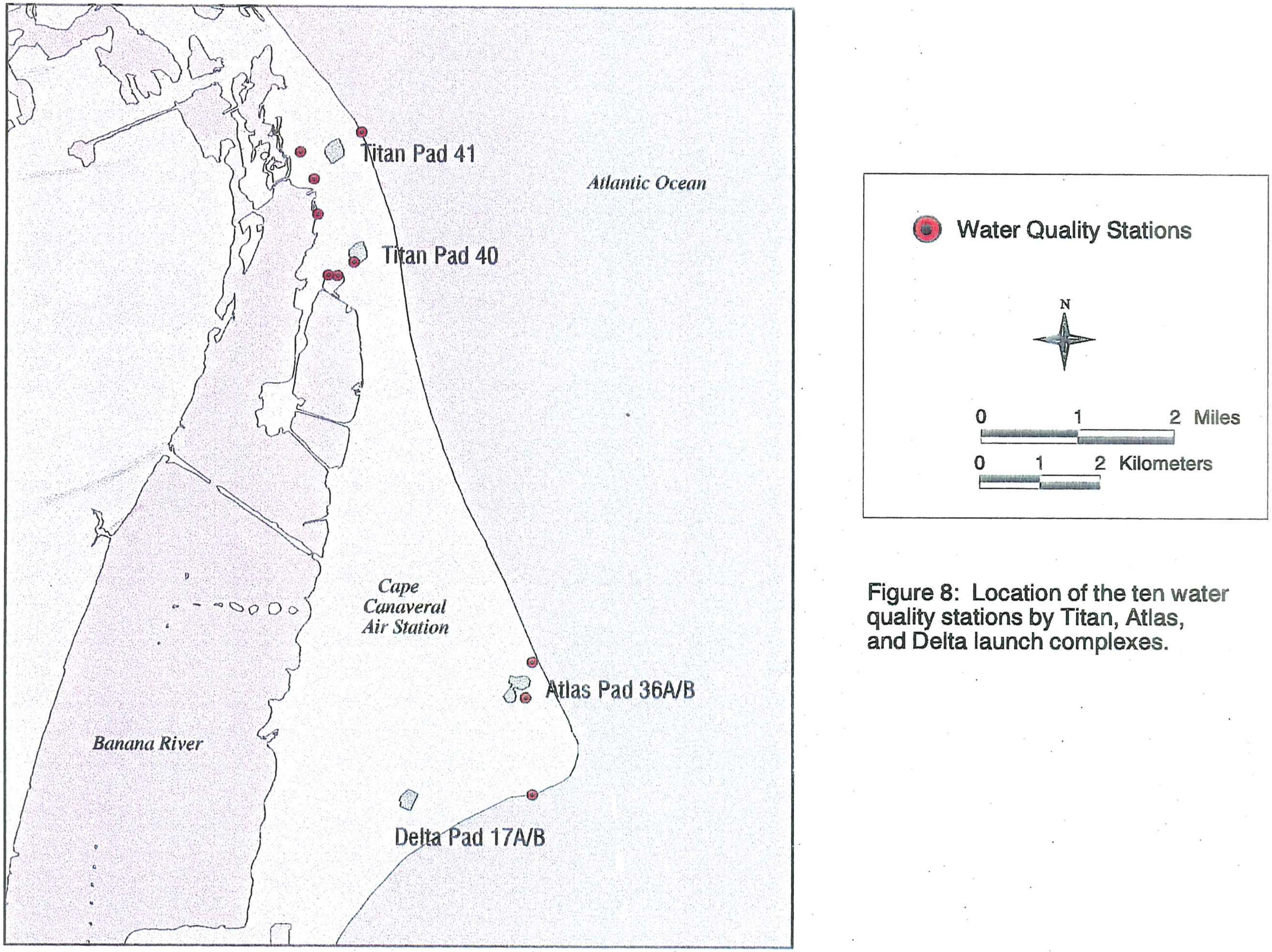


Figure 8: Location of the ten water quality stations by Titan, Atlas, and Delta launch complexes.

Table 5. Mean, minimum, and maximum values for all water quality stations and both sampling periods.

		LC17OC	*LC36A*	*LC36B*	*T40IMPN*	*T40IMPS*	*T40IMPW*	*T41IMPN*	*T41IMPS*	*T41IMPW*	*T41OC*
Aluminum	Min	0.35	0.05	0.05	0.05	0.05	0.05	0.5	0.05	0.153	0.13
mg/l	Max	1.93	0.06	0.51	0.05	0.052	0.22	1.27	0.05	0.5	0.31
	Mean	0.974	0.05	0.13	0.05	0.051	0.097	0.81	0.05	0.352	0.23
Calcium	Min	397	63.9	55.5	55.6	54.7	65.3	121	74.7	174	386
mg/l	Max	451	84.3	68.3	71.8	104	104	184	84.3	203	448
	Mean	415	74.4	62.2	64.2	79.4	84.45	153	78.3	188	403
Cadmium	Min	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
ug/l	Max	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Mean	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Chloride	Min	18610	158	115	1100	1380	6.65	4640	2240	6810	20500
mg/l	Max	23900	247	222	1670	2830	28.1	7420	2640	7760	23345
	Mean	21235	197	168	1325	2102	15.2	5962	2467	7243	22122
Conductivity	Min	48100	1045	829	3930	3870	496	12740	6630	18680	49000
umhos/cm	Max	51200	1110	922	4370	8040	889	19110	7450	20200	51000
	Mean	50100	1067	866	4052	6005	648	15905	6955	19443	49867
Chromium	Min	0.0007	0.0005	0.00067	0.0005	0.0005	0.00054	0.00083	0.00051	0.0005	0.0005
mg/l	Max	0.006	0.0021	0.0019	0.00163	0.0015	0.001	0.0041	0.00147	0.0026	0.003
	Mean	0.0028	0.00099	0.00132	0.00106	0.00101	0.00081	0.00256	0.00102	0.0015	0.0014
Iron	Min	0.2	0.02	0.002	0.02	0.02	0.03	0.2	0.02	0.106	0.065
mg/l	Max	1.1	0.033	0.38	0.062	0.082	0.24	1.25	0.025	0.208	0.79
	Mean	0.61	0.222	0.185	0.031	0.05	0.13	0.63	0.021	0.18	0.279
Magnesium	Min	1210	21	16	78	80.1	19.2	253	138	386	1230
mg/l	Max	1370	25.6	20.5	86.6	167	35.3	427	154	461	1350
	Mean	1290	23.1	18.5	83.5	124	27.1	340	146	422	1287
Sodium	Min	8700	105	81.7	600	587	7.4	2325	1070	3320	9520
mg/l	Max	10200	117	98.7	668	1300	20.3	3350	1190	3500	10100
	Mean	9512	109	92.7	624	940	11	2834	1133	3439	9825
Nickel	Min	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
mg/l	Max	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	Mean	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Table 5 (continued).

		LC17OC	LC36A	LC36B	T40IMPN	T40IMPS	T40IMPW	T41IMPN	T41IMPS	T41IMPW	T41OC
pH	Min	8.08	8.04	7.65	7.91	7.58	7.59	7.98	7.82	7.61	8.07
	Max	8.21	8.14	8.09	7.97	7.98	7.84	8.2	8.18	7.96	8.21
	Mean	8.15	8.1	7.93	7.94	7.82	7.72	8.11	8.03	7.81	8.15
Tot. Alkalinity mg/l $CaCO_3$	Min	110	199	225	212	206	165	173	194	172	106
	Max	130	205	256	234	247	351	183	263	186	253
	Mean	121	203	241	223	228	258	178	229	180	140
Total Organic Carbon mg/l as C	Min	1	5.8	10.2	32.1	18.9	9.71	26.1	30.1	12.8	1
	Max	7	10.3	37	20.6	28.3	15.8	54	40.3	24.7	6.92
	Mean	3.64	7.99	18.4	27.3	26.3	14.3	36.4	35.2	18.4	3.58
Zinc mg/l	Min	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
	Max	0.1	0.06	0.03	0.1	0.03	0.05	0.1	0.03	0.1	0.1
	Mean	0.055	0.03	0.015	0.03	0.013	0.029	0.047	0.017	0.062	0.055

Calcium (Ca)
Calcium concentrations ranged from 54.7 mg/l to 451 mg/l with an overall mean of 157 mg/l. Higher Ca concentrations were observed at LC17OC and T41OC, the two stations located in the ocean, than at the other launch complexes. Ca is one of the major constituents of sea salts (Gross 1972).

Cadmium (Cd)
All samples were below detection (0.2 ug/l - 9/95, 0.4 ug/l - 1/96) for Cd. The state surface water quality standard for Cd is 9.3 ug/l.

Chloride (Cl)
Chlorides ranged from 6.65 mg/l to 23,900 mg/l with the highest concentrations found at LC17OC and T41OC. Cl^- is the most abundant constituent of sea salts (Gross 1972). The overall mean Cl concentration was 6,284 mg/l. The lowest concentrations were observed at T40IMPW.

Conductivity (COND)
Conductivity values ranged from a low of 496 umhos/cm at T40IMPW to a high of 51,200 umhos/cm at LC17OC. Conductivity was also high at T41OC. The mean conductivity value for all stations was 15,490 umhos/cm. The mean value for the inland sites only was 6,868 umhos/cm.

Chromium (Cr)
Chromium values were fairly consistent for all stations during both sampling periods. The values ranged from 0.0005 mg/l (detection limit) to 0.006 mg/l. The mean Cr concentration was 0.003 mg/l. Cr levels were below the state standard of 0.05 mg/l at all sites.

Iron (Fe)
Iron concentrations ranged from 0.0019 mg/l to 1.25 mg/l. The highest levels were found at LC17OC and T41IMPW. The mean Fe concentration was 0.23 mg/l. The state water quality standard of 0.3 mg/l was exceeded a total of six times at four different stations (LC17OC, LC36B, T41IMPN (3 times), T41OC).

Magnesium (Mg)
The minimum magnesium concentration observed was 16 mg/l while the maximum was 1,370 mg/l. Stations LC17OC and T41OC had the highest values. Mg is a major constituent of seawater (Gross 1972). The overall mean Mg concentration was 363 mg/l.

Sodium (Na)
Sodium concentrations were the highest at LC17OC and T41OC. Na^+ and Cl^- make up 86 percent of sea salt (Gross 1972). The lowest values were observed

at T40IMPW. Na concentrations ranged from 7.4 mg/l to 10,200 mg/l with a mean of 2,758 mg/l.

Nickel (Ni)
All samples were below the detection limit of 0.005 mg/l. The state standard for Ni is 0.0083 mg/l.

pH
The pH ranged from 7.58 to 8.21 with a mean of 7.97 pH units. These values were fairly consistent between stations.

Total Alkalinity (TAK)
Alkalinity is the capacity of water to neutralize acid (Tchobanoglous and Schroeder 1985). The lowest total alkalinity values were observed at LC17OC and T41OC, the ocean sites. TAK concentrations ranged between 106 mg/l $CaCO_3$ and 351 mg/l $CaCO_3$ with a mean value of 200 mg/l. The highest concentration was found at T40IMPW.

Total Organic Carbon (TOC)
Total organic carbon concentrations ranged from 1.0 mg/l as C to 54 mg/l as C. The overall mean was 19.1 mg/l as C with the lowest average values found at LC17OC, LC36A, and T41OC. The highest concentrations were observed at T41IMPN.

Zinc (Zn)
The mean zinc concentration for all sample stations was 0.03 mg/l. Values ranged from 0.01 mg/l to 0.1 mg/l. Both of these values were laboratory detection limits. The state water quality standard for Zn is 0.086 mg/l.

The environment surrounding the launch complexes on CCAS has a large natural buffering capacity or acid neutralizing capacity (ANC) present in soils and surface waters. This ANC is composed primarily of $CaCO_3$ and $MgCO_3$, common constituents found in seawater and geologically recent, marine derived soils. Acid deposition in rainfall and that resulting from space vehicle launches will consume this acid-neutralizing capacity through chemical reactions between acids and bases. However, the natural background levels are high, and there are natural sources for replacement of this $CaCO_3$ buffer including: ocean spray and aerosol deposition, sediments, soils, runoff, and groundwater. Depletion of the $CaCO_3$ system can result in changes to ecosystem physical and chemical properties including disruption of the natural cation exchange complex, alteration of soil microbiological communities, loss of soil organic matter, changes in particle adsorption metal associations, and other complex biological and chemical relationships (Altshuller and Linthurst 1984, Dillon et al. 1984, Dreschel and Hall 1990). The acid-neutralizing ability of the impoundment and oceanic waters adjacent to the launch pads has been calculated from the total alkalinity

(TAK) measurements expressed as mg/l of $CaCO_3$. Based on mass balance equations, the TAK measured in these surface waters will be consumed by the amount of HCl listed in Table 6. Buffering capacities based on TAK as $CaCO_3$ concentrations observed at the ocean sampling stations were estimated for LC17 and LC41. These values represent the mg of HCl that will consume the acid-neutralizing capacity, or $CaCO_3$, of one liter of surface water at the launch sites.

Table 6. Acid-neutralizing capacity of surface waters at launch pads.

Launch Complex	Total Alkalinity as $CaCO_3$ (mg/l)	HCl (mg)
LC17 (ocean)	121	87
LC36A	203	146
LC36B	241	174
LC40	236	170
LC41	196	141
LC41 (ocean)	140	101

Conclusions

Water quality samples were collected at the Titan, Atlas, and Delta launch complexes in September 1995 and January 1996. Samples were analyzed for heavy metals, Cl, TOC, Ca, Fe, Mg, Na, TAK, pH and COND. Values for metals and mineral constituents were consistently higher at LC17OC compared to the other sampling sites. T41OC also had high concentrations of Ca, Cl, Mg, and Na, major constituents of seawater. Both LC17OC and T41OC are located in the ocean. Cadmium and Ni levels were below detection at all sample sites during both sampling periods. Only Al (at LC17OC) and Fe (at LC17OC, LC36B, T41IMPN, and T41OC) concentrations were above state standards in some of the samples. The Atlas, Delta, and Titan launch systems currently employed produce relatively minor amounts of acid deposition. The natural buffering capacity of the environment surrounding the CCAS launch complexes is adequate for neutralizing acid deposition in rainfall and launch deposition.

Recommendations

An effort should be made to work with the analytical laboratory to obtain consistent detection levels that are below the state standards. Bi-annual water samples should be collected to determine natural variability in water quality at these launch complexes. Permanent sampling stations should be established as part of a long-term monitoring program.

Threatened, Endangered, and Species of Special Concern found within a One Kilometer Radius of the Titan, Delta, and Atlas Launch Complexes.

Florida Scrub-Jay Biology

The Florida Scrub-Jay is a federally and state listed threatened species (Wood 1996). Most habitat on CCAS is marginal for Florida Scrub-Jays because of fire suppression. However, CCAS and KSC combined provide potential habitat for one of three of the largest core populations that remain (Cox 1984, 1987; Breininger 1989, Stith et al.1996).

Florida Scrub-Jays inhabit all-purpose territories defended year-round by one breeding pair (Woolfenden and Fitzpatrick 1984, Breininger et al. 1995). The Florida Scrub-Jay has a cooperative breeding system where young Florida Scrub-Jays usually remain as nonbreeders (helpers) with the breeding pair for at least a year, assisting in territory defense, predator identification and mobbing, and the care of nestlings (Woolfenden and Fitzpatrick 1984).vvBreeders with helpers have greater reproductive success and lower mortality rates than breeders without helpers (Woolfenden and Fitzpatrick 1984, Breininger et al. 1996a). Florida Scrub-Jays (nearly always) mate for life and defend the same territory. Florida Scrub-Jay mortality is almost always caused by predation (Woolfenden and Fitzpatrick 1984, Woolfenden and Fitzpatrick 1991). They have a highly developed sentinel system that is important for detecting hawks (McGowan and Woolfenden 1989). Hawks are especially common at both CCAS and KSC during migration because the Atlantic coast is a hawk migration route (Heintzelman 1986). When mortality of a breeder occurs, the vacancy is typically filled in a week to a few months by the excess of potential breeders, which are the current helpers in the population. The timeliness in which replacement of dead breeders takes place depends on the suitability of the habitat in the vacated territory and the number of excess nonbreeders within a reasonable immigration distance to the vacancy (Breininger et al. 1996a). Florida Scrub-Jays are characterized as sedentary, having a low average dispersal distance, 1000 m for females and 300 m for males (Breininger et al. 1995) from their natal territory.

Areas occupied by Florida Scrub-Jays include oak, oak/palmetto and coastal scrub habitats as well as ruderal and disturbed areas in the coastal regions of Merritt Island and Cape Canaveral (Breininger 1981, Breininger et al. 1991). Many of these areas include patches of remnant scrub in a human altered landscape (e.g., areas surrounding LC40, LC41, PS7, LC17, and LC36). Population size of the Florida Scrub-Jay is influenced by the amount of available habitat and habitat suitability. Scrub oak cover, open space (i.e., sandy areas or areas of sparse vegetation <15 cm tall) and fire are important factors in evaluating the quality of Scrub-Jay habitat (Breininger 1992, Breininger et al. 1995). Several studies indicate significant correlations between Florida Scrub-

Jay demographic success and habitat characteristics (Breininger 1981, 1992; Cox 1984, Breininger et al. 1995, Duncan et al. 1995).

Scrub is a fire driven natural community (Myers 1999, Woolfenden and Fitzpatrick 1990). At Archbold Biological Station (ABS) the quality of the habitat for Florida Scrub-Jays is influenced by a 8-20 year fire regime (Woolfenden 1974, Fitzpatrick et al. 1991, Woolfenden and Fitzpatrick 1991). This fire regime may be suitable for the Lake Wales Ridge but is not frequent enough for KSC/MINWR/CCAS (Breininger et al. 1996b). Scrub at KSC/MINWR/CCAS has a higher water table, more nutrients, and a more poorly drained matrix than some mainland scrubs (Schmalzer and Hinkle 1987, 1992; Breininger et al. 1991a, 1995). Prior to European settlement, fire was frequent in the landscape at KSC/MINWR/CCAS (Breininger et al. 1996b). This frequent fire resulted in an open landscape. Agricultural practices and the development of the space program resulted in soil disturbances, fire suppression, and increased habitat fragmentation from roads and facilities (Breininger et al. 1996b). As a result, many patches of scrub and marsh became forests, most open sandy areas in scrub became closed, and shrub height and pine densities increased (Breininger et al. 1996b, Duncan et al. 1996, Duncan et al. 1999).

Although Scrub-Jays occupy a variety of habitat conditions, they aren't demographically successful in all areas (Breininger et al. 1998). This situation, where mortality exceeds reproductive success (i.e., population sink), may affect a large portion of the population (Pulliam 1988, Howe et al. 1991, Pulliam and Danielson 1991). Demographic attributes such as the number of breeders lost to mortality and the number of one year old birds produced can be assigned to territories to study source (i.e., reproductive success exceeds mortality) and sink patterns within the study areas. Long-term Florida Scrub-Jay studies on KSC are characterizing the complex spatial and temporal relationship between habitat and demographic patterns (Breininger et al. 1995, Breininger et al. 1996a, Duncan et al. 1995, 1996).

Methods

This study was conducted from July 1995 to March 31, 1998. The normal Scrub-Jay study year begins on April 1st and ends March 31st. Standard bird banding and census techniques (Woolfenden and Fitzpatrick 1984, Verner 1985) as well as habitat mapping procedures (Breininger et al. 1995, Duncan et al. 1995) wer highest stress during launch operations. The study areas LC40, PS7 and LC41 at the Titan area were analyzed together.

The Titan area jays had been previously monitored (1990-1995); many were already banded, although immigrants and nestlings continued to be banded throughout the study. The Nature Conservancy (TNC) personnel banded many of the jays at LC17 in 1995, while jays at LC36 were banded in 1995 and 1996. Additional unbanded residents, immigrants, and nestlings continued to be banded throughout the study. Scrub-Jays were trapped using Potter and drop traps baited with peanut bits. Each jay was banded with two-three colored bands and one USFWS aluminum band allowing recognition of individual birds.

A complete census of each study area was conducted once per month, except when access to the study areas was denied for safety or security purposes. Each family was visited at least once per week during nesting (March-June) to determine the status of nesting. Censuses were performed to determine presence/absence of residents and changes in family composition. Breeders, nonbreeders, and sexes were distinguished using behavioral attributes described by Woolfenden and Fitzpatrick (1984). Changes in family composition (i.e., the number of individuals comprising a territory) were defined in four ways: mortality, budding of a new territory, dispersal, or by creation of a *denovo* territory. Family composition was determined in April, during peak nesting season, based on behavior (Woolfenden and Fitzpatrick 1984). Since breeders have shown a very low incidence of divorce (Woolfenden and Fitzpatrick 1984), breeders that disappeared from the study areas were assumed dead.

Territory boundaries were mapped on false color aerial infrared imagery during April and May of each year and were delineated within a few meters. Boundaries were determined by observing territorial disputes and inciting disputes between neighboring families when necessary. If a territory did not persist through May (i.e., a breeding pair was lost and the territory dissolved) no boundary was mapped for that family; however, demographic data for these families were included in analyses. In addition, if a territory was formed during this time period but didn't nest, the territory boundary was still mapped and used in analyses. Territory maps for 1996 and 1997 were digitized as separate GIS coverages using ARC/INFO version 6.11 (ESRI 1992), and territory sizes were determined.

Nest attempts for each group were located between March and June. Nest locations were mapped and digitized into GIS coverages. All GIS coverages were registered in state plane coordinates, from GCP locations, collected in the field using a GPS (Trimble Navigation, LTD 1991). Nests were checked at least once a week. Nestlings and fledglings were aged according to descriptions by Woolfenden (1974). Nestlings were banded when the youngest bird was 11 days old. Fledglings were estimated as the number of young counted in or near the nest around day 16-17 after hatching. A nest was considered successful if at least one fledgling was observed. Undetermined successes occurred when there was no evidence of nest failure or predation, but no fledglings were observed. Nests that failed as eggs or nestlings for any reason (e.g., predation, abandonment) were considered unsuccessful. Field surveys conducted in July determined the number of young per family that were approaching independence (i.e., 90 days old) within the study areas.

Pre-launch surveys of the study areas were conducted before each launch (usually twenty-four hours) when permitted. Post-launch surveys were conducted during the nearest daylight hours after launch. Field investigations included a census of families and observations regarding individual's behavior.

Territory sizes were quantified by totaling the amount of suitable habitat within territory boundaries (Woolfenden and Fitzpatrick 1984, Breininger et al. 1995). Estimates of mortality, reproductive success, territory success and dispersal were calculated from census data and were used to characterize demography of each study area. Mortality estimates were derived from breeders that disappeared between April and March of the following year. The number of young birds surviving to one year old determines reproductive success. Estimates of success for territories within the study are calculated by subtracting the number of breeders lost from the number of yearlings produced within the territory. Because this study ranged from July 1995-March 31, 1998 and a Scrub-Jay year is from April 1-March 31, reproductive and territory success and mortality estimates were incomplete for 1995.

Results

Launch Impacts

A total of eight Titan, fifteen Delta, and twenty-two Atlas launches occurred during the study (see Schmalzer et al. 1998, Tables 3, 4, and 5). These launches affected the habitat surrounding the Titan, Delta, and Atlas Launch Complexes. Launch effects included scorching of areas adjacent to the flame trenches of the launch complexes, near-field deposition (acid and particulate), and far-field deposition (primarily particulate) (Figures 5, 6, and 7). In addition, entrained sand grains from the blasts were often observed on leaf surfaces. No Scrub-Jay mortality could be associated with impacts from any of the launches. No Scrub-Jays showed signs of distress, and each responded to calls by investigators.

Thirty-seven to forty-one territories were located at Titan, Atlas, and Delta Launch Complexes between 1995 and 1997 (Figures 9, 10, and 11). Mean territory size ranged from 2.45 to 4.86 ha for 1996 and 2.6 to 5.7 ha for 1997 with a total mean for the three study areas of 4.06 ha and 4.83 ha for 1996 and 1997 respectively (Table 7). Yearly mean family size ranged from 2.15 to 2.70 with a total mean equal to 2.39 for the three study areas (Table 8). Family size was slightly larger at Delta and Titan than at Atlas in 1997, while in 1996 Atlas was the largest followed by Titan and Delta. Annual breeder survival ranged from 0.50 to 1.00 both at Atlas with a mean breeder survival rate of 0.76 (Table 9). The number of breeders lost was nearly equal at the three study areas in 1996, but more than doubled at both Titan and Delta in 1997 (Table 8). The annual number of yearlings produced per pair was higher at Atlas than Delta and Titan with 0.46 yearlings per pair compared to 0.30 and 0.25 yearlings per pair, respectively (Table 10).

Table 7. Mean territory sizes for Florida Scrub-Jays at Titan, Atlas, and Delta Launch Complexes for 1996 and 1997.

	1996			1997		
Area/ Habitat Type (ha)	Titan (n = 23)	Atlas (n = 5)	Delta (n = 13)	Titan (n = 23)	Atlas (n = 3)	Delta (n = 15)
Fair *	3.72	2.45	4.86	4.18	2.6	5.7
Poor	1.83	3.87	2.34	1.86	2.34	1.55
Non	0.39	5.26	0.53	0.34	1.87	0.52
Total Area Defended	5.83	11.58	7.73	6.76	6.81	7.76

* Territory sizes are determined from this habitat type only.

The number of yearlings produced was subtracted from the number of breeders lost per territory to determine territory success. Territories at Atlas were commonly more successful (i.e., yearling production > breeder mortality) than territories at Delta or Titan (Table 11).

Nests were most common in oak and coastal scrub where tough buckthorn and dwarf live oak accounted for 65% of the nest site species (Table 12) for 1996 and 1997. The remaining 35% included the following species: wax myrtle, nakedwood, sea grape, Brazilian pepper, Surinam cherry (*Eugenia uniflora)*, rapenea and Florida privet. Nests were most common along edges of scrub, mowed grass, or sand habitats or in isolated shrubs in open habitat (Figures 9, 10, and11).

Fifty-six percent of all nests in 1996 at Titan, Delta, and Atlas were unsuccessful and 33% produced fledglings or nestlings that were nearly old enough to fledge (Day 16) (Table 8). In 1997, 65% of nests were unsuccessful, and 16.7% were successful. Delta had the highest percent of successful nests for 1996/1997 at 31.1% followed by Titan at 16.9%. Nest success was lowest at Atlas for 1996/1997, in which only 16.7% of the nests were successful. Nearly two times

Table 8. Yearly demographic characteristics of Florida Scrub-Jay territories at Titan, Atlas and Delta Launch Complexes, Cape Canaveral Air Station.

	Years of Study								
	Titan		Atlas		Delta				
	1996	1997	1996	1997	1996	1997	Total	Mean	SD
Study area (ha)	134.15	155.38	57.90	20.42	100.47	116.42		N/A	N/A
No. Families	23	23	5	3	13	15		N/A	N/A
No. Families/ha	0.17	0.15	0.09	0.15	0.13	0.13		0.14	0.03
No. Birds	53	65	12	7	30	41		N/A	N/A
Mean Family Size	2.21	2.60	2.40	2.30	2.14	2.7		2.39	0.20
Nest Attempts	27	34	7	5	18	27	118	N/A	N/A
Nest Attempts/Family	1.13	1.36	1.40	1.67	1.29	1.8		1.44	0.23
Successful Nests	6	9	1	1	11	3	31	N/A	N/A
Successful Nests/Family	0.25	0.36	0.20	0.33	0.79	0.2		0.36	0.20
No. Fledglings	11	18	1	2	15	6	53		
Fledglings/Nest Attempts	0.41	0.53	0.14	0.40	0.83	0.22		0.42	0.22
Dispersals	1	4	0	0	1	0	6	1.00	1.41
Breeders Lost	6	14	5	2	5	13	45	N/A	N/A
Breeders Lost/Total	0.11	0.22	0.42	0.29	0.17	0.31		0.25	0.10
Nonbreeding Adults Missing	1	4	0	1	1	2	9	N/A	N/A
Nonbreeding Adults Missing/Total	0.02	0.06	0.00	0.14	0.03	0.05		0.05	0.04
Young Lost (1)	3	17	0	0	5	5	30	N/A	N/A
Young Lost/Total	0.06	0.26	0.00	0.00	0.17	0.12		0.10	0.09

SD= standard deviation
Total= total number of birds within study area
(1) birds less than one year old

Table 9. Annual survival rates of Florida Scrub-Jay breeding adults at Titan, Atlas, and Delta Launch Complexes, Cape Canveral Air Station.

