National Park Service
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Natural Resource Stewardship and Science

Palo Alto Battlefield National Historical Park

Natural Resource Condition Assessment

Natural Resource Report NPS/PAAL/NRR—2013/723

ON THE COVER
Replica cannon from the 1846 Battle of Palo Alto, located outside of park's Visitor Center.
Photograph by: Shannon Amberg, SMUMN GSS

Palo Alto Battlefield National Historical Park

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from this NRCA will help Palo Alto Battlefield National Historical Park (PAAL) managers to develop near-term management priorities, engage in watershed or landscape scale partnership and education efforts, conduct park planning, and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at PAAL. The final project framework contains 18 resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current conditions and trends in selected resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of each component. Weighted Condition Scores, ranging from zero to one, were divided into three categories of condition: low concern, moderate concern, and significant concern. These scores help to determine the current overall condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, including unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was reviewed by PAAL resource managers and NPS Gulf Coast Network staff.

Existing literature, short- and long-term datasets, and input from NPS and other outside agency scientists support condition designations for components in this assessment. However, in a number of cases, data were unavailable or insufficient for several of the measures of the featured components. In other instances, data establishing reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. In these cases, it was not possible to assign condition for the components. Current condition could not be determined for 14 of the 18 components (78%) due to these data gaps.

For the four components with sufficient available data, the overall condition varied. Only one component was determined to be of low concern: the Tamaulipan brushlands. This component showed a stable trend in recent times. Air quality was determined to be of moderate concern and showed a stable trend. The pollution from the nearby cities of Brownsville, TX, and Matamoros, Mexico, is closely tied to the condition of air quality in the park; the proposed development of a power plant near the park further threatens the park's air quality. Similar to air quality, viewshed was determined to be of moderate concern, although this resource has exhibited a declining trend due to the rapid development and expansion of Brownsville, TX that is taking place in the viewable area outside of the park.

The dark night skies component was the only component deemed to be of high concern. While detailed data are not available for this component, park managers are concerned about the amount of light present in the park at night; this light pollution stems from the nearby cities and developments. No trend was assigned to this component. Detailed discussion of these designations is presented in Chapters 4 and 5 of this report.

Several park-wide threats and stressors influence the condition of priority resources in PAAL. Those of primary concern include the presence of exotic plants and animals, extreme weather events (e.g., hurricanes, drought), habitat loss and human development, and nearby energy developments (specifically nearby power lines, power plants, and wind farms). Understanding these threats, and how they relate to the condition of these resources, can help the NPS prioritize management objectives and better focus conservation strategies to maintain the health and integrity of park ecosystems.

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Acronyms and Abbreviations

ARD – NPS Air Resources Division

CAA – Clean Air Act of 1977

CASTNet – Clean Air Status and Trends Network

CCD – Charge-Coupled Device

CL – Condition Level

DAMS – Water Impoundments Database

DEM – Digital Elevation Model

DDT – Dichlorodiphenyltrichloroethane

DO – Dissolved Oxygen

DRINKS – Drinking Water Supplies Database

EIS – Environmental Impact Statement

EPA – U.S. Environmental Protection Agency

ESA – Endangered Species Act

GAGES – Flow Gages Database

GPRA – Government Performance and Results Act

GULN – Gulf Coast Network

IFD – Industrial Facilities Discharge

IMPROVE – Interagency Monitoring of Protected Visual Environments

IRMA – Integrated Resource Management Application

ITIS - Integrated Taxonomic Information System

LANWR – Laguna Atascosa National Wildlife Refuge

LRGV – Lower Rio Grande Valley

mV – Millivolt

NAAQS – National Ambient Air Quality Standards

Acronyms and Abbreviations (continued)

NABA – North American Butterfly Association

NADP – National Atmospheric Deposition Program

NED – National Elevation Dataset

NLCD – National Landcover Database

NPS – National Park Service

NRCA – Natural Resource Condition Assessment

NST – NPS Night Sky Team

NVCS – National Vegetation Classification Standard

NWI – National Wetland Inventory

O_3 – Ozone

PAAL – Palo Alto Battlefield National Historical Park

PM – Particulate Matter

ppb – Parts per Billion

RF3 – River Reach File

RSS – Resource Stewardship Strategy

SEPTCT – Southeastern Point Counts

SL – Significance Level

SMUMN GSS – Saint Mary's University of Minnesota, GeoSpatial Services

STORET – Storage and Retrieval

T&E – Threatened and Endangered

TCEQ – Texas Commission on Environmental Quality

TDS – Total Dissolved Solids

TPWD – Texas Parks and Wildlife Department

USFWS – U.S. Fish and Wildlife Service

Acronyms and Abbreviations (continued)

USGS – U.S. Geological Survey

USMFS – U.S. Marine Fisheries Service

VOCs – Volatile Organic Compounds

WCS – Weighted Condition Score

ZLM – Zenith Limiting Magnitude

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs Strive to Provide…
Credible condition reporting for a subset of important park natural resources and indicators
Useful condition summaries by broader resource categories or topics, and by park areas

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]
- identify or develop reference conditions/values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products;[4]
- summarize key findings by park areas; and[5]
- follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource

[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decisionmaking, planning, and partnership activities.

> ***Important NRCA Success Factors***
>
> *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
>
> *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
>
> *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://nature.nps.gov/water/nrca/index.cfm

NRCA Reporting Products…
Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)
Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)
Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Palo Alto Battlefield, the only national park unit commemorating the U.S.-Mexican War, was designated as a National Historic Landmark on 19 December 1960. On 10 November 1978, Palo Alto National Historic Site was authorized by Congress and was established

> In order to preserve and commemorate for the benefit and enjoyment of present and future generations an area of unique historical significance as one of only two important battles of the Mexican War fought on American soil, the Secretary [of the Interior] is authorized to establish the Palo Alto Battlefield National Historic Site [now Palo Alto Battlefield National Historical Park] in the State of Texas (Public Law 95-625).

A boundary change was authorized for the Historic Site on 23 June 1992. On 30 March 2009, Palo Alto Battlefield National Historic Site was re-classified as Palo Alto Battlefield National Historical Park (PAAL) and the park acquired the 13.76 ha (34 ac) Resaca de la Palma Battlefield (Public Law 102-304; 106 Stat. 256; 16 U. S. C. 461) located approximately 8 km (5 mi) south of PAAL.

2.1.2 Geographic Setting

PAAL is located in the Lower Rio Grande Valley (LRGV) of Cameron County, Texas. The nearest major city is Brownsville, Texas (population 180,097; U.S. Census Bureau [2013]), which is located nearly adjacent to the park's boundaries. The PAAL and Resaca de la Palma units, which were the scenes of the first and second major battles of the U.S.–Mexican War in 1846, encompass 1,376 ha (3,400 ac) within the park's authorized boundaries (NPS 2011). However, the NPS owns or controls only about 50% of the battlefield, as several areas within the authorized boundaries are still privately owned (NPS 2013a).

PAAL is located on the Rio Grande delta plain, which is considered one of the largest deltas formed by "melt waters" from Pleistocene glaciers (Cooper et al. 2004, p. 9). The three primary soil types in the park are salt prairie, levee, and transition soils (Farmer 1992). Salt prairie soils are known for their high salinity levels; this soil type is found in the floodplains and typically holds moisture well (Cooper et al. 2004). The levee soils are well-drained, lower in salinity, and found just above the floodplains. Transition soils are found between the salt prairie and levee soils (Cooper et al. 2004).

Photo 1. A blowing field of Gulf cordgrass in PAAL (Photo by Shannon Amberg, SMUMN GSS).

Resacas are old channels of the Rio Grande that are found in southern Cameron County; many of these are now consistently dry except during times of heavy rains or when being used by municipalities to transport water (Robinson III 2012). Remnant resacas are the only natural bodies of water found in PAAL, although these only hold water during times of increased precipitation; the resacas in the park are at risk of drying out due to sediment erosion and extended drought (Farmer 1992). Some resacas in the PAAL region have been modified into man-made troughs used for livestock watering; others, such as the resaca that borders the Resaca de la Palma unit of PAAL, have been modified to transport water through Brownsville, Texas (Whisenant and Wu 2007). Resacas in PAAL are hotspots of biodiversity (Whisenant and Wu 2007), particularly when water is present. At these times, various mammals, amphibians, and reptiles utilize the areas.

The primary land use around PAAL is agriculture, although the urbanization of nearby Brownsville, Texas is rapidly encroaching on the park's borders (Rolando Garza, PAAL Archaeologist and Integrated Resource Manager, phone interview, 29 June 2012). Urban development and building of roads around PAAL have become potential problems to wildlife in the park (Cooper et al. 2004). There have also been several alterations to the land within PAAL, as land that was once brushland was cleared for farming and grazing in the 1800s and has not returned to its natural vegetative composition (Cooper et al. 2004).

PAAL is located in a warm-temperate to semiarid climate, and the average precipitation is approximately 70 cm (27.6 in) per year (NCDC 2013). Climate in the PAAL area can be greatly affected by El Niño and La Niña events, which can result in periods of drought or heavy precipitation. Regional drought events can be linked with La Niña events, while El Niño events may cause cool winter and spring temperatures, as well as unusually high winter precipitation (Segura et al. 2007). The late-summer months typically yield the highest average precipitation totals, with September having the highest average precipitation (13.5 cm [5.3 in], Table 1). The gulf coast experiences several tropical storms and hurricanes each year in the late summer; these contribute to the moisture of the region's climate (Segura et al. 2007). Table 1 displays the monthly temperature and precipitation normals for PAAL.

Table 1. Monthly temperature and precipitation normals for PAAL from 1971-2000 (Station: Brownsville AP, TX) (NCDC 2013).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	20.4	22.3	25.6	27.9	30.5	32.5	35.6	33.7	31.9	28.9	24.9	21.2	27.8
Min	10.3	11.8	15.3	18.4	21.9	23.8	24.1	24.1	22.6	18.8	14.8	11.1	18.1
Average Precipitation (cm)													
Total	3.5	3.0	2.4	5.0	6.3	7.4	4.5	7.6	13.5	9.6	4.4	2.8	70.0

Winter in the PAAL region is mostly mild due to the warm Gulf of Mexico waters, and temperatures typically remain in the mid 20 °C (68 °F) range (Table 1). The summer months in PAAL are typically hot and humid, with average high temperatures in July of 35.6 °C (96.1 °F; Table 1).

2.1.3 Visitation Statistics

In 2011, PAAL had 24,752 visitors to the park (NPS 2012a), while the average number of recreational visitors to the park from 2004-2011 was 31,265 visitors (NPS 2012a). There are several activities available for visitors at PAAL. The visitor center offers pamphlets, videos, books, interactive exhibits on the Battle of Palo Alto, and an interactive eBird Trail Tracker kiosk where visitors can learn abou the park's birds and enter bird sitings (NPS 2012b). PAAL has one interpretive trail that leads visitors to an overlook of the battlefield; several replica cannons also sit in the field near this location. Two additional trails lead visitors to the battle lines for the U.S. and Mexican forces during the Battle of Palo Alto (NPS 2012b). The Resaca de la Palma unit also has an interpretive trail that is open to the public for specific events (Photo 2).

Photo 2. Interpretive trail at the Resaca de la Palma unit of PAAL (Photo by Shannon Amberg, SMUMN GSS).

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

PAAL is part of the Environmental Protection Agency's (EPA) Western Gulf Coastal Plain Level III Ecoregion. This ecoregion stretches from the Mississippi River delta in Louisiana, and extends southwest down the Gulf coast to the southern tip of Texas. According to the EPA (2010, p. 7),

> The principal distinguishing characteristics of the Western Gulf Coastal Plain are its relatively flat coastal plain topography and mainly grassland potential natural vegetation. Inland from this region the plains are older, more irregular, and have mostly forest or savanna-type vegetation potentials. Largely because of these characteristics, a higher percentage of the land is in cropland than in bordering ecological regions. Urban and industrial land uses have expanded greatly in recent decades, and oil and gas production is common.

The EPA divides Level III Ecoregions into smaller Level IV Ecoregions. In PAAL, the Western Gulf Coastal Plain Ecoregion includes one Level IV Ecoregion: the Lower Rio Grande Alluvial Floodplain (EPA 2010). PAAL lies within the South Laguna Madre Watershed, which is part of the Texas-Gulf Resource Region (USGS 2013).

2.2.2 Resource Descriptions

PAAL is an inland extension of the coastal plains, and small changes in elevation affect the vegetation type (the park's elevation ranges from 2.9-6.4 m [9.7-20.9 ft] above sea level) (Richard and Richardson 1993). The most recent vascular plant survey in the park (Lonard et al.

2004) identified 243 plant species from 66 families, and the NPS Certified Vascular Species List (NPS 2013) identifies 275 plant species as present in the park.

There are three habitat types that are generally recognized within PAAL: brushlands, salt prairies, and wetlands (Cooper et al. 2004). The brushland habitat in PAAL is found on the slightly elevated portions of the park, primarily along the western and northern boundaries, and occupies approximately 23% of the landcover. The soil type of the brushland habitat is of lower salinity, and can support unique species of plants when compared to the other regions of PAAL (Cooper et al. 2004). Common brushland species include honey mesquite (*Prosopis glandulosa*), spiny hackberry (*Celtis pallida*), and lotebush (*Ziziphus obtusifolia*).

The most dominant habitat in the park is the salt prairie, which occupies 75% of the park's area (Cooper et al. 2004). The salt prairies occur in the low elevation areas of the park, and the soil in this habitat has a high salt content. The erosion and subsequent infill of the park's resacas have likely resulted in an increase in this habitat type in the park. Common species found in PAAL's salt prairies include Gulf cordgrass (*Spartina spartinae,* Photo 1) and sea oxeye (*Borricha frutescens*) (Cooper et al. 2004).

The least abundant of the three habitat types, the wetlands of PAAL occupy approximately 2% of the park's landscape (Cooper et al. 2004). This habitat type is made up of resacas that formerly acted as channels or tributaries of the Rio Grande, but have since filled in with sediment over time. Also included in this habitat type are the man-made cattle tanks that hold water for periods of time during the year. Some wetland plant species found in the park include marsh parsley (*Cyclospermum leptophyllum*), least duckweed (*Lemna minuta*), and longbarb arrowhead (*Sagittaria longiloba*) (NPS 2013b).

There are 14 native mammals known to occupy PAAL. Common native mammals found in PAAL include coyote (*Canis latrans*), raccoon (*Procyon lotor*), southern plains woodrat (*Neotoma micropus*), white-footed mouse (*Peromyscus leucopus*), and hispid cotton rat (*Sigmodon hispidus*) (NPS 2013b). Uncommon mammal species include bobcats (*Lynx rufus*) and eastern cottontail (*Sylvilagus floridanus*) (NPS 2013b).

PAAL has confirmed the presence of 108 bird species within park boundaries (NPS 2013b), and over 60 breeding species are found in the park. Common breeding birds in the park include the eastern meadowlark (*Sturnella magna*) and Cassin's sparrow (*Peucaea cassinii*) (NPS 2012c). Several resident and migratory raptor species are found in PAAL; examples of these include red-tailed hawks (*Buteo jamaicensis*), Harris's hawks (*Parabuteo unicinctus*), white-tailed kites (*Elanus leucurus*), northern harriers (*Circus cyaneus*), American kestrels (*Falco sparverius*) and the endangered northern aplomado falcon (*Falco femoralis septentrionalis*) (NPS 2013b).

The park also supports several species of reptiles and amphibians; perhaps most notable of these species is the Texas tortoise (*Gopherus berlandieri*). The Texas tortoise is a species of conservation concern in the park, and is monitored biannually by the NPS (Photo 3). Other reptiles present in the park include the yellow mud turtle (*Kinosternon flavescens*), Texas horned lizard (*Phrynosoma cornutum*), western diamondback rattlesnake (*Crotalus atrox*), bullsnake (*Pituophis catenifer*), Texas indigo snake (*Drymarchon melanurus erebennus*), and the Texas spotted whiptail (*Aspidoscelis gularis*). Examples of the amphibians present in the park include the spotted chorus frog (*Pseudacris clarkia*), Mexican treefrog (*Smilisca baudinii*), and Couch's spadefoot toad (*Scaphiopus couchii*). The ephemeral resaca wetlands of the park also support locally substantial populations of Rio Grande leopard frogs (*Lithobates berlandieri*) during wetter seasons/years (Robert Woodman, GULN Ecologist, written communication, 30 August 2013).

Photo 3. Rolando Garza, PAAL Archeologist and Integrated Resource Manager, measures a Texas tortoise's carapace during the park's biannual Texas tortoise monitoring efforts (NPS Photo).

2.2.3. Resource Issues Overview

The landscape and natural resources in PAAL have experienced changes in the last 160 years, some of which have altered the landscape's composition compared to the time of the Battle of Palo Alto. Urban development, conversion of land to agriculture, and grazing activities in and around PAAL have impacted park resources. The park itself has been largely free of urban development. However, the encroachment of nearby urban development represents a significant threat to all native resources in the park; continued urbanization around PAAL may result in the park becoming an "island" of natural habitat in an area dominated by human development (Garza, phone interview, 29 June 2012).

Historic agricultural practices on the land that is now the park cleared many of the brushlands of PAAL and introduced non-native plants for livestock grazing; these practices also contributed to increased erosion rates in the resacas, as well as alterations to the historic hydrologic cycle (Cooper et al. 2004, Segura et al. 2007). As a result, plant communities found in the park's resacas have changed due to sedimentation and changes in soil moisture (Segura et al. 2007).

Exotic species are a significant concern to park mangers. Four exotic mammals have been recorded in PAAL: nilgai (*Boselaphus tragocamelus*), feral hogs/pigs (*Sus scrofa*), black rat (*Rattus rattus*), and Norway rat (*Rattus norvegicus*) (NPS 2013). Nilgai were brought to a Texas ranch as an exotic game species (Davis and Schmidly 1997) and have since established feral breeding populations in extreme southern Texas. Unlike the intentional introduction of the nilgai, the Norway rat and black rat were accidently introduced to the United States. The Norway rat likely entered the continent as a stowaway on a cargo ship in the late 1700s (ISIS 2011), while the black rat's expansion into the U.S. is poorly documented; the species is of Southeast Asian origin.

Feral hogs are prevalent in the park, and were introduced to southern Texas over 300 years ago by Spanish explorers (Taylor 2012). Hogs were a source of cured meat and lard for early settlers, and according to Taylor (2012), a good number of hogs escaped and became the feral population known today. Feral hogs and other exotic animal species compete extensively with native animals for food and other habitat resources and are extremely destructive to the vascular plant communities. In addition to being destructive to the native plant and animal communities, feral hogs can cause considerable damage to the cultural artifacts that are present in PAAL's soils (Garza, personal interview, 15 December 2011). Many of the undiscovered cultural artifacts are found in the park's soil between the depths of 0 cm and around 30 cm (11.8 in), and the rooting activity of the feral hogs poses a significant threat to these battlefield relics.

Exotic plants are an increasing threat to natural areas across the country. Many of these species have the ability to outcompete native plants and can alter ecological processes such as fire (Brooks and Pyke 2001, Reiser et al. 2012). Twenty-one non-native plant species have been documented in PAAL (Table 2), out of a total 275 plant species (NPS 2012). This means there is one non-native species for approximately every 12 native plant species. According to Lonard et al. (2004), non-native species were found primarily on "disturbed sites"; no non-native plants were documented at that time in the salt flats or wetlands.

Table 2. Non-native species documented in PAAL (Lonard et al. 2004, GULN 2010).

Scientific name	Common name
Pennisetum ciliare	buffelgrass
Sorghum halapense	Johnson grass
Sisymbrium irio	London rocket
Angalis arvensis	scarlet pimpernel
Cynodon dactylon	Bermudagrass
Dichanthium annutlatum	Kleberg's bluestem
Dichanthium aristatum	Angleton bluestem
Dichanthium sericeum	silky bluestem
Urochloa maxima	guineagrass
Urochloa panicoides	panic liverseed grass
Eriochloa pseudoacrotricha	perennial cupgrass
Chloris canterai	Paraguayan windmill grass
Amaranthus blitoides	prostrate pigweed
Cyclospermum leptophyllum	slim-lobe celery, marsh parsley
Sonchus asper	rough sow thistle
Sonchus oleraceus	common sow thistle
Chenopodium murale	nettle-leaf goosefoot
Kalanchoe delagoensis	chandelier plant
Melilotus officinalis	sweetclover
Tamarix aphylla	Athel tamarisk
Verbena brasiliensis	Brazilian vervain

Some resources in the park are temporarily altered during large-scale weather events, such as hurricanes and tropical storms. Typically, local dams near the park prevent flooding from occurring; however, heavy rain events are the only time the ephemeral resacas and other drainage areas are filled with water (Cooper et al. 2004, Photo 4). The additional moisture provides resources and significant habitat for many plant and animal species in the park. However, hurricane and tropical storm events can inundate the park with saltwater and detrimentally affect the park's open prairie community.

Photo 4. Standing water in one of PAAL's typically dry resaca beds (Photo by Rolando Garza, PAAL).

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

PAAL has a General Management Plan that outlines the management objectives for the park unit (NPS 1998). The objectives are as follows:

- Protect and maintain the park's natural and cultural resources while keeping in mind the ecosystem as a whole and cultural value.
- Scientific information on the natural and cultural resources in PAAL is used by managers and park staff to make decisions about managerial practices and educational programs for visitors.
- Ensure a safe and captivating visit for all by providing adequate facilities, activities, and educational programs.
- Educate the public and visitors of the important resources PAAL preserves so they can develop an appreciation and help educate future generations.
- Keep management practices and technology up-to-date so the unit can complete its mission in a timely manner.
- Cooperate with agencies, organizations, and individuals to create high quality management practices for PAAL.