	Titan				Atlas				Delta			
Year	N	Deaths	Annual Mortality	Mean Survival	N	Deaths	Annual Mortality	Mean Survival	N	Deaths	Annual Mortality	Mean Survival
1995 *	48	8	0.17	0.83	4	0	0.00	1.00	22	3	0.14	0.86
1996	48	6	0.13	0.88	10	5	0.50	0.50	28	5	0.18	0.82
1997	50	14	0.28	0.72	6	2	0.33	0.67	30	13	0.43	0.57
Total	146	28	0.57	2.42	20	7	0.83	2.17	80	21	0.75	2.25

* Data for this year is incomplete (July-December)

Table 10. Annual production of young Florida Scrub-Jays at Titan, Atlas, and Delta Launch Complexes, Cape Canaveral Air Station.

	Titan				Atlas				Delta			
Year	No. pairs	Fledgl./ pair	Juven./ pair	Yearl./ pair	No. pairs	Fledgl./ pair	Juven./ pair	Yearl./ pair	No. pairs	Fledgl./ pair	Juven./ pair	Yearl./ pair
1995*	24	1.08	0.71	0.38	2	---	1.50	0.50	11	---	0.27	0.18
1996	24	0.46	0.42	0.33	5	0.20	0.20	0.20	14	1.07	0.86	0.71
1997	25	0.72	0.48	0.04	3	0.67	0.67	0.67	15	0.40	0.20	0.00
Mean Production		0.75	0.54	0.25		0.44	0.79	0.46		0.74	0.44	0.30

*Data incomplete (collected from July 1995-March 1996).

Table 11. The success of Florida Scrub-Jay territories at Titan, Atlas, and Delta Launch Complexes, Cape Canaveral Air Station.

	Titan				Atlas				Delta			
	*1995	1996	1997	TOTAL	*1995	1996	1997	TOTAL	*1995	1996	1997	TOTAL
Yearlings Production	9	8	1	18	1	1	2	4	2	10	1	13
Breeders Lost	8	6	14	28	0	5	2	7	3	5	13	21
Territory Success (1)	1	2	-13	-10	1	-4	0	-3	-1	5	-12	-8

(1) Territory success = yearling production - breeders lost
* Data for this year is incomplete (July-December)

Table 12. Plant species in which Florida Scrub-Jay nests were located at Titan, Atlas, and Delta Launch Complexes for 1996 and 1997.

Plant Species	Number of Nests		
	1996	1997	Total
Launch Complex 40			
Bumelia tenax	2	3	5
Quercus virginiana	1	1	2
Coccoloba uvifera	0	1	1
Rapenea punctata	0	1	1
Schinus terebinthifolius	1	0	1
Subtotal	4	6	10
Launch Complex 41			
Bumelia tenax	5	4	9
Forestiera segregata	4	3	7
Coccoloba uvifera	1	0	1
Myrica cerifera	1	2	3
Quercus virginiana	3	3	6
Rapenea punctata	0	1	1
Schinus terebinthifolius	1	3	4
unconfirmed species	0	1	1
Subtotal	15	17	32
Pump Station 7			
Bumelia tenax	3	2	5
Myrcianthes fragrans	1	1	2
Myrica cerifera	1	1	2
Quercus virginiana	3	6	9
unconfirmed species	0	1	1
Subtotal	8	11	19
Launch Complex 17			
Bumelia tenax	8	12	20
Coccoloba uvifera	4	4	8
Myrica cerifera	1	2	3
Quercus virginiana	4	8	12
unconfirmed species	1	1	2
Subtotal	18	27	45
Launch Complex 36			
Bumelia tenax	2	4	6
Forestiera segregata	1	1	2
Eugenia uniflora	1	0	1
Quercus virginiana	3	0	3
Subtotal	7	5	12
TOTAL	52	66	118

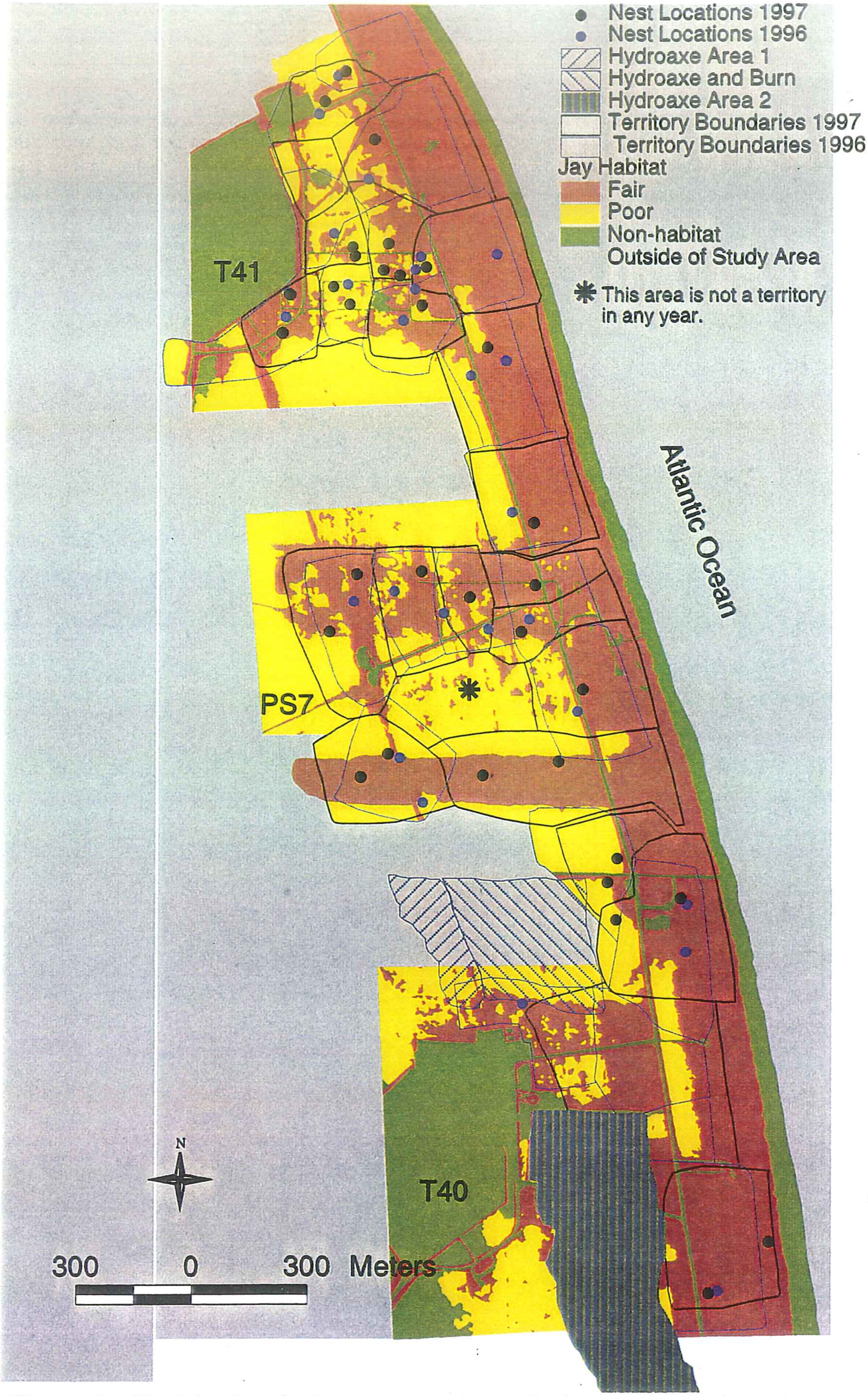


Figure 9. Florida Scrub-Jay territory boundaries and nest locations at Titan (LC41, PS7 & LC40) for 1996 and 1997. Legend categories refer to Scrub-Jay habitat quality and depict land management techniques for restoration.

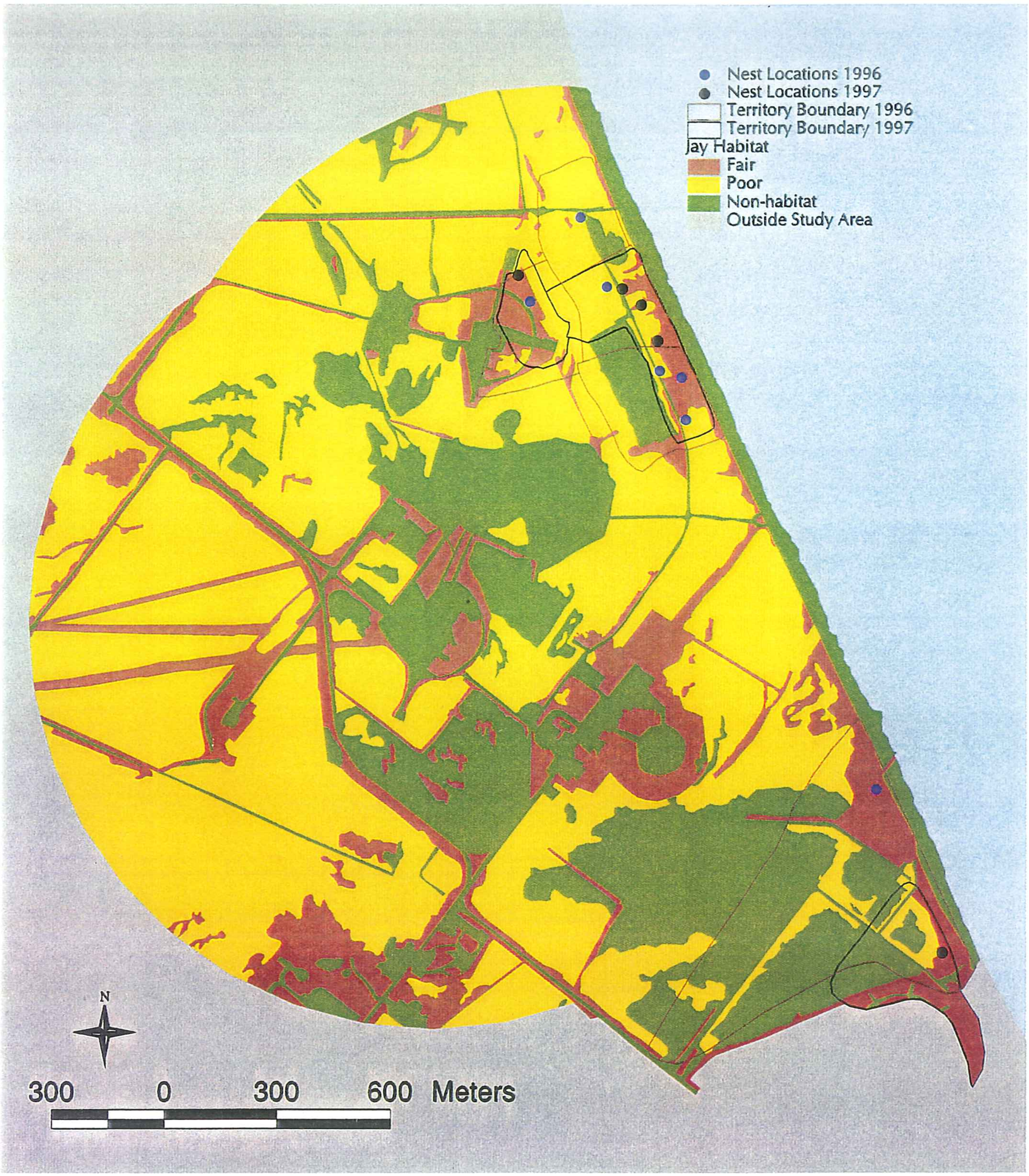


Figure 10. Florida Scrub-Jay territory boundaries and nest locations at Atlas (LC36) for 1996 and 1997. Legend categories refer to Scrub-Jay habitat quality.

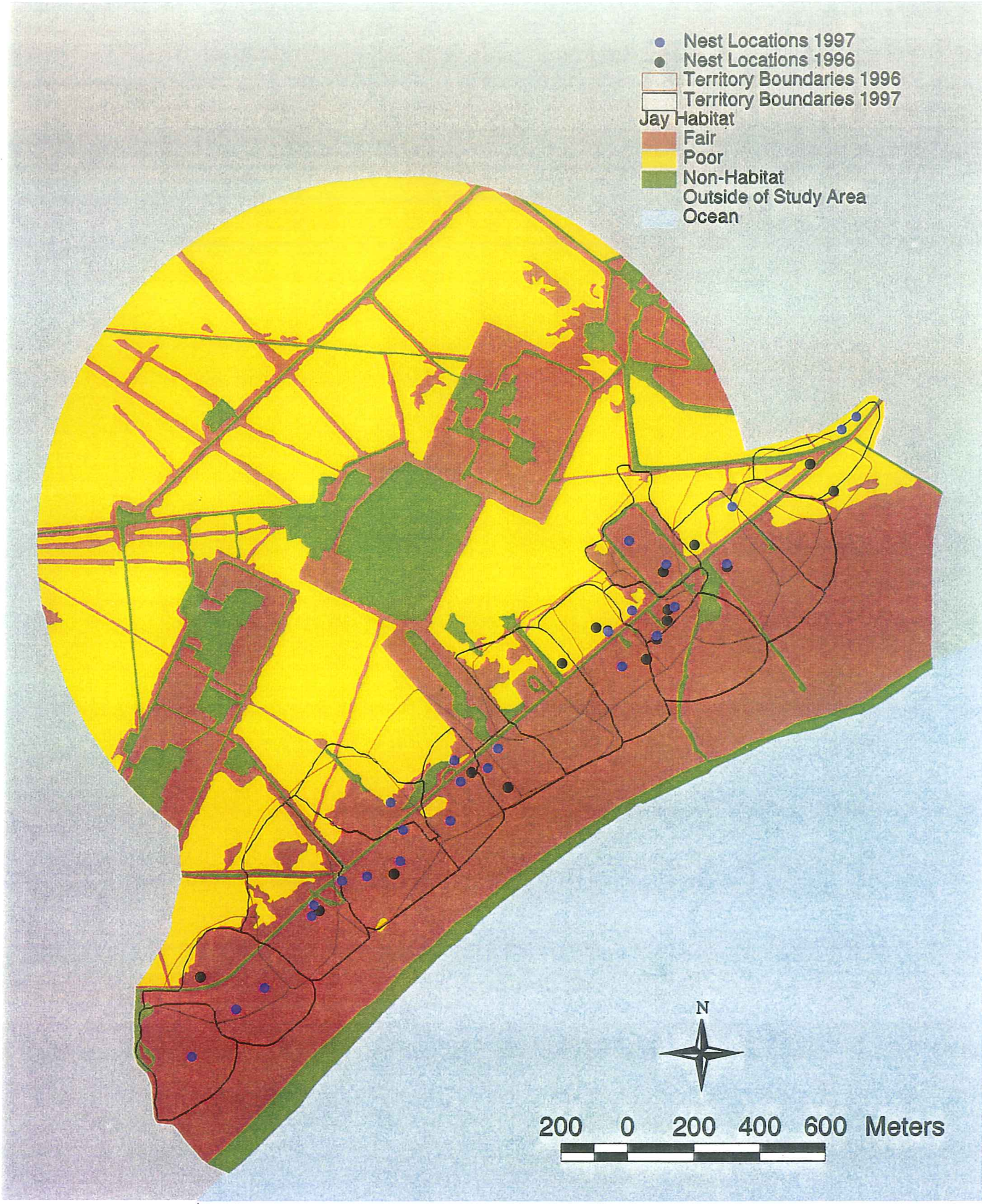


Figure 11. Florida Scrub-Jay territory boundaries and nest locations at Delta (LC17) for 1996 and 1997. Legend categories refer to Scrub-Jay habitat quality.

the number of fledglings was produced at Titan and Delta than at Atlas (Table 10). Only 0.3 fledglings were produced per nest attempt at Atlas compared to 0.5 fledglings per nest attempt at Titan and Delta (Table 8). On the other hand, the number of juveniles per pair was higher at Atlas than Titan and Delta.

Discussion

Launch Impacts

Immediate mortality of Scrub-Jays has not been observed from Titan, Delta, or Atlas launches. Subtle launch effects could include cumulative and long-term exposure to noise and exhaust products. The significance of these more subtle launch effects to the Scrub-Jay population can not be determined from this short-term study.

Demography

The mean family size of 2.4 for the Titan, Atlas, and Delta study areas were lower than the mean family sizes of 2.9 and 3.0 determined from KSC (Breininger et al. 1995) and ABS (Woolfenden and Fitzpatrick 1984), respectively. Territories were much smaller, means ranged from 2.45 to 5.70 ha, than mean sizes calculated from KSC (mean=9.6 ha; Breininger et al. 1995) and Archbold Biological Station (mean=9.0 ha; Woolfenden and Fitzpatrick 1984). Territories were smallest at the Atlas area (2.45 and 2.6 ha) and largest at Delta area (4.86 and 5.7 ha). At Titan, LC41 and PS7, where there are more open sandy areas, were the smallest territories for both 1996 and 1997, while territory sizes were greatest at LC40, where the habitat is dense and overgrown.

Another potential impact is Scrub-Jay road mortality in the area of LC40, LC41, PS7, and LC17 (Dreschel et al. 1990, Fitzpatrick et al. 1991). Territories that included the edge of SR 8 at ABS had higher mortality rates than reproductive rates (Fitzpatrick et al. 1991). From July 1995-August 1997, six jay mortalities (3 breeders, 1 juvenile, and 2 helpers) were associated with Phillips Parkway or Pier Road.

Habitat

Scrub-Jay habitat at LC40, LC41, PS7, LC17, and LC36 differs in structure and composition from typical Scrub-Jay habitat (Woolfenden and Fitzpatrick 1984, Cox 1987, Breininger 1992). Scrub habitat on CCAS is structurally different because most of the area has remained unburned for long periods (greater than 25 years) so that scrub oaks are in excess of 3 m in height. Scrub-Jays prefer a mean shrub height of approximately 1.5 m (Breininger 1992). Studies at ABS showed that Scrub-Jay reproductive success and occupation of tall unburned habitat gradually declined with increasing time since fire until Scrub-Jays no longer occupied the area (Woolfenden and Fitzpatrick 1984). Studies on KSC have also found that breeder mortality is high and reproductive success is especially low in long unburned areas (Breininger et al. 1996a). Therefore, available information on habitat suitability indicates that a decline and eventual extinction of the Scrub-Jay population on CCAS would be expected even without launch effects should the unburned condition prevail over most of the landscape (Breininger et al. 1996b).

Forests represent unsuitable habitat for Scrub-Jays as they reduce the suitability of surrounding areas (Breininger et al. 1995). Furthermore, studies have shown that Scrub-Jays can not persist in areas with tall scrub (Woolfenden and Fitzpatrick 1984, Schaub et al. 1992, Breininger et al. in press).

Scrub-Jays prefer and perhaps require an abundance of low, sparsely vegetated openings scattered among scrub oaks (Westcott 1970, Woolfenden 1974, Breininger 1981, 1992; Cox 1984, Breininger and Schmalzer 1990, Breininger et al. 1995). These openings are rare in undisturbed scrub on KSC and CCAS, especially in unburned areas (Schmalzer and Hinkle 1987, Breininger et al. 1988, Schmalzer et al. 1994).

These openings are abundant in some of the study areas and along roadsides and other unnatural corridors on CCAS. Openings were abundant in the historic landscape and most closed during the period of fire suppression (Duncan et al. 1996, 1999). The preference for openings combined with the limited distribution of openings suggests that Scrub-Jay families compete for these areas and that vacancies would be filled quickly if immigrants were available. Long-term demographic studies are needed to further address these questions and, long-term management is needed to deal with forestation and other habitat restoration concerns.

Southeastern beach mouse

Introduction

The southeastern beach mouse is a small, nocturnal, buff colored mouse with a white underside that extends from its chin to the tip of its tail. The dorsal side of the mouse is a tawny, buff color from the back of the head to the tail in adults, and gray in juveniles. Chapman (1889) first described the southeastern beach mouse as *Hesperomys niveiventris* from the east peninsula, opposite Micco, Brevard County, Florida (Humphrey et al. 1987). In 1898, Bangs called both the beach and oldfield mouse *Peromyscus polionotus*, while Osgood in 1909 referred the southeastern population to subspecies *niveiventris* (Humphrey et al. 1987).

The beach mouse is a monogamous species (Blair 1951, Foltz 1981) whose principal habitat is the sea oats zone of the primary dune (Humphrey and Barbour 1981). Additional habitats occupied by this species include open, sandy areas with scattered shrubs behind the foredune, stands of woody shrubs dominated by oaks, rosemary, saw palmetto, and grasslands (Keim 1979, Stout 1980, Humphrey et al. 1987). Ehrhart (1978) confirmed that beach mice are habitat specialists. Sea oats, seeds, and various beach grasses are the primary food resources for this species (Blair 1951), although invertebrates, (Smith 1966, Ehrhart 1971, Layne 1978) and vertebrates (Gentry and Smith 1968) are also consumed. Food use may change seasonally since seeds are often scarce in late spring and early summer (Blair 1951).

The beach mouse digs burrows and may have many within its homerange (Smith 1966). The burrow of *polionotus* is one of the most characteristic features of the species' biology (Ehrhart 1971). The three main parts of a typical burrow are: 1) the entrance tunnel, 2) a nest chamber, 3) and an escape tunnel (Smith and Criss 1967, Ehrhart 1971). It was discovered that the entrance of an occupied burrow was nearly always plugged by 8-10 cm of sand and that the escape tunnel almost never opened to the surface (Smith and Criss 1967). In addition, the sand plug was so solidly packed in the entrance that it sealed the burrow from the air above ground (Smith 1966).

The southeastern beach mouse was listed by the U.S. Fish and Wildlife Service as a threatened species in 1989 under the Endangered Species Act of 1973 (USFWS 1989). The Florida Game and Fresh Water Fish Commission listed the species as threatened in 1990 (FGFWFC 1996).

Historically, this small mammal ranged from Ponce Inlet (Volusia County) south to Hollywood (Broward County), a distance of approximately 360 km (Figure 12) (Humphrey et al. 1987). Bangs (1898) reported the species to be extremely abundant along the East Coast of Florida between Ponce Inlet and Palm Beach.

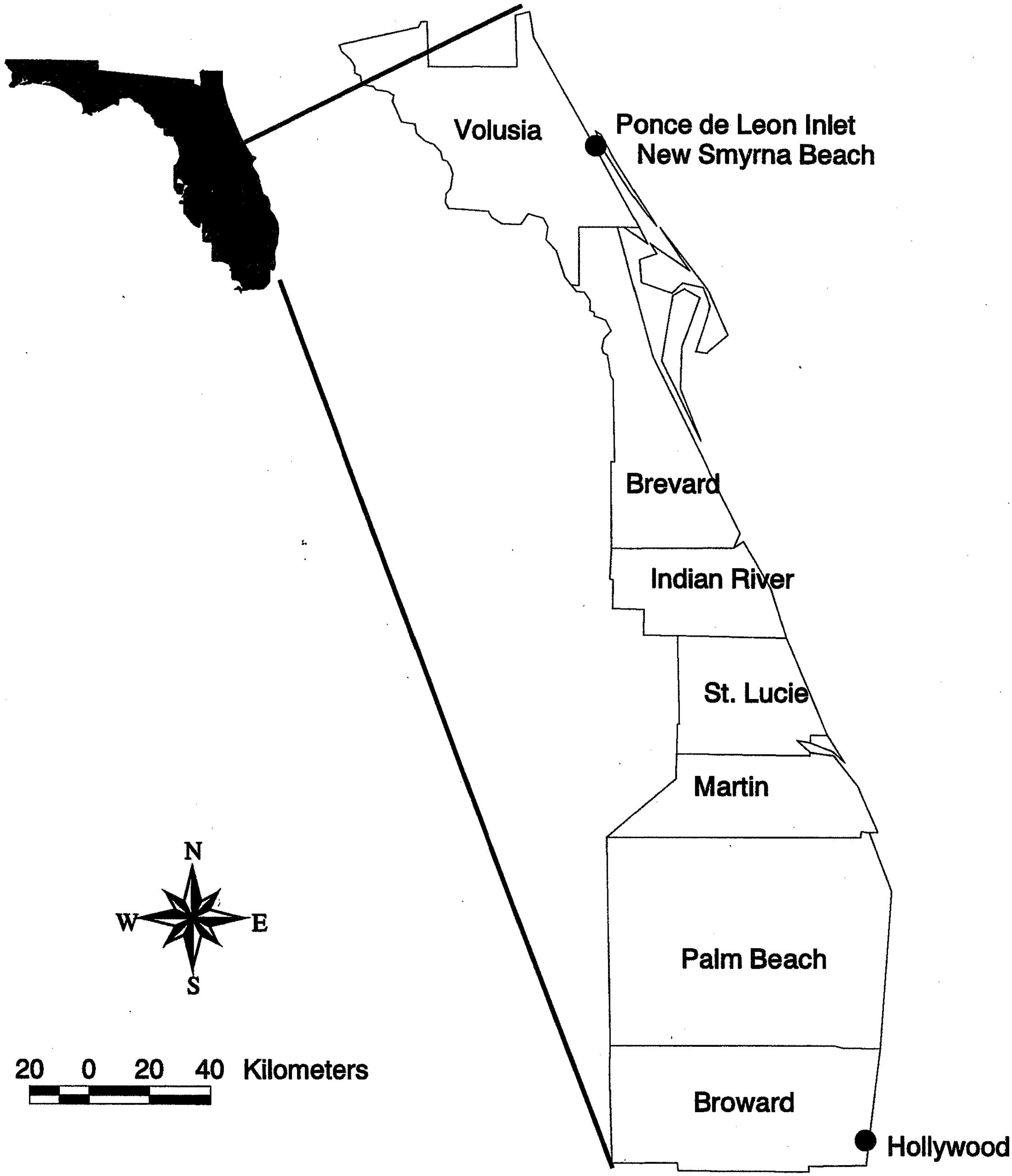


Figure 12. The historical range of the southeastern beach mouse.

Presently the species exists only at Canaveral National Seashore (CNS), KSC, CCAS, and one small population has been documented at the southern half of Sebastian Inlet State Recreation Area (Figure 12) (Stout 1992). The extinction of the Pallid beach mouse (*P. p. decoloratus*), which occurred north of Ponce Inlet, (Humphrey and Barbour 1981) has left the southeastern beach mouse isolated from the only other Atlantic coast subspecies (i.e., Anastasia Island beach mouse, *P. p. phasma*).

The abundance of small mammals varies seasonally, annually, and among habitats (Ehrhart 1976). Populations of southeastern beach mice are often lowest in the summer and highest in winter and spring (Stout 1980). Breeding activity is most evident from November through January when juveniles are present. Potential predators include raccoons (*Procyon lotor*), spotted skunks (*Spilogale putorius*), hawks, owls, snakes, bobcats (*Felis rufus*), house cats (*Felis cattus*), and dogs (*Canine familiaris*). In addition, the house mouse (*Mus musculus*) is a potential competitor. Reasons for decline in southeastern beach mouse populations include habitat loss due to development and erosion, habitat fragmentation, isolation, competition from the house mouse, and predation from increasing numbers of house cats (Stout 1992). The species is also vulnerable to ocean surges from storms and natural catastrophes such as hurricanes and tropical storms.

Methods

For this study, seven grids and four 100 m transects (Figure 13) were established in order to determine potential impacts from launches. Field surveys and aerial photography was used to determine suitable habitat for grid and transect placement. Three of the seven grids (LC17, AQ, and JETTY) contained 11 north-south lines and 11 east-west lines, a fourth grid (LC2529) had 16 north-south lines and 11 east-west lines, and the three remaining grids (LC17N, ST40, and PS7) had 4 north-south lines and 11 east-west lines. Ten meter spacing was used between trapping stations on the four transects and the four large (11 x 11, 11 x 16) coastal dune grids. Fifteen-meter spacing was used on the three smaller (4 x 11) coastal strand/scrub grids. Considering each trap to be the center of a 10 x 10 meter square, an area of 1.0 ha was obtained for each of the three 11 x 11 grids and 1.5 ha for the 11 x 16 grid. The 4 x 11 grids had 15 m spacing, so 30 fifteen by fifteen squares yielded an area of 0.67 ha. Trapping grids and transects were set up using a compass and meter (m) tapes. PVC poles marked the location of the trapping stations within the grid and along the transects. The poles were spray painted and labeled for identification and a 1.8 m pole was placed at the four corners of the grid and at each end of the transects. A GPS was used to record the end points of each transect and the corners of the grids. Data were differentially corrected and transferred into ARC/INFO as a point coverage file. These grids were overlaid onto a 1990-1991 land cover map (Larson and Swain 1991) to show the extent of the habitat

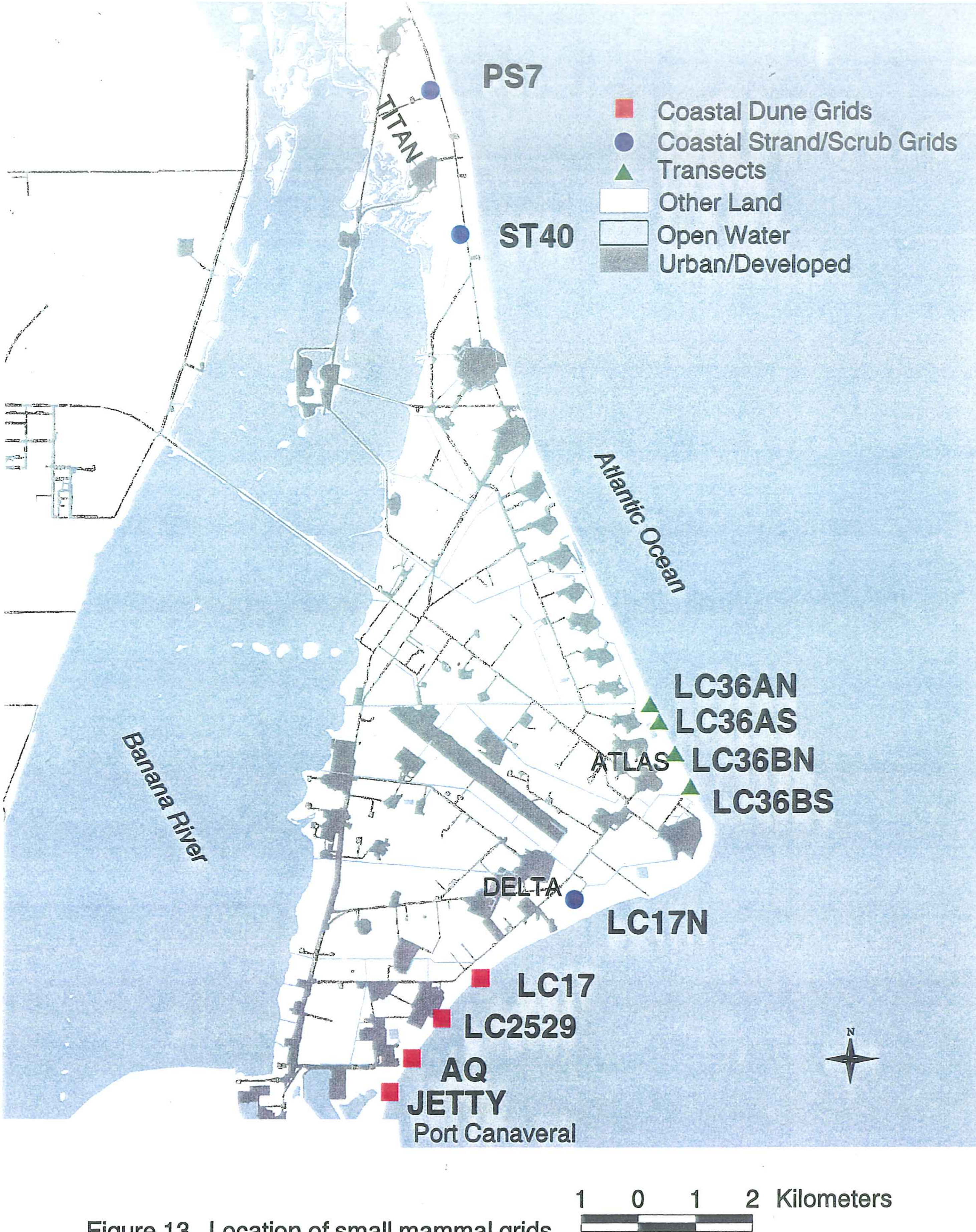


Figure 13. Location of small mammal grids and transects on Cape Canaveral Air Station.

trapped at each grid. A Sherman live trap (23x23x8 cm) was placed at each trapping station. Two traps were used at the three coastal strand/scrub grids for the first two quarters of trapping. Traps were baited with sunflower seeds, opened in the late afternoon, and checked at approximately 05:30 am or first light the next morning. Cotton was placed in each trap to provide thermal protection and nesting material. Traps were closed when air temperatures were expected to dip into the low 50's °F. A mark-recapture method was employed for this survey.

The total number of possible trapnights was based on the size of the grids, (i.e., 11 x 11 grid = 121, 11 x 16 grid = 176, 4 x 11 grid = 44 possible traps per night) transects, (i.e., 4 transects x 10 traps = 40 possible traps per night), and the number of nights trapped. The actual number of trapnights was adjusted for data analysis by subtracting the disturbed or inoperable traps and any that were unable to be set due to weather or habitat conditions from the total. The total number of potential trapnights for the study was 18,743, while the actual number of trapnights differed with each transect and grid (Tables 13, 14, and 15).

Table 13. The number of potential and actual trapnights per season for the four coastal dune grids at Cape Canaveral Air Station from September 1995-October 1997.

	POTENTIAL TRAPNIGHTS					ACTUAL TRAPNIGHTS				
GRID	FALL	WINT	SPRG	SUMM	TOTAL	FALL	WINT	SPRG	SUMM	TOTAL
JETTY	890	440	550	660	2540	827	403	514	631	2375
AQ	895	396	495	594	2380	821	352	445	531	2149
LC2529	1180	924	924	770	3798	1029	845	788	715	3377
LC17	796	440	541	573	2533	726	422	541	573	2262
TOTALS	3761	2200	2510	2597	11251	3403	2022	2288	2450	10163

Table 14. The number of potential and actual trapnights per season for the three coastal strand/scrub grids at Cape Canaveral Air Station from September 1995-October 1997.

	POTENTIAL TRAPNIGHTS					ACTUAL TRAPNIGHTS				
GRID	FALL	WINT	SPRG	SUMM	TOTAL	FALL	WINT	SPRG	SUMM	TOTAL
LC17N	484	176	264	264	1188	425	123	206	178	932
ST40	528	176	264	264	1232	468	157	235	244	1104
PS7	528	176	264	264	1232	483	172	235	248	1138
TOTALS	1540	528	792	792	3652	1376	452	676	670	3174

Table 15. The number of potential and actual trapnights per season for the four 100 m small mammal transects at Cape Canaveral Air Station from September 1995-October 1997.

	POTENTIAL TRAPNIGHTS					ACTUAL TRAPNIGHTS				
GRID	FALL	WINT	SPRG	SUMM	TOTAL	FALL	WINT	SPRG	SUMM	TOTAL
LC36AN	280	240	200	240	960	277	238	200	239	954
LC36AS	280	240	200	240	960	269	226	197	238	930
LC36BN	280	240	200	240	960	274	228	187	236	925
LC36BS	280	240	200	240	960	271	221	189	235	916
TOTALS	1120	960	800	960	3840	1091	913	773	948	3725

Trapping began in September 1995 and continued on a quarterly basis through September 1997. Seasons are as follows: Fall (September-November), Winter (December-February), Spring (March-May), and Summer (June-August). Each of the seven grids and four transects was trapped for 2-5 consecutive days depending on the presence/absence of beach mice and weather conditions. All captured beach mice were examined and the following data were recorded: line number, station number, status, species, sex, reproductive condition, weight, pelage, tag number, and general condition. Reproductive activity in females was recorded as pregnant, lactating, perforate, and/or mammaries visible, while, in males, testes position was recorded as descended or abdominal. During the second quarter, we also began recording data on the number of tubercles on each hind foot and the length of the hind foot. In addition, the phase of the moon was recorded for each trap night. All beach mice captured were ear tagged in the right ear near the dorsal origin using a Fingerling fish tag (weight approx. 0.08 g, 8 mm x 2 mm). Animals with scars or tears in the right ear that prevented them from being tagged in the right ear were tagged in the left ear. Captured animals were weighed in a plastic bag with a Pesola 50 g scale. The weight of the bag was then determined and the difference subtracted to determine the actual weight. Animals were generally processed within 2-3 minutes and then released at the point of capture. On a few occasions, animals were lethargic due to cold stress. They were treated for dehydration with water, fed, externally warmed, and then released into burrows.

Protective measures were taken to insure the safety of the biologists conducting the survey due to the outbreak of hantavirus, a rodent borne disease, in the southwest. Hantavirus is transmitted in the urine, feces, and saliva of infected rodents (primarily the deer mouse, *Peromyscus maniculatus*, from the western U.S.). As a result, contact with the animals and the aerosols produced were minimized. Respirators equipped with High Efficiency Particulate Filters (HEPA) and gloves were worn while handling rodents. Due to possible contamination, all mammal work up bags, gloves, and HEPA filters were disposed of as biohazardous material after their use. The Sherman live trap was sprayed with Lysol disinfectant in the field and soaked in an EPA approved disinfectant for 10 minutes, scrubbed, rinsed, and dried. Respirators were cleaned and scrubbed with microbiological soap, and the biologists showered and laundered their clothes. These steps were all part of a protocol developed for handling small mammals and followed the recommendations of the Center for Disease Control (CDC) (Mills et al. 1995).

A Chi square 2x2 contingency table was used to determine if deviations in sex ratios of the beach mice were statistically significant.

Results

Coastal Dune Grids

Figure 14 shows the percent capture for all small mammal species captured during the period September 1995-October 1997 on the four coastal dune grids (this number includes recaptures). The southeastern beach mouse was the predominant small mammal captured followed by the cotton rat, spotted skunk, and cotton mouse. In addition to the small mammal species captured, one invertebrate species, the ghost crab (*Ocypode quadrata*) was also caught. The total number of possible trapnights for the four coastal dune grids for the nine quarters was 11,251 (see Table 13). The actual number of trapnights was 10,163 (see Table 13). LC2529, the largest grid had the highest total southeastern beach mouse captures followed by AQ, LC17, and JETTY (Figure 15) for a total of 1708 beach mice. JETTY and AQ, the two southernmost grids fluctuated the most over the sampling period (Figure 15). Both increased from Fall 1995 and peaked in the Summer and Fall of 1997. LC17 steadily increased in numbers from Fall 1995 till Winter/Spring of 1997 where it leveled off (Figure 15). Trapping was not conducted at LC17 in the Winter of 1996/1997 due to an explosion of a Delta rocket that resulted in closure of the area. LC2529 exhibited steady increases in numbers from Fall 1995 to Fall 1997 (with the exception of Summer 1997) when the population peaked at 179 total mice captured (includes recaptures) (Figure 15). Highest total numbers of beach mice captured at the four coastal dune grids combined occurred in the Fall followed by Spring (Figure 16).

Sex ratio of beach mice captured on the four coastal dune grids was 927:757 males to females or 55% male, and 45% female (Figure 17). This deviation from unity was statistically significant ($p = 0.05$). Average weight of male beach mice were 12.8 grams ($n = 901$, std = 2.0). Female body weights are not used in these analyzes, because they can be significantly altered by pregnancy. Four hundred and ninety-two (65%) of the 757 female beach mice were reproductively active. Fall yielded the highest number of reproductively active females for the four coastal dune grids (Figure 18). The greatest proportion of beach mice captured were adults ($n = 1361$) followed by subadults ($n = 155$) and juveniles

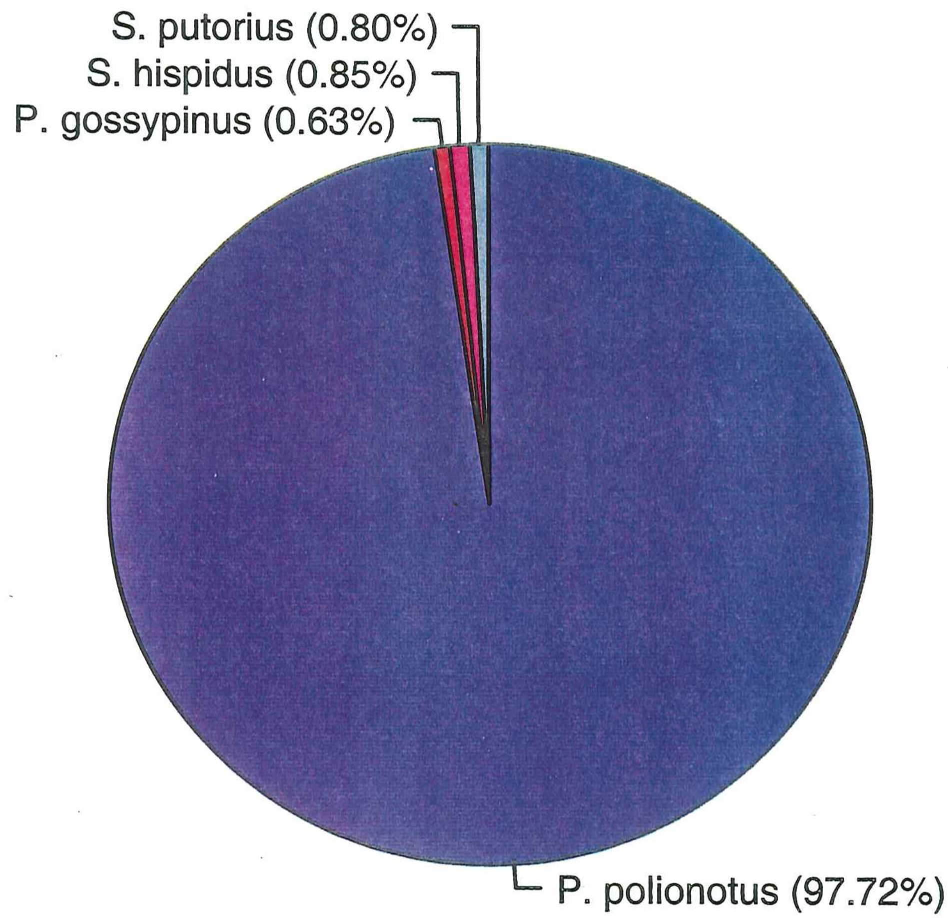


Figure 14. Percent capture of small mammals on the coastal dune grids for the period of September 1995 to October 1997.

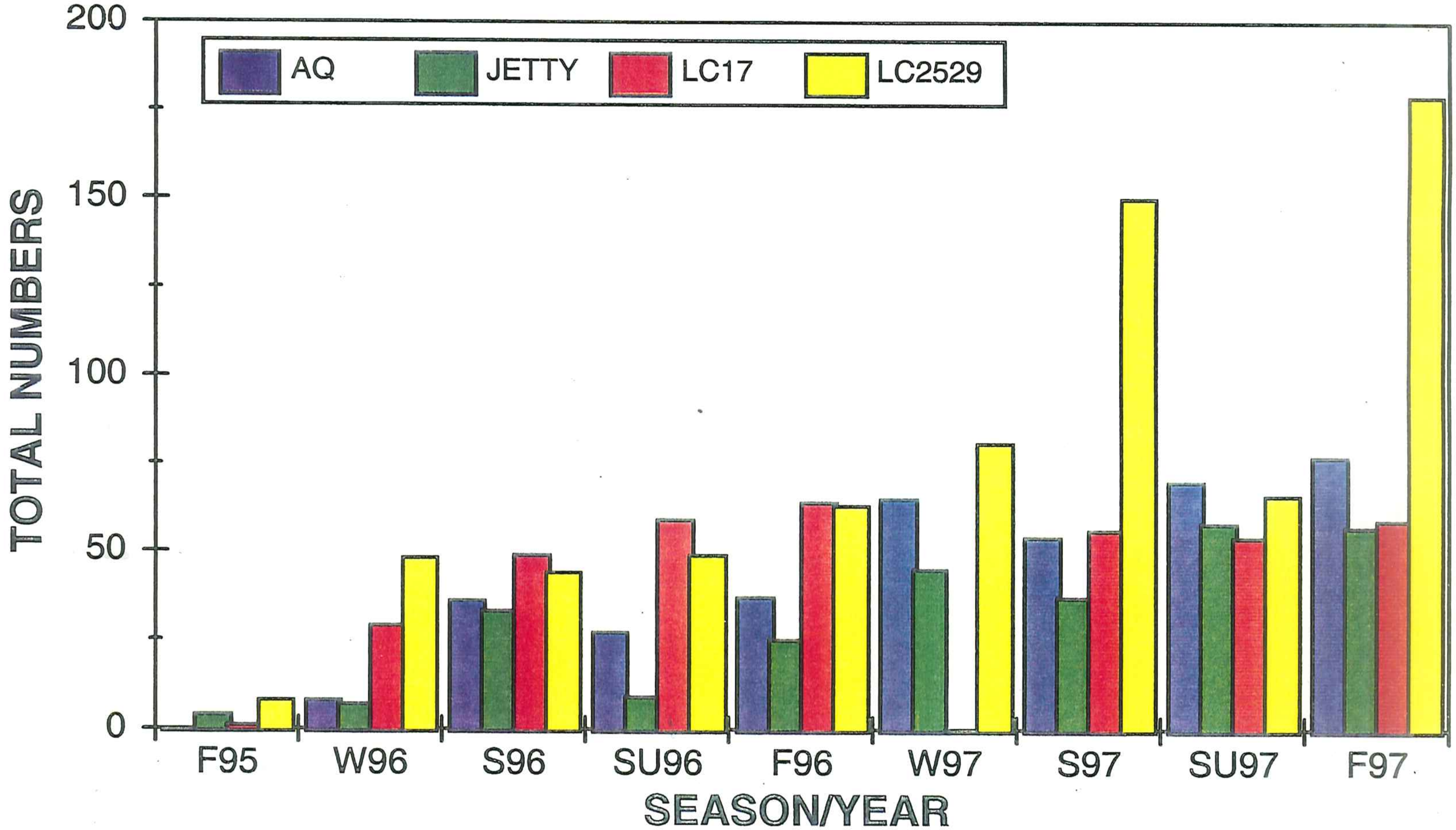


Figure 15. Total number of southeastern beach mice captured on the coastal dune grids by season and year.

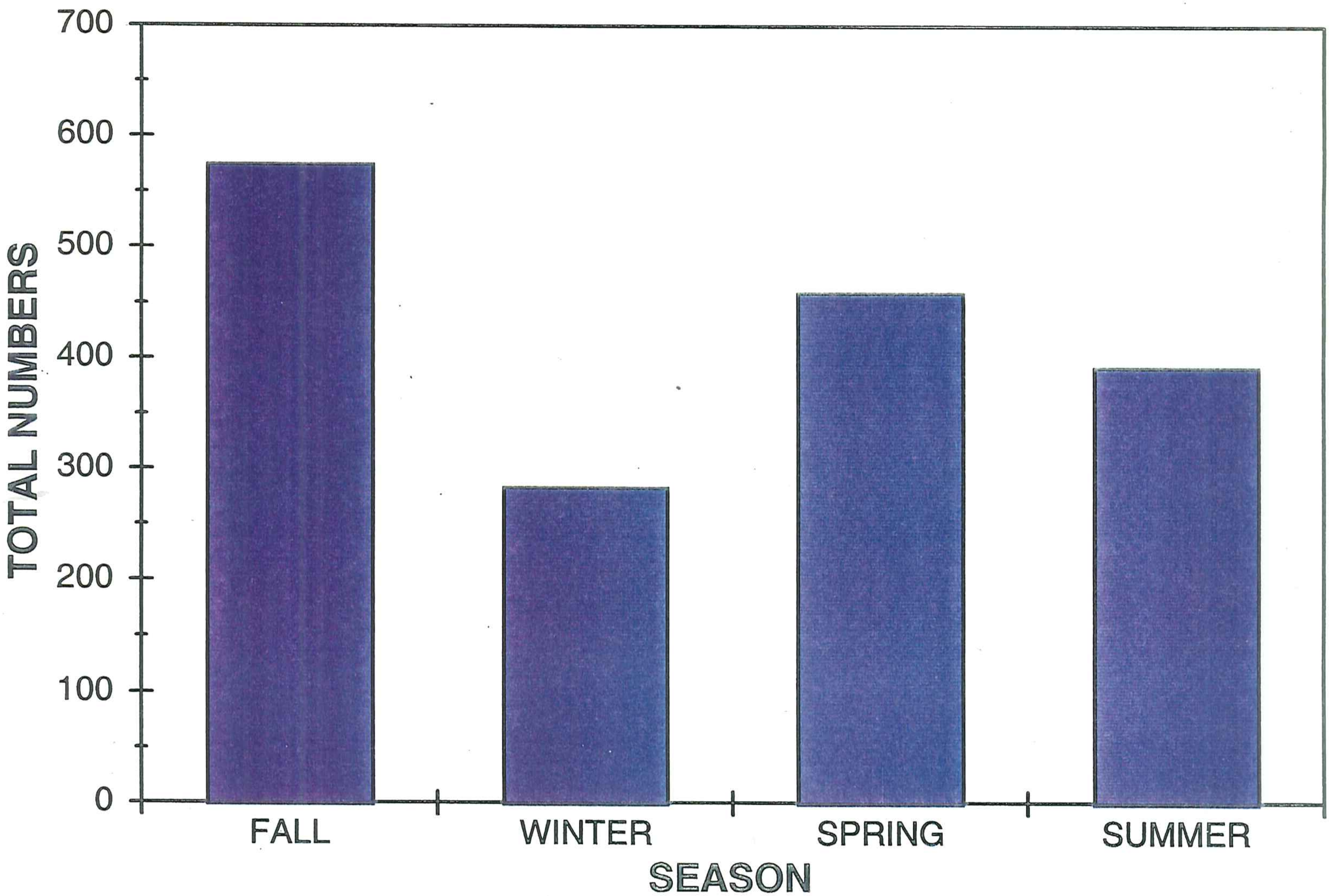


Figure 16. Seasonal abundance of southeastern beach mice on the coastal dune grids (grids and years are combined).

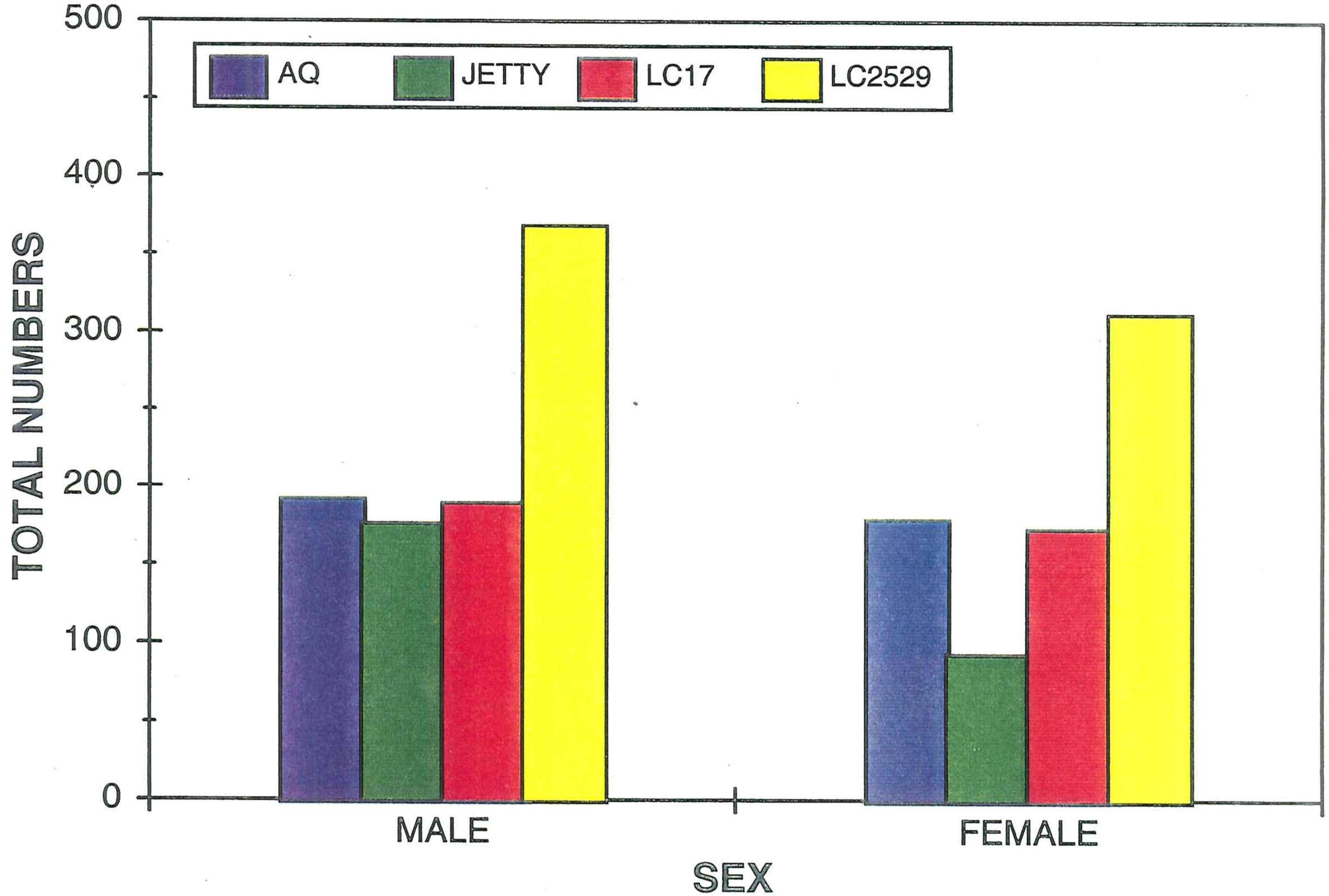


Figure 17. Sex ratio totals for southeastern beach mice captured on the coastal dune grids during the period of September 1995 to October 1997.

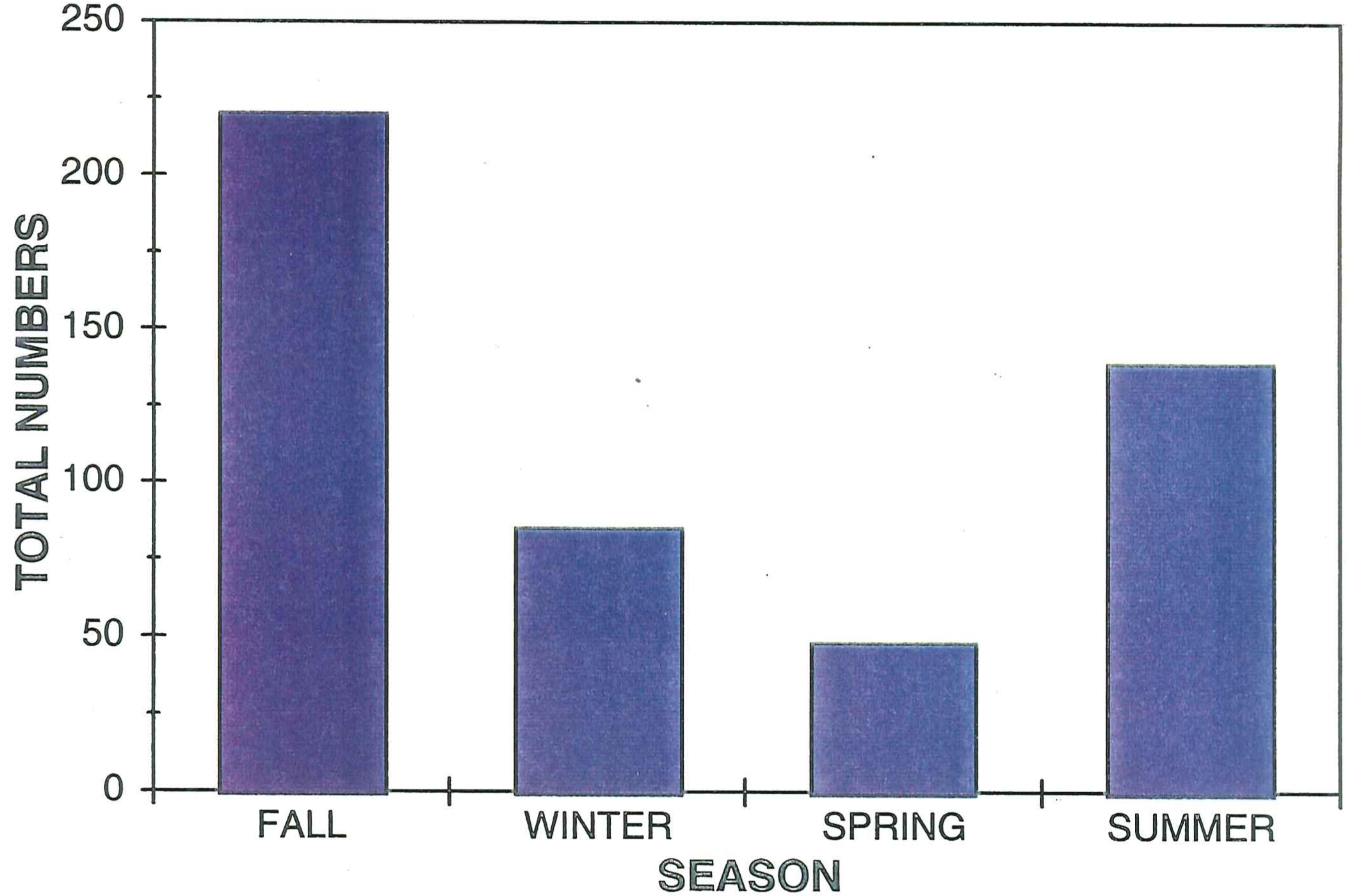


Figure 18. Abundance of reproductively active female southeastern beach mice on the coastal dune grids (grids and years are combined).