PAAL has an Integrated Vegetation Management Plan (NPS 2010) that provides guidance for achieving the park's vegetation management goals. The goals outlined in this plan are as follows:

1. Utilize natural processes (e.g., prescribed fire, flooding), to the extent possible, to maintain and improve native plant community health and species diversity.

2. Control or eradicate non-native or undesirable plant species using the widest integration of cultural, biological, chemical and mechanical techniques as determined by appropriate compliance and public review.

3. Restore damaged habitats to reflect as best as possible the structure, function and composition of vegetation assemblages as were present at the time of the 1846 battle.

4. Develop monitoring for native plant communities and/or key species of interest.

5. Monitor and mitigate any visitor-use impacts to park vegetation resources (NPS 2010, p. 27).

During the completion of this NRCA, PAAL completed a Foundation Document. Because this document was completed during the late stages of this NRCA (2013), the contents of the foundation document were not available, and the document is not summarized here.

2.3.2 Status of Supporting Science

The Gulf Coast Network (GULN) identifies key resources for each of its parks network-wide. The identified resources, called “Vital Signs”, are used to determine the overall health of the parks. In 2007, the GULN completed and released a Vital Signs Monitoring Plan (Segura et al. 2007); Table 3 shows the GULN Vital Signs selected for monitoring in PAAL.

Table 3. GULN Vital Signs selected for monitoring in PAAL (Segura et al. 2007).

Category	GULN Vital Sign	Category 1[A]	Category 2[B]	Category 3[C]	No Monitoring Planned
Air and Climate	Ozone		X		
	Air Contaminants		X		
	Weather/Climate		X		
Geology and Soils	Erosion and Deposition				X
	Soil Biota				X
	Soil Chemistry				X
	Soil Structure and Stability				X
Water	Groundwater Hydrology				X
	Water Chemistry	X			
	Water Nutrients	X			
	Water Toxics		X		
Biological Integrity	Non-native Vegetation	X			
	Non-native Animals			X	
	Freshwater Wetland Communities	X			
	Riparian Communities	X			
	Forest Health	X			
	Freshwater Invertebrates				X
	Terrestrial Invertebrates				X
	Amphibians	X			
	Non T&E Reptiles	X			
	Migratory Birds				X
	Resident Birds	X			
	Non T&E Small Mammals				X
	Terrestrial Vegetation	X			
	T&E Rare Birds			X	
	T&E Rare Reptiles				X
Human Use	Visitor Usage				X
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	X			
	Land Cover/Land Use	X			
	Soundscape				X

[A] **Category 1** represents Vital Signs for which the network will develop protocols and implement monitoring.

[B] **Category 2** represents Vital Signs that are monitored by PAAL, another NPS program, or by another federal or state agency using other funding.

[C] **Category 3** represents high-priority Vital Signs for which monitoring will likely be done in the future.

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Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the NPS and Saint Mary's University of Minnesota Geospatial Services (SMUMN GSS). Project stakeholders include the PAAL resource management team, and GULN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1 Preliminary Scoping

A preliminary scoping meeting was held on 14-15 December 2011. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the PAAL NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to PAAL managers. Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information;
- Identification of data needs and gaps is driven by the project framework categories;
- The analysis of natural resource conditions includes a strong geospatial component;
- Resource focus and priorities are primarily driven by PAAL resource management;

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid PAAL resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including PAAL resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project.

- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point.

- Clearly identify "management critical" data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process.

- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.

- Utilize "gray literature" and reports from third party research to the extent practicable.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

<u>Selection of Resources and Measures</u>
As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

"Components" in this process are defined as natural resources (e.g., birds), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more "measures" that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain "stressors," which are also considered during assessment. A "stressor" is defined as any agent that imposes adverse changes upon a component. These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the PAAL NRCA scoping process, key resource components were identified by NPS staff and are represented as "components" in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, or are of greatest concern or highest management priority in PAAL. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

<u>Selection of Reference Conditions</u>
A "reference condition" is a benchmark to which current values of a given component's measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an

established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In most cases, reference conditions represent a historical reference to the appearance and composition of the landscape at the time of the Battle of Palo Alto. In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science's "State of Our Nation's Ecosystems 2008" (Heinz Center 2008). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized in March 2012, following acceptance from NPS resource staff. It contains a total of 18 components (Table 4) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

Table 4. Palo Alto Battlefield National Historical Park natural resource condition assessment framework.

PAAL Framework
Natural Resource Condition Assessment Framework

	Component	Measures (Significance Level)	Stressors	Reference Condition
Biotic Composition				
Ecological Communities				
	Open Prairie Community	Change in extent of woody spp. coverage (3), change in extent of grassland spp. coverage (3), species richness (3), ratio of native to non-native species (3)	Hydrologic changes over time, altered fire regime, invasive species (plants and animals), drought, significant weather events (e.g., hurricanes)	Similar to conditions and composition/structure at time of battle.
	Tamaulipan Brushland	Species diversity of native species (3), areal extent of brushlands (3)	Hydrologic changes over time, altered fire regime, invasive species (plants and animals), drought, significant weather events (e.g., hurricanes)	Similar to conditions and composition/structure at time of battle.
	Resaca Wetland and Riparian Community	Native species richness (3), frequency and duration of innunadation events (3), extent of wetland and riparian communities (2), redox potential of the soil (3), soil moisture (3)	Cultural recontouring of the resaca to facilitate drainage of cattle tanks (ponds), drought, wild hogs,	Similar to conditions and composition/structure at time of battle.
Birds				
	Breeding Birds	Species abundance and diversity (3), species distribution (3),	Wind farm development, drought, habitat loss and human development	Undefined
	Raptors	Species abundance and diversity (3), aplomado falcon abundance (3),	Wind farm development, drought, habitat loss and human development	Undefined
Mammals				
	Coyotes	Population density (3), distribution (3)	Habitat loss/destruction (human development), disease?, drought, vehicle collisions on highway	Population at time of battle
	Collared Peccary	Population density (3), distribution (3)	Habitat loss and fragmentation, exotic species competition (feral hogs at water sites, nilgai), drought, hunting pressure	Population at time of battle
	Wild Cats	Species abundance (3), distribution (3)	Habitat loss/fragmentation, vehicle collision, potential competition,	Population at time of battle
	Native Rodents	Species abundance and diversity (3), distribution (3)	habitat loss/fragmentation, predation, drought, major flooding/weather events	Population at time of battle

Table 4. Palo Alto Battlefield National Historical Park natural resource condition assessment framework (continued).

PAAL Framework
Natural Resource Condition Assessment Framework

	Component	Measures (Significance Level)	Stressors	Reference Condition
Insects				
	Butterflies	Species abundance and diversity (3), distribution (3)	Host specificity, habitat loss, drought, extreme weather events,	Population at time of battle
Herptiles				
	Amphibians	Species abundance and diversity (3), distribution (3)	Drought, habitat loss and disturbance, feral hogs,	Population at time of battle
	Reptiles	Species abundance and diversity (3), species distribution (3),	Land use outside of the park, carrying capacity of the park (especially with urban sprawl surrounding park), habitat loss, climate change,	Population at time of battle
	Texas Tortoise	Population density and distribution (3), age class structure (3), sex ratio (3)	Land use outside of the park, carrying capacity of the park (especially with urban sprawl surrounding park), habitat loss, climate change,	Undefined
Environmental Quality				
	Air Quality	OZONE (3), deposition of nitrogen (3), deposition of sulfur (3), visibility (3), particulate matter (3)	Adjacent land use, international contribution to air pollution, vehicle emissions, refinery and plants, burning of agricultural fields	NPS Air Resources Division air quality index values
	Water Quality	Temperature (3), specific conductance (3), dissolved oxygen (3), pH (3), indicator bacteria (fecal coliform, *e. coli*) (3), presence of heavy metals (3), presence of chemicals (3)	Flooding, urban runoff (fertilizer, waste mgmt),	TCEQ water quality criterion considered to be protective of aquatic life and human recreation and bathing
	Viewscape	Change in land use cover type inside the park (internal viewshed) (3), change in land use cover type outside the park (external viewshed) (3)	Construction of overpass and associated light fixtures, cranes at port of Brownsville, Brownsville city expansion	Unobstructed view similar to historic battlefield
	Soundscape	Occurence of human-caused sound (3), natural ambient sound level (3)	Adjacent land use, traffic, human development, air traffic	Undefined
	Dark Night Skies	NPS Night Sky Team suite of measures (3)	Adjacent land use, development, urban light pollution, vehicle lights, park infrastructure lighting (security)	Night sky visibility as observed on historic battlefield

3.2.2 General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time PAAL staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were provided by NPS staff. Additional data and literature were also acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component and recommendations from NPS reviewers and sources of expertise including NPS staff from PAAL and the GULN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A “Significance Level” represents a numeric categorization (integer scale from 1-3) of the importance of each measure in assessing the component’s condition; each Significance Level is defined in Table 5. This categorization allows measures that are more important for determining condition of a component (higher significance level) to be more heavily weighted in calculating an overall condition. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 5. Scale for a measure’s significance level in determining a components overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level for each measure on a 0-3 integer scale (Table 6). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 6. Scale for condition level of individual measures.

Condition Level (CL)	Description
0	Of **NO** concern. No net loss, degradation, negative change, or alteration.
1	Of **LOW** concern. Signs of limited and isolated degradation of the component.
2	Of **MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of **HIGH** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

Weighted Condition Score

After the Significance Levels (SL) and Condition Levels (CL) are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\#\ of\ measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\ of\ measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: condition of low concern (WCS = 0.0 – 0.33); condition of moderate concern (WCS = 0.34 - 0.66); and condition of significant concern (WCS = 0.67 to 1.00). Figure 1 displays all of the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern and green circles a condition of low concern. Gray circles are used to represent situations in which SMUMN GSS analysts and park staff felt there was currently insufficient data to make a statement about the condition of a component. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5-10 years, as well as expert opinion. An upward pointing arrow indicates the condition of the component has been improving in recent times. A right-pointing arrow indicates a stable condition or trend and an arrow pointing down indicates a decline in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. A gray, triple-pointed arrow is reserved for situations in which the trend of the component's condition is currently unknown.

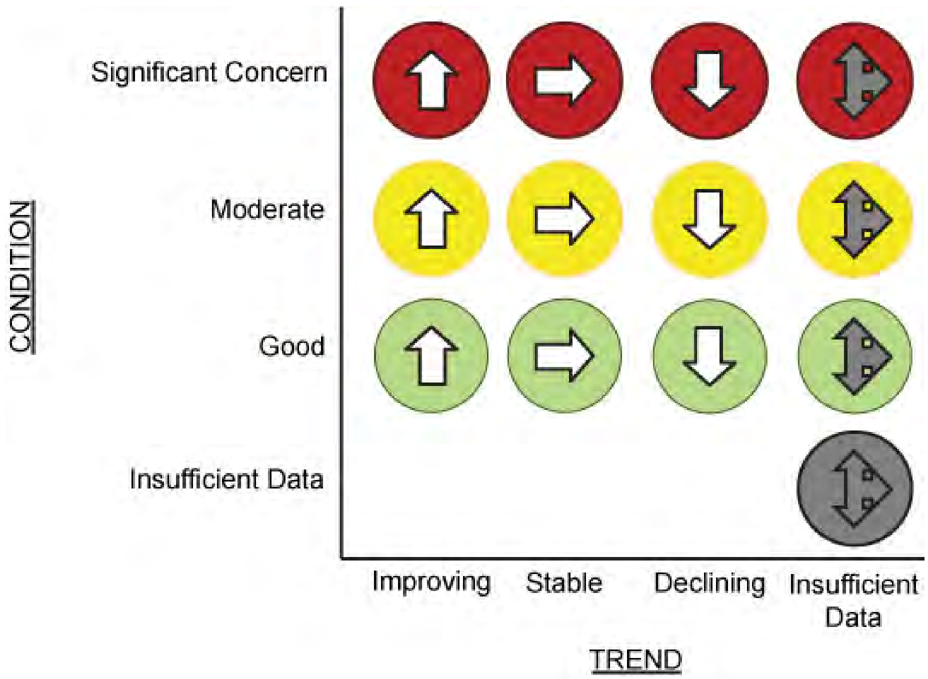

Figure 1. Symbols used for individual component assessments with condition or concern designations along the vertical axis and trend designations along the horizontal.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and PAAL and GULN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or conference call with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by PAAL resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and resource experts.

Format of Component Assessment Documents

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description
This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology, or it may be a resource that is of high management priority in the park. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures
Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values
This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods
This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend
This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component is presented and interpreted in this section.

Threats and Stressor Factors
This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps
This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to

determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition

This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

Literature Cited

This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component. Note, citations used in appendices and plates referenced in each section (component) of Chapter 4 are listed in that section's "Literature Cited" section.

Literature Cited

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Chapter 4 Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 18 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

The order of components follows the project framework (Table 4):

4.1 Open Prairie Community
4.2 Tamaulipan Brushland
4.3 Resaca Wetland and Riparian Community
4.4 Breeding Birds
4.5 Raptors
4.6 Coyotes
4.7 Collared Peccary
4.8 Wild Cats
4.9 Native Rodents
4.10 Butterflies
4.11 Amphibians
4.12 Reptiles
4.13 Texas Tortoise
4.14 Air Quality
4.15 Water Quality
4.16 Viewscape
4.17 Soundscape
4.18 Dark Night Skies

4.1 Open Prairie Community

Description

The open prairie community covers approximately 75% of PAAL (Cooper et al. 2004), and provides habitat for numerous invertebrates, including insects, snails, and fiddler crabs (*Uca subcylindrica*), as well as songbirds and rodents (Richard and Richardson 1993). There are three types of prairie vegetation in the park: coastal prairie, sacatal prairie, and borrichia prairie. The distribution of this prairie vegetation is influenced primarily by soil type (Cooper et al. 2004). The coastal prairie occurs on highly saline soils, partly due to its low-lying location (Cooper et al. 2004). The sacatal prairie habitat, which is the most common type in PAAL, also occurs at lower elevations but is underlain with a different soil type. Sacatal is found in heavy, clay soils that regularly crack when dried out, while coastal prairie soils are light, sandy, and do not crack when dry (Richard and Richardson 1993). Borrichia prairie is the rarest grassland habitat in the park, consisting of former resacas that were filled in by erosion over time (Cooper et al. 2004).

According to Richard and Richardson (1993, p. 10), the coastal prairie vegetation within PAAL "has likely not changed much since 1846," although it may have expanded into areas where old resacas have filled in. Plant species in the coastal prairie are generally salt tolerant and include seepweed (*Suaeda* sp.), saltbush (*Atriplex* sp.), sea oxeye, seaside heliotrope (*Heliotropium curassavicum*), horse crippler (*Echinocactus texensis*), shoregrass (*Monanthochloe littoralis*), and sea-lavender (*Limonium carolinianum*). Dwarf saltroot (*Salicornia bigelovii*) and turtleweed (*Batis maritima*) also occur in small patches (Richard and Richardson 1993).

Sacatal covers much of the eastern, south-central, and southwestern portion of the park, often intermixing with coastal prairie in the east (Richard and Richardson 1993). This habitat is almost purely gulf cordgrass, with some sea oxeye in heavier soils.

Photo 5. Borrichia prairie (foreground) and sacatal (left, background) in PAAL (Photo by Shannon Amberg, SMUMN GSS).

Borrichia prairie (Photo 5) consists nearly exclusively of sea oxeye with only a few other forbs. It is found in three locations in PAAL: a partially filled Resaca near the western boundary and two in the north, near the former location of El Tule Grande (Richard and Richardson 1993).

Measures

- Change in extent of woody species coverage
- Change in extent of grassland species coverage

- Species richness
- Ratio of native to non-native species

Reference Conditions/Values
Park management would like the open prairie community to be similar to conditions at the time of the historic battle (1846). According to Ulysses S. Grant's war diary, the wet battlefield was dominated by shoulder-high grass (gulf cordgrass) at that time (Sanchez 1985, as cited in Lonard et al. 2004).

Data and Methods
The vegetation in PAAL is described in Farmer (1992), Richard and Richardson (1993), Lonard et al. (2004), and Cooper et al. (2004). Archer et al. (1988) and GULN (2010) provided additional information regarding threats to the open prairie community.

The U.S. Geological Survey's (USGS) National Wetlands Research Center created a vegetation map for PAAL using color infrared aerial imagery from February 2000 (Ramsey et al. 2004). Vegetation classes were based on the National Vegetation Classification Standard (NVCS) and field site data was collected to ensure accuracy, which was found to be >89%. The USGS also analyzed historical aerial photos of PAAL to explore vegetation change from 1934 (the earliest photos available) through 2000 (Ramsey et al. 2004).

Current Condition and Trend

<u>Change in Extent of Woody Species Coverage</u>
In the absence of disturbance (e.g., fire, flooding), woody species often invade and take over prairie communities as part of natural succession. Woody species such as mesquite (*Prosopis* sp.) and cacti have been increasingly encroaching upon many southwestern grasslands over the past century, including the grasslands in PAAL (Archer et al. 1988, Caran et al. 2005). The invasion of woody vegetation takes away from the open feeling of the historic battlefield, making it difficult for park staff to interpret the historical landscape for visitors (Garza, phone communication, 26 July 2012). A USGS analysis of aerial photos from 1934 and 2000 suggests that several woody communities decreased in coverage over that time. However, mesquite grassland (a mix of shrub and herbaceous vegetation) increased substantially over this same period, so that overall woody species coverage was slightly higher in 2000 than in 1934 (Table 7, Ramsey et al. 2004). According to park staff, woody species have encroached even further into open prairie communities since 2000 (Garza, phone communication, 26 July 2012).

Table 7. Extent of various woody vegetation communities within current PAAL boundaries in 1934 and 2000 (Ramsey et al. 2004).

Woody vegetation community	1934 coverage (ha)	2000 coverage (ha)
Tamaulipan brushland	158.4	163.8
Mesquite forest	75.6	41.8
Huisachal	24.7	4.9
Mesquite grassland	13.4	106.2
Total	272.1	316.7

Change in Extent of Grassland Species Coverage

The extent of grassland species coverage can be reduced by woody species encroachment and/or conversion to agricultural uses (Archer et al. 1988, Caran et al. 2005). At PAAL, changes in hydrology may have decreased soil moisture, allowing woody species to invade areas that previously supported grasslands (Cooper et al. 2004). However, grassland species may have been able to spread into former resacas that have filled with sediment due to erosion (Cooper et al. 2004). According to Ramsey et al. (2004), the overall coverage of grassland species in the park (e.g., gulf cordgrass, sea oxeye) decreased from 936.4 ha in 1934 to 896.8 ha in 2000. The reduction was more dramatic in gulf cordgrass alone, which dropped from 686.2 ha to 396.9 ha (Ramsey et al. 2004). The extents of both grassland and woody vegetation communities in 1934 and 2000 are represented in Plate 1 and Plate 2.

Species Richness

While several sources have described the characteristic plant species of PAAL's open prairie community (e.g., Richard and Richardson 1993, Lonard et al. 2004), none have focused specifically on the community's species richness. Lonard et al. (2004) divided the park into five vegetative zones: resacas and tanks, salt flats, coastal marshes (sacatal), brush-grasslands, and disturbed sites. The majority of PAAL's prairie likely falls into the salt flats and coastal marshes zones, although some lower-lying areas could have been included in resacas and tanks. Within the salt flats and coastal marshes, Lonard et al. (2004) documented 23 plant species (Table 8).

Table 8. Plant species documented in the salt flats and coastal marshes of PAAL by Lonard et al. (2004).

Scientific name	Common name	Salt flats	Coastal marshes
Sesuvium verrucosum	verrucose sea-purslane	x	
Borrichia frutescens	sea oxeye	x	x
Clappia suaedifolia	fleshy-leaf clappia, fleshy clapdaisy	x	
Rayjacksonia phyllocephala	camphor daisy	x	
Trichocoronis wrightii	Wright's bugheal		x
Batis maritima	vidrillos	x	x
Heliotropium curassavicum	seaside heliotrope	x	x
Maytenus phyllanthoides	mangle-dulce, Florida mayten	x	
Atriplex matamorensis	Matamoros saltbush	x	
Atriplex pentandra	crested saltbush	x	
Salicornia depressa	Virginia glasswort, perennial saltwort	x	
Suaeda linearis	annual seepweed	x	
Suaeda tampicensis	coastal seepweed	x	
Acacia farnesiana	huisache		x
Parkinsonia aculeata	retama		x
Prosopis glandulosa	honey mesquite		x
Prosopis reptans var. *cinerascens*	tornillo	x	x
Limonium carolinianum	sea-lavender	x	x
Lycium carolinianum var. *quadrifidum*	coastal wolfberry, Carolina desert-thorn	x	x
Monanthochloe littoralis	shoregrass	x	x
Spartina spartinae	gulf cordgrass		x
Sporobolus pyramidatus	whorled dropseed	x	
Sporobolus virginicus	seashore dropseed	x	x

Ratio of Native to Non-Native Species

Twenty-one non-native plant species have been documented in PAAL (Table 9), out of a total 275 plant species (NPS 2013). This means there is one non-native species for approximately every 12 native plant species. However, it is unknown how many of these non-natives occur in the open prairie community. According to Lonard et al. (2004), non-native species were found primarily on "disturbed sites"; no non-native plants were documented at that time in the salt flats or coastal marshes.

Table 9. Non-native species documented in PAAL (Lonard et al. 2004, GULN 2010).