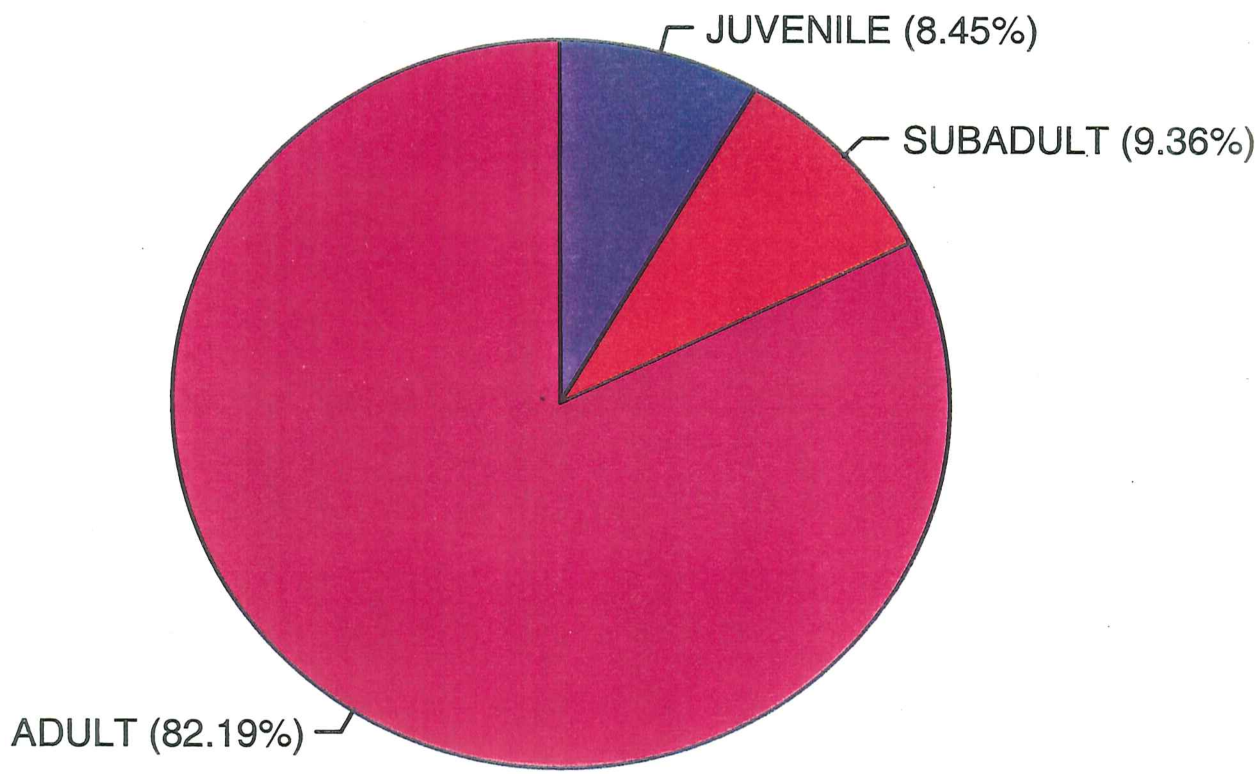


Figure 19. Age class distribution of southeastern beach mice captured on the coastal dune grids during the period of September 1995 to October 1997.

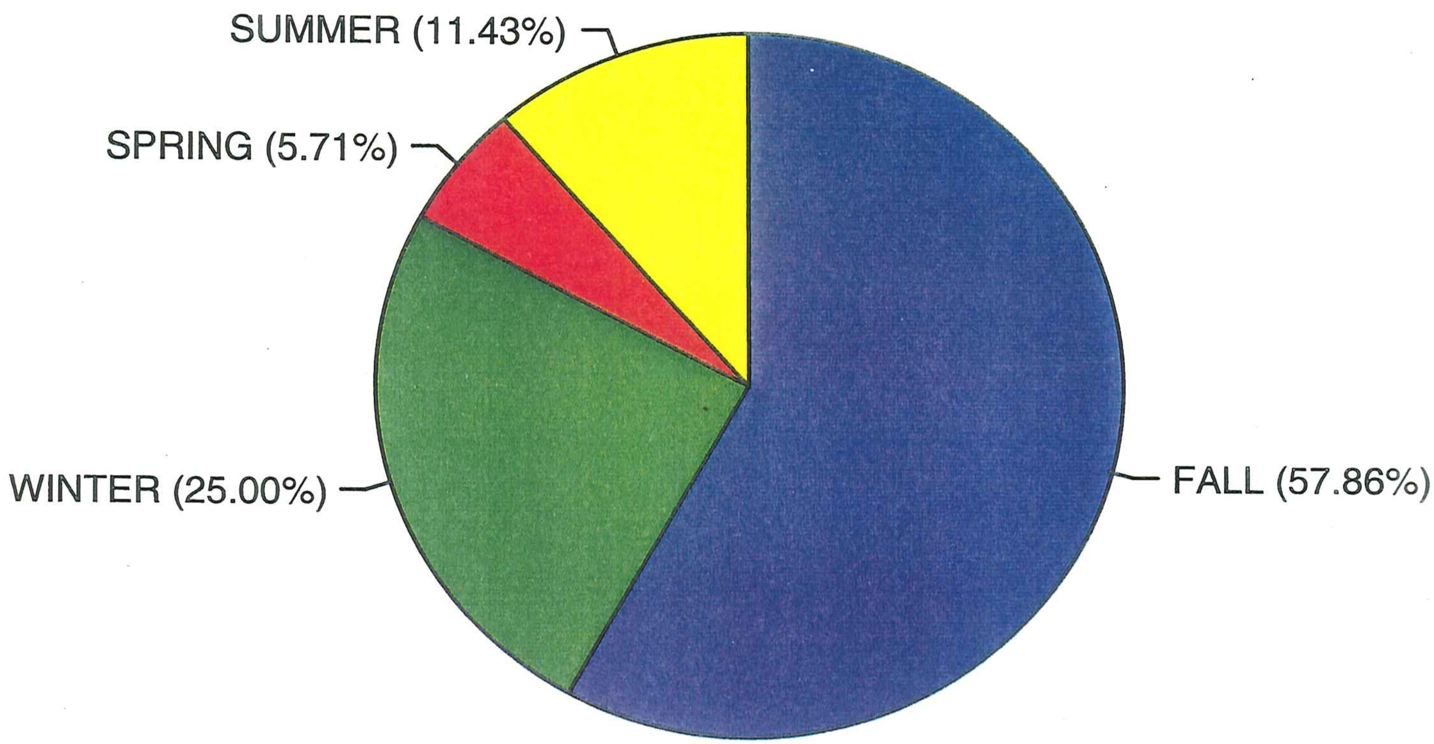


Figure 20. Abundance of juvenile southeastern beach mice on the coastal dune grids (grids and years are combined)

({n= 140} Figure 19). Juveniles were observed in all seasons, although 83% of the captures were in the Fall and Winter (Figure 20).

Coastal Strand/Scrub Grids

The southeastern beach mouse was the predominant small mammal captured on the three coastal strand/scrub grids followed by the cotton mouse, spotted skunk, and cotton rat (Figure 21). The total number of potential trapnights for the coastal strand/scrub grids for the period September 1995-October 1997 was 3652 (see Table 14). The actual number of trapnights was 3174 (see Table 14).

LC17N had the highest total numbers of beach mice followed by PS7 and ST40 for a total of 508 beach mice. LC17N had the highest numbers in all quarters except for Winter 1997 (Figure 22) when it wasn't trapped due to the explosion of a Delta rocket. In addition to having the highest numbers of beach mice, LC17N also had the most cotton rats, and the least number of cotton mice of the three grids (Figures 23 and 24). PS7 had the second highest total number of beach mice (n = 92), cotton mice, and cotton rats, while ST40 had the least number of beach mice (n = 53), the highest number of cotton mice, and the second highest number of cotton rats (Figures 23 and 24). Beach mouse captures at both PS7 and ST40 followed a similar pattern with increasing numbers from Fall 1995, peaks in Spring and Summer 1996, followed by decreasing numbers and peaks again in Summer 1997 (Figure 22). Highest total numbers of beach mice captured at the three coastal strand/scrub grids combined occurred in the Summer followed by Spring (Figure 25).

Sex ratio of beach mice captured on the three coastal strand/scrub grids was 236:260 males to females or 46.5% male, and 51.2% female (Figure 26). The closest 1:1 ratio of males to females was at ST40 where the numbers of beach mice were low. This deviation from unity was not statistically significant ($p > 0.05$). Average weight of male beach mice was 14.3 grams (n = 231, std = 2.7). Female body weights are not used in these analyzes, because they can be significantly altered by pregnancy. One hundred and fifty-eight (60.8%) of the 260 female beach mice were reproductively active. Spring, followed by Summer yielded the highest number of reproductively active females for the three coastal strand/scrub grids (Figure 27). The greatest proportion of beach mice captured were adults (n = 394) followed by subadults (n = 55) and juveniles ({n= 28} Figure 28). Juveniles were observed in all seasons, although 89% of the captures were in the Spring and Winter (Figure 29).

Transects

The southeastern beach mouse was the predominant small mammal captured on the four transects followed by the cotton rat and cotton mouse (Figure 30). In addition to the small mammal species captured, one invertebrate species, the

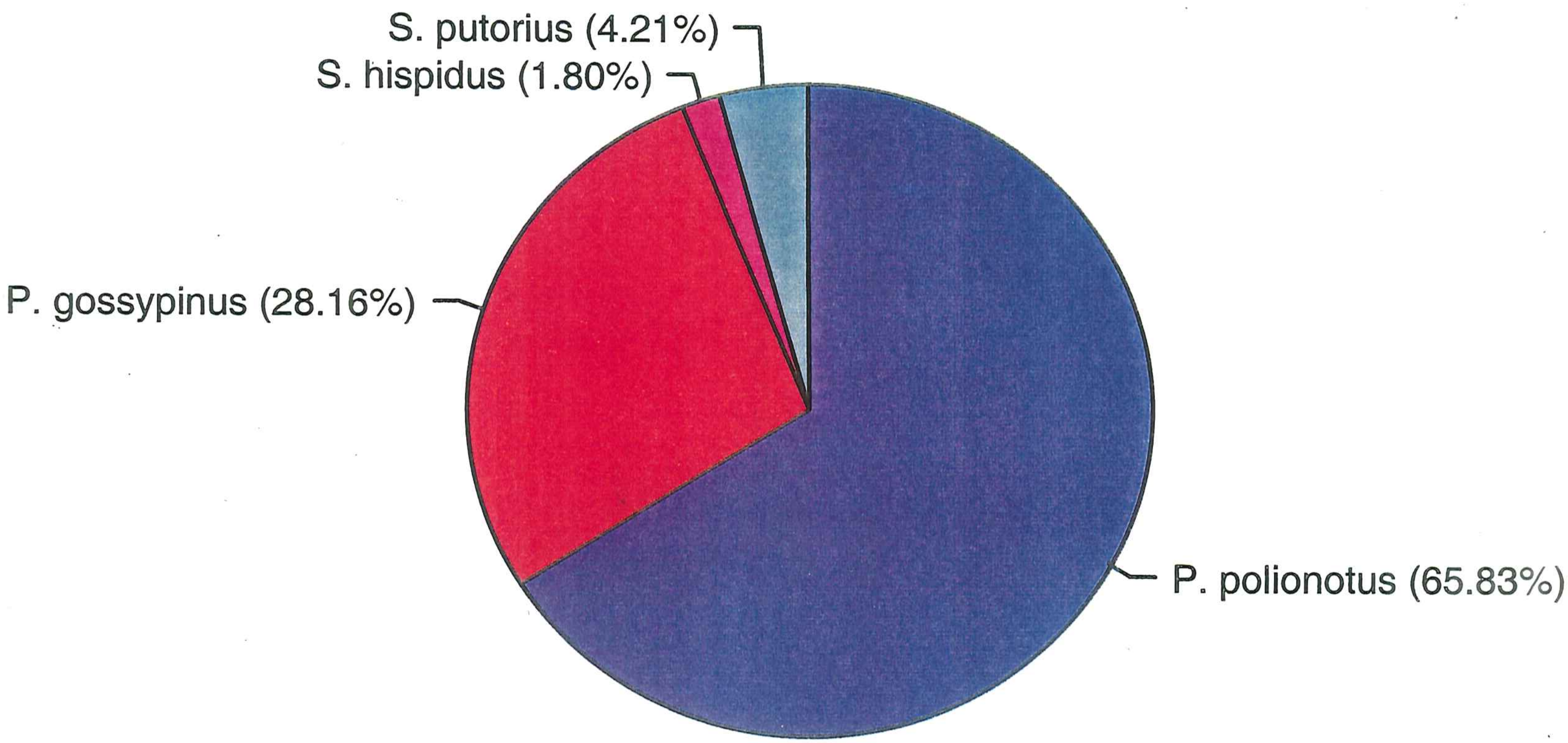


Figure 21. Percent capture of small mammals on the coastal strand/scrub grids for the period of September 1995 to October 1997.

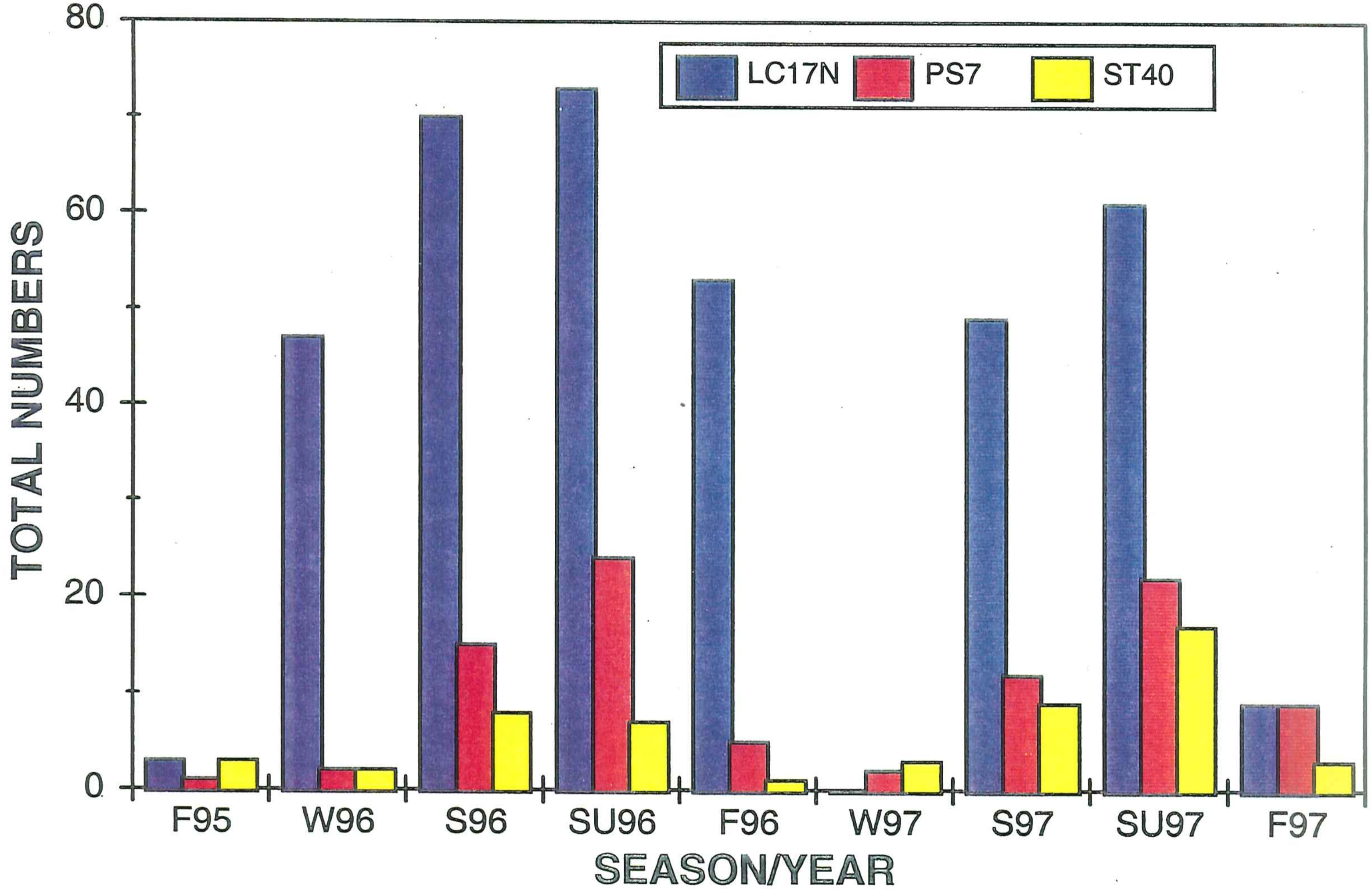


Figure 22. Total number of southeastern beach mice captured on the coastal strand/scrub grids by season and year.

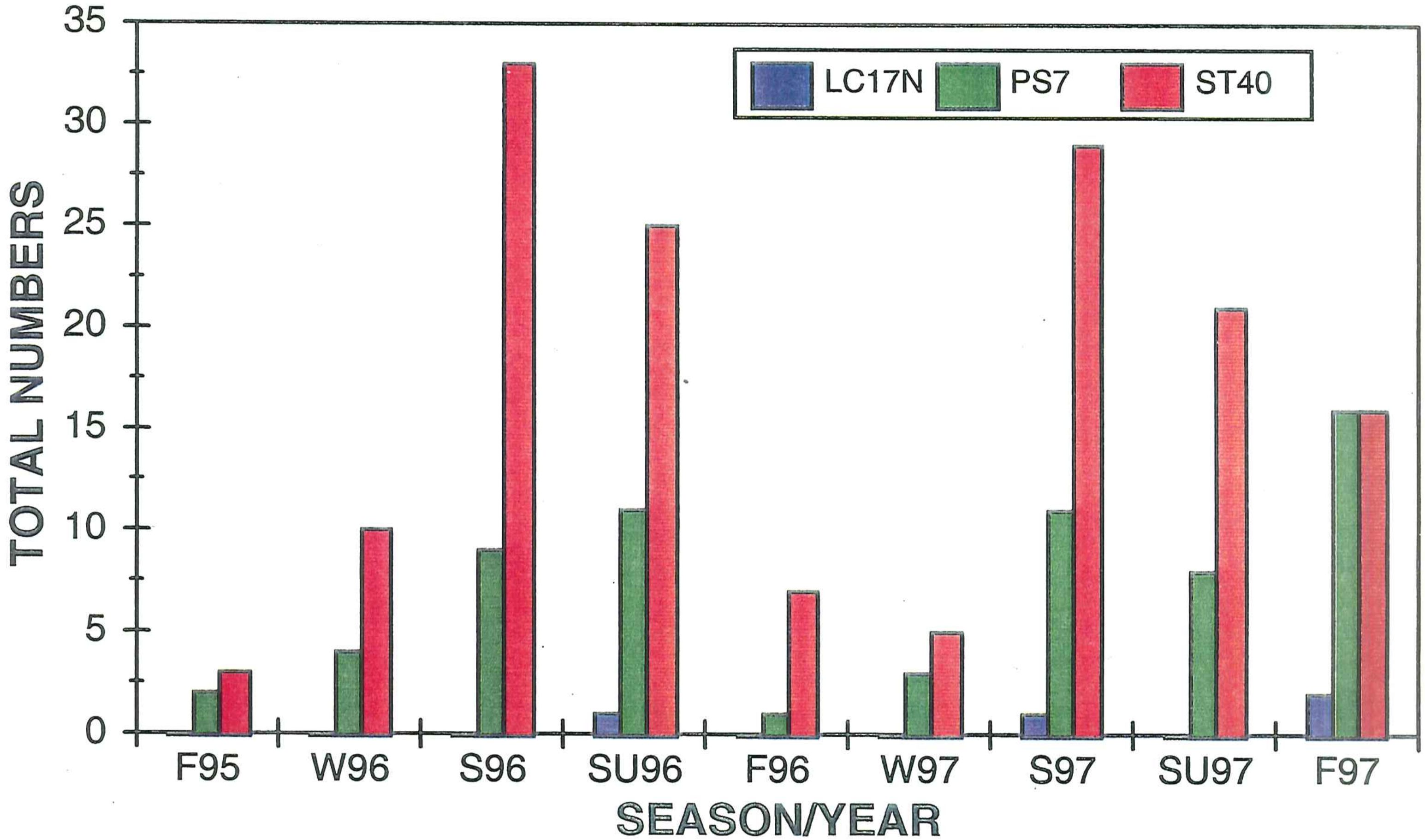


Figure 23. Total number of cotton mice captured on the coastal strand/scrub grids by season and year.

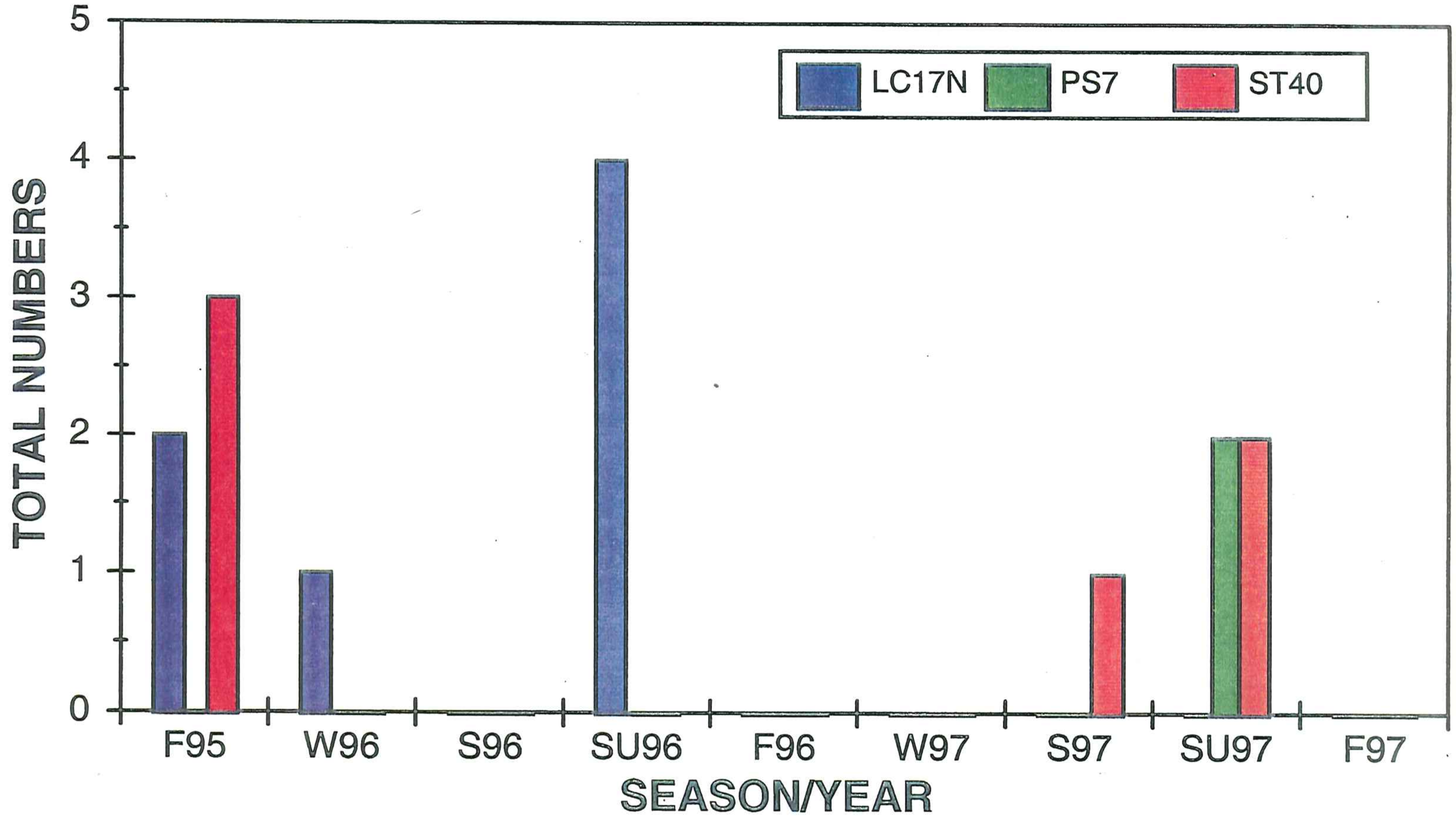


Figure 24. Total number of cotton rats captured on the coastal strand/scrub grids by season and year.

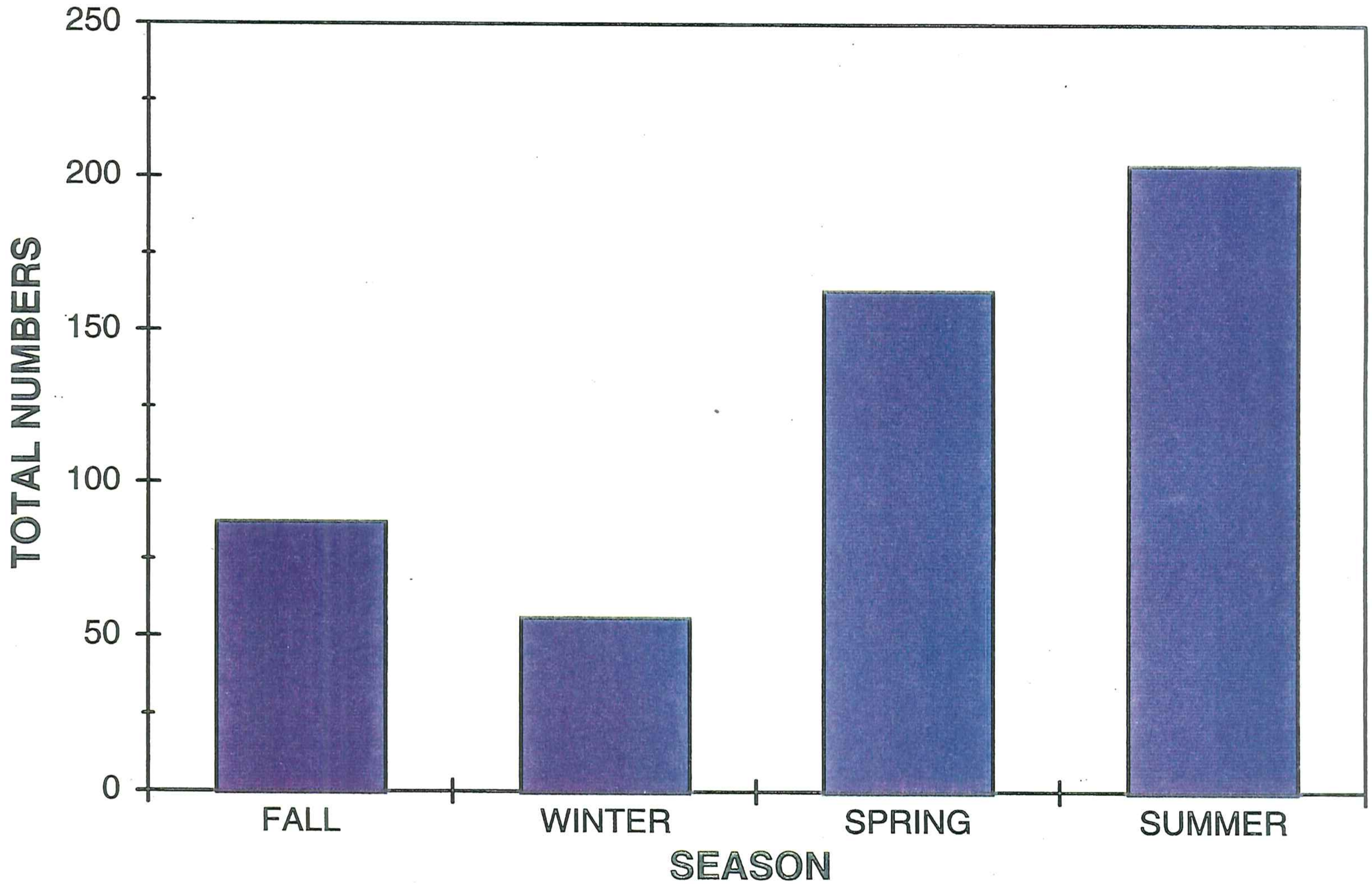


Figure 25. Seasonal abundance of southeastern beach mice on the coastal strand/scrub grids (grids and years are combined).

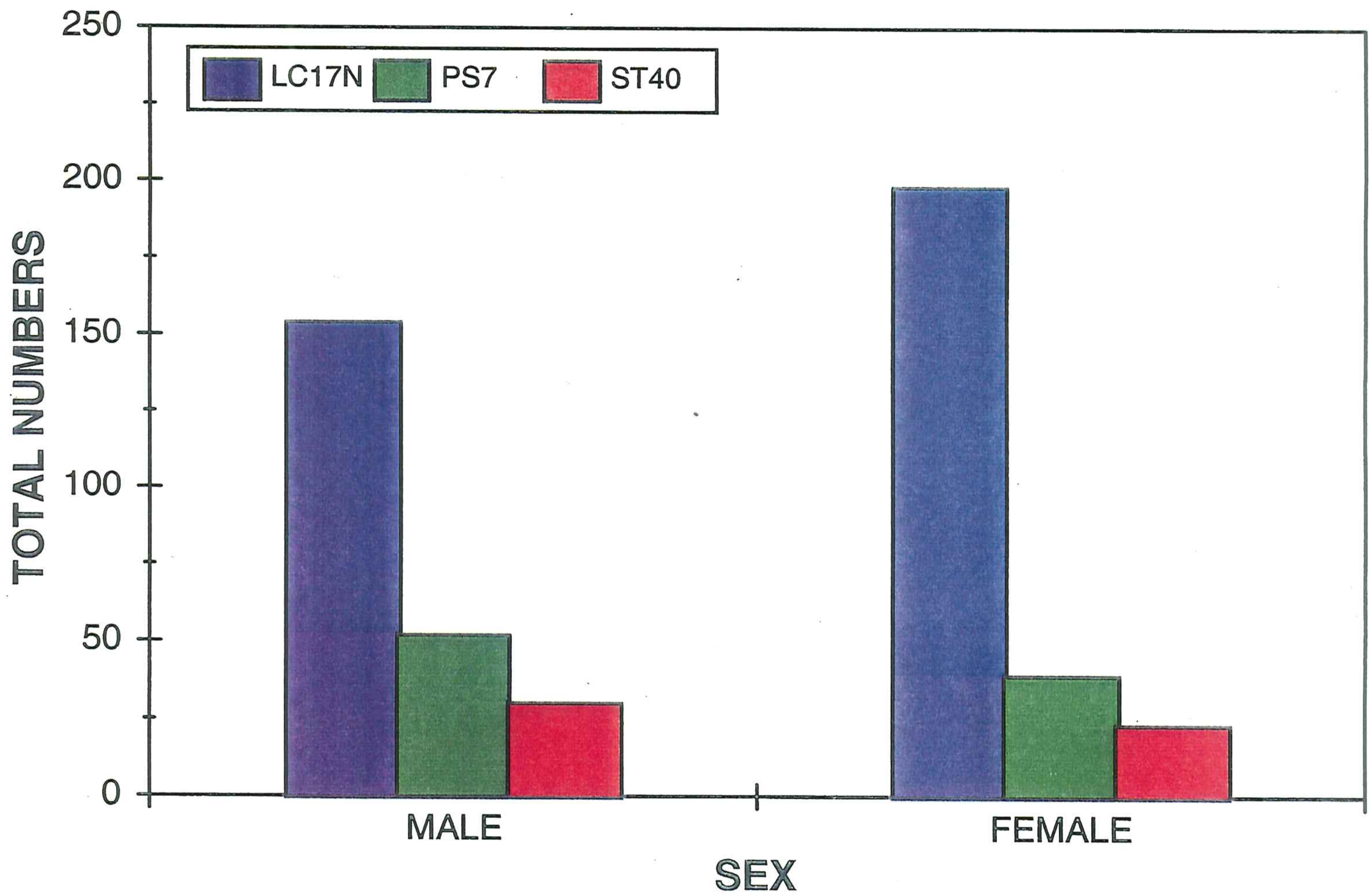


Figure 26. Sex ratio totals for southeastern beach mice captured on the coastal strand/scrub grids during the period of September 1995 to October 1997.

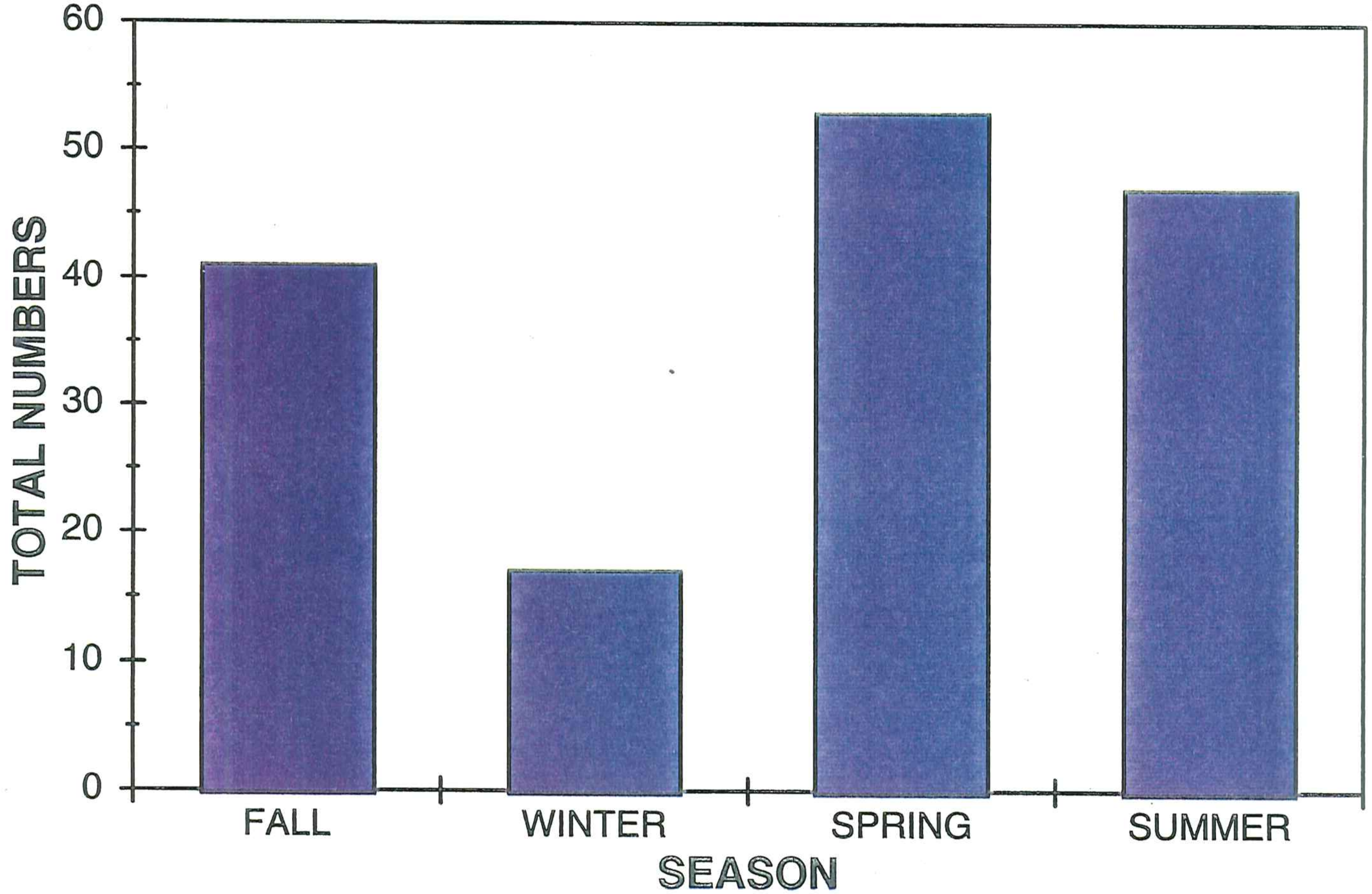


Figure 27. Abundance of reproductively active female southeastern beach mice on the coastal strand/scrub grids (grids and years are combined).

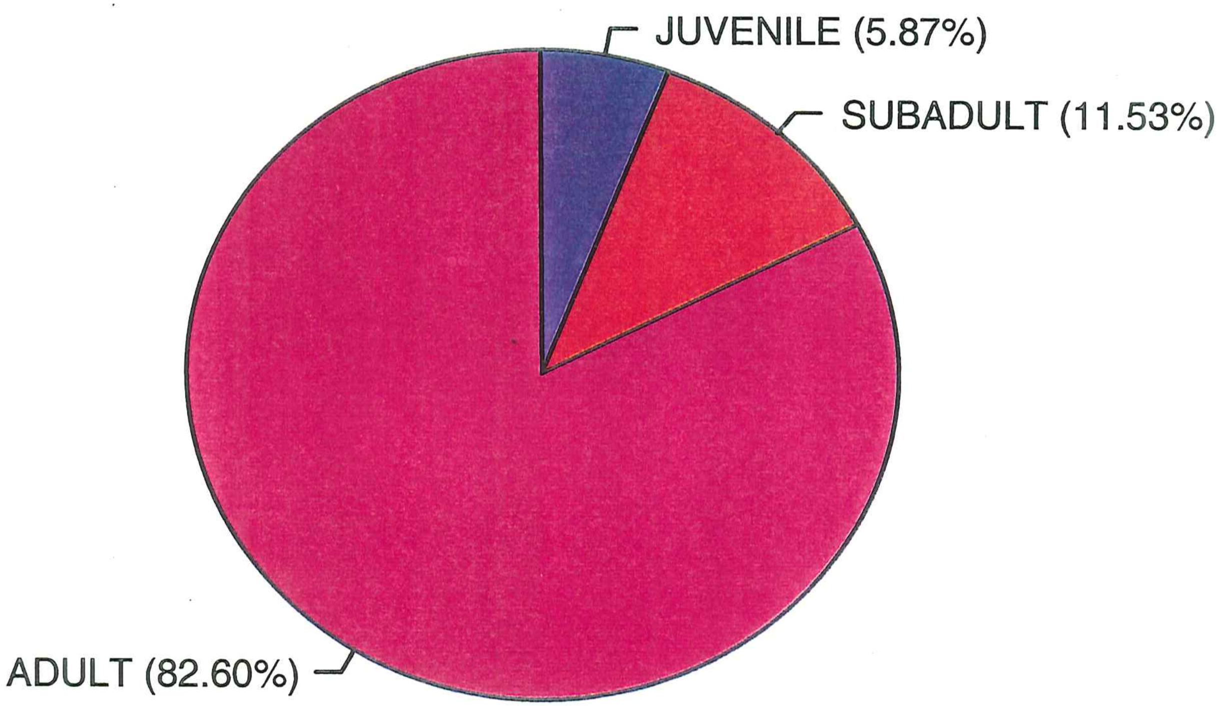


Figure 28. Age class distribution of southeastern beach mice captured on the coastal strand/scrub grids during the period of September 1995 to October 1997.

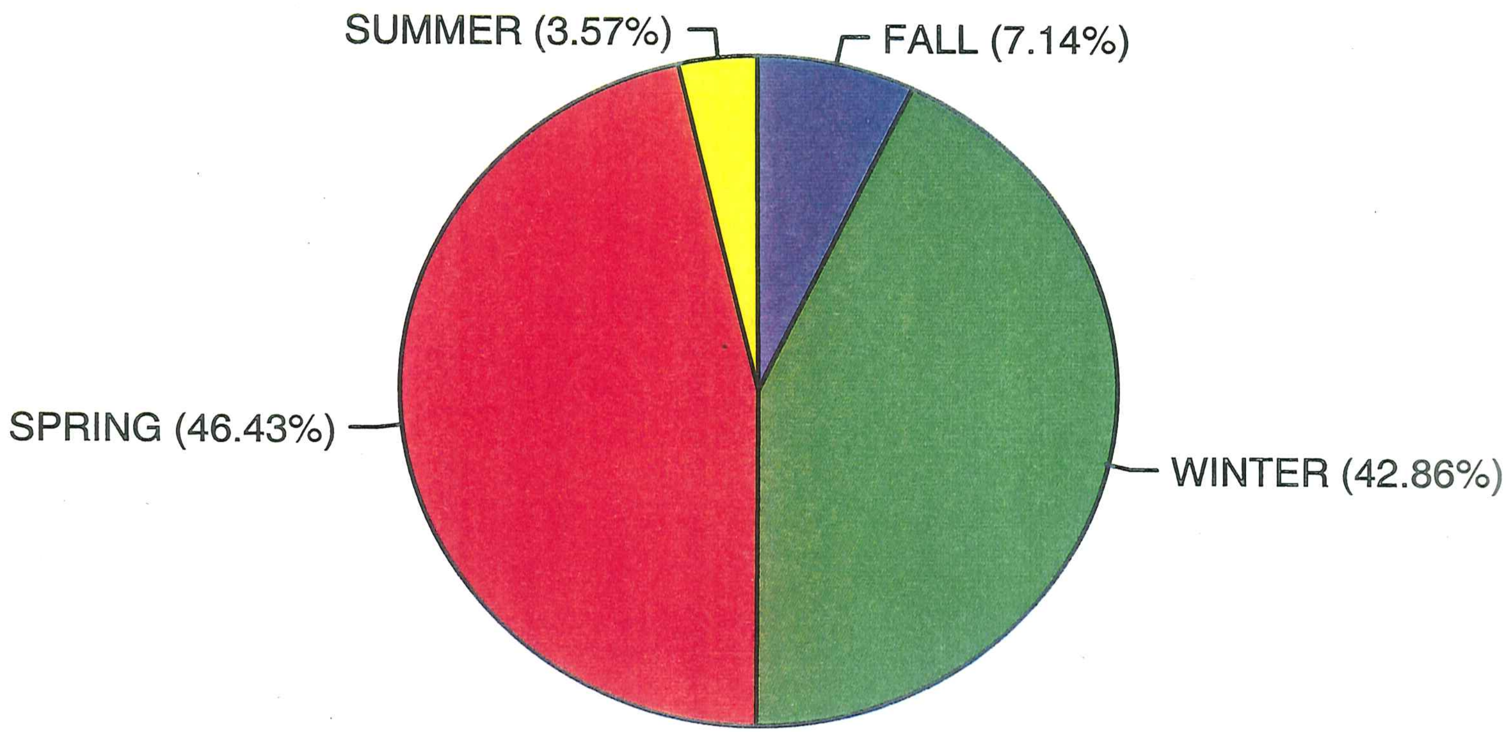


Figure 29. Abundance of juvenile southeastern beach mice on the coastal strand/scrub grids (grids and years are combined)

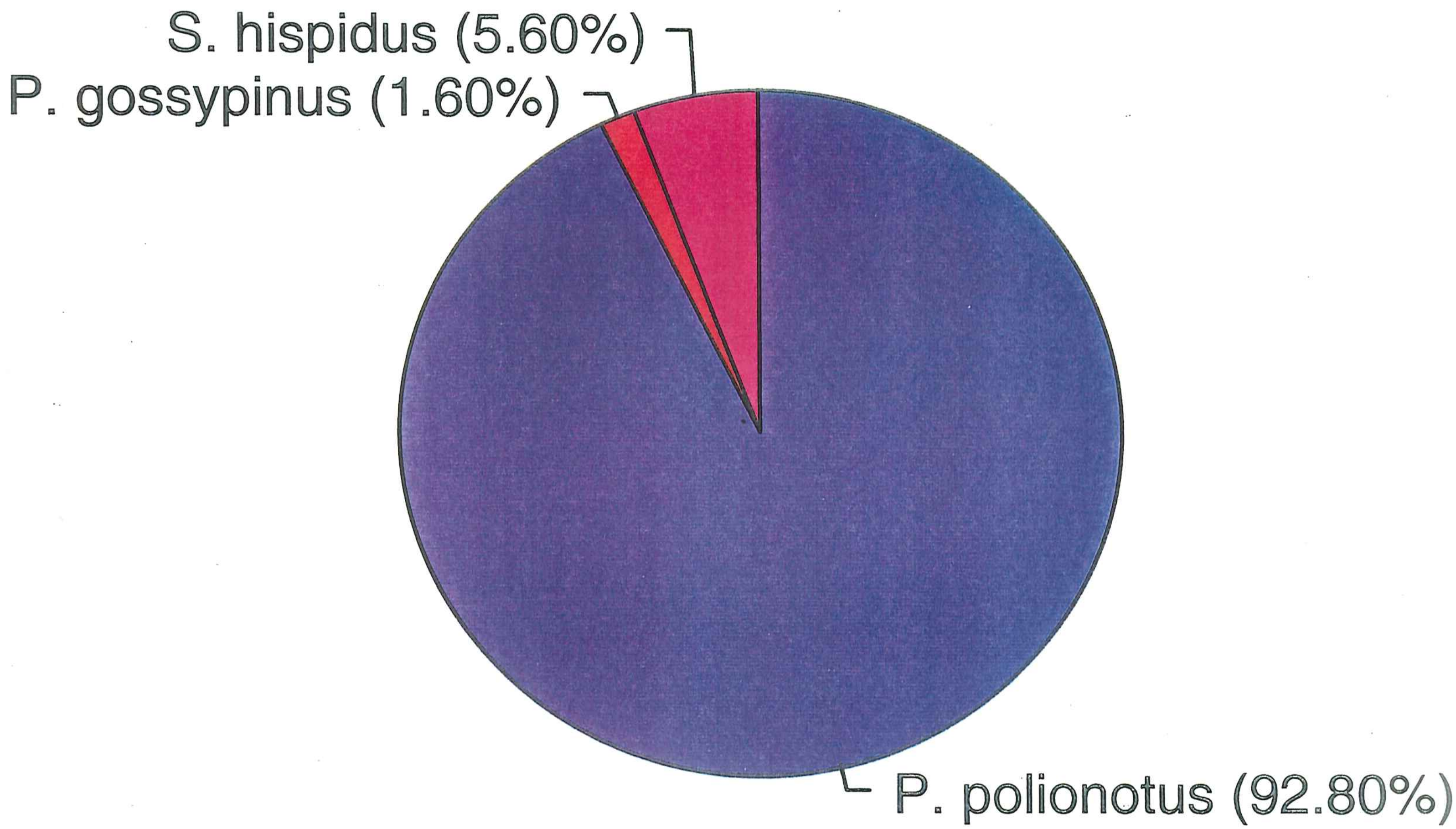


Figure 30. Percent capture of small mammals on the LC36 transects for the period of September 1995 to October 1997.

ghost crab (*Ocypode quadrata*) was also caught. The total number of possible trapnights for the four transects during the period September 1995-October 1997 was 3840 (see Table 15). The actual number was 3725 (see Table 15).

Beach mice captures were highly variable between transects, seasons, and years as demonstrated by Figure 31. The highest total numbers of beach mice were captured on transect LC36BS followed by almost equal numbers at LC36BN and LC36AS and the lowest numbers at LC36AN for a total of 117 beach mice. Highest total numbers of beach mice captured at the four transects combined occurred in the Winter and Spring (Figure 32). The sex ratio of beach mice (Figure 33) for the four transects was 71:46 males to females or 60.7% male and 39.3% female. This deviation from unity was not statistically significant ($p > 0.05$). Average weight of male beach mice was 13.7 grams (n = 65, std = 1.7). Female body weights are not used in these analyzes, because they can be significantly altered by pregnancy. Of the 46 females (58.7%), 27 were reproductively active. Summer, followed by Winter yielded the highest number of reproductively active females for the four transects (Figure 34). The greatest proportion of beach mice captured were adults (n = 102) followed by subadults (n = 8) and juveniles ({n= 2} Figure 35).

Discussion

Coastal Dune Grids

Just prior to the Fall quarter, on August 1, 1995 Hurricane Erin hit Brevard County, followed by Tropical Storm Jerry on August 22-25, and Hurricane Luis passed by from August 28 through September 11, 1995. These storms caused increased precipitation (15.59 inches {39.6 cm} total) and high winds ranging from 42.6 mph (68.6 km/hr) to 80.6 mph (129.7 km/hr) (National Weather Service pers. comm.). The high of 80.6 mph (129.7 km/hr) was a direct result of Hurricane Erin. These storms, together with an astronomical high tide caused by a full moon (September 8, 1995) and the seasonal warming of the water, produced sea levels that were higher than at any other time of the year. This sequence of events allowed water to rise over the beach and inundate many of the dunes resulting in extensive damage to the sea oats and other dune vegetation.

Overwash from these storms and the heavy rainfall coupled with the high winds and high tide affected each grid differently. The LC17 grid was the least affected. The beach was now extended approximately 30 m west into and on top of the primary dune. A majority of the sea oats were buried and approximately 0.30-0.46 m (1-1 1/2 ft) of sand was deposited here. The sand road that went to the beach just north of this grid had experienced high tide with

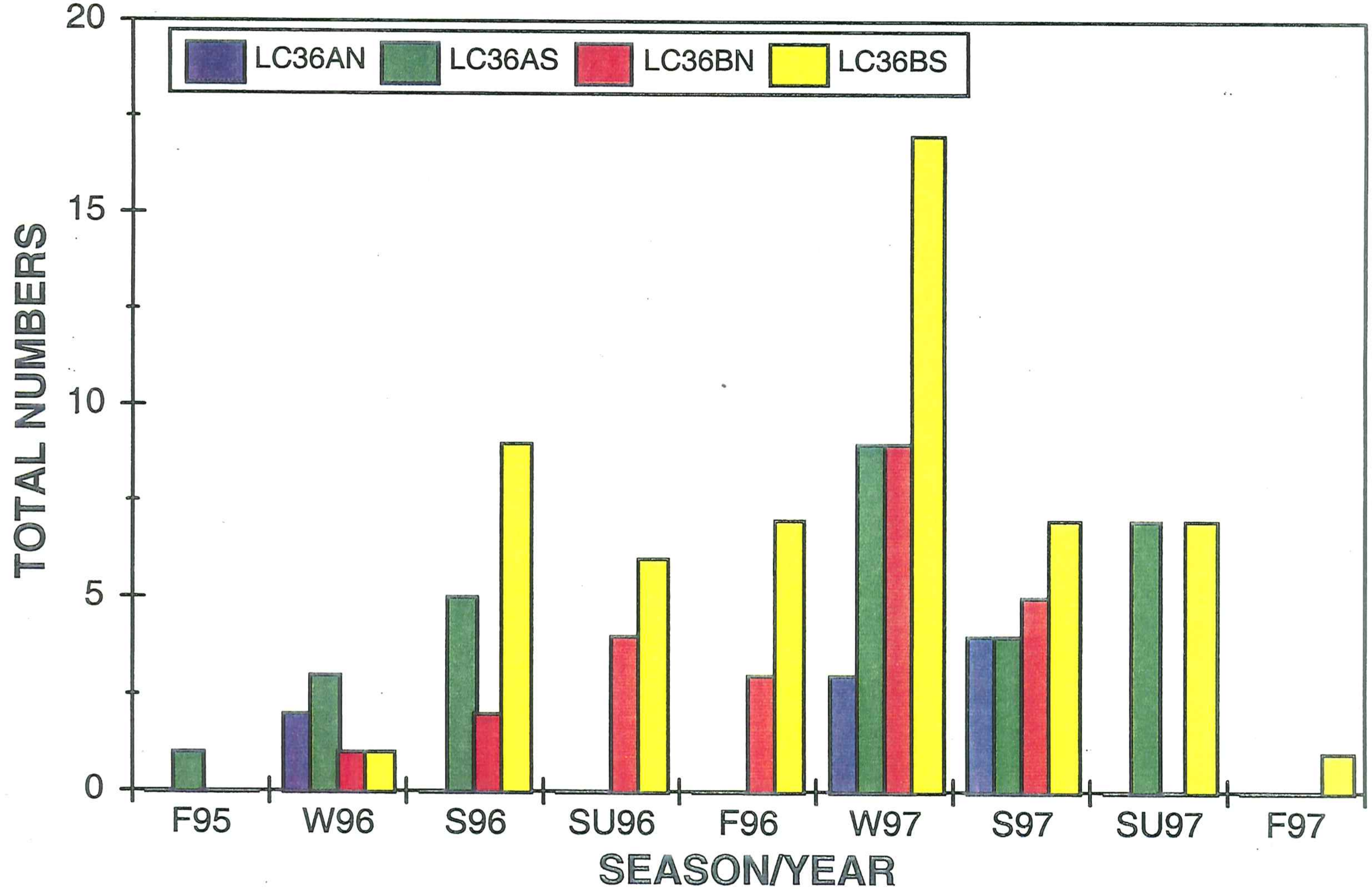


Figure 31. Total number of southeastern beach mice captured on the LC36 transects by season and year.

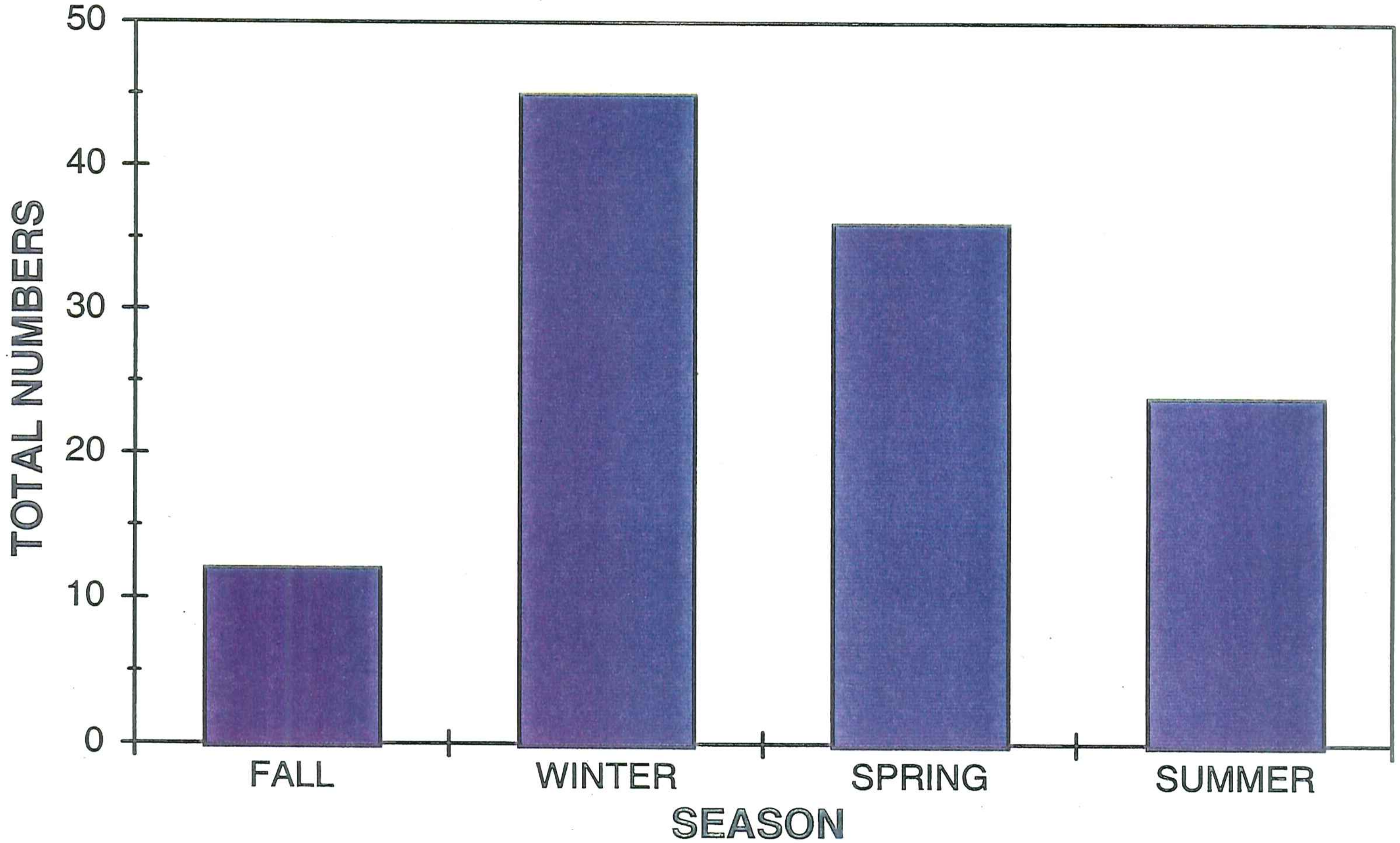


Figure 32. Seasonal abundance of southeastern beach mice on the LC36 transects (transects and years are combined).