Scientific name	Common name
Pennisetum ciliare	buffelgrass
Sorghum halapense	Johnson grass
Sisymbrium irio	London rocket
Angalis arvensis	scarlet pimpernel
Cynodon dactylon	Bermudagrass
Dichanthium annutlatum	Kleberg's bluestem
Dichanthium aristatum	Angleton bluestem
Dichanthium sericeum	silky bluestem
Urochloa maxima	guineagrass
Urochloa panicoides	panic liverseed grass
Eriochloa pseudoacrotricha	perennial cupgrass
Chloris canterai	Paraguayan windmill grass
Amaranthus blitoides	prostrate pigweed
Cyclospermum leptophyllum	slim-lobe celery, marsh parsley
Sonchus asper	rough sow thistle
Sonchus oleraceus	common sow thistle
Chenopodium murale	nettle-leaf goosefoot
Kalanchoe delagoensis	chandelier plant
Melilotus officinalis	sweetclover
Tamarix aphylla	Athel tamarisk
Verbena brasiliensis	Brazilian vervain

Threats and Stressor Factors

Threats to the open prairie community in PAAL include changes in the hydrologic and fire regimes, invasive species, drought, and other extreme weather events (e.g., hurricanes). Historically, periodic flooding of the Rio Grande filled the park's resacas and contributed to hydric soils, which favored gulf cordgrass. This cyclic flooding no longer occurs due to dams and other upstream diversions on the Rio Grande (Lonard et al. 2004). Flooding occurs only rarely now, usually after heavy rains. Unless this cycle of flooding can be restored, it may be impossible to restore the sacatal to its condition at the time of the historic battle (Lonard et al. 2004).

While little is known about the historical occurrence of fire in the PAAL region, scientists suggest that a lack of burning is contributing to brush encroachment into prairie communities (Whittaker et al. 1979, Archer 1988, Cooper et al. 2004). Several pioneers and explorers reported recurring fires throughout the Texas Coastal Plain during the 19th century (Ilkin 1841, Olmstead 1857, as cited in Box et al. 1967). There is also evidence that cordgrass prairies within PAAL were burned to remove litter and promote new growth for grazing (Farmer 1992). Box et al. (1967) showed that fire reduced the frequency and canopy cover of shrubs such as wolfberry (*Lycium berlandieri*) and lotebush in south Texas chaparral for one year while slightly increasing grass production.

Of the non-native species listed in Table 9, several are invasive and could displace native prairie species in the park. These include buffelgrass (*Pennisetum ciliare*) and Johnson grass (*Sorghum halapense*), which were planted on the site by ranchers prior to park establishment, as well as Kleberg's bluestem (Caran et al. 2005, GULN 2010; Garza, written communication, January

2013). Mowing and other park maintenance activities along the entrance road may be spreading invasive grasses into the park from the highway along the park border, where they have been planted by the state highway department (Garza, phone communication, 26 July 2012). Non-native wildlife at PAAL, such as feral hogs and nilgai, can also destroy native vegetation (Cooper et al. 2004). Finally, extreme weather events such as drought and hurricanes, which occasionally inundate the park with saltwater, can negatively impact PAAL's open prairie community.

Data Needs/Gaps

Several data needs exist for the open prairie community within PAAL. Park staff have observed woody species encroachment into open prairies, a trend that has been noted throughout the southwest (Archer et al. 1988). Potential causes of this encroachment include lack of fire, grazing, and climate shifts (Bogusch 1952, as cited in Archer et al. 1988, Neilson 1986). Some climate modeling suggests that grasslands in semiarid regions will become even more vulnerable to woody encroachment under predicted global climate changes (Emanuel et al. 1985, as cited in Archer et al. 1988). Further research is needed into the extent and rate of woody encroachment in the park, as well as the potential role of fire in controlling this encroachment. Invasive plant surveys would also be helpful to determine if these species are present in the undisturbed prairie communities and if they are impacting native species.

Overall Condition

Change in Extent of Woody Species Coverage

The project team defined the *Significance Level* for change in extent of woody species coverage as a 3. Woody species are likely less prevalent now than at the time of the historic battle, as some of the park's brushlands were cleared for agricultural use. More recently, woody coverage has increased as these species encroach upon grassland species in the park. Mesquite grasslands have expanded rapidly since 1934 (Ramsey et al. 2004). This woody encroachment is impeding interpretation of the battlefield, which was historically much more open. Therefore, the change in extent of woody species is of high concern to park management (*Condition Level* = 3).

Change in Extent of Grassland Species Coverage

The *Significance Level* for change in extent of grassland species coverage is also a 3. The overall extent of grassland species in the park may have increased since 1846, as coastal prairie and borrichia have become established in former resacas. However, grassland species coverage has decreased in recent times due to woody encroachment. According to Ramsey et al. (2004), overall grassland species coverage has decreased slightly since 1934 while gulf cordgrass has decreased by about 40%. As a result, the *Condition Level* for this measure is a 3, indicating high concern.

Species Richness

The project team defined the *Significance Level* for species richness as a 3. With only 23 documented plant species, richness seems relatively low in PAAL's open prairie communities. However, there is no indication that this is unusual for the type of prairie community in the park, and it is not currently a cause for concern among park management. Since there is little historical or recent data for comparison with the available species list (Lonard et al. 2004), a *Condition Level* cannot be determined at this time.

Ratio of Native to Non-Native Species
The project team defined the *Significance Level* for this measure as a 3. Twenty-one non-native plant species have been documented throughout PAAL, or approximately one non-native for every 12 native plant species. It is unknown if these non-natives are actually present in the park's open prairie community. Therefore, a *Condition Level* could not be determined.

Weighted Condition Score
Since *Condition Levels* were only determined for two of the four measures, a *Weighted Condition Score* was not calculated for PAAL's open prairie community. However, the expansion of woody species into grassland areas is a significant concern for park management.

Open Prairie Community

Measures	SL	CL
• Extent of woody species coverage	3	3
• Extent of grassland species coverage	3	3
• Species richness	3	n/a
• Ratio of native to non-native species	3	n/a

WCS = N/A

Sources of Expertise
Rolando Garza, PAAL Archeologist and Integrated Resource Manager

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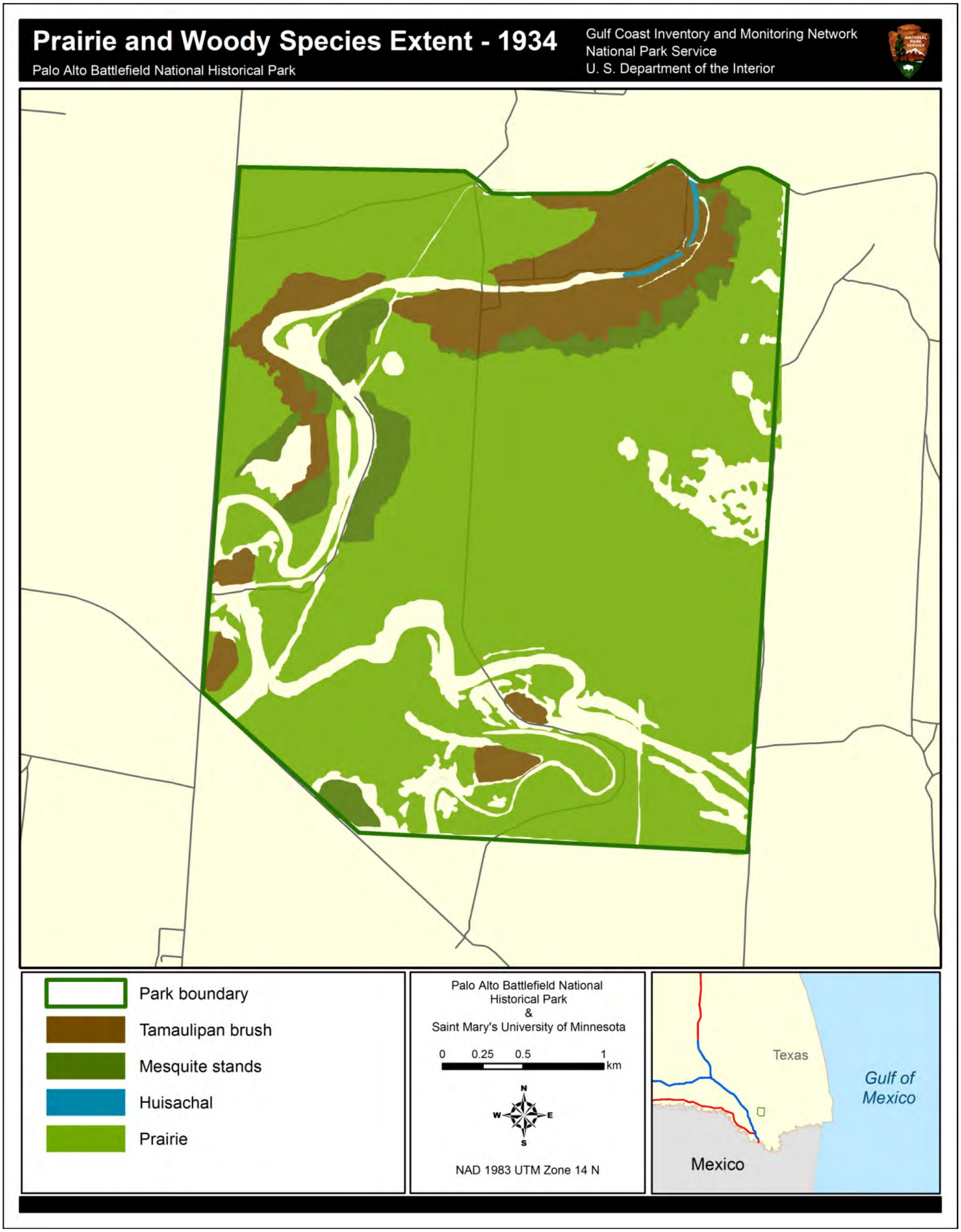

Plate 1. Distribution of grassland and woody communities within PAAL, 1934 (USGS 2003).

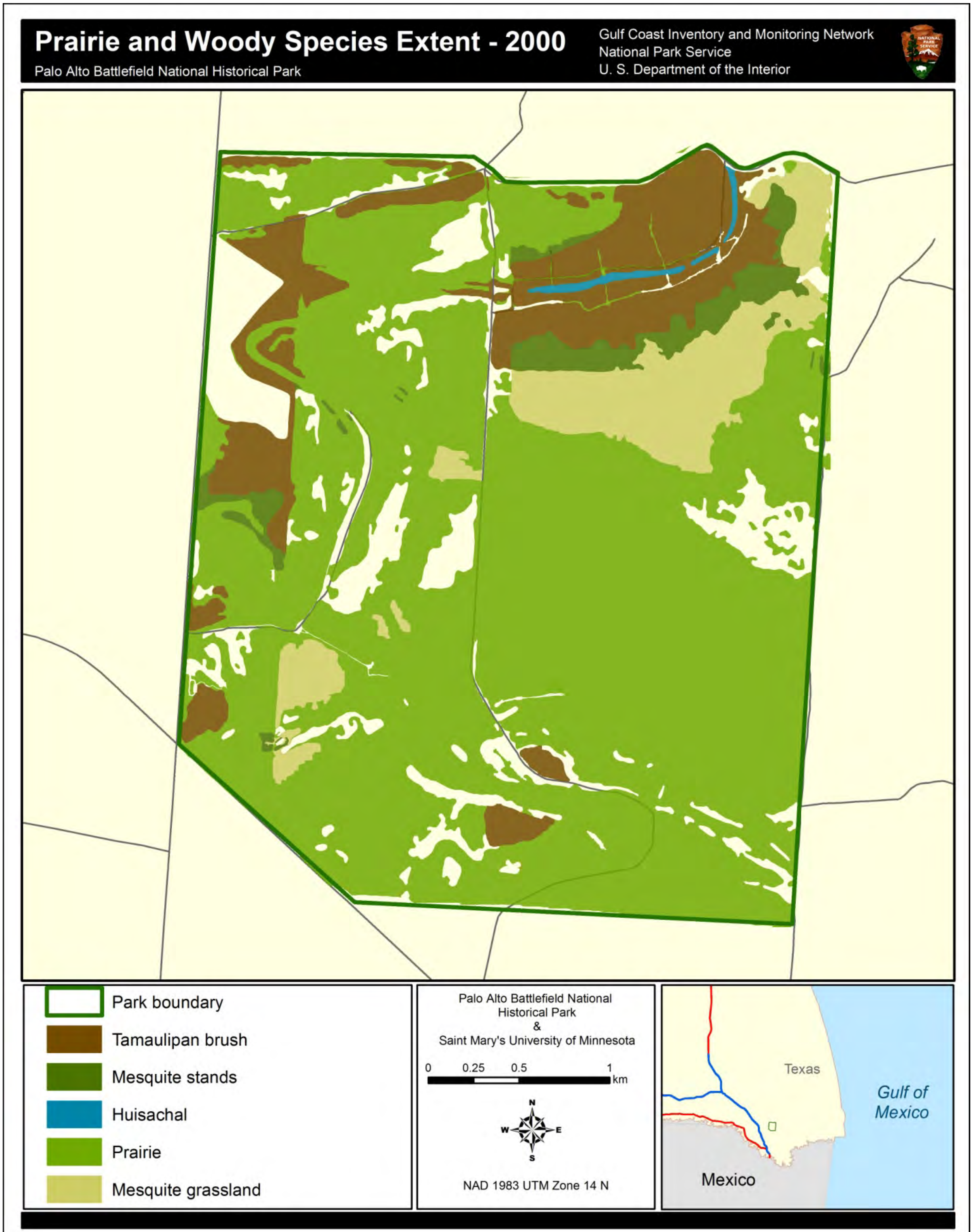

Plate 2. Distribution of grassland and woody communities within PAAL, 2000 (USGS 2003).

4.2 Tamaulipan Brushland

Description

The Tamaulipan brushland ecosystem is found only in south Texas and northeastern Mexico (Jahrsdoerfer and Leslie 1988). The vegetation of this ecosystem is typically dense and thorny, characterized by "spiny shrubs and stunted trees" (Jahrsdoerfer and Leslie 1988, p. 1, citing Clover 1937). In PAAL, the most common brushland species include honey mesquite, Texas ebony (*Ebenopsis ebano*), and spiny hackberry, with an understory of lotebush, lime pricklyash (*Zanthoxylum fagara*), and Lindheimer's prickly pear (*Opuntia lindheimeri*) (Cooper et al. 2004). These brushlands occur at slightly higher elevations than grasslands, with better drainage and therefore lower soil salinity (Cooper et al. 2004). Many wildlife species utilize this dense vegetation for food, cover, or nesting sites. Tamaulipan brushland is considered the northern extent for several Neotropical taxa of reptiles, salamanders, and mammals (Blair 1950, as cited in Jahrsdoerfer and Leslie 1988). It also provides the only known habitat in the U.S. for many species of birds (USFWS 1980, as cited in Jahrsdoerfer and Leslie 1988).

Photo 6. Tamaulipan brushland in PAAL (photo by Shannon Amberg, SMUMN GSS, 2011).

Human impact, primarily through brush clearing for agricultural and urban use, has severely decreased the extent of Tamaulipan brushland over the last century. Over 95% of native brushland in the Lower Rio Grande Valley has been lost due to human use since the 1920s (Parvin 1988, as cited in Jahrsdoerfer and Leslie 1988). Mesquite and other thorny vegetation were often removed by ranchers to improve range conditions for grazing livestock (Fisher et al. 1973). Due to the diversity of wildlife it supports, and its rarity in the surrounding region, Tamaulipan brushland is considered an important resource within the park.

Measures

- Native species diversity
- Areal extent of brushlands

Reference Conditions/Values

Park management would like the Tamaulipan brushland to be similar to conditions at the time of the historic battle (1846). While brushlands are not described in historic accounts of the actual battlefield, Captain E. Kirby Smith described the regional vegetation while traveling with the U.S. Army in 1846. He reported that the prairie was “sprinkled with ‘mots’ of stunted timber”, and noted the presence of giant prickly pears and the small cactus known as horse crippler (Smith 1917, as cited in Richard and Richardson 1993, p. 33).

Data and Methods

The park’s vegetation is described in Farmer (1992), Richard and Richardson (1993), Lonard et al. (2004), and Cooper et al. (2004). Jahrsdoerfer and Leslie (1988, p. iii) conducted a thorough literature search and data synthesis for the Tamaulipan brushlands of the Lower Rio Grande Valley, with the goal of providing “a single-source reference of historical review, land use planning, and management of brushland habitats and wildlife populations of the Lower Rio Grande Valley”.

As described in Chapter 4.1 of this document, the USGS used aerial photography from 1934 and 2000 to create and compare vegetation maps for the park (Ramsey et al. 2004). These maps were used to assess the areal extent of Tamaulipan brushlands within the park.

Current Condition and Trend

Native Species Diversity

Richard and Richardson (1993) documented 75 native plant species in PAAL’s Tamaulipan brushlands, while Lonard et al. (2004) identified 84 species in the park’s brush-grassland vegetative zone. Some species documented by Lonard et al. (2004) were not seen by Richard and Richardson (1993), and vice versa. The two lists combined contain a total of 115 native plant species (Appendix A). The differing lists are likely the result of sampling different areas rather than a change in species diversity over time. However, neither survey observed anacua (*Ehretia anacua*), a common Tamaulipan brushland species (Cooper et al. 2004). No endangered or threatened plant species were found in the park, but one species (reflexed airplant [*Tillandsia baileyi*]) is on the Texas Organization for Endangered Species’ “watch list” (Lonard et al. 2004).

Areal Extent of Brushlands

Brushland habitat covers approximately 23% of the park, primarily from the southwest corner, along the western boundary, and curving along the northern park boundary (Cooper et al. 2004). Smaller pockets of brush also occur in the south on dunes elevated above the surrounding grassland. An estimated 13% of the park is specifically Tamaulipan brushland; other brushy habitats include mesquite forest (9%) and huisachal, consisting of huisache (*Acacia farnesiana*), bordering former resacas (Richard and Richardson 1993, Cooper et al. 2004). Much of the disturbed area in the park (approximately 19% of its total acreage) was likely Tamaulipan brushland before it was cleared for human use (Cooper et al. 2004). According to Cooper et al. (2004), any land within PAAL above 4.5 m (15 ft) in elevation was likely covered by a brush community. Ramsey et al. (2004) found that Tamaulipan brushland extent actually increased in the park between 1934 and 2000 (158.4 ha to 163.8 ha) (Plate 3). However, many of the areas that were cleared and are now returning to brushland are dominated by early successional species such as mesquite and prickly pear, and are not representative of the historic/old growth Tamaulipan brush stands (Garza, written communication, 12 November 2012).

Threats and Stressor Factors

Threats to the park's Tamaulipan brushland are similar to those for the open prairie community and include changes in the hydrologic regime, invasive species, drought, and other extreme weather events (see Chapter 4.1). Buffelgrass has been recognized as a particular concern since stands of this invasive grass can outcompete most other plant species (Jahrsdoerfer and Leslie 1988). Additional invasive species documented in the Tamaulipan brushlands by Richard and Richardson (1993) are guineagrass (*Urochloa maxima*), Paraguayan windmill grass (*Chloris canterai*), bermudagrass (*Pennisetum cilare*), and balloon vine (*Cardiospermum halicacabum*). Exotic animals in the park (nilgai and feral hogs) create trails through the brushlands that could allow exotic plants to invade these areas (Garza, phone communication, 26 July 2012). Drought has been linked to a decrease in woody cover in south Texas brushlands (Archer et al. 1988), likely due to high mortality among mesquite plants (Carter 1964, Norwine 1978, as cited in Archer et al. 1988).

Data Needs/Gaps

Little is known about the dynamics of the conversion or succession (e.g., mechanisms, rates) from grassland to brushland in south Texas (Archer 1988). For example, the role of fire and hydrology (e.g., flooding) in possibly limiting brushland distribution is unclear. Additionally, an invasive plant survey would help determine if these species are present in the park's brushlands and if they are impacting native species. Some brushlands are present at the Resaca de la Palma unit, but have not been surveyed to determine their condition or species composition.

Overall Condition

Native Species Diversity

The project team defined the *Significance Level* for native species diversity as a 3. With 115 native plant species, the diversity in PAAL brushlands appears relatively high. Richard and Richardson (1993, p. 7) suggest that the park's brushland vegetation, "has probably changed very little since 1846." Therefore, this measure is assigned a *Condition Level* of 1, or low concern.

Areal Extent of Brushlands

The project team defined the *Significance Level* for areal extent of brushlands as a 3. While the extent of Tamaulipan brushlands within PAAL today is likely less than it was in 1846, these brushlands have actually increased slightly since 1934. However, the brushlands contributing to this increase often consist of early successional species (e.g., mesquite, prickly pear) and do not provide the same ecological/habitat qualities as old growth Tamaulipan brushland. As a result, this measure is currently of low concern to park management (*Condition Level* = 1).

Weighted Condition Score

The *Weighted Condition Score* for Tamaulipan brushlands at PAAL is 0.333, indicating low concern. Given the slight expansion in extent since the 1930s, this community appears to be stable.