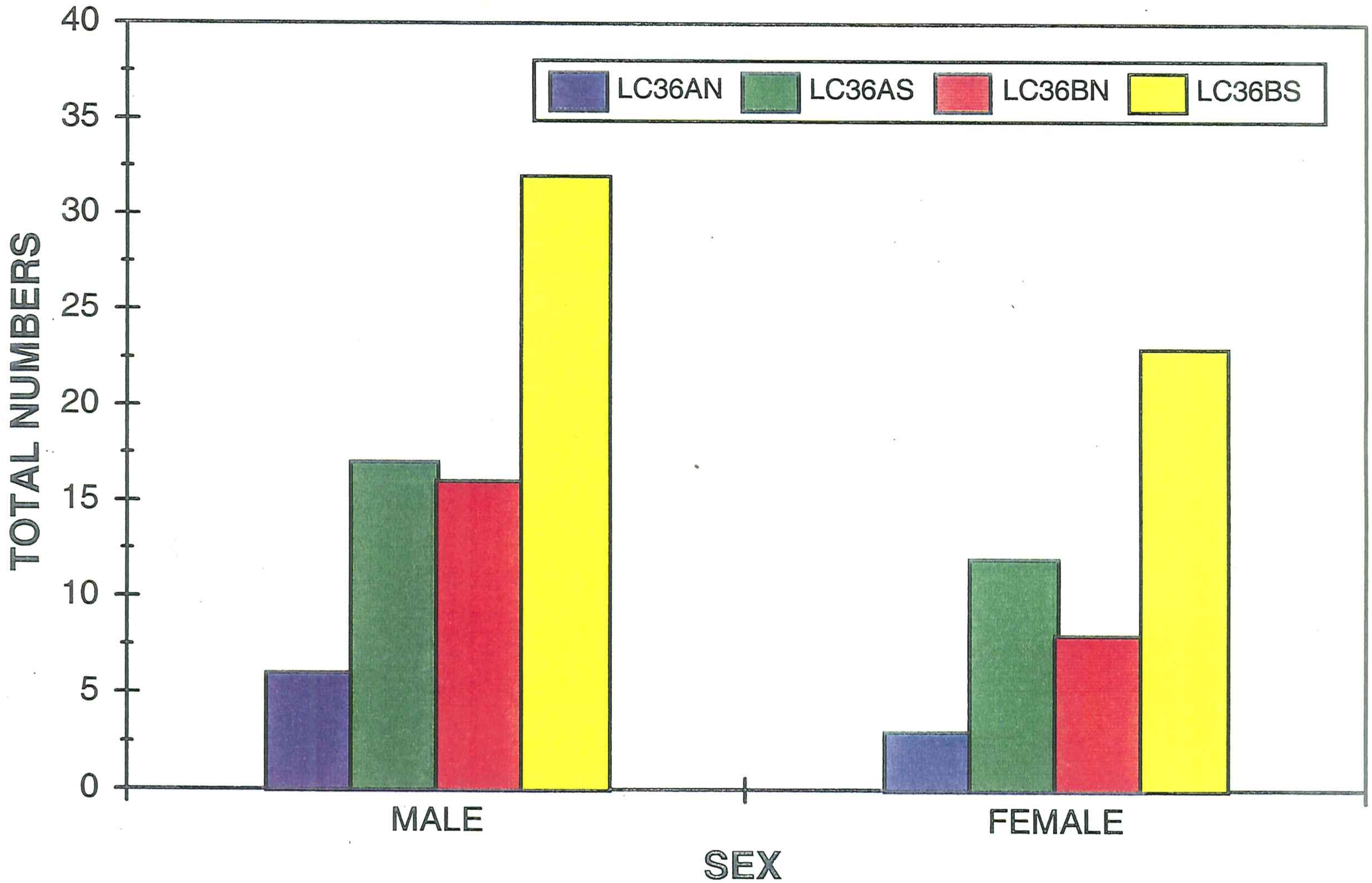


Figure 33. Sex ratio totals for southeastern beach mice captured on the LC36 transects during the period of September 1995 to October 1997.

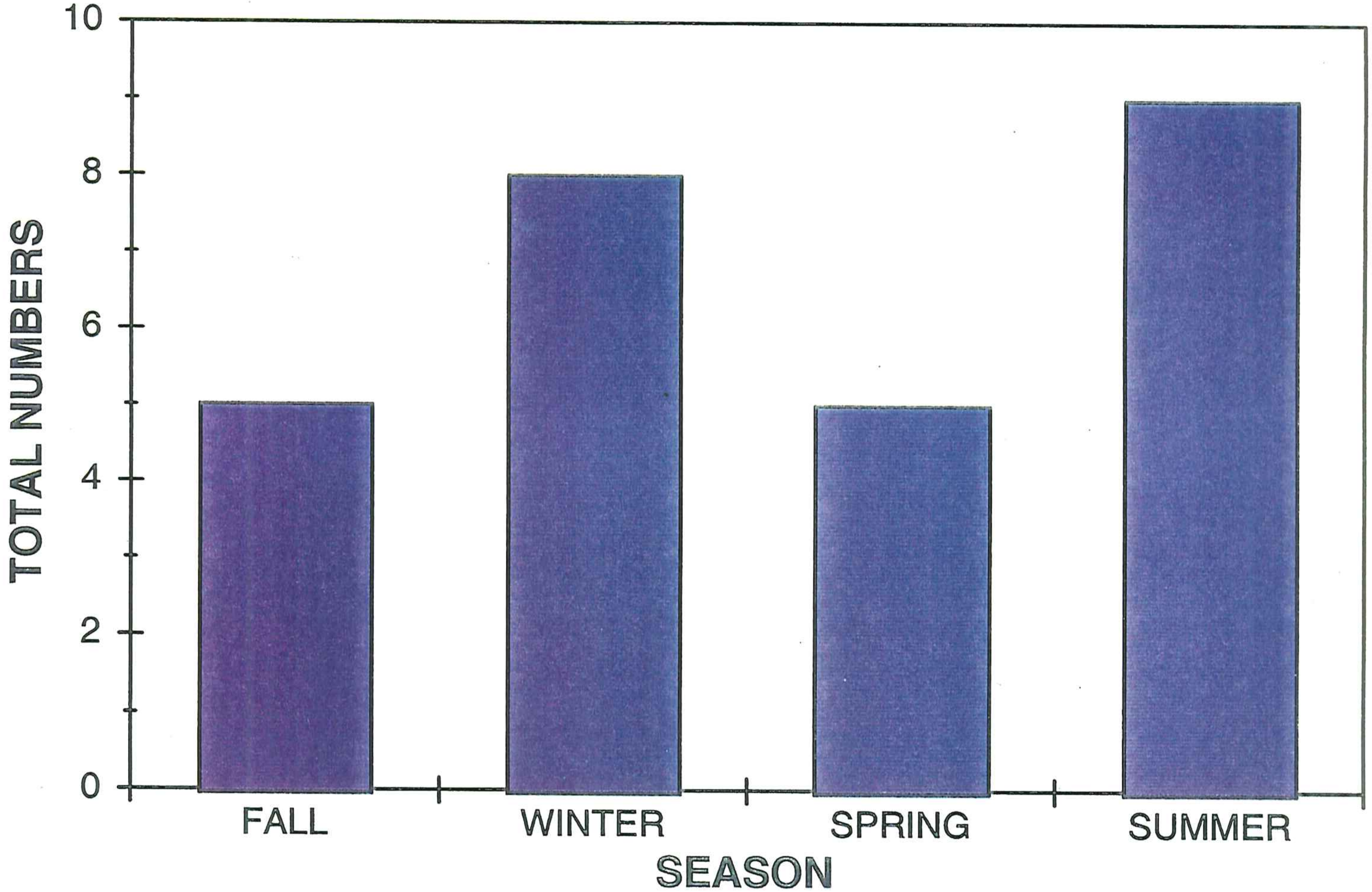


Figure 34. Abundance of reproductively active female southeastern beach mice on the LC36 transects (transects and years are combined).

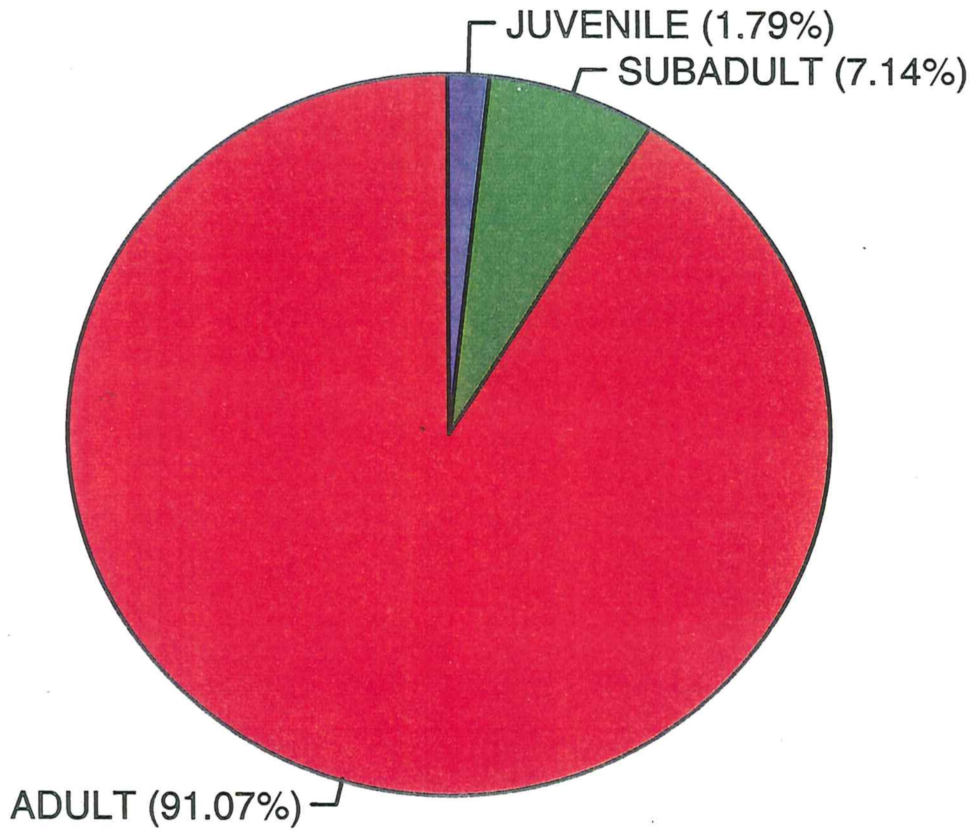


Figure 35. Age class distribution of southeastern beach mice captured on theLC36 transects during the period of September 1995 to October 1997.

waves breaking over the dune causing water to flow down the road like a small inlet.

The AQ grid, like LC17, had standing water still present in the swales and had similar topographical changes to the primary dune. The first two lines of the grid had 0.30-0.46 m (1-1 1/2 ft) sand deposited on top of the sea oats. In addition to the sand and standing water, debris was deposited 50-60 m into the coastal strand vegetation. Most of the vegetation in the interdunal swales was dead due to overwash. The southernmost grid, JETTY, was like the previous two. Sea oats were buried by sand on the primary dune and there was quite a bit of dead vegetation (sea oats included) due to inundation, and debris was present inland.

LC2529 was the largest grid and had a large amount of water present in most of the grid. Once again 0.30-0.46 m (1-1 1/2 ft) of sand was deposited on top of the sea oats on the primary dune, and debris from high water extended landward 150 m or more.

By the Winter of 1996 the standing water in the interdunal swales of the four grids had dried out, and the vegetation had begun to recover from the salt water intrusion. The primary dune and slope of the beach were still altered, preventing the running of line one on all of the four grids and line two on the AQ and LC2529 grid. This trend remained for the other trapping periods with the exception of LC17. LC17, the least effected by the series of fall 1995 storms, was the only grid that recovered completely during the trapping period. Sea oats and other dune species recolonized the primary dune providing food and cover, allowing the entire grid to be trapped.

Stout (1980) found three resident species of small mammals (beach mouse, cotton mouse, and cotton rat) on his beach grid, which was located at LC41. One resident (the beach mouse) and three transient (cotton mouse, cotton rat, and spotted skunk) small mammal species were found on our four coastal dune grids. A total of 10163 actual trapnights were recorded for the four coastal dune grids with beach mice representing the majority of animals captured (97%). This proportion was higher than the 92% recorded by Mercadante (1989) on his dune/strand grids and the 74% and 67% reported by Stout (1980) on his beach grid and Keim (1979) on her coastal strand grid, respectively. Overall trap success for the beach mouse at the four coastal dune grids was 16.8% (1708/10163). This was lower than the 34% (771/2256) recorded by Extine (1980) and the 31.1% (316/1016) observed by Mercadante (1989) but comparable to the 16.9% (257/1520) reported by Keim (1979).

Garten and Smith (1974) described a predictable seasonal flux in numbers with a distinct peak in Winter. Stout (1980) also found the highest number of beach mice in the Winter and Spring. Our data showed the highest numbers in Fall and Spring, while Extine (1980) found peak densities in March/April and Keim (1979) in Fall and Winter. The total numbers for Winter were lower due to only one quarter of data being able to be collected at LC17, which had a high number of beach mice in almost every other quarter. Mercadante (1989) did not look at seasonal trends, reproduction, sex ratios, weight, or age.

Sex ratio is a significant population parameter, which influences spacing, reproductive behavior, and population growth rates (Keim 1979). The basic social unit is one male per female in this monogamous species, although field studies have found that males often comprise more than the theoretical fifty percent of the population (Manville 1956). In addition, oldfield mice (*Peromyscus polionotus*) have been shown to produce higher numbers of male offspring (Terman and Sassaman 1967), but the sex ratio of the adult population has been shown to be close to unity (Smith 1967, Smith and Criss 1967, Kaufman and Kaufman 1982). The skewed sex ratio of 927:757 males to females, while statistically significant ($p = 0.05$), is most likely the result of a male bias in trapping, considered typical because of the behavioral differences in the sexes whereby males are highly trappable (Smith 1968).

Stout (1992) reported average weight of male beach mice as 14.4 g ($n = 19$) which was similar to Keim's (1979) value of 14.8 g ($n = 138$) on her coastal strand grid. These values are higher than our average of 12.8 g ($n = 901$). This is probably due to the larger number of juveniles captured during our study than Keim's (1979) ($n = 140$ compared to $n = 4$) which helped to decrease the average weight of male beach mice.

The largest percentage (72%) of females in reproductive condition occurred in the Fall (44%) and Summer (28%). Stout (1980) found peak reproductive activity in females to be concentrated between August and January, while Extine (1980) found a peak in September/October and Keim (1979) found highest rates February through October. Juveniles were observed in every season, but the largest numbers were seen in the Fall (58%) and Winter (25%). This was comparable to Stout's (1980) observation of 40% of all juveniles between October and December.

Coastal Strand/Scrub Grids

None of the coastal strand/scrub grids, which were located north of the coastal dune mice grids, was affected adversely by the hurricane and tropical storms of Fall 1995. LC17N exhibited the highest numbers of beach mice in all seasons except Winter 1997 when it wasn't trapped due to an explosion of a Delta rocket. These grids were located in open coastal strand and scrub habitat and spaced 15 m apart rather than 10 m in order to increase the chances of capturing a Florida mouse. No Florida mice were captured on any of the three grids.

Stout (1980) found three resident species of small mammals (beach mouse, cotton mouse, and cotton rat) on his dune grid. Two resident and two transient small mammal species were found on our coastal strand/scrub grids. The residents were the beach mouse and cotton mouse with the cotton rat and spotted skunk being the transients. A total of 3174 actual trapnights were recorded for the three coastal strand/scrub grids with beach mice representing the majority of animals captured (65%). This proportion was higher than the 45% reported by Stout (1980) and the 37% observed by Keim (1979) on their dune grids but lower than the 78% recorded by Mercadante (1989) on his scrub grid. Overall trap success for the beach mouse at the three coastal strand/scrub grids was 16.0% (508/3174). This was higher than the 11% (99/896) recorded by Extine (1980) on his dune grid and the 12% (119/960) observed by Keim (1979) on her dune scrub grid but once again lower than the 29% (35/120) obtained by Mercadante (1989).

Stout (1980) found the highest number of beach mice in the Winter and Spring. Our data showed the highest numbers in Summer and Spring and were comparable to Extine's (1980) peak in May. Once again the total numbers for Winter were lower due to only one quarter of data being able to be collected at LC17N, which had the most beach mice of the three grids in every other quarter.

Average weight of male beach mice on our coastal strand/scrub grids was 14.3 g (n = 231) which was comparable to the 14.4 g (n = 66) average found by Keim (1979) on her dune scrub grid and the 14.4 g (n = 19) reported by Stout (1992).

The largest percentage (64%) of females in reproductive condition occurred in the Spring (34%) and Summer (30%). Stout (1980) found peak reproductive activity in females to be concentrated between August and January, while Extine (1980) found a peak in September/October. Juveniles were observed in every season, but the largest numbers were seen in the Spring (46%) and Winter (43%). Stout (1980) observed 40% of all juveniles between October and December. Extine (1980) discovered that his dune scrub grid was composed of a greater portion of adults than his beach population as the dune scrub grid yielded juveniles in March only.

Cotton mice captures represented 28% of all captures on our coastal strand/scrub grids but only 2.2% on Mercadante's (1989) scrub grid. Our percent capture was comparable to Stout's (1980) 23% on the dune grid. Seasonal trap success for this species was highest in Spring and Summer. The cotton mouse, although a permanent resident on PS7 and ST40 grids seemed to be a transient on the LC17N grid. This may be in part be a result of the location of the grids, both PS7 and ST40 are located on the west side of Phillips Parkway in coastal scrub while LC17N is on the east side of Pier road in coastal strand. The percent of captures represented by cotton rats (1.8%) was much lower than that reported for Stout's (1980) dune grid at 31% and Mercadante's (1989) scrub grid at 11.1%. This low density was not unexpected, as this area does not represent optimum cotton rat habitat. Cotton rats have been reported to prefer and in some cases to be restricted to areas of dense grassy cover (Arata 1959, Goertz 1964). The second transient species, the spotted skunk, made up 4% of all captures on our coastal strand/scrub grids and was absent from Stout's and Mercadante's dune grids.

Transects

Provancha et al. (unpub. data) found six species (beach mouse, cotton mouse, cotton rat, Florida mouse, spotted skunk, and roof rat) of small mammals on their transects which were located in coastal dune, strand, and scrub habitat on KSC. We found only three species of small mammals (beach mouse, cotton mouse, and cotton rat) on our four transects. A total of 3725 actual trapnights were recorded for the four transects with beach mice representing the majority of animals captured (92%). This proportion was higher than the 61% recorded by Provancha et al. (unpub. data) and the 26.7% observed by Stiner (1991,1992). Overall trap success for the beach mouse at the four transects was 3.1% (117/3725). This proportion was lower than the 8.2% (9/109.5) and 10.2% (11/107.5) reported by Humphrey et al. (1987) for two transects at the southern portion of CCAS. It was also lower than the 13.6% (539/3937) recorded by Provancha et al. (unpub. data) but was higher than the 2.2% (36/1632) observed by Stiner (1991,1992).

The highest numbers of beach mice on the four transects were captured in the Winter and Spring. Provancha et al. (unpub. data) results coincided with ours. The highest total number of beach mice was found on transect LC36BS which was in better habitat than the others. The other three transects were located along a very narrow dune that was often comprised of dense patches of *Spartina patens* and other grasses more suitable for cotton rats. Behind the dense patches of grass the vegetation quickly became a dense thicket of coastal strand. This habitat was similar to the habitat on CNS where Stiner (1991, 1992) obtained a trap success for cotton rats of 63%. Stiner (1991,1992) did not look at seasonal trends and his reproductive, sex ratio, weight, and age data were incomplete so we were unable to compare our results to his in these areas.

The largest percentage (63%) of females in reproductive condition occurred in the Summer (33%) and Winter (30%) on our transects and in the Winter on the transects run by Provancha et al. (unpub. data). Beach mouse captures on the four transects were biased towards males at 60.7%. This is higher than the 52% recorded by Provancha et al. (unpub. data). Juveniles were observed only in Winter and then in very low numbers (n = 2). Provancha et al. (unpub.data) on the other hand, observed juveniles in all seasons with a peak in Winter.

Summary

No discernable impacts were observed as a result of normal launch operations from the Titan, Atlas, or Delta launch complexes. The explosion of a Delta rocket in January 1997 caused direct impacts to the LC17 grid by burning/heat scorching some portion of the last three lines of the grid. If any mortality occurred as a direct result of the explosion, it could not be documented due to the closure of the area, which resulted in the lack of sampling for that Winter period.

Habitat alterations associated with hurricanes, tropical storms, inundation from seawater, and man-made and natural erosion probably had a greater negative effect than launch operations in the immediate vicinity of the launch complexes. In addition, fire suppression, which leads to habitat degradation also, has a negative effect. Not much is known about the food resources of this subspecies other than sea oats, seeds, various beach grasses, and some invertebrates are consumed. Some of these dune plants that are potential food sources for the beach mouse are sensitive to acid deposition from launches (Schmalzer per. comm.). In addition to food utilization, not much is known about impacts of lights from the surrounding launch complexes on the activity of beach mice. There are a number of studies that show that many small mammals have decreased activity on moon lit nights versus dark nights. This decrease is primarily attributed to an increase in predation on moon lit nights. Many small mammals, including the beach mouse, experience population fluctuations of a cyclic nature. Long-term studies are needed to determine and understand the nature and duration of these cycles to distinguish them from populations that are in danger of extinction. In addition, an understanding of habitat utilization of the dune, strand, and scrub are needed in order to assess impacts from alterations and loss of the habitat from natural disasters and man-induced changes (i.e., development, fire suppression, sand transfer projects, etc.). Long-term studies of this nature can provide the means for us to understand the population dynamics and future of this threatened species on CCAS.

Waterbirds

Introduction

CCAS is located on the eastern shore of the Banana River, which is part of an extensive estuarine system known as the Indian River Lagoon System (IRL). The IRL is an important site for wading birds (herons and egrets) in Florida; as much as one tenth of all Florida wading birds use the system for at least part of the year (Schikorr and Swain 1995, Sewell et al. 1995, Smith and Breininger 1995, Mikuska et al. 1998). Almost all of the natural salt marsh in the northern part of the IRL was impounded for mosquito control by the 1970's (Brockmeyer et al. 1997). Some species of birds appear to have benefited from the changes in habitat resulting from impounding (Breininger and Smith 1990, Smith and Breininger 1995, Schikorr and Swain 1995). Others, such as the Dusky Seaside Sparrow (Kale 1996) and the Black Rail (Breininger et al. 1994) have been adversely effected. On CCAS, impounded salt marsh habitat is located adjacent to the LC40 and LC41 launch complexes (Figure 36). The adjacent MINWR contains 74 shallow impoundments in former salt marsh habitat. A recent effort to reconnect much of this impounded salt marsh habitat with the IRL is underway; the effects of reconnection on wildlife populations are unknown (Brockmeyer et al. 1997).

The term waterbirds refers to species of birds that utilize wetland habitats for foraging and/or nesting activities. Fifty-one species of waterbirds are expected to occur on CCAS (Table16). There are several distinct subgroups within the waterbirds, each with unique ecological characteristics and conservation concerns. The egrets, herons, ibises, and storks (Class Aves, Order Ciconiiformes) are often referred to as wading birds. These birds inhabit a variety of wetland habitats and usually nest in colonies near water. This group of birds includes many species of conservation concern at the state and federal level; six species of wading birds expected to occur on CCAS are listed as species of special concern by the State of Florida, and the Wood Stork (*Mycteria americana*) is listed as Federally endangered (Wood 1996).

Wading birds in Florida have undergone two periods of drastic decline over the past century (Odgen 1978a, 1991). The first occurred around the turn of the century and was the result of hunting for the plume trade. After a brief period of recovery, wading birds again underwent drastic reduction in numbers beginning around 1930 and continuing to the present. This more recent decline is believed to be due to the use of pesticides that caused eggshell thinning, and the disturbance and destruction of wading bird nesting and foraging habitat, especially in south Florida. Current threats to wading birds include habitat loss and degradation, habitat fragmentation, pollution, and pesticide contamination (Odgen 1978a, 1991, Stevenson and Anderson 1994, Kushlan 1993, 1997). Some wading birds, such as the Wood Stork, are vulnerable to artificial

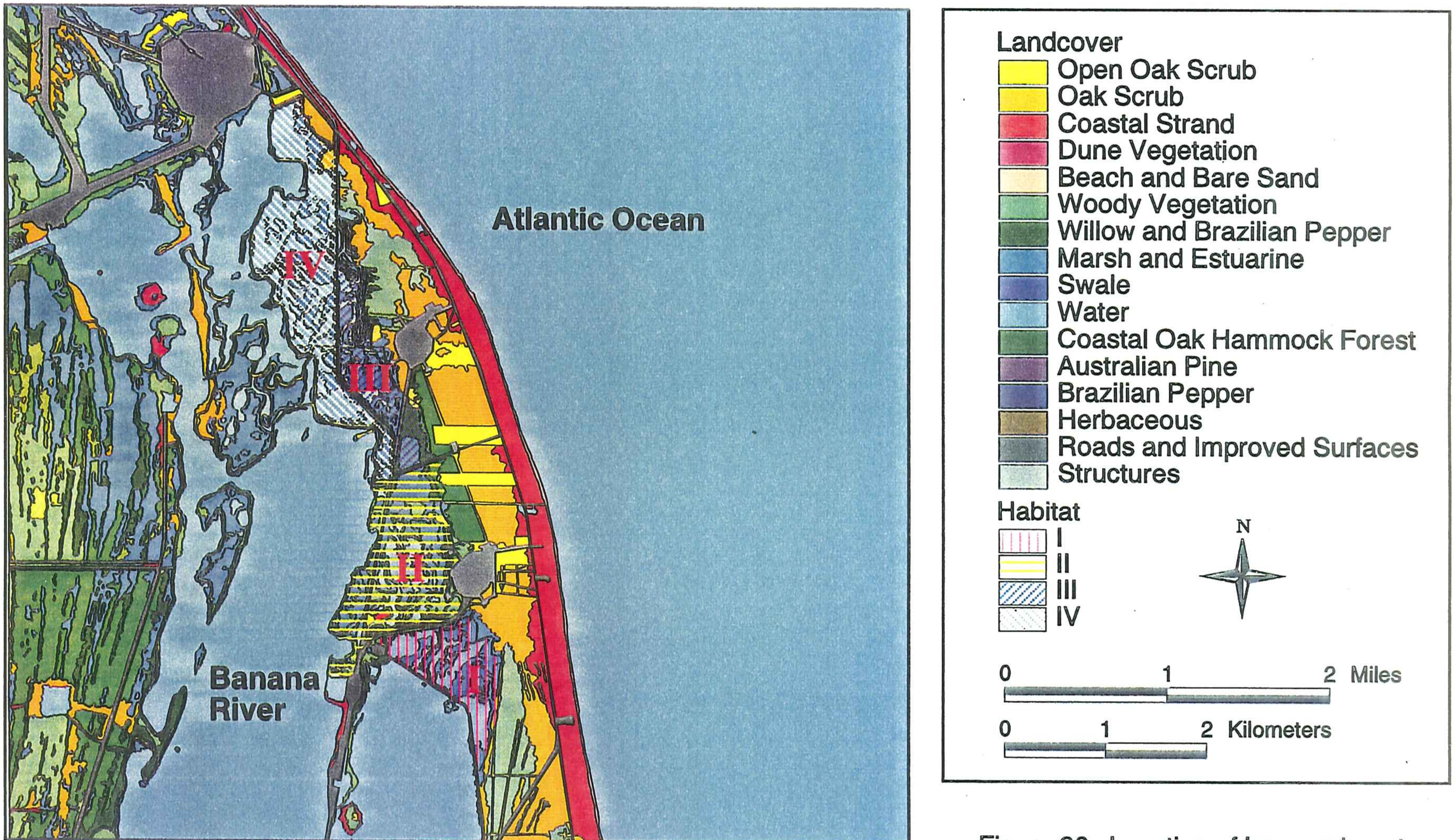


Figure 36: Location of Impoundments on Cape Canaveral Air Station surveyed for waterbirds from June 1995 - December 1997. Surveys were conducted monthly from a helicopter or fixed wing aircraft.

Table 16. Waterbirds expected to occur on Cape Canaveral Air Station. (Based on Cruickshank 1980, Kale and Maehr 1990, Robertson and Woolfenden 1992, Stevenson and Anderson 1994)

SPECIES	HABITAT [a]	SEASON [b]	FORAGING METHOD / DIET [c]
Podicipediformes			
Podicipedidae			
Pied-billed Grebe (*Podilymbus podiceps*)	Fw (Bm,I,Oc)	R,Wm	Dives; fish, aq. invert., some veg.
Horned Grebe (*Podiceps auritus*)	E,I (Fw,Oc)	Wm	Dives; fish, crustaceans, amphibians, aq. insects
Gaviiformes			
Gaviidae			
Common Loon (*Gavia immer*)	Oc, E (occ. large lakes)	Wm	Dives; fish, crustaceans, small amount veg.
Pelicaniformes			
Pelecanidae			
American White Pelican (*Pelecanus erythrorhynchos*)	Fw,I,E	Wm	Surface; fish
Brown Pelican (*Pelecanus occidentalis*)	Oc,E,I	R	Dives; fish
Phalacrocoracidae			
Double-crested Cormorant (*Phalcrocorax auritus*)	Fw,I,E,Oc	R, Wm	Dives; fish, aq. invert., occ. sm. vert.
Anhingidae			
Anhinga (*Anhinga anhinga*)	Fw (I, E)	R, Wm	Dives; fish, aq. invert., occ. sm. vert.
Ciconiiformes			
Ardeidae			
American Bittern (*Botaurus lentiginosus*)	Fm (Bm)	Wm	Surface; fish,aq. insects, sm. vert.
Least Bittern (*Ixobrychus exilis*)	Fm,Bm	R, Wm	Surface; sm. fish, aq. invert., sm. vert.
Great Blue Heron (*Ardea herodias*)	E,I,Fw,Bm (Be,Oc,Up)	R, Wm	Surface; fish, sm. vert., invert.
Great Egret (*Casmerodius albus*)	E,I,Fw,Bm (Be,Up)	R, Wm	Surface; fish, sm. vert., invert.
Snowy Egret (*Egretta thula*)	Fw,E,I,Bm (Up)	R, Wm	Surface; aq. invert., sm. fish, sm. vert.
Little Blue Heron (*Egretta caerulea*)	Fw,E,I,Bm (Up)	R, Wm	Surface; aq. invert., sm. fish, sm. vert.
Tricolored Heron (*Egretta tricolor*)	E,I,Bm (Fw)	R, Wm	Surface; sm. fish, (also sm. vert., invert.)
Reddish Egret (*Egretta rufescens*)	E,I,Bm (Fw)	R, N	Surface; fish (also aq. invert.)
Cattle Egret (*Bubulcus ibis*)	Up (also aquatic habitats)	R, Wm	Surface; invert., sm. vert.
Green Heron (*Butorides striatus*)	Fw (Bm)	R, Wm	Surface; sm. fish, sm. vert., invert.
Black-crowned Night Heron (*Nycticorax nycticorax*)	Fw,Bm, E, I	R, Wm	Surface; fish, sm. vert., invert.
Yellow-crowned Night Heron (*Nyctanassa violacea*)	Fw,Bm, E, I,Be	R, Wm	Surface; crustaceans (also fish, sm. vert.)
Threskiornithidae			
Whit Ibis (*Eudocimus albus*)	Fw,E,I,Up	R, Wm, N	Substrate; invert., snakes
Glossy Ibis (*Plegadis falcinellus*)	Fw (Bm,Up)	R, Wm, N	Substrate; insects, crayfish, snakes, fish
Roseate Spoonbill (*Ajaia ajaj*a)	Bm,E,I (Fm)	R, N	Strains water; sm. fish, insects, crustaceans, some veg.
Ciconiidae			
Wood Stork (*Mycteria americana*)	Fw,Bm,E,I	R, Wm, N	Snatches fish (also invert., sm. vert.)

Table 16. Continued.

SPECIES	HABITAT [a]	SEASON [b]	FORAGING METHOD / DIET [c]
Anseriformes			
Anatidae			
Fulvous Whistling-Duck (*Dendrocygna bicolor*)	Fw	Wm	Strains aquatic veg., occ. diving
Wood Duck (*Aix sponsa*)	Fw	R, Wm	Shallow; 30% animal (vert., invert.)
Green-winged Teal (*Anas crecca*)	Fw (Bm, E, I)	Wm	Dabbling; 11% animal (invert.)
American Black Duck (*Anas rubripes*)	Fw, Bm, E, I	Wm (rare)	Dabbling; mostly veg.
Mottled Duck (*Anas fulvigula*)	Fw, Bm, E, I	R	Dabbling; 44% invert., 56% veg.
Mallard (*Anas platyrhynchos*)	Fw (Bm, E, I)	Wm	Dabbling; 97% veg.
Northern Pintail (*Anas acuta*)	Fw, Bm, E, I	Wm	Dabbling; mostly veg.
Blue-winged Teal (*Anas discors*)	Fw (Bm, E, I)	Wm	Dabbling; aquatic veg., aquatic invert.
Northern Shoveler (*Anas clypeata*)	Fw	Wm	Dabbling; aquatic veg., aquatic invert.
Gadwall (*Anas strepera*)	Fw (Bm, E)	Wm	Dabbling; aquatic veg.
American Wigeon (*Anas americana*)	Fw, E	Wm	Dabbling; aquatic veg.
Canvasback (*Aythya valisineria*)	Fw, E	Wm	Diving; >80% aquatic veg.
Redhead (*Aythya americana*)	E, Fw	Wm	Diving & Dabbling; 90% aquatic veg.
Ring-necked Duck (*Aythya collaris*)	Fw (E)	Wm	Diving & Dabbling; >97% aquatic veg.
Greater Scaup (*Aythya marila*)	E (Fw)	Wm	Diving; 52% animal, 48% aq. & emerg. veg.
Lesser Scaup (*Aythya affinis*)	E, Fw	Wm	Diving; 40% animal, 60% aq. & emerg. veg.
Hooded Merganser (*Lophodytes cucullatus*)	Fw, E, Bm	Wm	Diving; fish, aquatic invert.
Red-breasted Merganser (*Mergus serrator*)	E (Fw)	Wm	Diving; fish, crustaceans
Ruddy Duck (*Oxyura jamaicensis*)	Fw, E, Bm	Wm	Diving; 80% aquatic veg., 20%, aquatic invert.
Gruiformes			
Rallidae			
Yellow Rail (*Coturnicops noveboracensis*)	Fm	Wm	Surface; invert., some veg.
Black Rail (*Laterallus jamaicensis*)	Bm	R	Surface; invert., some veg.
Clapper Rail (*Rallus longirostris*)	Bm	R	Surface; invert., sm. fish, 10% veg.
King Rail (*Rallus elegans*)	Fm (Bm)	R	Surface; invert., sm. fish, some veg.
Virginia Rail (*Rallus limicola*)	Fm, Bm	Wm	Surface; insects, invert., sm. fish, some veg.
Sora (*Porzana carolina*)	I, Bm, Fw	Wm	Surface; insects, seeds
Purple Gallinule (*Porphyrula martinica*)	Fw	R, Wm	Surface; insects, seeds
Common Moorhen (Gallinula chloropus)	Fw	R, Wm	Surface; aq. veg, insects,snails, aq. worms
American Coot (*Fulica americana*)	Open Water	R, Wm	Dives; mostly aq. veg, some animal

a Fw=fresh water habitats (marshes, lakes, streams), Fm=freshwater marsh, Bm=brackish marsh (incl. mangroves), I=impondment, E=estuary, Be=beach, Oc=ocean, Up=upland. Habitats in brackets are less commonly used.

b R=resident, Wm=winter migrants, N=nomadic

c First part of entry gives method of foraging, second part gives specific diet. Abbreviations: aq.=aquatic, emerg=emergent, invert.=invertebrate, occ.=occasionally, sm.=small, veg.=vegetation, vert. = vertebrate.

fluctuations of water levels in wetlands that interfere with their feeding or nesting behaviors (Breininger et al. 1994).

A variety of ducks occur year-round in Florida wetlands; 19 species are expected to occur on CCAS (Table 16). Several of these species have undergone drastic declines during this century. The main cause of declines in the numbers of ducks is the loss of wetlands that are used for breeding (Stevenson and Anderson 1994). Lead poisoning resulting from lead shot used by hunters also has had dramatic impacts on duck numbers. Laws now prohibit the use of lead shot in the United States, but much lead shot remains in wetland sediments. Other threats facing ducks include oil spills that threaten species that use coastal waters, and other sources of water pollution. Ducks exhibit a variety of dietary preferences and foraging strategies. Some species are mostly vegetarian, while others are carnivorous or omnivorous. Some ducks forage on the substrate often diving several feet to reach the bottom, while others skim food off the surface or tip-up to reach shallow food items below the surface (Stevenson and Anderson 1994). These different foraging strategies make ducks useful monitors of environmental change in Florida wetlands (Furness 1993).

Nine species of rails have the potential to occur in wetland habitats on CCAS (Table 16); six species have the potential of breeding in wetland habitat on the station. Rails face many of the same conservation threats as do wading birds and ducks, including the loss or disturbance of habitat, and contamination from environmental pollutants. Globally, many species of rails have undergone drastic declines in recent years (Eddleman et al. 1988). Historically, large populations of the Black Rail may have inhabited salt marsh habitat within the IRL (Breininger et al. 1994). Much of the habitat suitable for Black Rails has been eliminated by impoundment of salt marsh on Merritt Island.

Other species of waterbirds expected to occur on CCAS include two species of grebes, the Common Loon, the Anhinga, the Double-crested Cormorant, and the Brown Pelican and American White Pelican (Table 16). All of these species have the potential of being threatened by the loss of habitat, pollution, and entanglement in lost or discarded fishing gear (Stevenson and Anderson 1994). Of these species, the most studied is the Brown Pelican. Brown Pelicans are long-lived birds that utilize a variety of Florida habitats (Table 16). The southeastern U. S. population of Brown Pelicans suffered a catastrophic decline in numbers in the 1960's and early 1970's due primarily to pesticides that caused eggshell thinning. By the late 1980's, populations in Florida, South Carolina, and North Carolina had recovered, and the Louisiana population was stable following the reintroduction of individuals there from Florida. The species was removed from the endangered species list in Florida (it is still listed as a species of special concern by the state), Alabama, Georgia, South Carolina, and North Carolina in 1985; the remainder of the population on the Atlantic and Gulf coasts and

California remains federally listed as endangered. Since the recovery of the Brown Pelican in the southeast, nesting has declined on the Gulf coast but has increased on the Atlantic coast. Loss of preferred nesting habitat (e.g., mangroves) will cause Brown Pelicans to move to other suitable locations (Wilkinson et al. 1994). A large number of Brown Pelican use beach habitat on CCAS (Stolen, in press).

The Titan Launch Complexes (LC40 and LC41) are located on a narrow barrier island between the Atlantic Ocean and the Banana River (Figure 1). Salt marshes adjacent to the launch complexes were impounded in 1960 to control mosquito populations in the area (Rey and Kain 1991). Due to the close proximity of launch complexes, Titan launches have the potential to impact adjacent impoundments and estuarine habitat in the Banana River. The Atlas Launch Complexes, LC36A and LC36B, are located approximately 0.5 km from the Atlantic Ocean on a wider portion of the barrier island (Figure 1). Extensive natural and man-made freshwater wetlands occur within 1 km of these launch complexes. These wetlands, which serve as habitat for a variety of waterbirds, have the potential to be impacted by Atlas launches.

Rockets launched from LC40, LC41, LC36A, and LC36B launch facilities use SRM's as boosters. Similar SRM's used on the Space Shuttle have been shown to be the major factor contributing to deposition of contaminants in the areas surrounding the launch pads (Schmalzer et al. 1993). Shuttle SRM's produce near-field deposition of HCl, Al_2O_3, paint, fire brick, and other debris dislodged during launch, and far-field deposition of HCl, and lesser amounts of Al_2O_3 (Schmalzer et al. 1986). These materials can contaminate water when they are deposited directly on the surface of the water, when they flow over the ground surface in the deluge water, or when they leach from the soils. Other effects of launches that might affect wildlife include noise, blast impact, fires, and vegetation changes (Schmalzer et al. 1993, Breininger et al. 1994). Schmalzer et al. (1998) found only a limited amount of deposition resulting from Delta, Atlas, and Titan rocket launches compared with launches of the Space Shuttle.

Launch effects that might directly impact waterbirds are those that affect water quality; specifically, acidification of surface waters and release and/or mobilization of metals, especially aluminum ions. These contaminants could affect the prey populations of the various species of waterbirds, or disrupt aquatic food webs (e.g., fish, mollusks, crustaceans, arthropods, benthic invertebrates, plankton, algae, and other plant species). Water pollution often occurs in pulsed events that are difficult to detect in a periodic sampling scheme. By monitoring many different species, each using particular aquatic resources and inhabiting specific niches, it is often possible to detect specific changes in water quality and identify their causes (Ormerod and Tyler 1993). Acidification of surface waters is particularly suited to the use of waterbirds as biomonitors (Furness 1993).

Because waterbirds comprise a diverse assemblage of species with a variety of foraging habits and prey types (Kushlan 1978, Rodgers 1983, Kale and Maehr 1990, Stevenson and Anderson 1994) monitoring them has the potential to determine the nature and magnitude of anthropogenic environmental impacts. Among the waterbirds, the wading birds are especially useful as monitors of environmental change, because many species are easy to survey in an unbiased manner, and many are long-lived allowing the effects of environmental change to accumulate over time (Kushlan 1993).

In addition to direct impacts by launches, habitat alteration has a large potential to effect waterbirds. Most of the declines in waterbird populations witnessed during this century have been caused wholly or in part as the result of habitat destruction and degradation. Waterbirds need a variety of habitats for foraging and nesting. As the result of decades of mosquito control efforts, one of the most limited natural habitat types in the IRL is natural (undisturbed) salt marsh. Impounding, ditching, and draining have resulted in substantial changes to salt marsh communities including the introduction of native and exotic nuisance species, changes in salinity and hydroperiod, and overall structural changes in salt marsh communities (Schmalzer 1995, Brockmeyer et al. 1997). In some cases, these changes have had serious negative effects on waterbird populations. All remaining intact salt marsh should be protected wherever it occurs within the system. Currently, impoundments make up the most important habitat type for many waterbird species (Breininger and Smith 1990, Schikkor and Swain 1995, Smith and Breininger 1995). Thus, impoundments are an important current resource for waterbird populations, and they should be protected from negative impacts.

Waterbirds are susceptible to a variety of diseases that can cause problems ranging from endemic infections of adults to high levels of adult and juvenile mortality and nesting failures at nesting colonies. One parasite that has caused problems in nesting wading birds in Florida is *Eustrongylides ignotus* (Spalding et al. 1993). This is a large, red nematode that primarily infects members of the family Ardeidae (herons and egrets) although it is also known to occur in the Therskiornithidae (ibises, spoonbill) and Pelecanidae (American White Pelican) (Spalding and Forrester 1993, Frederick and McGehee 1994). It is acquired by the birds through the ingestion of infected fish that are the second intermediate host of the parasite. It is believed that oligochaetes act as the first intermediate host, although the specific species involved have yet to be found (Spalding et al. 1993).

A study in central and south Florida found that epizootic infection by this disease was associated with birds feeding on infected fish which were most prevalent at sites with both physical disturbance and a source of nutrient enrichment (Spalding et al. 1993). Adults feeding at such sites brought back infected fish to nestlings, which resulted in a high rate of infection, and a fledgling mortality rate as high as 80%. The authors believed that the high prevalence of the parasites was not a normal part of the disease etiology but was due to physical and/or chemical alteration of the feeding sites resulting in high populations of the oligochaete intermediate host. The presence of the parasite in nestlings is believed to be unusual and due to disturbance of the feeding habitat used by the parents (Spalding et al. 1993).

Potential sites for the occurrence of *Eustrongylides* intermediate hosts include impoundments behind LC40 and LC41, the numerous freshwater ditches and canals on CCAS, and the large freshwater wetlands near the Atlas Launch Complex. As pointed out by Spalding et al. (1993), an *Eustrongylides* epizootic might easily be overlooked or attributed to other factors. Further investigation of the water quality in these areas is warranted. If high nutrient concentrations are found, nearby nesting colonies of Ardeids on the MINWR should be monitored and nestlings examined for infection. Since *Eustrongylides* infection is not known to occur in marine environments (Spalding et al. 1993), re-connecting the impoundments to the estuary might reduce the chance of outbreaks occurring. Re-connection of the impoundments might also reduce the level of nutrients and the physical alteration of the habitat; two other factors associated with this disease.

Methods

Banana River Impoundments at the Titan Area

Surveys of the impoundments west of the Titan launch complexes were conducted monthly when possible (several months were skipped due to constraints on the use of aircraft or space flight operations). The sampling period began in June 1995 and continued through December of 1997. Surveys were conducted between 0900-1100 EST, using either a NASA Huey helicopter flying at an altitude of 60 m with a speed of 60 knots, or an NOAA amphibious plane flying at an altitude of 60 m with a speed of 75 knots. Two observers were present during all surveys. To prevent repetition of observations, one observer recorded all data during the flights. The impoundments were divided into four regions to facilitate data collection and analysis (Figure 36). Observers recorded the species, numbers and cover type (mangrove, open water, salt grass, sand cordgrass, cattail, shrub, or undetermined) for all waterbirds observed.

Borrow Pit and Canal at the Atlas Launch Complexes

Monthly surveys of a rectangular borrow pit (ca. 2.8 ha) located east of the Atlas launch complexes were conducted to determine waterbird use. Surveys were conducted between August 1995 and March 1998. Surveys were conducted within three hours of sunrise. A 5 m ladder was used to observe the borrow pit from the north and south ends of the pit. During a survey, all birds present upon the arrival of the observer were recorded. Species, number, and behavior (foraging, perched, loafing, flying, or other) were recorded for all waterbirds observed. Emergent vegetation around the edges of the freshwater borrow pit was dominated by cattail and extended inward an average of 5 m from the edge of the pit. Above the emergent vegetation zone, Brazilian pepper formed a dense shrub zone around all sides of the borrow pit.

Monthly surveys along a canal extending approximately 900 m along the north end of the Atlas study area were conducted from September 1996 through May 1998. During canal surveys, the observer drove slowly along the edge of the canal, recording all species of birds encountered. Species, number, and behavior (foraging, perched, loafing, flying, or other) were recorded for all waterbirds observed. Vegetation along the edges of the canal was dominated by cattail and *Sagittaria* spp., with wax myrtle and willow on the banks.

Quick-look surveys of the borrow pit and canal were conducted opportunistically when researchers were in the area conducting other fieldwork. Quick-look surveys of the borrow pit were conducted from ground level at the north and south ends of the pit, at various times throughout the day (most before 1200 EST). Quick-look surveys of the canal were conducted from ground level along the length of the canal at various times throughout the day (most before 1200 EST). Species, number, and behavior (foraging, perched, loafing, flying, or other) were recorded for all waterbird observations. The quick-look surveys were intended to increase our knowledge of the diversity of species using these areas.

Results

Eighteen aerial surveys of the impoundments west of the Titan launch complexes were conducted between June 1995 and December 1997. Eleven species of wading birds were observed during the surveys (Figure 37). Snowy Egrets, White Ibis and Great Egrets were the most numerous species observed, with total numbers of individuals observed over the study period above 800 for these species. Tricolored Herons, Roseate Spoonbills, and Glossy Ibis were also numerous; total numbers of these species observed were above 100. Great Blue Herons, Little Blue Herons, and Reddish Egrets were observed less often (62, 57, and 19 individuals, respectively). Only four Wood Storks and two Cattle Egrets were observed during the study period. Large numbers of Mottled Ducks were observed, especially in Area II (Figure 37). Much higher numbers of wading birds were observed in Spring (March through May) and Fall (September through November) than were seen in Winter (December through February) and Summer (June through August) (Figure 38). The majority of the wading birds were observed in open water habitat (Figure 39). The other four cover types accounted for slightly less than 22% of the observations.

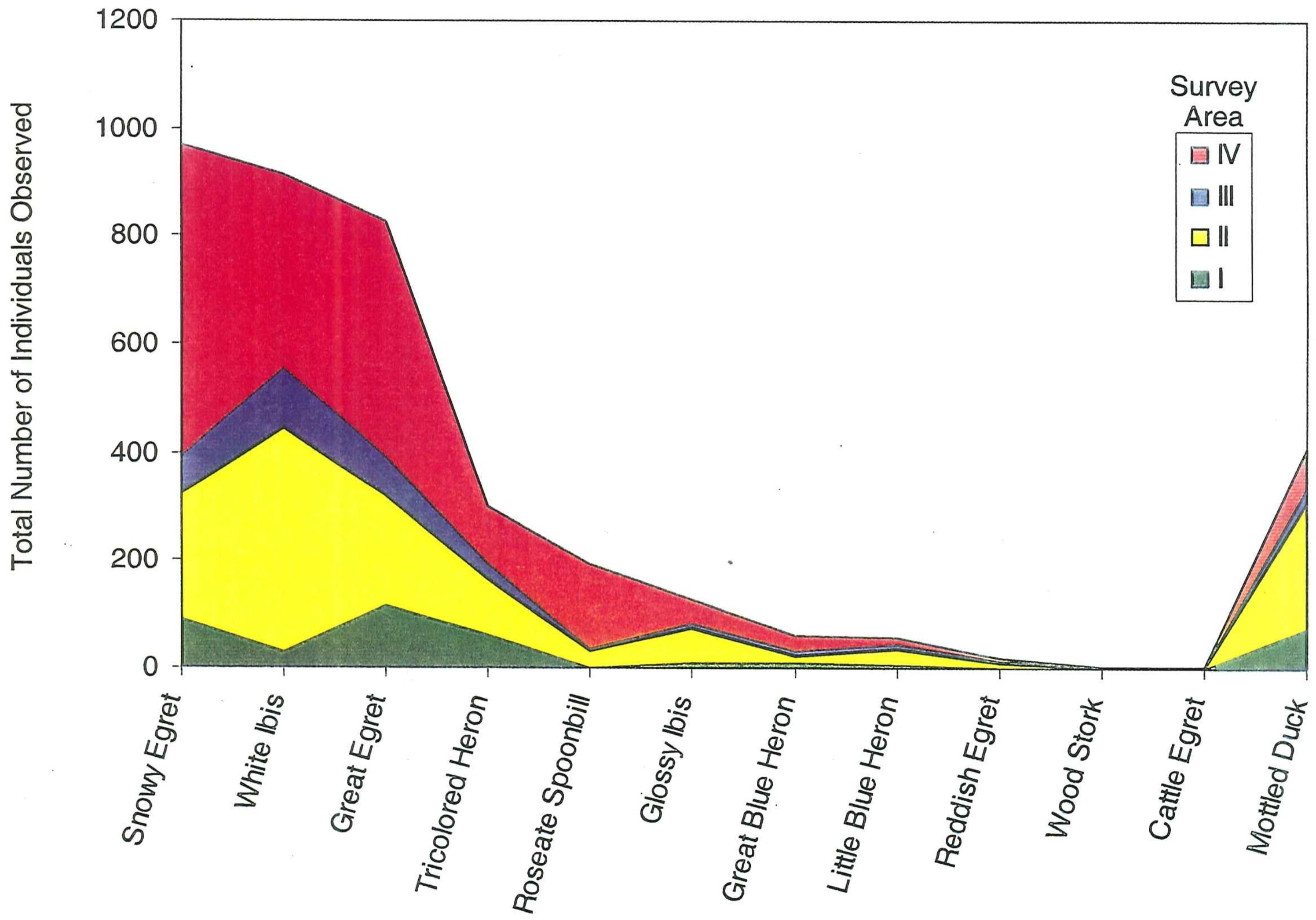


Figure 37. Numbers of twelve species of waterbirds observed on Cape Canaveral Air Station During aerial surveys. The figure shows the total number of individuals observed in each of four survey area (see Figure 36 for locations of the survey areas).

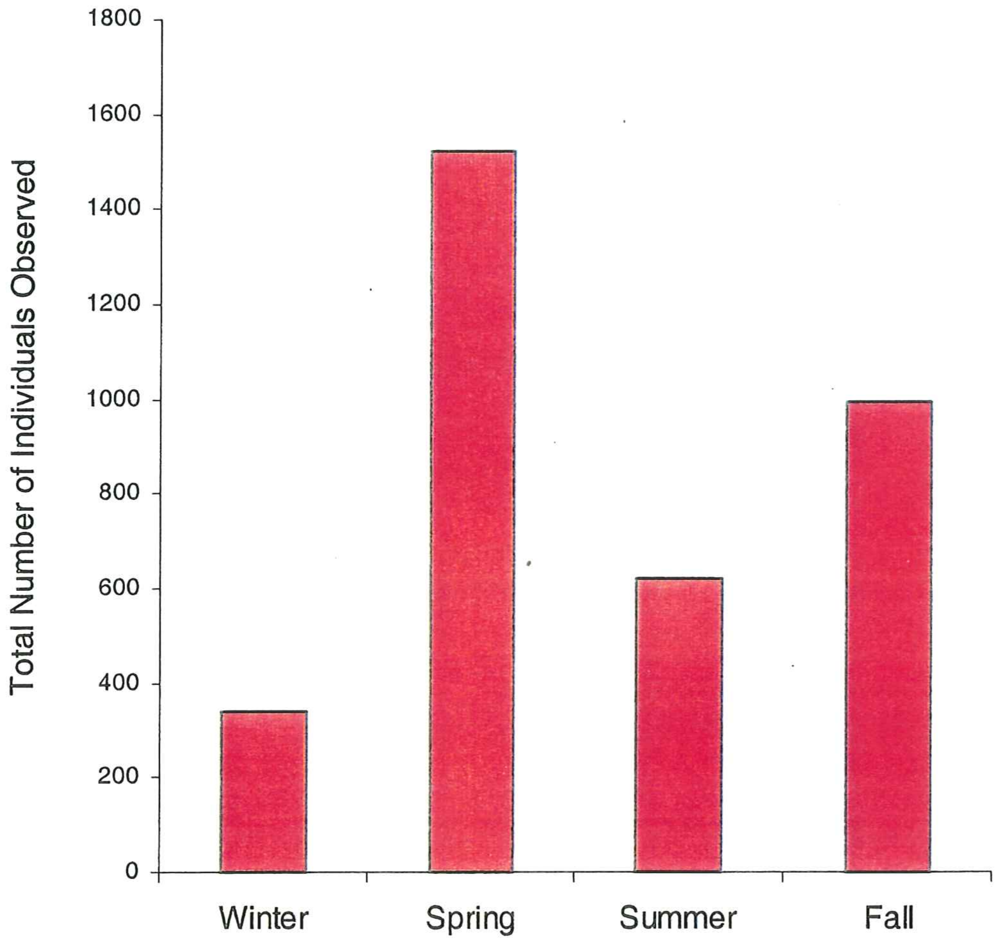


Figure 38. Seasonal numbers of wading birds observed during aerial surveys in the Titan Area. Seasons are: Spring (March through May), Fall (September through November), Winter (December through February), and Summer (June through August).