Tamaulipan Brushland

Measures	SL	CL
• Diversity of native species	3	1
• Areal extent	3	1

WCS = 0.333

Sources of Expertise

Rolando Garza, PAAL Archeologist and Integrated Resource Manager

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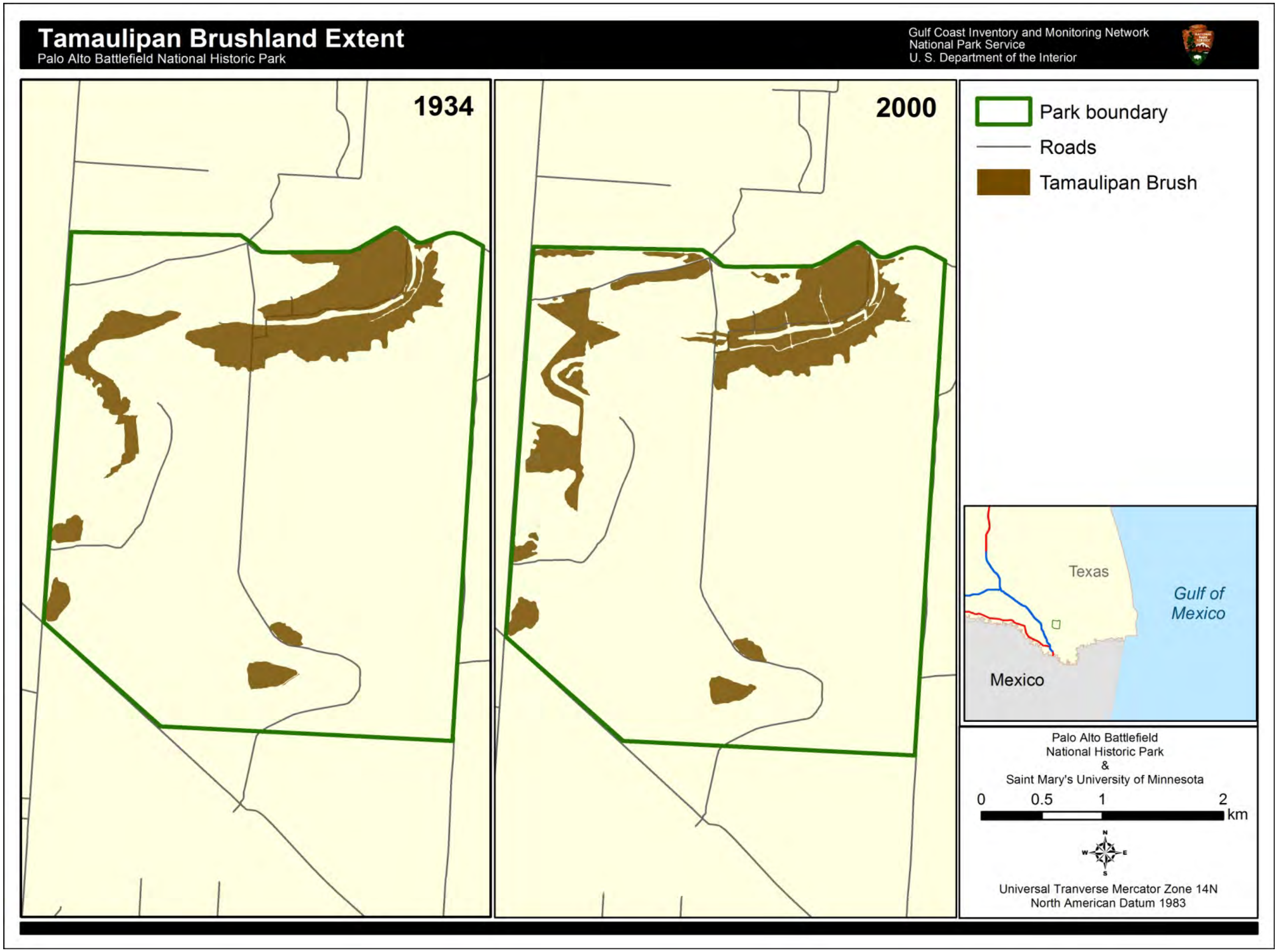

Plate 3. Extent of Tamaulipan brushland at PAAL in 1934 (left) and 2000 (right) (USGS 2003).

4.3 Resaca Wetland and Riparian Community

Description

Resaca wetland and riparian communities are key features in PAAL, providing habitat for plants and wildlife that would otherwise not survive in the park's semi-arid climate. The resacas also played a significant role in the historic battle by providing water for soldiers, and limiting the movements of the Mexican and American armies (Lonard et al. 2004, Caran et al. 2005). Resacas, similar to oxbow lakes, are abandoned river channels that still hold water. In the case of PAAL, the resacas are former branches of the Rio Grande that historically spread across its vast delta (Photo 7; Caran et al. 2005). Nearly all the resacas and wetlands within the park are temporary or seasonal, and do not hold water during dry periods (Farmer 1992, Caran et al. 2005). However, they still provide important habitat for wading birds, waterfowl, and amphibians (Farmer 1992, Judd and Lonard 2004).

Photo 7. A resaca in PAAL (NPS photo).

Most of the park's remaining resacas have begun to fill in with sediment, partly due to erosion from adjacent agriculture (Farmer 1992). A decrease in the Rio Grande's flow and local drainage efforts over the past century have reduced the water table in the PAAL area, which in turn reduces the amount of surface water in resacas and wetlands (Caran et al. 2005). The Palo Alto Resaca (located near the western park boundary) and several other wetland areas have been modified to form "stock tanks", which are small ponds that provide a reliable water source for livestock (Caran et al. 2005). While some of these resacas and wetlands still support riparian vegetation such as sedges and cattails, many are dominated by sea oxeye, which is characteristic of borrichia prairies (Caran et al. 2005).

Measures

- Native species richness
- Frequency and duration of inundation events
- Extent of wetland and riparian communities
- Redox potential of the soil
- Soil moisture

Reference Conditions/Values

The reference condition for the resaca wetland and riparian community is similar to the composition and structure at the time of the 1846 battle. Historical maps from that time show several prominent wetland features: Palo Alto Resaca in the northwest area of the current park, Palo Alto Pond east of the Resaca, and a large circular marsh within the battlefield (Caran et al. 2005, Figure 2). Palo Alto Resaca at the time of the battle was a "chain of ponds and marshes" that likely held water year-round and supported thick stands of emergent wetland vegetation (Caran et al. 2005, p. 96).

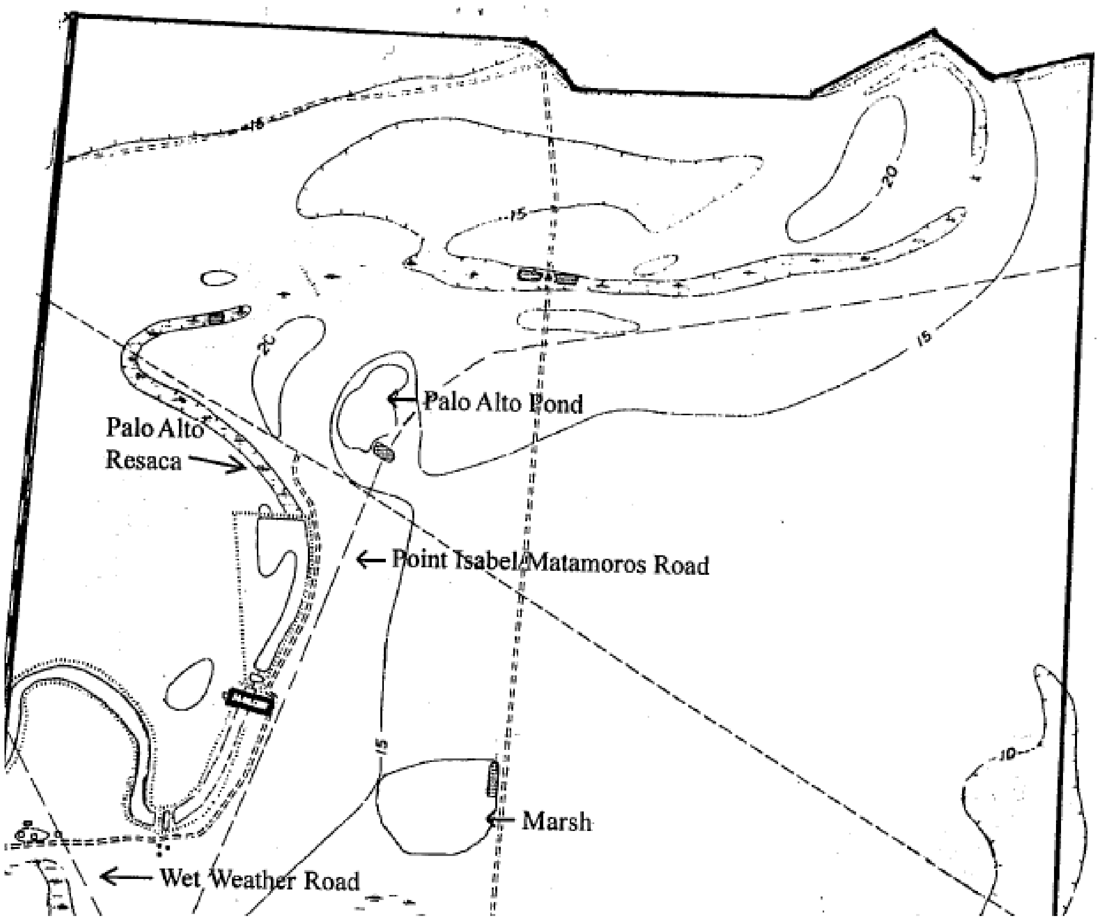

Figure 2. Prominent wetland features noted on historical maps of the Palo Alto Battlefield (Caran et al. 2005).

Data and Methods

Caran et al. (2005) conducted a geoarcheological study of Palo Alto Resaca to explore how the Resaca had changed over time, particularly through human modification. Their work included archival research (e.g., historical maps and publications, aerial photos) and several trench excavations to collect soil/sediment samples for analysis (Caran et al. 2005). Cooper and Wolf (2012) studied the landscape hydrology of PAAL, including soil redox potential, to support resaca restoration efforts. They installed shallow water wells with data loggers and three automated redox measuring stations to collect data from March of 2010 through February of 2011 (Cooper and Wolf 2012).

The park's vegetation and other natural resources, including Resaca communities, are described in Farmer (1992), Richard and Richardson (1993), and Lonard et al. (2004). Judd and Lonard (2004) studied the species composition of various marshes across the Rio Grande Delta and included two brackish marshes at PAAL. Margo (2006) studied the hydrology of Palo Alto Resaca and explored strategies for restoring its wetland ecosystem to more historic conditions. National Wetland Inventory (NWI) GIS data from the U.S. Fish and Wildlife Service (USFWS) provides wetland information for the park. USFWS interpreted color infrared aerial imagery from the 1990s to generate the GIS data, which provide an indication of the prevalence and distribution of wetland types (according to the Cowardin et al. 1979 classifications) throughout the park.

Current Condition and Trend

Native Species Richness

Lonard et al. (2004) documented 60 native and one non-native plant species in the resacas and tanks vegetative zone of PAAL (Table 10).

Table 10. Plant species documented in the resacas and tanks vegetative zone by Lonard et al. (2004).

Scientific name	Common name	Scientific name	Common name
Marsilea macropoda	waterclover	*Sesuvium verrucosum*	verrucose sea-purslane
Alternanthera paronychioides	smooth joyweed	*Eryngium nasturtiifolium*	hierba del sapo
Bidens laevis	smooth beggarticks	*Borrichia frutescens*	sea oxeye
Coreopsis tinctoria	golden tickseed	*Eclipta prostrata*	yerba de tago
Helenium microcephalum var. *ooclinium*	smallhead sneezeweed	*Packera tampicana*	Great Plains ragwort, Tampico butterweed
Pluchea odorata	marsh fleabane	*Trichocoronis wrightii*	Wright's bugheal
Symphyotrichum divaricatum	saltmarsh aster	*Heliotropium angiospermum*	scorpion's-tail, taper-leaf heliotrope
Batis maritima	vidrillos	*Heliotropium curassavicum*	seaside heliotrope
Acacia farnesiana	huisache	*Mimosa asperata*	black mimosa
Parkinsonia aculeata	retama	*Prosopis glandulosa*	honey mesquite
Prosopis reptans var. *cinerascens*	tornillo	*Sesbania drummondii*	poisonbean
Sesbania herbacea	bigpod sesbania	*Eustoma exaltatum*	catchfly prairie gentian
Clinopodium brownei	Browne's savory	*Salvia coccinea*	scarlet or blood sage
Lythrum alatum var. *lanceolatum*	winged lythrum	*Lythrum californicum*	California loosestrife
Malvastrum americanum	Rio Grande or Indian Valley false mallow	*Malvastrum coromandelianum*	threelobe false mallow
Nymphaea elegans	royalblue waterlily	*Rumex chrysocarpus*	amamastla dock
Samolus ebracteatus	bractless brookweed	*Spermacoce glabra*	smooth false buttonweed
Salix nigra	black willow	*Bacopa monnieri*	coastal waterhyssop
Mecardonia procumbens	baby jump-up, yellow-flowered mecardonia	*Veronica peregrina* subsp. *xalapensis*	purslane speedwell
Lycium carolinianum var. *quadrifidum*	coastal wolfberry, Carolina desert-thorn	*Solanum americanum*	American black nightshade
Solanum campechiense	redberry nightshade	*Melochia pyramidata*	angle-pod broomweed, pyramidflower
Urtica chamaedryoides	heartleaf nettle	*Phyla nodiflora*	frogfruit
Echinodorus beteroi	upright burhead	*Sagittaria longiloba*	long-lobe arrowhead
Bolboschoenus maritimus ssp. *paludosus*	cosmopolitan bulrush	*Cyperus articulatus*	jointed flatsedge
Cyperus esculentus	yellow nutgrass	*Eleocharis acicularis*	needle spikerush
Eleocharis austrotexana	Rio Grande spikerush	*Lemna minuta*	least duckweed
Eragrostis reptans	creeping lovegrass	*Eriochloa pseudoacrotricha**	perennial cupgrass
Eriochloa punctata	Louisiana cupgrass	*Leptochloa fusca* ssp. *uninervia*	Mexican sprangletop
Leptochloa nealleyi	Neally's sprangletop	*Paspalidium geminatum*	Egyptian panicgrass
Paspalum denticulatum	longtom	*Heteranthera dubia*	grassleaf mudplantain
Typha domingensis	southern cattail		

* = non-native species

In a study of Rio Grande Delta marshes, Judd and Lonard (2004) identified 81 plant species across nine brackish marshes, including two marshes in PAAL. Species richness per marsh varied from 7 to 24 with an average of 17.9; the two marshes in PAAL supported 13 and 14 species each (Judd and Lonard 2004). Judd and Lonard (2004) identified four additional plant and algae species in marshes at PAAL that had not been documented previously by Lonard et al. (2004) (Table 11).

Table 11. Additional plant and algae species documented in PAAL marshes by Judd and Lonard (2004).

Scientific name	Common name	Scientific name	Common name
Chara sp.	muskgrass (algae)	*Monanthochloe littoralis*	shoregrass
Chlorophyta filaments	green algae	*Spartina spartinae*	gulf cordgrass

Frequency and Duration of Inundation Events

Very little information is available regarding inundation events at PAAL. Historically, the Rio Grande likely overflowed its banks nearly every year (Judd and Lonard 2004, Caran et al. 2005), and many of these floods could have reached the PAAL region. Due to dam construction and other water diversions on the Rio Grande, as well as local and regional developments (e.g., groundwater development, agriculture, flood control), flooding in the area is now extremely rare (Judd and Lonard 2004, Caran et al. 2005). During Cooper and Wolf's (2012) study, heavy precipitation (>15 cm [>6 in] a day) from two hurricanes caused short-term inundation at the park. Shallow well data loggers showed that standing water was 10-20 cm (3.9-7.9 in) deep for several hours during each storm (Cooper and Wolf 2012). Portions of the battlefield's resacas were also filled with water during a 2008 hurricane and during two tropical storms in 2010 (Mark Spier, PAAL Superintendent, written communication, November 2012). However, no major inundation events (e.g., prolonged, widespread flooding) have impacted PAAL in the past 15 years (Caran et al. 2005; Garza, phone communication, 26 July 2012). According to a former landowner interviewed by Richard and Richardson (1993), the current park area was inundated twice by hurricanes in the 1900s: once in 1933, and again in 1967, when the "flats" were covered with nearly 0.6 m (2 ft) of water.

Extent of Wetland and Riparian Communities

Analysis of NWI data indicates that approximately 9.6% or 132.2 ha (326.6 ac) of the park is classified as wetland (Plate 4). All of PAAL's wetlands are palustrine, a classification that includes vegetated wetlands traditionally known as marshes, swamps, bogs, or ponds, and includes intermittent or seasonal water bodies (Table 12; Cowardin et al. 1979). The majority of these areas support emergent wetland vegetation and are temporarily or seasonally flooded. A small percentage of the wetlands (3.7 ha [9.1 ac]) have been modified by human activities such as excavation or impoundment.

Table 12. Major National Wetland Inventory (NWI) classifications (Cowardin 1979) by area in PAAL.

NWI Code	NWI Description	Total wetland area (ha)
PEM1A	Palustrine, emergent, persistent, temporary flooded	92.8
PEM1Ad	Palustrine, emergent, persistent, temporary flooded, partially drained/ditched	0.6
PEM1Ax	Palustrine, emergent, persistent, temporary flooded, excavated	0.2
PEM1C	Palustrine, emergent, persistent, seasonally flooded	27.8
PEM1Ch	Palustrine, emergent, persistent, seasonally flooded, diked/impounded	0.3
PEM1Cx	Palustrine, emergent, persistent, seasonally flooded, excavated	0.8
PEM1Fh	Palustrine, emergent, persistent, semipermanently flooded, diked/impounded	0.2
PEM1Fx	Palustrine, emergent, persistent, semipermanently flooded, excavated	0.3
PSS1A	Palustrine, scrub-shrub, broad-leaved deciduous, temporary flooded	1.6
PUBFx	Palustrine, unconsolidated bottom, semipermanently flooded, excavated	0.8
PUBHx	Palustrine, unconsolidated bottom, permanently flooded, excavated	0.5
PUSA	Palustrine, unconsolidated shore, temporary flooded	6.3
	Total	132.2

NWI data for Resaca de la Palma shows that the resaca forming most of the park's boundary is classified as a palustrine, permanently flooded wetland (PUBH). At the time of the classification, the resaca was approximately 3.6 ha (8.8 ac) in size (Plate 5).

According to Hayes (2004), natural wetlands (Photo 8), artificial tanks, and canals covered only an estimated 2% of PAAL in 2002. Due to seasonal and temporal variations of the park's wetlands, it can be difficult to determine the extent of wetland and riparian communities. These areas can expand during wet years and nearly disappear during droughts. For example, Richard and Richardson (1993, p. 12) noted an abundance of water lily (*Nymphaea* sp.) "…in places which were thought to be almost always dry."

Photo 8. An emergent wetland in PAAL (NPS photo).

Redox Potential of the Soil

Redox (reduction-oxidation) potential is a measurement of electrochemical potential or electron availability, which plays a key role in all chemical reactions (DeLaune and Reddy 2005). More specifically, it is determined by the concentration of oxidants or "electron acceptors" (e.g, oxygen, nitrate, iron, sulfate, CO_2) and reductants (electron donors, e.g., organic material, reduced inorganic compounds). Redox potential helps predict the stability of compounds that regulate nutrient availability and is useful in determining if an area is functioning as a wetland (DeLaune and Reddy 2005). Redox potential is measured in millivolts (mV); negative and low values indicate reduced, anaerobic conditions while higher values indicate oxidized, aerobic conditions. Wetland soils typically exhibit a redox potential between -300 and 700 mV (DeLaune and Reddy 2005).

Caran et al. (2005) indicate that soils under the resacas can be anoxic (oxygen deficient) at shallow depths, and that conditions in the Palo Alta Resaca sediment are suitable for anaerobic sulfate-reducing bacteria. These anoxic conditions are also favorable for ammonia and ammonium-producing bacteria (Caran et al. 2005). This suggests that soil conditions under the Palo Alto Resaca have a low redox potential. Measurements by Cooper and Wolf (2012) at three sites (approximate location in Plate 6) during 2010-2011 confirmed this. While soils were aerobic for most of the year (>350 mv), soil redox values dropped sharply (as low as 150-250 mV) after heavy rains (Figure 3). During 2010, these low redox values persisted for at least 2 weeks on two separate occasions (Cooper and Wolf 2012).