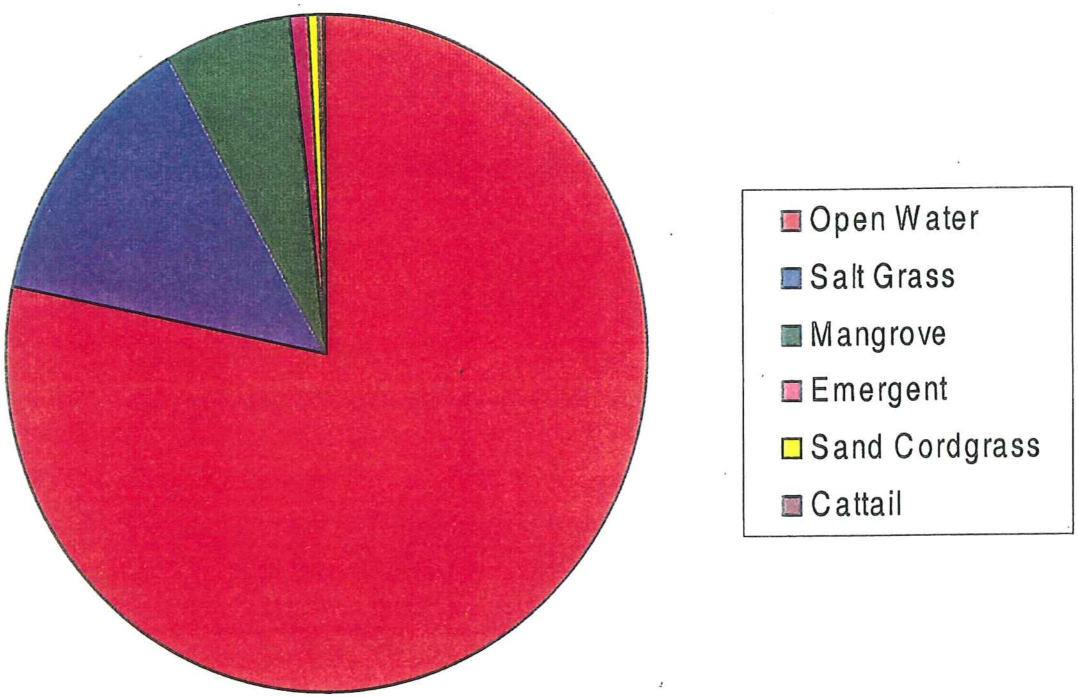


Figure 39. Proportion of wading birds observed in each of six cover types during aerial surveys in the Titan Area.

Thirty-one monthly surveys of the borrow pit at the Atlas Launch Complex were conducted between August 1995 and March 1998. Fourteen species of birds were observed during these surveys (Table 17). The two most numerous species were the Common Moorhen and American Coot. Over half of all waterbirds observed during the systematic surveys of the borrow pit were engaged in foraging activities (Figure 40). Four additional species of waterbirds were observed during 28 opportunistic surveys of the borrow pit conducted between August 1995 and July of 1997 (Table 17). The proportions of individuals of each species observed during opportunistic surveys were similar to those observed during the systematic surveys.

Twenty monthly surveys of the canal extending along the north end of the Atlas study area were conducted from September 1996 through May 1998. Nine species of waterbirds were observed during these surveys (Table 17). The Common Moorhen was the most numerous species observed in the canal. Half of all waterbirds observed during the systematic surveys of the canal were engaged in foraging activities (Figure 40). One additional species (Wood Duck) was observed during the eleven opportunistic surveys of the canal; this was the only species of waterbird observed in the canal that was not also seen in the borrow pit (Table 17).

Discussion

The numbers of waterbirds observed in the Titan Area impoundments during this study were highly variable between months. This is typical for studies of bird populations (e.g., Gawlik et al. 1998). Similar variability was observed in a multi-year study of waterbird use of impoundments on the adjacent MINWR (Breininger and Smith 1990, Smith and Breininger 1995). No conclusions concerning trends in populations of waterbirds can be made based on this short time-period study. The data from this study might be useful as a baseline for future comparisons of waterbird use of the impoundments. However, the study period may not be representative of the long-term trends in bird use of this area. Any interpretations based on these data must be made with caution. However, it is clear from these results that the Titan Area impoundments are used by many species of waterbirds including several species of conservation concern, such as Wood Stork, Snowy Egret, White Ibis, Tricolored Heron, Roseate Spoonbill, Little Blue Heron, and Reddish Egret.

Most of the wading birds observed in the Titan Area impoundments during the study were using open water habitat (Figure 39). This is similar to results for the MINWR study (Breininger and Smith 1990, Smith and Breininger 1995). Because of the apparent preference by wading birds for open water habitat, it has been argued that impounding salt marsh habitat may benefit wading birds (Smith and Breininger 1995, Schikoor and Swain 1995). However, this benefit will only be realized if the water levels in the impoundments are properly

Table 17. Species of waterbirds observed in the Atlas (LC36) area. Entries give the total number of observations of individuals of each species recorded during surveys.

	Borrow Pit		Canal	
Species	Monthly[a]	Opportunistic[b]	Monthly[a]	Opportunistic[b]
Pied-billed Grebe	43	26		
Double-crested Cormorant	36	14	1	
Anhinga	38	20	5	2
Great Blue Heron	2	2	4	5
Great Egret	2		3	2
Snowy Egret		5		
Little Blue Heron	2		2	2
Tricolored Heron	1		2	
Reddish Egret				
Green Heron		3	3	
White Ibis	14			
Wood Stork				
Spotted Sandpiper		1		
Wood Duck				1
Mottled Duck		1		
Blue-winged Teal	1			
Northern Shoveler	1			
Common Moorhen	172	112	87	67
American Coot	326	111	3	2
Osprey	6	1		
Belted Kingfisher	1			

[a] Monthly refers to systematic monthly surveys of the borrow pit and canal.

[b] Opportunistic refers to observations made during visits other than monthly surveys.

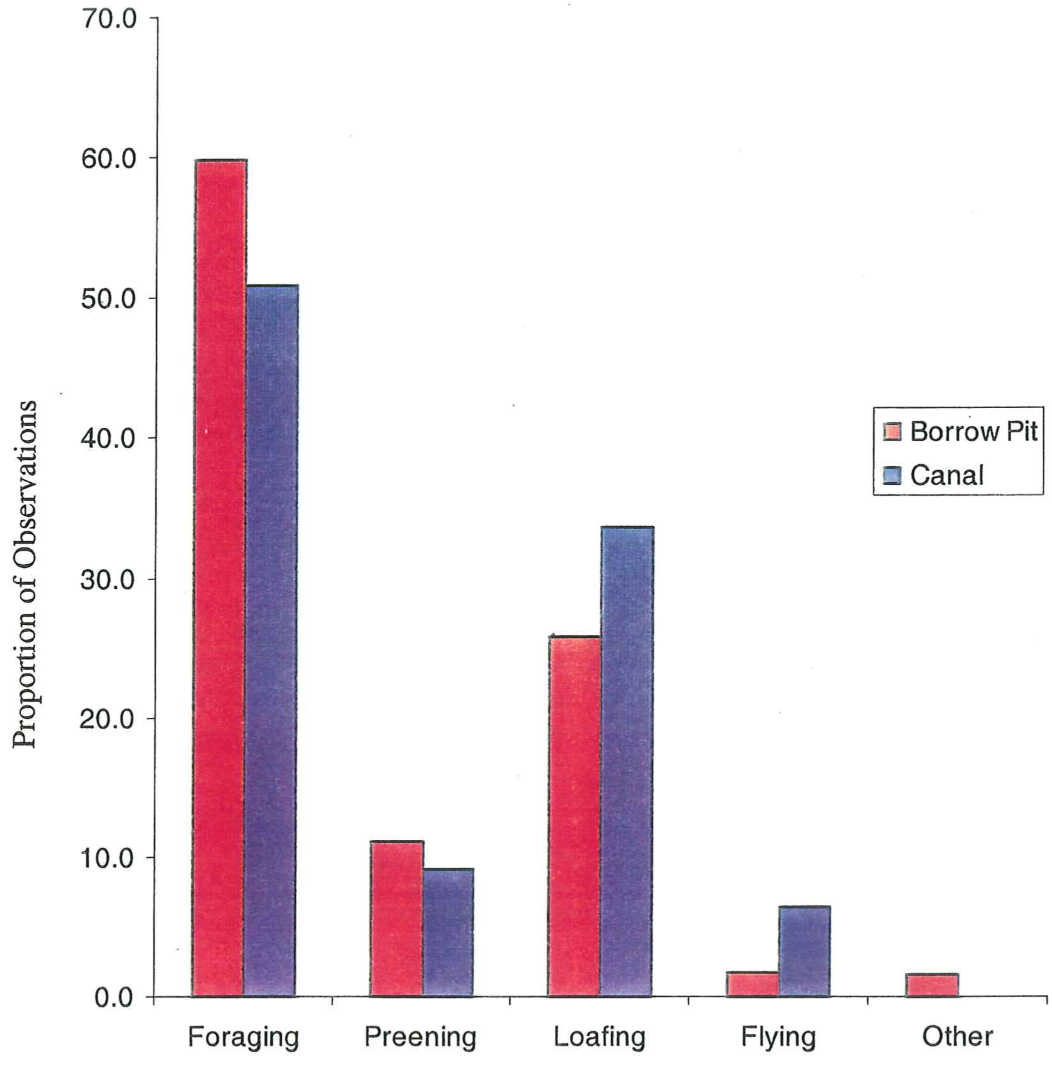


Figure 40. Activities of waterbirds observed during systematic surveys in Atlas Area.

managed for these species. Although open water habitat is favored by wintering duck populations, the Mottled Duck, a resident species, may prefer vegetated habitat (Breininger and Smith 1990). Despite this preference, large numbers of Mottled Ducks were seen during some surveys (Figure 37). Large numbers of several species of migratory ducks also use the Titan Area impoundments in winter (E. Stolen, pers. obs.). Thus, it is unclear whether reconnection of the Titan impoundments with the Banana River would be beneficial to waterbird populations. Further research is necessary to determine the potential effects of reconnection of impoundments on wildlife.

The list of species observed during waterbird surveys of the Atlas area borrow pit and canal documents the use of the area by a variety of waterbirds (Table 17). This information might be useful as a baseline for future comparisons of waterbird use of the borrow pit and canals. Some of the species observed are of conservation concern, such as Wood Stork, Snowy Egret, White Ibis, Tricolored Heron, Little Blue Heron, and Reddish Egret. Thus, some form of water quality monitoring may be warranted to ensure that no environmental contamination occurs to these wetlands. If high levels of nutrients or chemical contaminants are found, monitoring of nearby nesting colonies may be warranted. Impacts other than direct launch effects, such as runoff from road surfaces and use of chemical pesticides and fertilizers may pose greater threats to these wetlands than does direct launch effects such as deposition or blast impact.

Gopher Tortoise

Introduction

The gopher tortoise is one of four tortoises that exist in North America. The gopher tortoise is the only tortoise east of Texas and ranges from southern South Carolina to eastern Louisiana and throughout mainland Florida. Some populations of gopher tortoises have been found to exist on coastal islands, but gopher tortoise population strongholds are in southern Georgia and the northern and central portions of the Florida peninsula (Diemer 1992b).

Suitable habitat for the gopher tortoise is generally characterized by well-drained, sandy soils for digging burrows, herbaceous ground cover for food, and an open canopy for sunlit nesting activities and herb growth (Auffenberg and Franz 1982, Diemer 1986, Cox et al. 1987). Most research for determining habitat requirements has been done in sandhill communities, which is considered prime habitat for the gopher tortoise. Additional research has shown that tortoises can be found in a variety of other habitats including sand pine scrub, coastal strand, coastal dune, dry prairies, mixed hardwood-pine communities, and pine flatwoods (Auffenberg and Franz 1982, Breininger et al. 1988, 1991, 1994; Smith et al. 1997).

Gopher tortoises have an estimated life span of 40-60 years (Landers 1980). Age at reproduction is dependent on size of the animal and varies with geographic location and genetics (Landers et al. 1982). In north Florida, the age of reproductive maturity is 10-15 years (Iverson 1980); mean clutch size is 5.2. Reproduction occurs from February (Dietlein and Franz 1979) to September with the peak in May and June (Diemer 1986). Nests are usually constructed in the burrow mound from mid-May to mid-June (Iverson 1980, Diemer 1992a). Incubation periods vary latitundinally; in north Florida the incubation period is from 80-90 days (Iverson 1980). The raccoon is the most prevalent predator on tortoise eggs and hatchlings (Iverson 1980), although there are a variety of other species, which prey on eggs and hatchlings of gopher tortoises.

The gopher tortoise is considered a keystone species. A keystone species refers to a species that if lost from the system would remove those that are dependent on that species for survival. Gopher tortoise burrows average 4.5 m in length, 2 m in depth, and often have extensive branches. Burrows are used for protection from extreme weather conditions, predators, and fire. This protection from the environment is also extended to the diverse biota (commensals) that share this system. Many commensals utilize tortoise burrows as feeding and reproduction sites (Jackson and Milstrey 1989). Jackson and Milstrey (1989) found that 60 vertebrate and 302 invertebrate species, some of which are protected species, use gopher tortoise burrows. Two such protected species are the Florida scrub lizard (*Sceloporus woodi*) which is listed as threatened by Florida Committee on Rare and Endangered Plants and Animals (FCREPA) (DeMarco 1992) and the eastern indigo snake (*Drymarchon corais couperi*) which is listed as threatened by the USFWS and FGFWFC (Wood 1996).

Human-influenced habitat destruction not only affects the gopher tortoise but will also hinder those species which rely on and visit tortoise burrows. Agricultural activity, clearing, urban expansion (real estate and road development), mining, and certain forestry practices have severely impacted gopher tortoise habitat (Auffenberg and Franz 1982) which in turn influences gopher tortoise distribution on such sites.

Gopher tortoise distributions have recently been affected by the highly contagious and often deadly upper respiratory tract disease (URTD) that exists in many gopher tortoise populations throughout the southeastern U.S. This disease was first documented in the California desert tortoise (*Gopherus agassizii*) in 1988 at multiple sites in the Mojave and Sonoran deserts (Jacobson et al. 1991). The first observation of URTD in wild populations of gopher tortoises in Florida was in 1990 on Sanibel Island (Smith et al. 1998). *Mycoplasma agassizii,* a species of bacteria that is particularly suited to colonizing the respiratory tract, has been confirmed to cause URTD (Brown et. al. 1994, Smith et al. 1998). The infected animals are characterized as having a mucous discharge from their nares and eyes. As the disease progresses, the discharge becomes more tenacious, eyes may become sunken into the orbits, and the general coloring of the tortoise may appear dull. Researchers don't know if this disease occurs naturally within tortoise populations. Brown et al. (1994) found that URTD can become active when the tortoise is under stressful conditions due to such circumstances as relocation and overcrowding. Factors that may contribute to the severity of this disease are habitat degradation, drought, and malnutrition (Jacobson et. al. 1991, Jacobson 1994).

Methods

Gopher tortoises within a 1 km radius of LC40, LC41, PS7, LC17, and LC36 were opportunistically marked and released. Gopher tortoises were hand captured and the following measurements and observations were made: sex, straight-line carapace length (cm), diagonal plastron length (cm), straight-line plastron length (cm), and general condition (rated as poor, fair, good). A rating of poor indicated the tortoise was gaunt, had cloudy eyes and visible discharge from the mouth and nose, a fair indicated cloudy eyes, and good meant there was no discharge or cloudiness of the eyes observed. Gopher tortoises were then marked, by drilling holes into scutes, according to the scheme devised by Cagle (1939, in Diemer 1992a). Gopher tortoise locations were marked as points on aerial photography and were entered into the GIS system as a point coverage using ARC/INFO (ESRI 1992). Once measurements were taken and locations recorded, tortoises were released at the point of capture. No URTD testing was performed on any tortoise captured during this study. Opportunistic observations were also made for Florida scrub lizards and eastern indigo snakes while performing these and other field surveys. If either of the species were observed the locations were recorded on aerial photography and entered into the GIS system as point coverages.

Results

Data presented in this report were collected from July 1995 to December 1997. A total of 65 tortoises were captured. This total includes one recaptured male that was first caught behind the LC36 borrow pit in August of 1995 and was recaptured in December 1995 behind LC36A. A total of 36 females, 27 males (includes recaptures), and 2 unknown sex tortoises (both juveniles) were captured. The sex ratios shown should not be viewed as the sex ratio of tortoises on CCAS, but only as the ratio of tortoises opportunistically captured during this study. The areas within CCAS where gopher tortoises were captured include LC40, LC41, PS7, LC36, LC17, and behind building AQ. Table 18, shows the average and standard deviations for the following measurements: straight-line carapace, straight-line plastron, and diagonal plastron for males and females. All tortoises, except four, were determined to be in good condition. Three tortoises were in fair condition (2 males and 1 female) while the fourth was in poor condition (a male). The observations of these tortoises included runny nose, cloudy eyes, gaunt appearance, and several ticks (which were removed). The general condition of the majority of the captured tortoises did not indicate, at least by physical appearance, any problems associated with URTD. While no URTD testing was performed during this study, a study done by Smith et al. (1998) found that it is present on CCAS.

Table 18. Average measurements and standard deviation for measurements of gopher tortoises taken July 1995 to December 1997 on Cape Canaveral Air Station.

Sex	Straight line Carapace (cm)	Diagonal Plastron (cm)	Straight Plastron (cm)
Females (n=32)	23.6	23.0	22.7
Std	(4.5)	(4.1)	(4.1)
Males (n= 27)	27.6	26.8	26.6
Std	(2.7)	(2.4)	(2.4)

Discussion

KSC/CCAS is the largest area of protected habitat for many species on the Atlantic coast. One such species is the gopher tortoise, listed as a species of special concern by the FGFWFC (Wood 1996). The estimated tortoise population in Florida suggests that 70% of the remaining gopher tortoise habitat will be lost by the year 2000 and that by 2025 virtually all the existing habitat will have been destroyed (Auffenberg and Franz 1982) with exception of protected lands. This therefore increases the importance of protected lands and management practices, which improve gopher tortoise habitat. Improving gopher tortoise habitat will also benefit the commensals, which use the burrows. Another reason for the need of proper restoration of gopher tortoise habitat is that this species has a small homerange size on KSC/CCAS and is more habitat specific than the eastern indigo snake. Average homerange sizes for gopher tortoises on KSC were determined to be 1.9 ha for males and 0.65 ha for females (Smith et al. 1997). The homerange size for the gopher tortoise is small when compared to that of the eastern indigo snake, which in 1991 was estimated to be 176.9 ha for males and 27.2 ha for females (Becky Smith unpub. data). Auffenberg and Franz (1982) suggested that forest clear-cutting may encourage an increase in tortoise populations or an increase in dispersal of gopher tortoises into previously unfavorable areas. Controlled burning is also important because it removes excessive leaf litter and increases herb growth.

Florida Scrub Lizard

The Florida scrub lizard, a spiny lizard, gray or gray brown in coloring with an average snout-vent length of 45 mm (Smith 1946) is an example of a gopher tortoise burrow commensal (Jackson and Milstrey 1989). FCREPA lists the Florida scrub lizard as threatened (DeMarco 1992). FNAI lists the Florida scrub lizard as G3S3 (FNAI 1995). The G3S3 listing is a global and state listing assigned by FNAI to those species that are either very rare and local throughout their range or found locally in a restricted range or are vulnerable to extinction because of other factors (FNAI 1995). Like the gopher tortoise, the Florida scrub lizard prefers open sandy areas. Due to the similarity in habitat preference, the Florida scrub lizard and gopher tortoise distributions face similar consequences as a result of human disturbance such as agricultural clearing, urban expansion, and certain forestry practices (Auffenberg and Franz 1982). No Florida scrub lizards were observed on CCAS during this study. No species specific survey was conducted for the Florida scrub lizard.

Eastern Indigo Snake

The eastern indigo snake is the largest nonpoisonous snake in North America with a maximum recorded length of 2.6 m (Moler 1992). The indigo is iridescent black in color with variable coloration on the throat and is often confused with the black racer (*Coluber constrictor*). Historically, the indigo occurred throughout Florida (including the Keys), Alabama, Georgia, Mississippi, and South Carolina. Habitat preferences include xeric sandhills and pinelands, mangrove swamps, wet prairies, and scrub (Moler 1992, Steiner et al. 1983). The average homerange size on KSC was estimated in 1991 as 176.9 ha for males and 27.2 ha for females (Becky Smith pers. comm.). Female homeranges were found to overlap while males did not. Prey consists of birds, turtles, frogs, other snakes, small mammals, lizards, and fish (Ashton and Ashton 1981, Moler 1992). The indigo snake is an example of a gopher tortoise burrow commensal. It depends on gopher tortoise burrows for refuge from heat in the summer and cold in the winter.

The eastern indigo snake is listed as threatened by FGFWFC and USFWS (Wood 1996). FNAI (1995) gives the indigo a global rating of G4T3 and a state rating of S3. The global ranking of G4T3 means that the indigo is apparently scarce globally. The global listing of T3 refers to the subspecies and is equivalent in meaning to the S3 listing. The S3 listing is a state listing and means that the indigo is very rare and local throughout its range or found locally in a restricted range or is vulnerable to extinction because of other factors (FNAI 1995). Due to the slow, docile, and diurnal nature of the indigo it was an easy target, prior to federal protection, for collection by the pet trade. Human exploitation combined with habitat loss and degradation now restricts the species mostly to Florida (Breininger et al. 1994). No species specific survey was conducted for the eastern indigo snake; however, while performing other surveys observers looked for indigos. One eastern indigo snake was observed during this study at PS7.

Summary

This project was initiated in 1995 with funding from the 45th Space Wing, Civil Engineering, Environmental Office, Patrick Air Force Base to develop a more comprehensive assessment of effects from Delta, Atlas, and Titan launch vehicles on the environment of CCAS.

In this report we:

1. Presented maps of the vegetation and landcover near the Delta, Atlas, and Titan launch complexes. We discovered that the dominant vegetation type within a 1 km radius of both the Atlas and Delta launch complexes was coastal oak hammock forest. At Titan the predominant vegetation type was oak scrub followed by coastal oak hammock forest. These dominant vegetation types were the result of fire suppression across the entire landscape for the last 40-50 years.

2. Summarized water quality data from selected aquatic systems near the launch complexes. Analysis of water quality samples from ten stations around the Titan, Atlas, and Delta showed that values for metals and minerals were consistently higher at the ocean sampling station by the Delta complex compared to the other sampling stations. Aluminum and iron were the only two metals that exceeded state standards at some of the stations. The natural buffering capacity of the environment surrounding the launch complexes was determined to be adequate for neutralizing acid deposition in rainfall and launch deposition.

3. Summarized data on Florida Scrub-Jay (*Aphelocoma coerulescens*) populations, a Federally-listed, threatened species, residing near the launch complexes. Thirty-seven to forty-one scrub-jay territories were located at Titan, Atlas, and Delta launch complexes between 1995 and 1997. No direct impacts to scrub-jays were observed as a result of normal launch operations. Direct impacts were observed to the habitat of several scrub-jays families as a result of the explosion of the Delta rocket in January 1997. Mortality exceeded reproductive output at all areas over the course of the study.

4. Summarized data on southeastern beach mouse (*Peromyscus polionotus niveiventris*) populations, a Federally listed, threatened species, residing near the launch complexes. Hurricane Erin and several other tropical storms impacted this area at the inception of the study in 1995. All of the coastal dune grids experienced habitat alterations as a result of salt-water intrusion. Both the habitat and the beach mice populations recovered during the course of the study. No direct impacts to southeastern beach mice were observed as a result of normal launch operations. Direct impacts were observed to the

habitat of the northernmost coastal dune grid as a result of the explosion of the Delta rocket in January 1997. This alteration of the habitat resulted in a shift in use of the grid (the mice moved on to the newly burned part of the grid).

5. Summarized data on waterbirds using wetlands and aquatic systems near the launch complexes. These include the Federally-listed, endangered Wood Stork (*Mycteria americana*) and several state-listed species of special concern including the Snowy Egret (*Egretta thula thula*), Reddish Egret (*Egretta rufescens rufescens*), White Ibis (*Eudocimus albus*), Roseate Spoonbill (*Ajaia ajaja*), Tricolored Heron (*Egretta tricolor ruficolis*), and Little Blue Heron (*Egretta caerulea*). Aerial surveys of the Titan impoundments showed the area to be used by many species of waterbirds and several species of migratory ducks. These data, while highly variable between months, provide a baseline for future comparisons of waterbird use of the impoundments. Surveys of the borrow pit and canal near the Atlas area provide baseline information on future waterbird use in these areas. No impacts to these populations resulting from any launch operations were observed.

6. Presented less detailed information on the gopher tortoise (*Gopherus polyphemus*) and other species of special concern near the launch complexes. A total of 65 gopher tortoises were opportunistically captured, marked and released around the Titan, Atlas, and Delta launch complexes during the study. All of the tortoises except four were determined to be in good condition, which seemed to indicate the absence of upper respiratory tract disease (URTD) in these tortoises. URTD testing was not performed during this study but URTD is known to exist on CCAS.

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Cape Canaveral has been modified by Air Force development and by 50 years of fire suppression. The dominant vegetation type around the Delta and Atlas launch complexes is coastal oak hammock forest. Oak scrub is the predominant upland vegetation type near the Titan launch complexes. Compositionally, these are coastal scrub communities that has been unburned for > 40 years and have developed into closed canopy, low-stature forests. Herbaceous vegetation around active and inactive facilities, coastal strand and dune vegetation near the Atlantic Ocean, and exotic vegetation in disturbed areas are common. Marsh and estuarine vegetation is most common west of the Titan complexes. Launch effects to vegetation include scorch, acid, and particulate deposition. Discernable, cumulative effects are limited to small areas near the launch complexes.

Water quality samples were collected at the Titan, Atlas, and Delta launch complexes in September 1995 (wet season) and January 1996 (dry season). Samples were analyzed for heavy metals, chloride, total organic carbon, calcium, iron, magnesium, sodium, total alkalinity, pH, and conductivity. Differences between fresh, brackish, and saline surface waters were evident. The natural buffering capacity of the environment surrounding the CCAS launch complexes is adequate for neutralizing acid deposition in rainfall and launch deposition.

Populations of the Florida Scrub-Jay (*Aphelocoma coerulescens*), a Federally-listed, threatened species, reside near the launch complexes. Thirty-seven to forty-one scrub-jay territories were located at Titan, Atlas, and Delta launch complexes between 1995 and 1997. No direct impacts to scrub-jays were observed as a result of normal launches. The explosion of the Delta rocket in January 1997 caused direct impacts to the habitat of several scrub-jays families, from fire and debris; however, no scrub-jay mortality was observed. Mortality exceeded reproductive output at all areas over the course of the study.

Populations of the southeastern beach mouse (*Peromyscus polionotus niveiventris*) populations, a Federally listed, threatened species, reside near all the launch complexes. Hurricane Erin and several other tropical storms impacted several areas at the inception of the study in 1995 causing coastal habitat alterations as a result of salt-water intrusion. Both the habitat and the beach mice populations recovered during the course of the study. No direct impacts to southeastern beach mice were observed as a result of normal launch operations. Direct impacts were observed to the habitat as a result of the explosion of the Delta rocket in January 1997. This alteration of the habitat resulted in a shift in use with the mice moving on to the newly burned part of the site.

Waterbirds use wetlands and aquatic systems near the launch complexes. Species include the Federally-listed, endangered Wood Stork (*Mycteria americana*) and several state-listed species of special concern including the Snowy Egret (*Egretta thula thula*), Reddish Egret (*Egretta rufescens rufescens*), White Ibis (*Eudocimus albus*), Roseate Spoonbill (*Ajaia ajaja*), Tricolored Heron (*Egretta tricolor ruficolis*), and Little Blue Heron (*Egretta caerulea*). No impacts to these populations resulting from any launch operations were observed.

Gopher tortoises (*Gopherus polyphemus*) also occur around the launch complexes. Most of those observed appeared to be in good condition; however, upper respiratory tract disease is known to occur in the population.

Cape Canaveral Air Station, including areas near active launch complexes, remains important habitat for a variety of native plants and animals including threatened and endangered species. Direct negative effects of current launch systems appear limited. Additional monitoring of these populations and habitats is required to determine if subtle, long-term changes are occurring, to determine if new launch systems and facilities cause other effects, and to determine the effects of habitat restoration and management.

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Launches of Delta, Atlas, and Titan rockets from Cape Canaveral Air Station have potential environmental effects. These could occur from direct impacts of launches or indirectly from habitat alterations. This report summarizes a three-year study (1995-1998) characterizing the environment, with particular attention to threatened and endangered species, near the Delta, Atlas, and Titan launch facilities.

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