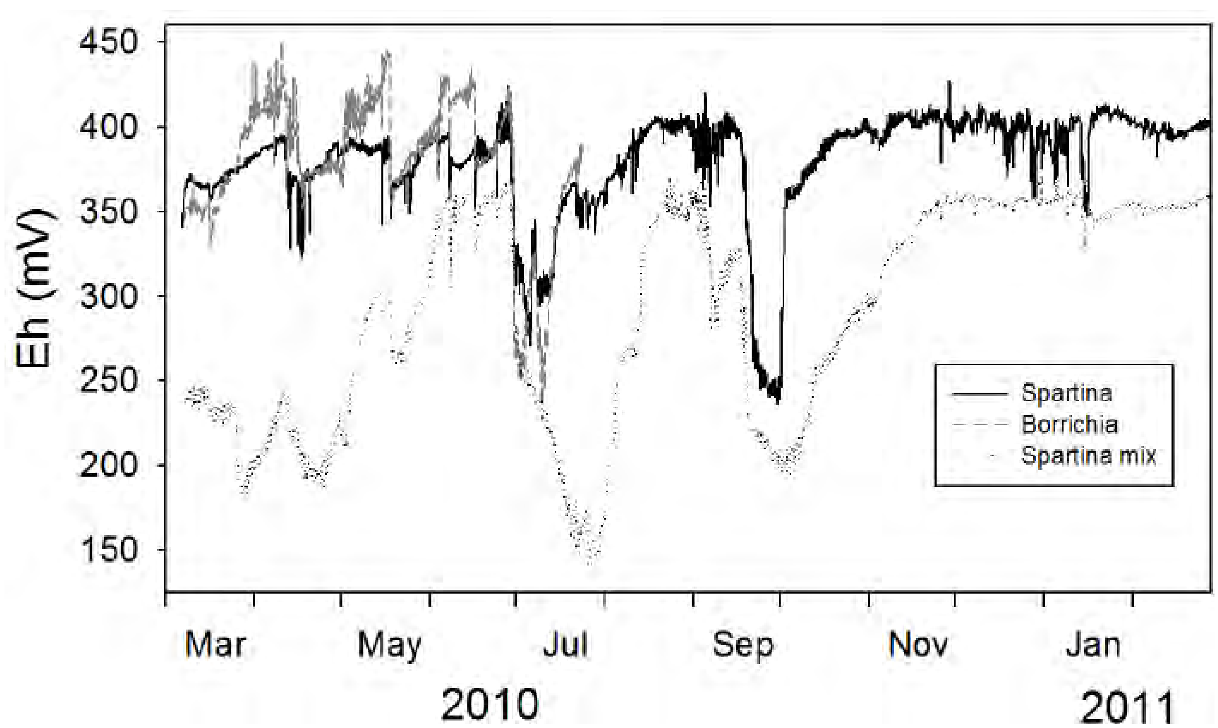

Figure 3. Soil redox potentials at three sites in PAAL from March 2010 through February 2011. The sharp drops occurred after heavy rain events (Cooper and Wolf 2012).

Soil Moisture

No soil moisture data are available for the park. Given the changes to the region's hydrological regime (e.g., lack of flooding, human developments), soil moisture levels are likely lower now than they were historically. However, there is no scientific evidence to support this theory.

Threats and Stressor Factors

Threats and stressors to the resaca wetland and riparian community include human modifications (e.g., stock tanks, drainage/irrigation ditches), drought, and feral hogs. During a multi-year drought in the early 2000s, many of the park's wetlands and standing water completely dried up (Hayes 2004). Droughts such as this can impact the composition and density of PAAL's wetland community (Cooper et al. 2004). Feral hog rooting and wallowing can disturb large patches of vegetation, destabilizing wetland areas and potentially exposing them to non-native plant invasion (Hayes 2004, Taylor 2012). At the Resaca de la Palma site, the remaining riparian areas have been heavily invaded by Brazilian peppertree (*Schinus terebinthifolius*) (Photo 9; Garza, phone communication, 26 July 2012).

Photo 9. Brazilian peppertree at Resaca de la Palma (photo by Shannon Amberg, SMUMN GSS).

The greatest impact on the resacas and wetlands has come from human alterations during the 20th century. Several resacas, Palo Alto Pond, and wet areas within the battlefield were excavated to form stock tanks (Plate 6, Caran et al. 2005, Margo 2006). A previous landowner also excavated two ditches along the edge of the Palo Alto Resaca to capture water for agricultural purposes (also shown in Plate 6). Each of these ditches is approximately 4.5 m (14.8 ft) wide and 0.5 m (1.6 ft) deep (Caran et al. 2005). The park's hydrologic regime was seriously impacted by the excavation of a drainage ditch between 1912 and 1915 along what is now the park's northern boundary (Caran et al. 2005). The purpose of this 30 m (100 ft) wide ditch was to prevent flooding on the prairie and in nearby towns. The ditch was effective, and essentially drained a large water body just northwest of PAAL known as El Tule Grande (Weaver 1999, as cited in Caran et al. 2005). Human activity has also indirectly affected resacas, as erosion due to agriculture has accelerated the filling of these areas with sediment, causing a shift in vegetation (Farmer 1992, Cooper et al. 2004). Many of these filled-in resacas are now dominated by sea oxeye (Cooper et al. 2004). The NPS estimates that 30 cm (12 in) of sediment have accumulated in the park's resacas since the 1846 battle (KellerLynn 2008).

Data Needs/Gaps

No data exist for soil moisture in the park, and very limited data are available for soil redox potential. This information would be helpful in understanding the current functioning and condition of PAAL's wetlands. Information regarding the frequency and duration of inundation events would also be useful, although this may be difficult to obtain. An updated survey of the native plant species in wetlands and riparian areas could determine if any species have been lost due to hydrological changes and if non-native species are threatening the native community. Updated wetland mapping with current aerial imagery could determine if wetland extent has changed since the most recent NWI update in the 1990s.

Several sources have suggested that the park's wetlands, particularly the resacas, could be restored by excavating sediment that has accumulated due to agricultural activity (Farmer 1992, Hayes 2004, Margo 2006). Potential restoration methods should be tested for cost-effectiveness in small areas before being applied at a larger scale throughout the park.

Overall Condition

Native Species Richness
The project team defined the *Significance Level* for native species richness as a 3. Species richness in the two PAAL marshes sampled by Judd and Lonard (2004) was lower than most other brackish marshes within their delta study area. However, there is little historical or recent data specifically from PAAL for comparison with the species lists from Lonard et al. (2004) and Judd and Lonard (2004). As a result, a *Condition Level* cannot be determined.

Frequency and Duration of Inundation Events
The project team defined the *Significance Level* for frequency and duration of inundation as a 3. Due to a lack of information, a *Condition Level* could not be assigned for this measure.

Extent of Wetland and Riparian Communities
The project team defined the *Significance Level* for extent of wetland and riparian communities as a 2. According to NWI data from the 1990s, approximately 9.6% of PAAL is classified as wetland. Based on historic accounts from around the time of the Palo Alto battle, wetland area was likely much greater at that time. Therefore, the *Condition Level* for this measure is a 2, indicating moderate concern. Unfortunately, given the significant alterations to the hydrological regime of the region, this measure is largely outside the control of park management.

Redox Potential of the Soil
The project team defined the *Significance Level* for redox potential of the soil as a 3. The limited soil redox data for PAAL show that conditions are generally aerobic for most of the year (>350 mV), but can drop as low as 150 mV after heavy rains. However, given the limited available data, a *Condition Level* could not be determined for the park's Resaca and wetland community as a whole.

Soil Moisture
The project team defined the *Significance Level* for soil moisture as a 3. Since no data is available regarding soil moisture within the park's wetland and riparian communities, a *Condition Level* could not be determined.

Weighted Condition Score
A *Weighted Condition Score* was not calculated for the Resaca wetland and riparian community, as *Condition Levels* could not be determined for >50% of the measures. While this community is a concern for the park due to the many stressors it faces, its condition and trend are currently unknown.

Resaca Wetland & Riparian Community

Measures	SL	CL
• Native species richness	3	n/a
• Frequency & duration of inundation	3	n/a
• Extent of wetland & riparian comm.	2	2
• Redox potential of soil	3	n/a
• Soil moisture	3	n/a

WCS = N/A

Sources of Expertise

Rolando Garza, PAAL Archeologist and Integrated Resource Manager

Joe Meiman, GULN Hydrologist

Mark Spier, PAAL Superintendent

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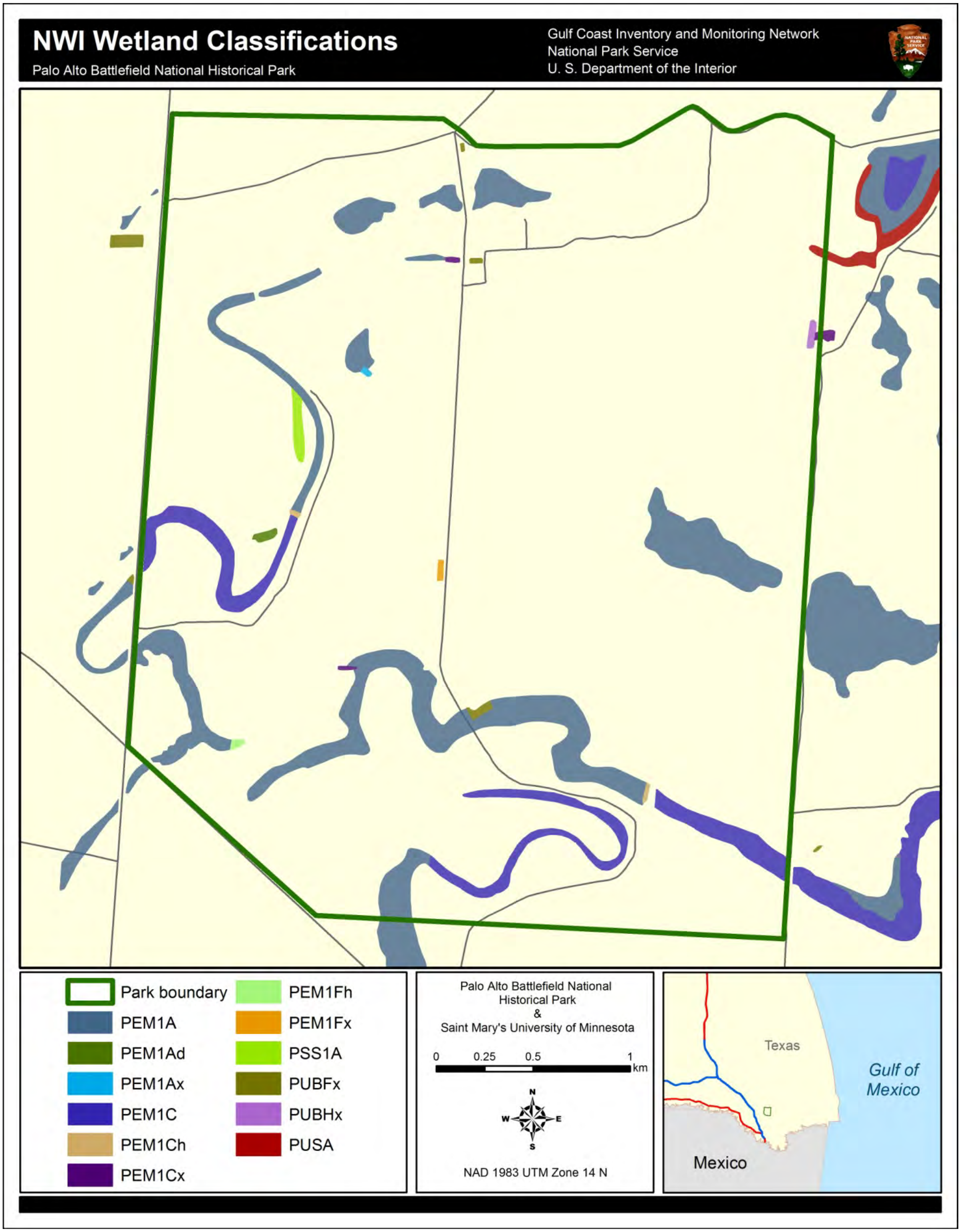

Plate 4. Wetlands in PAAL according to NWI data (USFWS 2012). Codes are defined in Table 12.

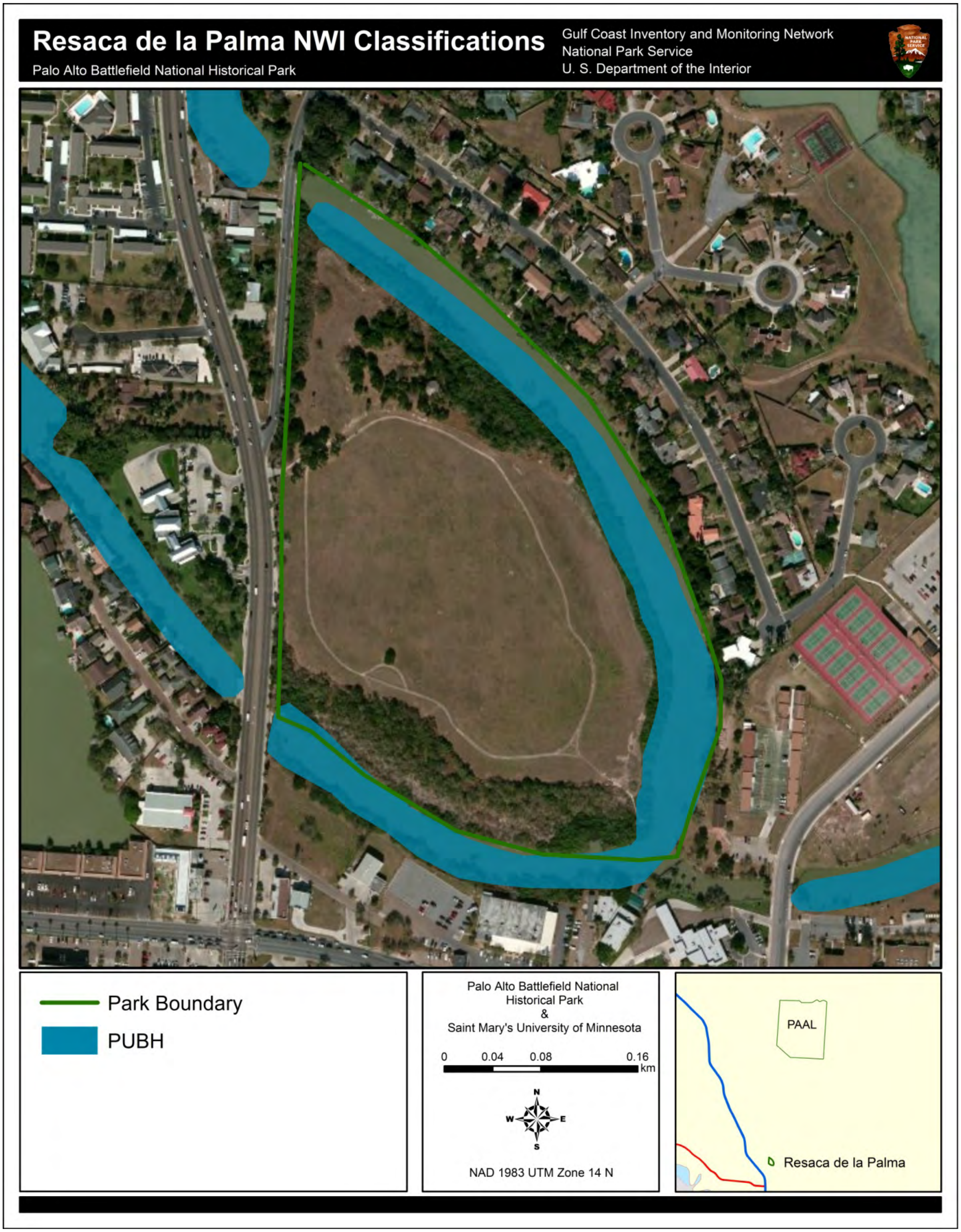

Plate 5. Wetland area at Resaca de la Palma according to NWI data (PUBH = palustrine, unconsolidated bottom, permanently flooded) (USFWS 2012).

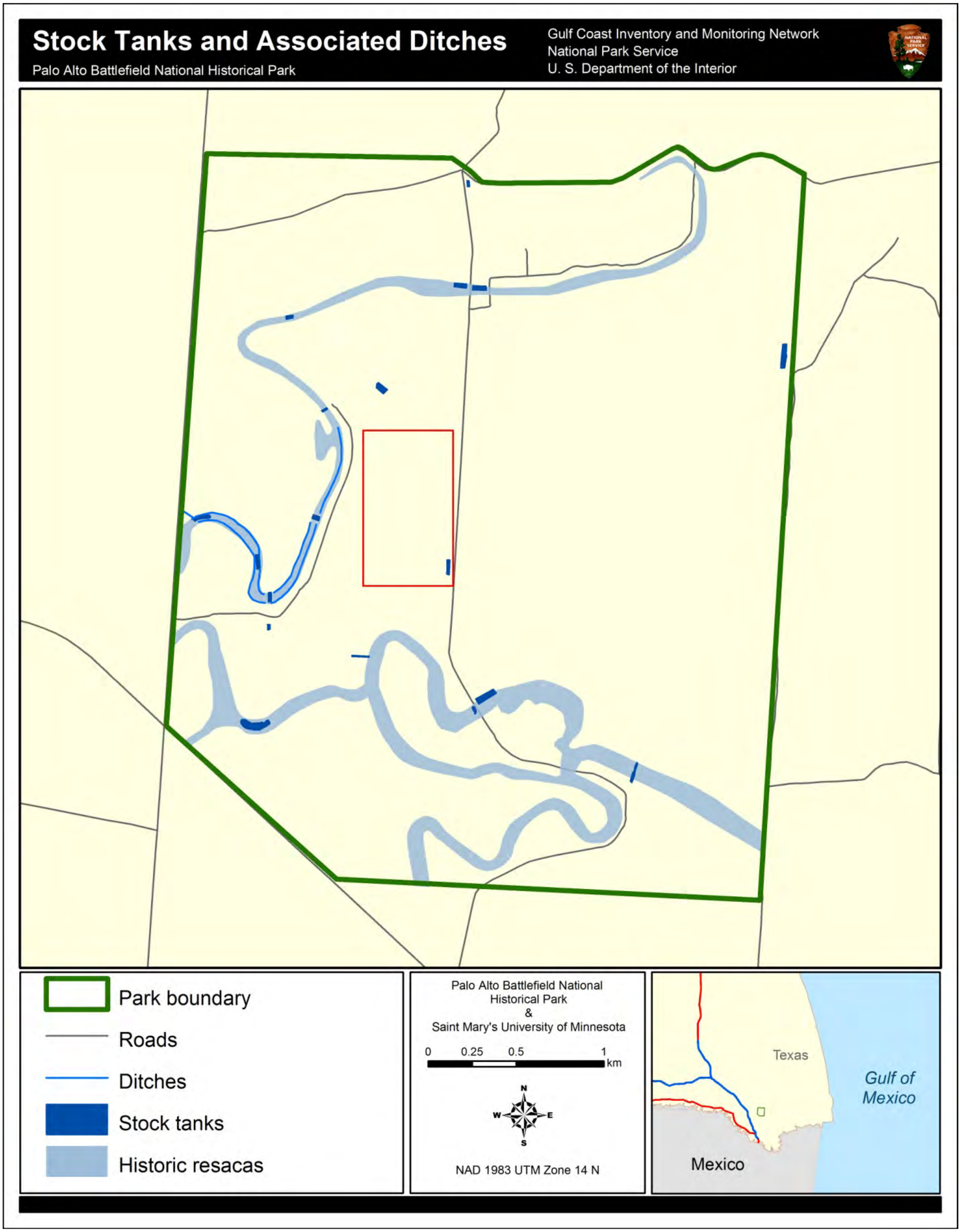

Plate 6. Locations of excavated stock tanks and ditches within PAAL. The red box shows the approximate location of Cooper and Wolf's (2012) soil redox potential measuring stations.

4.4 Breeding Birds

Description

It has been 167 years since the Battle of Palo Alto took place at PAAL, and gone are the gunshots, cannons, and soldiers, but the vibrant bird population of the park still remains on the site. Bird populations often act as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are often highly visible components of ecosystems, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). Despite being a small park, PAAL is home to several unique habitat types including open prairies, dense thickets of mesquite, thorny undergrowth, and a series of resacas criss-crossing the landscape (NPS 2012a). The unique ecosystems and landforms in PAAL provide bird species with a wealth of habitat types and food sources. Monitoring avian population health and diversity in PAAL habitats will be important for detecting population and ecosystem changes.

Photo 10. Great kiskadee (photo from Audubonbirds.org).

Many of the breeding bird species present in PAAL are common to other areas of the U.S. and Mexico (e.g., northern cardinal [*Cardinalis cardinalis*], northern mockingbird [*Mimus polyglottos*]). However, PAAL is also home to several unique breeding species whose home ranges only extend into the U.S. near the U.S./Mexico border. Examples of these species include the Texas Botteri's sparrow (*Aimophila botterii texana*), the plain chachalaca (*Ortalis vetula*), and the great kiskadee (*Pitangus sulphuratus*) (Photo 10).

PAAL is also home to two breeding bird species listed as threatened by the Texas Parks and Wildlife Department (TPWD). These species are the white ibis (*Eudocimus albus*), and the Texas Botteri's sparrow (TPWD 2013). The white-tailed hawk (*Buteo albicaudatus*) (state-listed as a threatened species) and the northern aplomado falcon (state- and federally-listed as endangered) are also species of concern that occur in the park, but these species are discussed separately in the Raptor component of this document (Chapter 4.5).

Measures

- Species abundance and diversity
- Species distribution

Reference Conditions/Values

No reference condition was assigned to this component. While the bird population at the time of the historic battle (1846) would be the ideal reference condition, no historic information exists detailing the composition of the breeding bird population. Laguna Atascosa National Wildlife Refuge (LANWR) could serve as a comparable population, but this park is home to several unique habitats (e.g., coastal shoreline) that likely provide homes for several breeding bird species that would not be found in PAAL. The historic inventories and the baseline data from NPS (2012b) summarized in this component could serve as a reference condition for future condition assessments.

Data and Methods

The NPS Certified Bird Species List (NPS 2013) for PAAL was used for this assessment; this list represents all of the confirmed bird species present in the park (Appendix B). The Certified Bird Species List was adjusted to only include species that were likely to breed in the PAAL area. Species that were not identified as 'breeding' or 'migratory' by NPS (2013) were assigned to a category by using The Cornell Lab of Ornithology's "All About Birds" online bird guide (http://www.allaboutbirds.org). Breeding raptor species were also removed from the list, as these species are discussed as a separate component in this document (Chapter 4.5).

Farmer (1992) completed the first natural resource survey within PAAL boundaries. This survey did not focus on breeding bird species; rather, it focused on identifying species that were federally/state listed as threatened or endangered (T&E) or species that were at risk for being listed as a candidate species. This survey identified 14 at risk bird species that were likely to occur at PAAL.

Richard and Richardson (1993) completed the first park-wide natural resource inventory in 1993. This inventory focused on the floral and faunal species in the park, and had a strong emphasis on identifying potential endangered and threatened species that may exist in the park. The park's next biological inventory did not occur until 2002, when Hayes (2004) conducted an inventory that attempted to create an annotated species list for at least 90% of the bird, fish, and mammal species expected to occur in the park. To accurately survey the entire park, Hayes (2004) used Southeastern point counts (SEPTCT). Stratifications of random habitats in the park were made, and each site (Plate 7) was surveyed during the breeding season (May-June), in November, and once during the fall migration. Each site was observed for 5 minutes, and all species seen or heard were identified; the distance from the observer was also recorded. Mist-netting was attempted at PAAL during this study, although poor wind conditions resulted in few specimens collected for banding (Hayes 2004).

In 2011, the GULN began a breeding bird-monitoring program at PAAL using a methodology that was developed by Dan Twedt, USGS Research Wildlife Biologist. The breeding bird surveys are conducted annually between 15 May - 15 June (NPS 2012b), and observers record each individual bird that is observed and heard within a 1 minute interval at each of the 29 sites. The estimated distance from the observer is also recorded (distance is estimated within four ranges; 0-<25 m, 25-<50 m, 50-<100 m, and > 100 m) (NPS 2012b). These breeding bird surveys were repeated for the 2012 breeding season; the locations of the breeding bird survey points are displayed in Plate 8.

Current Condition and Trend

<u>Species Abundance and Diversity</u>
Prior to 2011 (when the GULN breeding bird monitoring project began), there were no avian surveys that documented species abundance or diversity in PAAL. The bird research that had been completed in the park focused on identifying which species occurred in the park, and did not survey how many individuals were observed or where they occurred in the park. The results of these inventories are provided below, but their data were not used in calculating a Condition Level for this measure.

NPS Certified Species List (NPS 2013)
The NPS Certified Bird Species List, which is compiled and certified by the NPS and is not the direct result of a field-based survey, confirms the presence of 67 breeding bird species within PAAL (Appendix B) (NPS 2013).

Farmer (1992)
Farmer (1992) identified 12 at-risk breeding bird species that were likely found in PAAL (Table 13). The species identified in this survey were species that were either listed as threatened or endangered by TPWD or the USFWS. Several candidate species were also included in this document.

Table 13. At-risk breeding bird species identified by Farmer (1992).

Species
white-faced ibis
reddish egret
wood stork
loggerhead shrike
northern beardless tyrannulet
rose-throated becard
tropical parula
Brownsville yellowthroat
Audubon's oriole
Sennett's hooded oriole
Texas Botteri's sparrow
Texas olive sparrow

Photo 11. Reddish egret (*Egretta rufescens*) (NPS Photo).

Richard and Richardson (1993)
The Richard and Richardson (1993) avian inventory identified 58 breeding bird species that were likely present in PAAL (Appendix B). No abundance data for these species were collected during the inventory. This inventory is the only inventory/survey conducted in the park that has identified the Inca dove (*Columbina inca*) within PAAL boundaries.

Hayes (2004)
Forty-two breeding birds were identified in PAAL during the 2002 park-wide inventory completed by Hayes (2004) (Appendix B). This inventory was the first bird survey in the park that utilized a strict protocol for bird observations, and likely represents the most reliable breeding bird data for PAAL for years before 2011.

NPS (2012b) - GULN Breeding Bird Surveys of PAAL
The establishment of the annual breeding bird surveys in PAAL represents the best data source for breeding birds in the park. The surveys have been completed from May to June of 2011 and 2012; these are the only surveys in the park that have documented the abundance of breeding bird species. However, because the project has only been established for 2 years, it is not advisable to attempt to discern any trends in abundance or diversity.

The 2011 breeding bird surveys identified 240 individuals of 36 different species (Table 14). The most abundant bird species during the survey period were the eastern meadowlark (Photo 12) (40 individuals) and the Cassin's sparrow (31 individuals).

Photo 12. Eastern meadowlark singing in PAAL (photo by Rolando Garza, NPS).

Table 14. Breeding birds identified during 2011 and 2012 breeding bird surveys in PAAL; while 36 species were observed each year of the survey, a total of 48 unique species were observed over the duration of the study (NPS 2012b).

Species	2011	2012	Species	2011	2012
black-bellied whistling-duck	1	2	indigo bunting	0	1
black-crested titmouse	5	2	killdeer	1	1
black-throated sparrow	0	4	ladder-backed woodpecker	2	0
blue grosbeak	2	4	lark sparrow	6	0
Botteri's sparrow	0	9	laughing gull	6	7
blue-gray gnatcatcher	1	0	lesser goldfinch	1	0
bronzed cowbird	18	0	loggerhead shrike	0	1
brown-crested flycatcher	8	6	long-billed thrasher	2	3
brown-headed cowbird	1	6	mourning dove	11	13
cactus wren	0	2	muscovy duck	1	3
Carolina wren	7	1	northern bobwhite	6	3
Cassin's sparrow	31	31	northern cardinal	20	13
chipping sparrow	1	0	northern lapwing	0	1
common ground-dove	2	1	northern mockingbird	21	19
common pauraque	1	0	olive sparrow	11	4
Couch's kingbird	1	0	pyrrhuloxia	0	7
curve-billed thrasher	5	3	red-winged blackbird	1	1
dickcissel	1	0	scissor-tailed flycatcher	2	1
eastern meadowlark	40	52	tricolored heron	1	0
European starling	0	1	tropical parula	4	0
golden-fronted woodpecker	1	1	verdin	11	8
great egret	2	1	whimbrel	0	2
great kiskadee	0	1	white-eyed vireo	4	0
great-tailed grackle	0	5	yellow-billed cuckoo	0	2
			# of Individuals	**240**	**222**
			# of Species	**36**	**36**

The 2012 breeding bird survey identified 222 individuals of 36 species (the same number of species identified in 2011); 48 unique species were observed during the 2011 and 2012 surveys combined (Table 14). Similar to 2011, the eastern meadowlark was the most abundant bird species, with 52 individuals identified during the survey. The northern lapwing (*Vanellus vanellus*), a European species, was also identified during this survey. This individual was likely a transient species, or was incorrectly identified during observation.

NPS (2012b) was the only bird survey to identify species abundance, and is the only study that allows for diversity estimates. Breeding bird diversity is a measure that takes into consideration both species richness and the relative abundance of different species. Often, the Shannon-Wiener species diversity index (H’) is used to represent this measure, and when properly calculated, this index can “… determine the uncertainty that an individual picked at random will be of a given species” (UC 2012, p. L 5-2). The equation for the Shannon-Wiener diversity index is listed below.

$$H' = -\sum_{i=1}^{s}(p_i)(\ln p_i)$$

p_i = proportion of individuals of species (*i*) in a community (=n_i/N; where n_i is the number of individuals of a given species and *N* is the total number of individuals in a sample) (UC 2012).

The diversity index will result in an H' value that will typically be between 0 and 4; a value of 0 indicates a community that displays low/no species complexity, while a value of 4 indicates a community of high species complexity.

As was the case with species abundance, the diversity estimates obtained from NPS (2012b) were not analyzed for potential trends, as such an analysis requires more than two years of data to yield a meaningful result. In 2011, the 29 survey locations sampled by NPS (2012b) resulted in an H’ value of 2.94; in 2012, the same survey locations resulted in an H’ value of 2.88.

Species Distribution

Hayes (2004)

Hayes (2004) was the first bird survey in the park to document the actual survey locations. The SEPTCT locations were scattered across the western part of the park, and occured in prairie habitats (BT002, BT003) and brush habitats (BT001, BT004; Plate 7). Researchers also recorded bird species that were observed in between transects, casually observed, or were observed while on a transect that was focused on another species group (e.g., mammals, plants).

The distribution results from this survey are only species-specific, as no abundance data were gathered for the species that were observed. The highest number of bird species were observed at locations outside of the established bird transects (Table 15). Among the established bird transects, survey point BT004, which was located in a brush habitat, had the highest number of observed species (18) (Table 15).

Table 15. Distribution of bird species observed during the Hayes (2004) breeding bird survey.

Species	BT001 (Brush)	BT002 (Prairie)	BT003 (Prairie)	BT004 (Brush)	Non-bird Transect
yellow-crowned night-heron					X
cattle egret					X
great egret					X
great blue heron					X
black-bellied whistling-duck					X
plain chachalaca					X
northern bobwhite	X		X	X	
killdeer		X			
black-necked stilt					X
laughing gull		X	X	X	X
mourning dove		X		X	X
common ground-dove		X	X	X	
groove-billed ani					X
common nighthawk		X	X		
ringed kingfisher					X
golden-fronted woodpecker		X		X	X
ladder-backed woodpecker					X
brown-crested flycatcher				X	
Couch's kingbird					X
scissor-tailed flycatcher		X		X	
great kiskadee				X	
loggerhead shrike					X
white-eyed vireo					X
barn swallow	X	X		X	
Bewick's wren					X
northern mockingbird	X	X	X	X	
curve-billed thrasher				X	
Botteri's sparrow	X			X	
Cassin's sparrow					X
lark sparrow	X			X	
grasshopper sparrow					X
northern cardinal					X
blue grosbeak					X
indigo bunting				X	
varied bunting					X
eastern meadowlark	X	X	X	X	
red-winged blackbird					X
great-tailed grackle				X	
brown-headed cowbird	X		X	X	
bronzed cowbird					X

Table 15. Distribution of bird species observed during the Hayes (2004) breeding bird survey (continued).

Species	BT001 (Brush)	BT002 (Prairie)	BT003 (Prairie)	BT004 (Brush)	Non-bird Transect
house finch		X			
house sparrow				X	
# of Species Observed	**7**	**11**	**7**	**18**	**24**

NPS (2012b) - GULN Breeding Bird Surveys of PAAL

In 2011, the GULN began a breeding bird monitoring program in PAAL. Twenty-nine survey points were scattered across various habitat types in PAAL, with the points occurring primarily in the west-central portion of the park (Plate 8). The majority of the survey points (17) were located in prairie habitat, while the other survey points were located in mesquite or Tamaulipan brush habitats (or at the edge of one of these habitats) (Table 16).

Table 16. Habitat types that were represented by the survey points of NPS (2012b).

Survey Point	Habitat Type	Survey Point	Habitat Type
PAAL 04	prairie	PAAL 51	prairie
PAAL 06	prairie	PAAL 54	prairie
PAAL 08	prairie	PAAL 58	prairie
PAAL 10	prairie	PAAL 09	mesquite stand
PAAL 12	prairie	PAAL 05	undefined
PAAL 16	prairie	PAAL 15	undefined
PAAL 31	prairie	PAAL 21	undefined
PAAL 33	prairie	PAAL 34	undefined
PAAL 36	prairie	PAAL 49	undefined
PAAL 38	prairie	PAAL 22	prairie/mesquite stand
PAAL 39	prairie	PAAL 26	prairie/tamaulipan brush
PAAL 40	prairie	PAAL 41	prairie/mesquite grassland
PAAL 43	prairie	PAAL 48	mesquite grassland
PAAL 45	prairie		

The prairie habitat had the highest number of birds sampled in both 2011 and 2012 (127 and 119 individuals, respectively) (Figure 4). However, 63% of the survey points were located in prairie habitats, which may partially explain why this habitat type had the most birds each year. The next closest habitat type (not including habitat-types that are undefined in Plate 8) were the mesquite stands which had 24 individuals in 2011, and 20 individuals in 2012 (Figure 4).

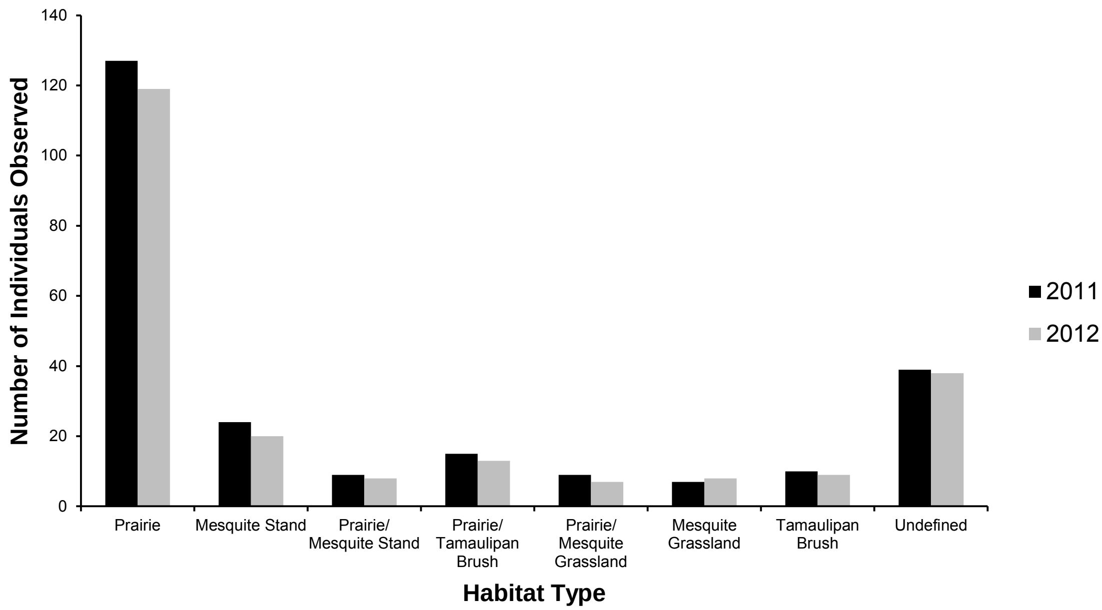

Figure 4. Number of breeding birds observed in each habitat type in PAAL in 2011 and 2012 (NPS 2012b).

The prairie habitat dominates the PAAL landscape (Plate 8), and it is likely that this habitat type is of high-importance for many bird species, especially grassland-dependent species such as the eastern meadowlark and the grasshopper sparrow (*Ammodramus savannarum*). With a high number of species utilizing the prairies and grasslands of PAAL, special attention should be given to surveying this habitat. Grassland bird species are among North America's most threatened bird communities; grassland birds have experienced "steeper, more consistent, and more geographically widespread declines than any other behavioral or ecological guild" (Knopf 1994, p. 251). NABCI (2009) indicates that grassland birds have been rapidly declining over the past 50 years, and that 55% of grassland species are showing significant population declines. Furthermore, 48% of North American grassland-breeding bird species are of conservation concern (NABCI 2009).

Threats and Stressor Factors

PAAL staff identified several threats and stressors to the breeding bird population in the park. Of the stressors identified, habitat loss and human development were the most significant threats to this group of species.

Brownsville, Texas has grown rapidly over the last 20 years, and residential and commercial developments around PAAL have especially increased in recent years (Garza, personal commmunication, 29 June 2012). This process of urbanization will likely result in a transformation of the natural landscape of the PAAL area, and PAAL will likely become an "island" of natural habitat in an area surrounded by urban structures. If this occurs, the breeding bird population in the area could become fragmented, lose valuable nesting habitat, and could lose vital food sources.

Drought is a major threat to all of the natural resources in PAAL. Not only do periods of drought remove many sources of water in PAAL, but these periods also affect availability of food for breeding birds. Drought may reduce forage items such as insects and plant species, and could lead to starvation for many breeding birds in the park. Hayes (2004) noted that periods of drought also led to a source of bias in their inventory of PAAL in 2002. Because the surveys took place during a period of drought, many species in the park did not have a source of surface water; drought likely results in lower than expected observation rates for many species in PAAL.

Another threat to the breeding bird populations of PAAL are wind farms in south Texas. Wind turbines are suspected to be a direct cause of mortality in bird species, as the rotating blades on a wind turbine can strike flying birds. The extent to which mortalities occur in bird species is likely dependent upon several factors, namely the species of birds in the area, the height of the turbine (i.e., higher turbines leading to more mortalities), and the elevation of the wind farm above sea level (de Lucas et al. 2008).

Recent efforts to develop alternative energy sources have resulted in more wind farm development across the planet (de Lucas et al. 2008). However, the exact effect that these wind farms have on birds is still poorly understood. Some studies have found that wind farms are responsible for no more mortalities than other human-made structures (e.g., buildings, communication towers) (Osborn et al. 2000), while other studies have found that turbines are responsible for unusually high numbers of bird mortalities (Smallwood and Thelander 2007).

In the PAAL area, there is only one active wind farm, the Magic Valley Wind Farm. This wind farm is located just east of Raymondville, TX, and is approximately 59 km (37 mi) from PAAL. Like all wind farms, the primary threat from this site is the fact that rotating turbine blades have the ability to strike flying birds; this threat is particularly elevated in this region, as the wind farm is located near a major migration corridor for birds. The Magic Valley Wind Farm first became operational on 24 August 2012, and consists of 112 turbines. The exact impact that this wind farm will have on the PAAL breeding bird population is unknown, and should be monitored in the future, with particular emphasis paid to the migratory period.

Recently, a second wind farm, the Baryonyx Wind Farm, has been proposed in the PAAL region. This wind farm would be located in the Gulf of Mexico, just off shore of Willacy and Cameron Counties, and would consist of 300-500 wind turbines (Hudson 2011, DoD 2012). A review of this proposed wind farm is being conducted by a number of federal, state, and regional agencies, including: the EPA, the USFWS, the U.S. National Marine Fisheries Service (USMFS), the Texas Commission on Environmental Quality, and the TPWD (DoD 2012). This wind farm likely poses a significant threat to the bird species that utilize the Central and Mississippi migratory flyways that bottleneck near PAAL (Figure 5) (Hudson 2011). An Environmental Impact Statement (EIS) is currently being prepared regarding the Baryonyx Wind Farm, and is expected to be available for public review by December 2014 (DoD 2012).

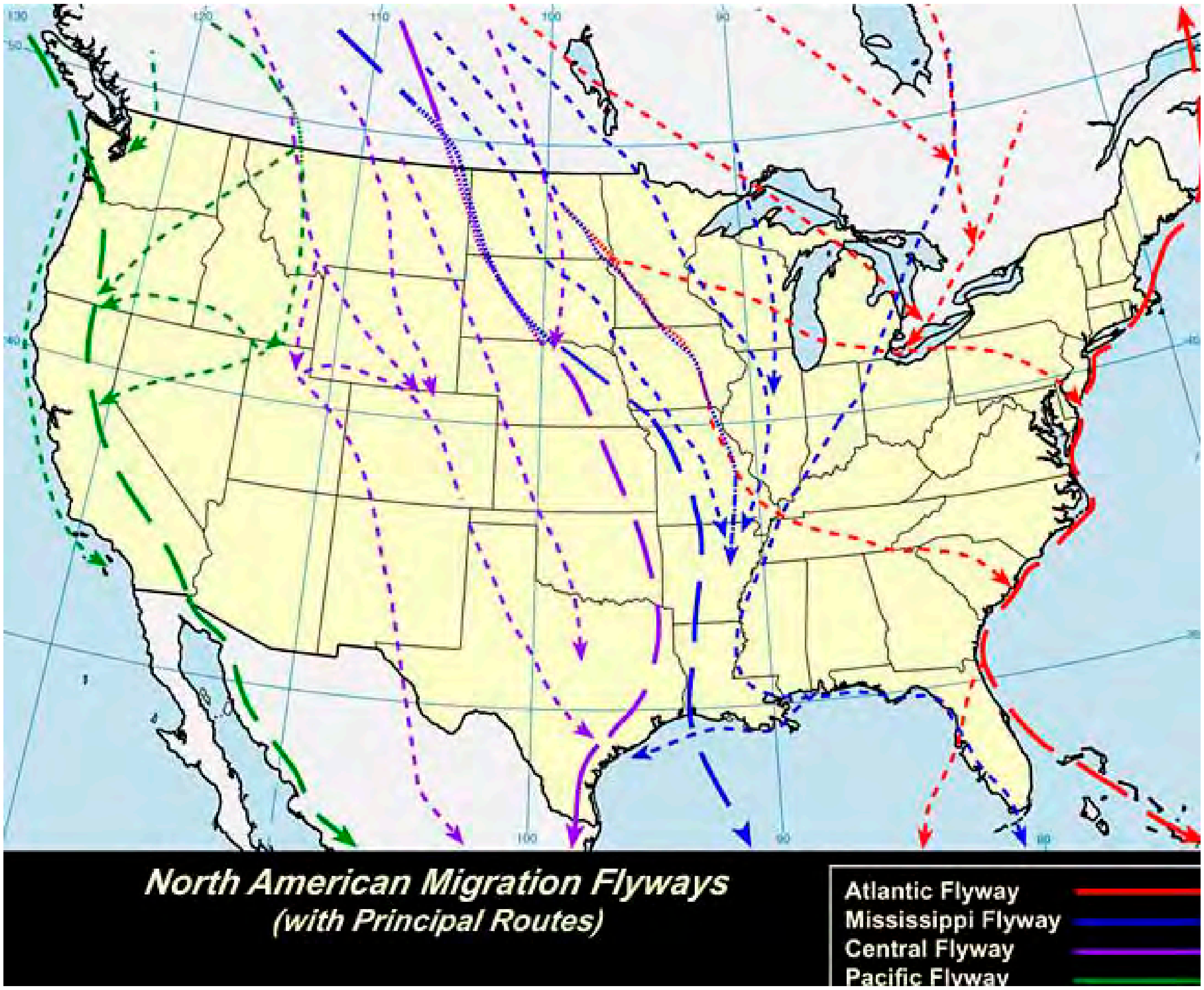

Figure 5. Major North American migratory flyways (NPS 2012c).

Another proposed wind farm, this one operated by Cielo Wind Power, has been proposed near the Port of Brownsville (approximately 8 km [5 mi] from the park's southern boundary). This wind farm would exist on the Port's navigation district property (directly east of the park), and is considered to be in its preliminary stages.

The development of wind and alternative energy necessitates the creation of high-tension power lines around the developments. Recently, a plan was approved to install high-tension 345 kV power lines along the U.S. Highway 550/511 corridor that borders the park along the south and east. The installation of these power lines will likely be accompanied by high levels of anthropogenic disturbance (machinery, noise, lights), and once in the ground the power lines may pose a risk for mid-air collision and electrocution in migratory bird species.

Data Needs/Gaps

Continuation of the annual breeding bird surveys are needed to allow managers to evaluate long-term trends in abundance and distribution. Furthermore, the establishment of additional surveys during the breeding season may help researchers and managers to more accurately assess the current health of the population. The eastern portion of the park was not sampled by Hayes

(2004) or by NPS (2012b). This portion of the park was not yet acquired by the NPS, and researchers did not have access to what is now the eastern portion of PAAL. By the end of 2013 or early 2014, PAAL hopes to have a nearly contiguous strip of land on the eastern side of the park that can be surveyed by researchers. Until access is allowed on that portion of the park, it is not possible to accurately assess current species abundance, diversity, or distribution. Future survey efforts in the park should also focus on this region of PAAL.

PAAL was the first NPS unit to install an eBird Kiosk. The eBird kiosk program was started by the Cornell Lab of Ornithology and the Audubon Society; the kiosks are an online, real-time bird checklist where park staff and visitors are allowed to input bird observations. Users can record species observed, date observed, and location of the observation. Utilization of the data from this kiosk will be useful for park managers to track the species that are present in the park, as well as areas in the park that may be home to rare breeding bird species.

Overall Condition

Species Abundance and Diversity
The project team defined the *Significance Level* for species abundance and diversity as a 3. Because of its location on the U.S./Mexico border, PAAL is home to several species that are not widely distributed in the U.S. Although point counts were established in PAAL in 2011, there are not enough historic baseline data to assign this measure a *Condition Level*. Continuation of these annual surveys will allow managers to detect any trends and to better understand species abundance and diversity in the park. An expansion of these surveys to include the eastern portion of the park is planned, and will provide managers with a more accurate understanding of the current condition of this resource.

Species Distribution
The project team defined the *Significance Level* for species distribution as a 3. This measure has only recently had data collected, and assigning a *Condition Level* is not appropriate at this time. Hayes (2004) only focused on two habitat types located on the western edge of the park, and it is unlikely that distribution results are indicative of the overall pattern that may exist in PAAL. NPS (2012b) has expanded the study area of Hayes (2004) and has sampled more habitat types. Continuation of these surveys will allow for an analysis of patterns in species distribution among the various habitat types in PAAL.

Weighted Condition Score
A *Weighted Condition Score* for PAAL's breeding birds was not assigned. Few data exist regarding the abundance, diversity, and distribution of the park's breeding birds. However, the recent establishment of an annual breeding bird survey in the park will allow for these measures to be accurately assessed in the future.

Breeding Birds

Measures	SL	CL
• Species abundance & diversity	3	n/a
• Distribution	3	n/a

WCS = N/A

Sources of Expertise

Rolando Garza, PAAL Archeologist and Integrated Resource Manager

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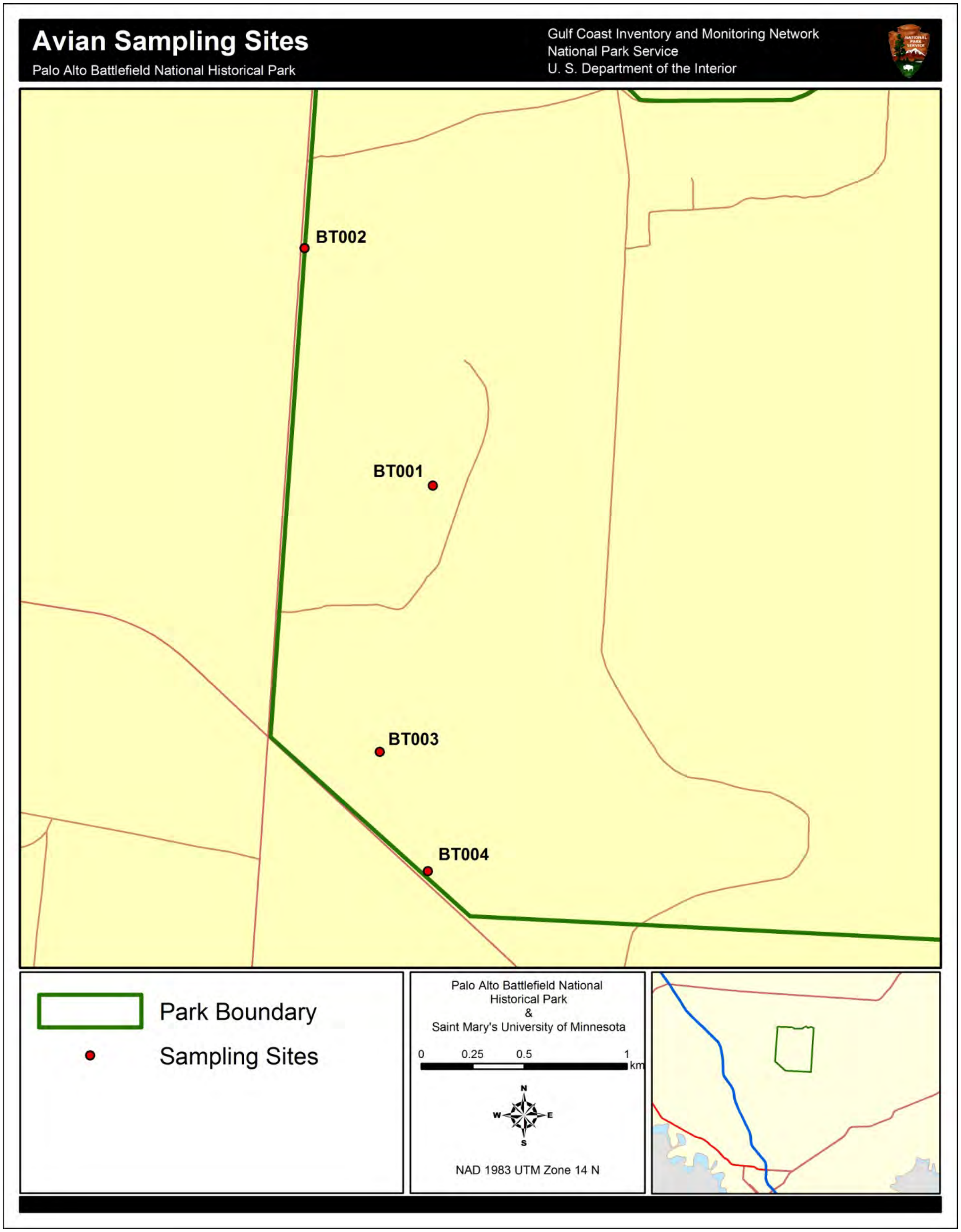


Plate 7. Hayes (2004) Southeastern point count (SEPTCT) locations within the boundaries of PAAL (BT = Bird Transect).

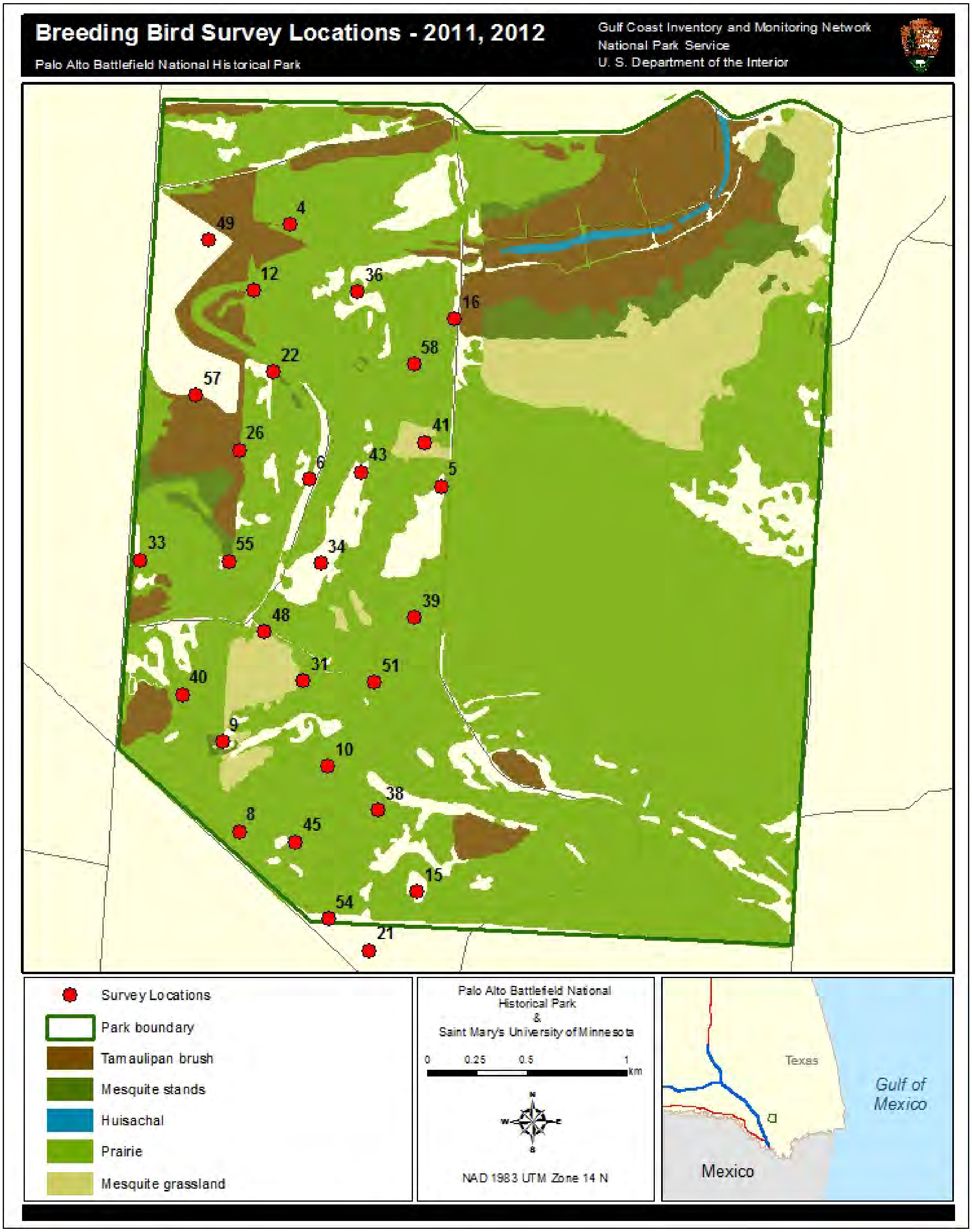


Plate 8. 2011-2012 breeding bird survey locations in relation to habtiat type in PAAL. The vegetation map used in the creation of this table is from 2000 and may now be outdated; the main change is likely that the mesquite stands extend further into the prairie habitat (Garza, written communication, 11 April 2013).

4.5 Raptors

Description

Raptors are top-level predators and are excellent bioindicators of the health of their associated ecosystem (Morrison 1986, Hutto 1998). In the 1940s, raptor populations across North America experienced a population decline due to the use of organophosphates (e.g., dichlorodiphenyltrichloroethane – DDT) as insecticides. Bioaccumulation of these chemicals (particularly DDE, a persistent metabolite of DDT) inhibited calcium metabolism in many raptor species (Fischer 2000). As a result, affected birds laid eggs that were too thin for successful incubation; eggs that did not break during incubation often contained dead embryos, and mortality rates for hatchlings were high (Fischer 2000).

DDT was banned in the United States in December 1972 and reproductive success rates subsequently increased following this ban (Fischer 2000). Species especially affected by the use of organochlorines, such as the peregrine falcon (*Falco peregrinus*), experienced a dramatic population recovery following the ban. These affected raptor species recovered to population levels that allowed for their removal from the Endangered Species List (the peregrine falcon was delisted in 1999) (USFWS 2003).

The many diverse habitats of PAAL (e.g., open prairie community, Tamaulipan brushlands) can support a variety of different raptor species; commonly observed raptor species in PAAL include the Harris's hawk, white-tailed kite, American kestrel, and the northern harrier (NPS 2013).

Photo 13. Northern aplomado falcon perching on a PAAL fence post with prey item (photo by Shannon Amberg, SMUMN GSS).

PAAL is also home to the northern aplomado falcon (Photo 13), which was listed as an endangered species in the United States in 1986 (USFWS 1986). The aplomado falcon is the only North American falcon species currently listed as endangered under the Endangered Species Act (ESA) (TPF 2005). The northern aplomado falcon was historically common throughout the American south and southwest; from 1880-1915, over 100 egg sets were collected in southern Texas, showing just how abundant and common this species was at the turn of the century (TPF 2005). The northern aplomado falcon relied upon the grasslands and savannahs of the American southwest, and utilized the abandoned nests of other bird species during the breeding season (TPF 2001, 2003). However, the species began experiencing population declines in the early part of the 20th century, and by 1952 the last known breeding pairs in the United States had been extirpated (TPF 2005). While the exact cause of the species' decline is poorly documented and understood, it is generally believed that habitat loss and conversion, coupled with widespread pesticide use (e.g., DDT), were primary factors in the species' decline (TPF 2001, DoD and USFWS 2007).

When the northern aplomado falcon was listed as endangered in 1986, the USFWS tasked the Peregrine Fund with captive breeding and reintroduction efforts (TPF 1999, DoD and USFWS 2007). Southern Texas was the target area for the reintroduction efforts, and the Peregrine Fund focused on reintroductions in two populations: the LANWR, and Matagorda Island areas of south Texas. Initial reintroductions occurred from 1985-1989, and the number of released birds increased when the project resumed in 1993 (DoD and USFWS 2007). In 1995, a pair of northern aplomado falcons was observed breeding in south Texas; this marked the first instance of breeding in the state since 1946. The number of breeding pairs in the area increased substantially during the reintroduction efforts, and several nesting platforms were constructed in the area in the years following the initial introductions. Several styles of platforms were constructed, although the structures built with vertical bars (Photo 14, Photo 15) had the highest levels of productivity (TPF 2004). These structures help to protect aplomado falcon chicks from both mammalian and avian predators (TPF 2004). By 2004, the Peregrine Fund had stopped releasing falcons to the area. These populations are surveyed annually by the Peregrine Fund, and survey results can be obtained from the Peregrine Fund's year-end annual reports (available online at: http://www.peregrinefund.org/annual-reports).

Photo 14. Peregrine Fund researchers installing a vertical-bar nesting platform in South Texas (Photo from Erin Gott, TPF 2003).

Photo 15. The interior of a vertical-bar nesting platform in South Texas (Photo by Bill Heinrich, The Peregrine Fund; TPF 2005).

Measures

- Species abundance and diversity
- Aplomado falcon abundance

Reference Conditions/Values

No reference condition has been defined for either the general raptor population or the aplomado falcon population in PAAL. A baseline survey of the current raptor population in PAAL could serve as a reference condition for future research efforts. An investigation into the current aplomado falcon population in the park would provide park managers with a baseline value that could be used as a reference condition going forward. In theory, nearby LANWR would be an appropriate reference condition for PAAL. LANWR has had extensive reintroduction efforts and has an established population of over 20 pairs of nesting aplomado falcon. However, the area of LANWR and the amount of available falcon habitat is not comparable to PAAL, and is not an appropriate comparison for this assessment.

Data and Methods

The NPS Certified Bird Species List (NPS 2013) for PAAL was used for this assessment; this list includes all of the confirmed raptor species present in the park.

No raptor-specific monitoring has been conducted within PAAL boundaries. However, several inventories, surveys, and monitoring efforts of all bird species in the park have taken place, and raptor species were observed frequently. The first natural resource survey of PAAL that documented the presence of raptors in the park was Farmer (1992). While this report did not survey the park specifically for raptors, it did identify raptor species that were either federal or state T&E species and were likely to occur in PAAL.

Richard and Richardson (1993) conducted the park's first floral and faunal inventory in PAAL during 1993. Special attention was given to identifying potential endangered and threatened species that may occur within the park's boundaries.

The park's next biological inventory did not occur until 2002, when Hayes (2004) conducted an additional inventory. This inventory sought to create an annotated list for at least 90% of the bird, fish, and mammal species expected to occur in the park. In order to accurately survey the entire park, Hayes (2004) utilized SEPTCTs. Stratifications of random habitats in the park were made, and each site (Plate 9) was surveyed during the breeding season (May-June), in November, and once during the fall migration. Each site was observed for 5 minutes, and all species seen or heard were identified; the distance from the observer was also recorded. Mist-netting was attempted at PAAL during this study, although poor wind conditions resulted in few specimens collected for banding (Hayes 2004).

Beginning in 2011, the GULN instituted two bird monitoring programs in PAAL. These programs have methodologies that were developed by Dan Twedt, USGS Research Wildlife Biologist. The first survey type, breeding bird surveys, is conducted annually between 15 May and 15 June (NPS 2012a). Observers record each individual bird that is observed and heard within a 1 minute interval for 10 minutes at each site. The estimated distance from the observer is also recorded (distance is estimated within four ranges; 0-<25 m, 25-<50 m, 50-<100 m, and > 100 m) (NPS 2012a). The second survey type, wintering bird surveys, began in 2012 and is conducted between 15 November and 15 February. Similar to the breeding bird survey, observers record all observed species and the estimated distance, this time within three distance ranges (>50 m, <50 m, and fly-overs) (NPS 2012a). Observers record each individual bird that is observed and heard within a 2-minute interval for 20 minutes. The survey locations for both the breeding and winter bird surveys are displayed in Figure 6.

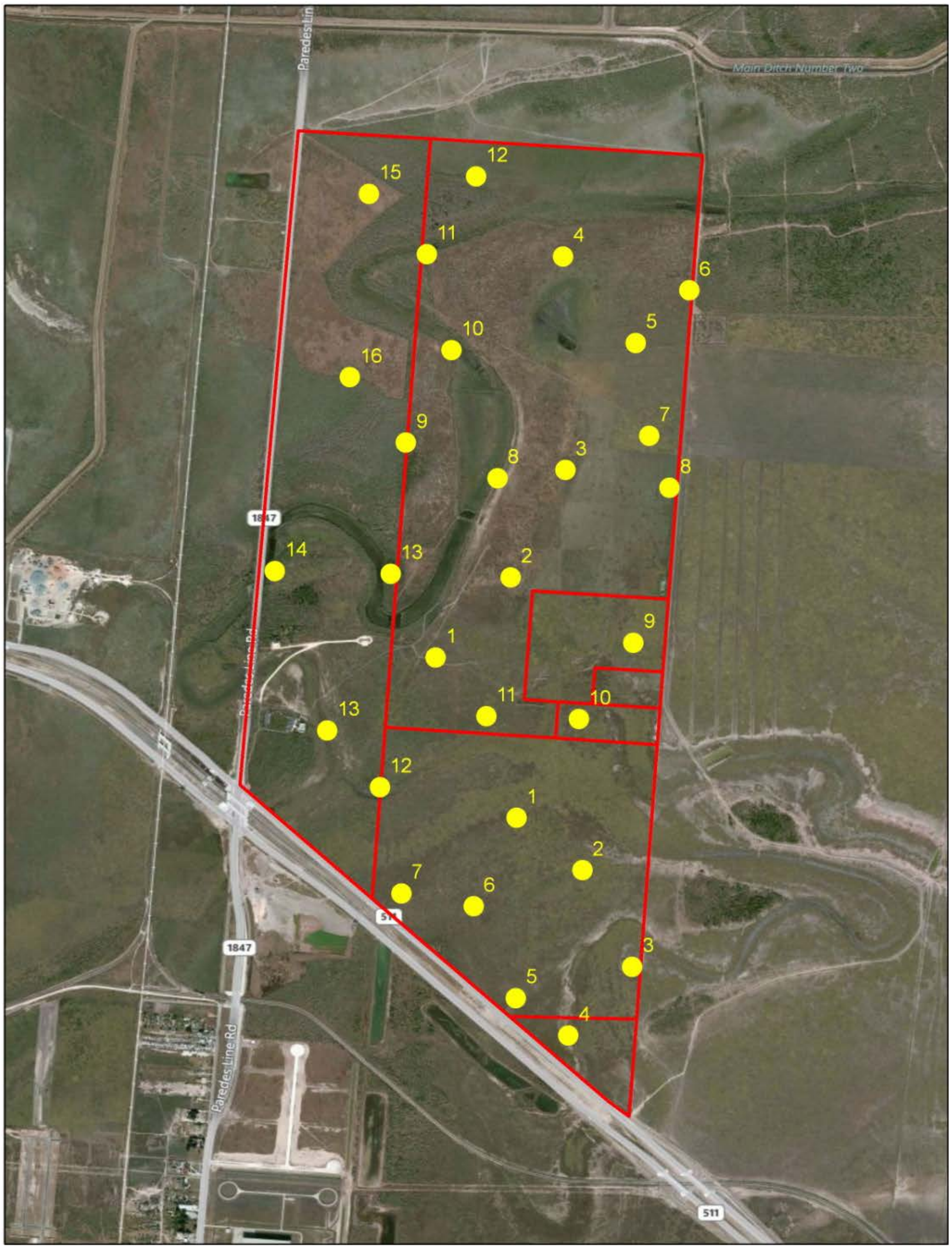


Figure 6. Breeding and winter bird survey locations within the boundary of PAAL. Note that the red lines in the interior of the park's boundaries are former property lines that are no longer pertinent (NPS 2009).

The Peregrine Fund creates annual status reports (e.g., TPF 2011) for all of their raptor-related work throughout the world. Each of these reports contains data regarding the northern aplomado falcon reintroduction project in south Texas; these reports were used to identify population size, number of reintroduced birds, and reproductive success of the falcons in the region around PAAL.

Current Condition and Trend

<u>Species Abundance and Diversity</u>

There have been no raptor-specific surveys that document the abundance or diversity of these species in PAAL. The NPS Certified Bird Species List, which is compiled and certified by the NPS and is not the direct result of a field-based survey, confirms the presence of 14 raptor species within PAAL (NPS 2013).

There have been several inventories and surveys of the general bird population in PAAL (Table 17). The two earliest inventories of the park, Farmer (1992) and Richard and Richardson (1993), identified 11 and 12 species of raptors, respectively. It should be noted that Farmer (1992) focused on rare species rather than common breeding species; many of the species mentioned in this report are not confirmed on the NPS Certified Species List (Table 17). Hayes (2004) represents the most recent avian inventory in PAAL; this survey took place in 2002 and identified 10 raptor species during surveys at designated plots (Plate 9).

Table 17. Raptor species identified on various inventories, surveys, and species lists that were focused on PAAL.

Species	Farmer (1992)	Richard and Richardson (1993)	Hayes (2004)	NPS (2013)*
turkey vulture		x	x	x
Harris's hawk		x	x	x
Swainson's hawk		x	x	x
ferruginous hawk	x		x	x
white-tailed hawk	x	x	x	x
aplomado falcon	x		x	x
crested caracara		x	x	x
barn owl		x	x	
black-shouldered kite		x		x
red-tailed hawk		x	x	x
northern harrier		x		x
American kestrel		x	x	x
merlin		x		x
eastern screech owl		x		x
white-tailed kite				x
American swallow-tailed kite	x			
bald eagle	x			
common black hawk	x			
gray hawk	x			
zone-tailed hawk	x			
American peregrine falcon	x			
arctic peregrine falcon	x			
ferruginous pygmy owl	x			

* species listed as present or probably present in park

Bird monitoring coordinated by the GULN was initiated in PAAL in 2011. These surveys document all species of birds observed during a set interval; from the available data, it is possible to isolate the raptor observations from each survey. To date, two breeding bird point counts (2011, 2012) have documented 10 raptors of five different species, while one winter bird count (2012) has documented 21 raptors of six different species (Table 18).

Table 18. Raptor species observed during the breeding and winter bird point counts in PAAL from 2011-2012.

	Breeding Bird Point Count		Winter Bird Point Count
Species	**2011**	**2012**	**2012**
black vulture	2		
turkey vulture		3	6
Harris's hawk	1	2	4
Cooper's hawk			2
white-tailed hawk		1	
red-tailed hawk			1
crested caracara	1		1
northern harrier			7

Aplomado Falcon Abundance

No studies have taken place in PAAL that focused on documenting the abundance of the aplomado falcon in the park. Historically, this falcon was abundant in southern Texas; TPF (2005) reported that over 100 egg sets were collected in southern Texas around the 1900s, indicating just how abundant the species was in the PAAL area. Furthermore, Farmer (1992) states that the highest concentration of nesting aplomado falcons in the United States was historically located on the Palo Alto prairie between Brownsville and Port Isabel; over 100 nests were recorded in this section of Cameron County.

Reintroduction efforts performed by the Peregrine Fund have been largely successful in the PAAL area. A nesting platform was constructed in PAAL during the late 1990s (Cooper et al. 2004). This platform consists of an elevated tower with vertical bars (Photo 16), and an observation station has been established approximately 100 m (328 ft) north of the platform. Aplomado falcons have been released from this platform, and several of these released birds have returned to, or remained in, the area (Garza 1997). The aplomado falcon release efforts (from 1999-2004) in the greater PAAL area are summarized in Table 19. Numbers specific to PAAL are not available, as most of the reintroduction and monitoring efforts focused on the LANWR and Matagorda Island areas (TPF 2005).

Photo 16. Aplomado falcon nesting platform constructed in PAAL (photo by Rolando Garza, PAAL).

Table 19. Summary of the northern aplomado falcon reintroduction efforts in the LANWR and Matagorda Island areas. Data summarized from The Peregrine Fund's annual reports (TPF 1999-2011).

	1999	2000	2001	2002	2003	2004	2011
# of Birds Released	115	112	n/a	75	32	31	0
Success Rate	75%	65%	n/a	68%	88%	74%	n/a
# of LANWR Breeding Pairs	14	20	n/a	24	26	21	20
# of Matagorda Is. Breeding Pairs	5	10	n/a	13	13	11	14
# of Young Fledged	12	8	n/a	32	37	54	n/a

*Note – release of captive-raised falcons in south Texas stopped in 2004. Numbers presented for 2011 represent the work of field observation during the breeding season.

After years of reintroduction efforts, the south Texas aplomado falcon population appears to be stable, although continued research is needed to evaluate whether it is currently self-sustaining (TPF 2011). From 1999-2004, the number of breeding pairs in the LANWR and Matagorda Island areas increased (Table 19), and a 2011 survey in the same area estimated that the breeding populations were at levels that were comparable to 2004 estimates (TPF 2011). No fledgling data was collected in 2011, so it is impossible to accurately assess the current status of reproduction in the populations. The species is listed on the Endangered Species List, and is infrequently observed across its range. However, the PAAL area represents one of the few strongholds for the species in the United States.

Threats and Stressor Factors

PAAL staff identified several threats and stressors to the raptor population in the park. Of the stressors identified, habitat loss and human development were the most significant threats to this group of species.

Brownsville, Texas has grown rapidly over the last 20 years, and residential and commercial developments around PAAL have especially increased in recent years (Garza, personal communication, 29 June 2012). This process of urbanization will likely result in a transformation of the natural landscape of the PAAL area, and PAAL will likely become an "island" of natural habitat in an area surrounded by urban structures. If this occurs, the raptor population (both breeding and migratory birds) in the area could become fragmented, lose valuable nesting and perching trees, and may lose priority prey species in the area. Fragmentation of the landscape could also affect the native rodent population of PAAL, which serves as a primary prey source for many raptors in the park. Native rodents are discussed in detail in Chapter 4.9 of this document.

Drought is a major threat to all of the natural resources in PAAL. Not only do periods of drought remove many sources of water in PAAL, but these periods also affect availability of food for raptors. Drought may reduce forage items such as rodents, small birds, or insects, and could lead to starvation for many resident raptors in the park. Hayes (2004) noted that periods of drought also led to a source of bias in their inventory of PAAL in 2002. Because the surveys took place during a period of drought, many species in the park did not have a source of surface water; drought likely resulted in lower than expected observation rates for many species in PAAL.

Another threat to the raptor population of PAAL are wind farms in south Texas. Wind turbines are suspected to be a direct cause of mortality in raptor species, as the rotating blades on a wind turbine can strike flying raptors. The extent to which mortalities occur in raptor species is likely dependent upon several factors, namely the species of raptors in the area, the height of the turbine (i.e., higher turbines leading to more mortalities), and the elevation of the wind farm above sea level (de Lucas et al. 2008).

Recent efforts to develop alternative energy sources have resulted in more wind farm development across the planet (de Lucas et al. 2008). However, the exact effect that these wind farms have on birds is still poorly understood. Some studies have found that wind farms are responsible for no more mortalities than other human-made structures (e.g., buildings, communication towers) (Osborn et al. 2000), while other studies have found that turbines are responsible for unusually high numbers of raptor mortalities (Smallwood and Thelander 2007).

In the PAAL area, there is only one active wind farm, the Magic Valley Wind Farm. This wind farm is located just east of Raymondville, TX, and is approximately 59 km (37 mi) from PAAL. Like all wind farms, the primary threat from this site is the fact that rotating turbine blades have the ability to strike flying raptors; this threat is particularly elevated in this region, as the wind farm is located near a major migration corridor for raptors. The Magic Valley Wind Farm first became operational on 24 August 2012, and consists of 112 turbines. The exact impact that this wind farm will have on the PAAL raptor population is unknown, and should be monitored in the future, with particular emphasis paid to the migratory period.

Recently, a second wind farm, the Baryonyx Wind Farm, has been proposed in the PAAL region. This wind farm would be located in the Gulf of Mexico, just off shore of Willacy and Cameron Counties, and would consist of 300-500 wind turbines (Hudson 2011, DoD 2012). A review of this proposed wind farm is being conducted by a number of federal, state, and regional agencies, including: the EPA, the USFWS, the USMFS, the Texas Commission on Environmental Quality, and the TPWD (DoD 2012). This wind farm likely poses a significant threat to the bird species that utilize the Central and Mississippi migratory flyways that bottleneck near PAAL (Figure 7) (Hudson 2011). An EIS is currently being prepared regarding the Baryonyx Wind Farm, and is expected to be available for public review by December 2014 (DoD 2012).

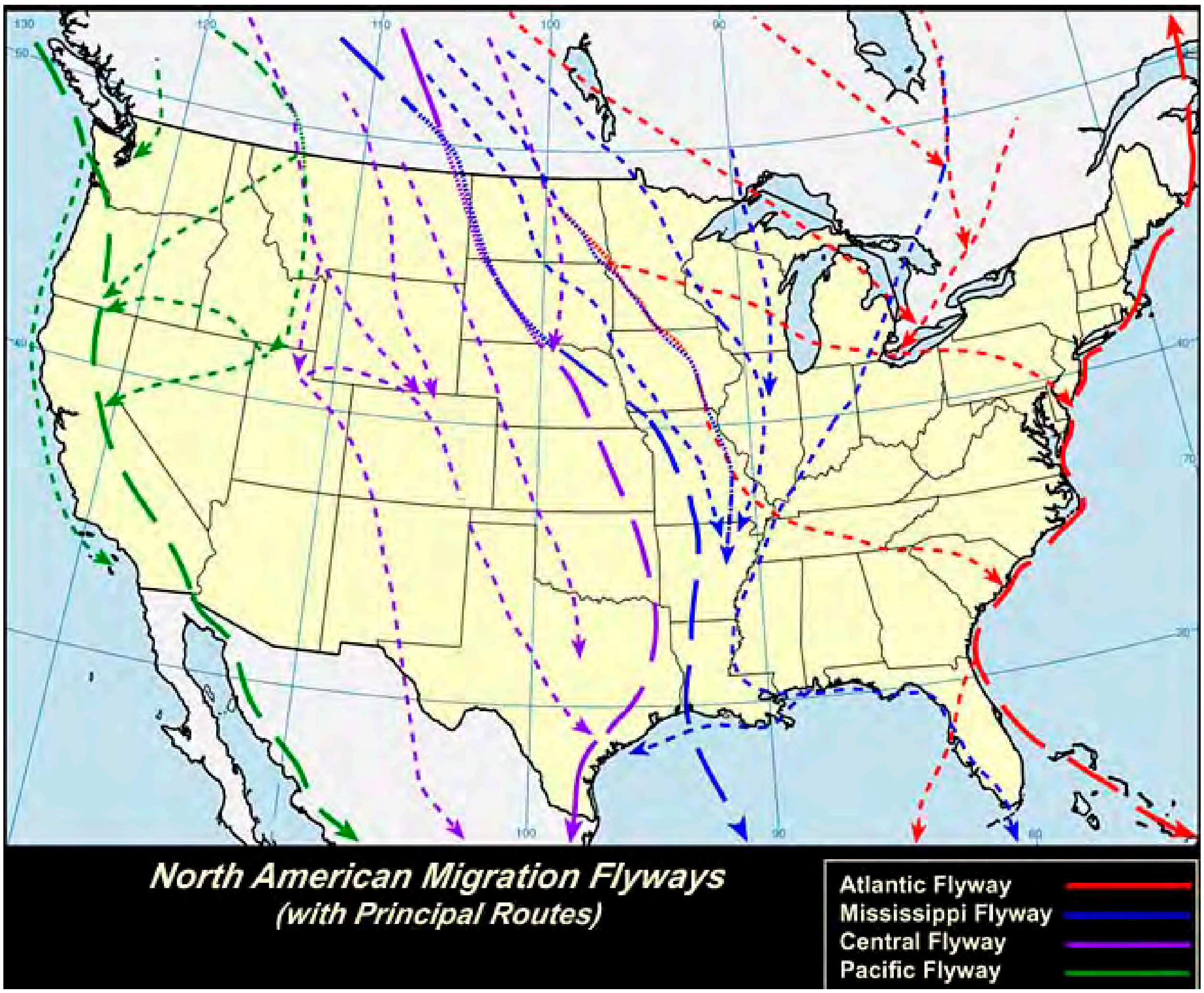


Figure 7. Major North American migratory flyways (NPS 2012b).

Another proposed wind farm, this one operated by Cielo Wind Power, has been proposed near the Port of Brownsville (approximately 8 km [5 mi] from the park's southern boundary). This wind farm would exist on the Port's navigation district property (directly east of the park), and is considered to be in its preliminary stages.

The development of wind and alternative energy necessitates the creation of high-tension power lines around the developments. Recently, a plan was approved to install high-tension 345 kV power lines along the U.S. Highway 550/511 corridor that border the park along the south and east. The installation of these power lines will likely be accompanied by high levels of anthropogenic disturbance (machinery, noise, lights), and once in the ground the power lines may pose a risk for mid-air collision and electrocution in migratory bird species.

Data Needs/Gaps

Bird monitoring surveys and protocols have been established in PAAL, although no raptor-specific survey currently exists. A raptor nesting survey may benefit park managers, and help to provide a more accurate description of the nesting raptor population size in the park. Current breeding raptor surveys are anecdotal; Rolando Garza, PAAL Archeologist and Integrated Resource Manager, reported seeing nesting Harris's hawks in the park in the summer of 2012 (Garza, phone communication, 29 June 2012). Continuation of the annual breeding bird and winter bird point counts are needed to detect any trends in raptor abundance or migration patterns.

Annual monitoring and surveys specifically designed to locate aplomado falcons in the park are needed. The aplomado falcon has not been identified on the park's breeding bird or winter bird point counts, although anecdotal observations have been reported by park staff and visitors (these observations are frequently recorded on the PAAL eBird Kiosk). With the Peregrine Fund no longer releasing captive-raised falcons in the area, it is imperative that managers in this area of Texas actively monitor the status of the population. The presence of any trends in breeding or abundance could help Peregrine Fund researchers better understand whether or not the population in the PAAL region is stable and self-sufficient.

Overall Condition

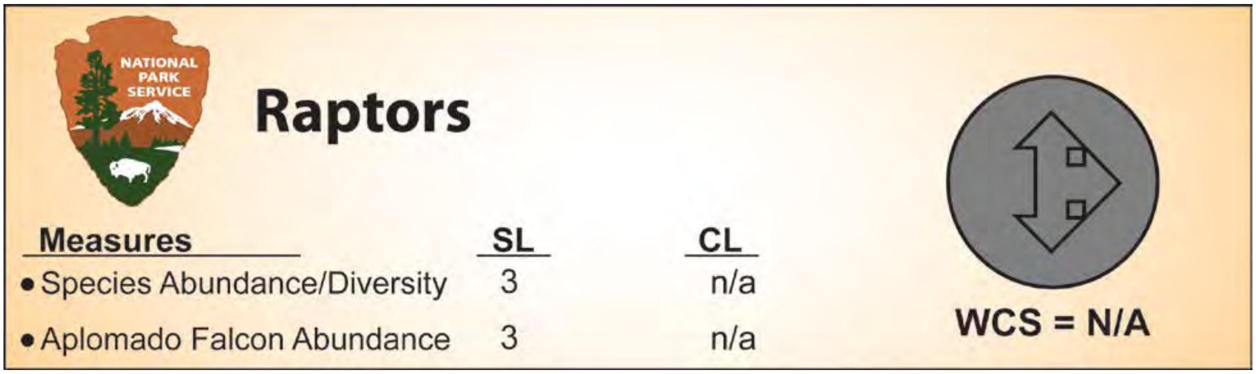
Species Abundance and Diversity

The project team defined the *Significance Level* for species abundance and diversity as a 3. PAAL likely represents a high-priority area for both resident and migratory raptor species, and although point counts were established in PAAL in 2011, there are not enough historic baseline data to assign this measure a *Condition Level*. Continuation of these annual surveys will allow managers to detect any trends and to better understand the species composition and abundance in the park.

Aplomado Falcon Abundance

The measure of aplomado falcon abundance was assigned a *Significance Level* of 3. The aplomado is the only endangered falcon species in the continental United States, and PAAL represents one of the only suitable habitat locations in the nation. While past efforts by the Peregrine Fund have established an apparently stable population in the LANWR and Matagorda Island areas, no survey information exists for PAAL. Because of this, a *Condition Leve*l cannot be assigned to this measure at this time.

Weighted Condition Score
Without detailed, contemporary information regarding the species abundance and diversity of raptors, and the current population abundance of aplomado falcons in PAAL, a *Weighted Condition Score* cannot be assigned.



Sources of Expertise
Rolando Garza, PAAL Archeologist and Integrated Resource Manager

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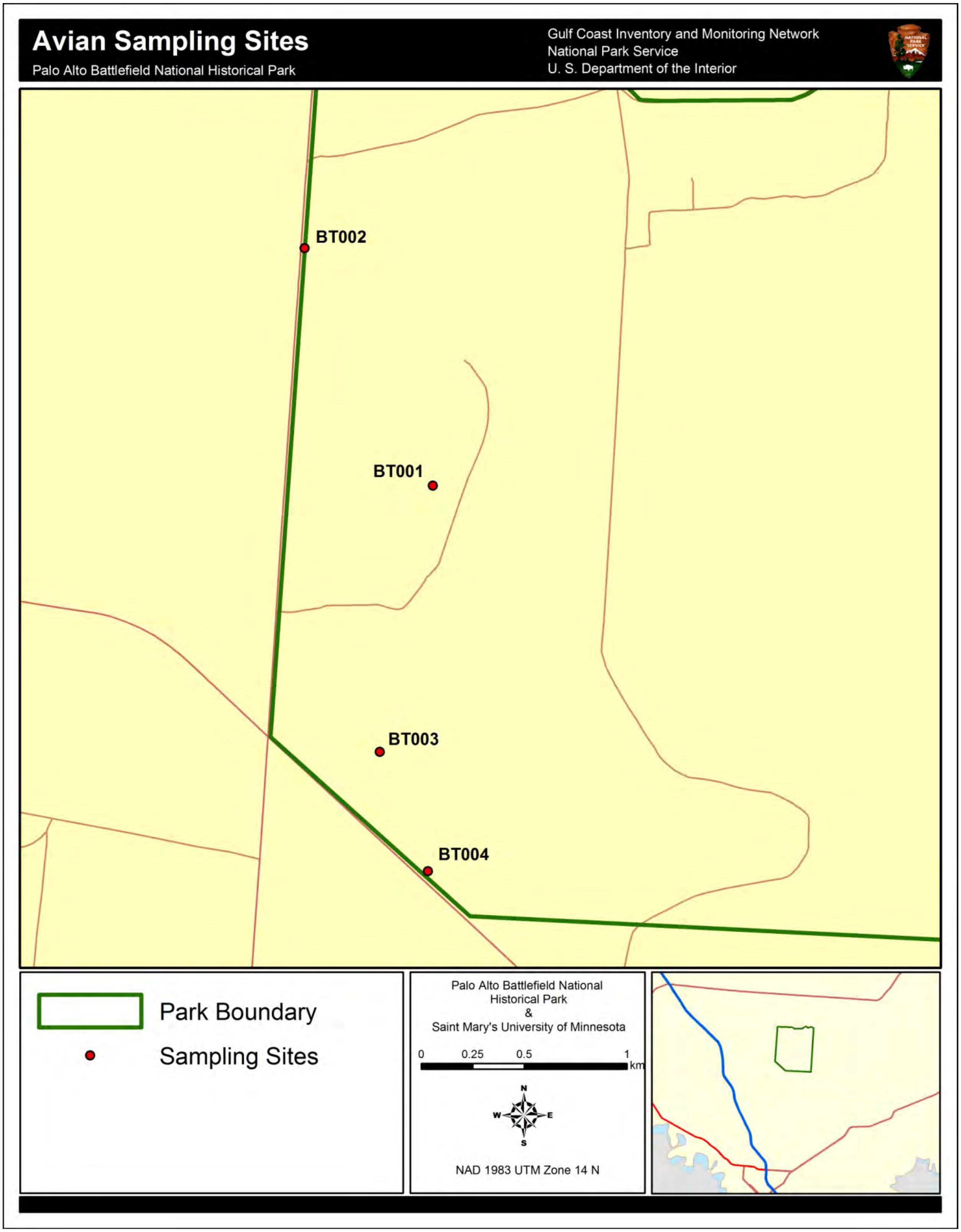


Plate 9. Hayes (2004) Southeastern point count (SEPTCT) locations within the boundaries of PAAL (BT = Bird Transect).

4.6 Coyotes

Description

Coyotes (Photo 17) are highly adaptive, top-level predators found throughout the continental United States (Bekoff and Gese 2003). There are 19 recognized subspecies of coyote, and PAAL is home to the lower Rio Grande subspecies (*C. l. microdon*). In PAAL, coyotes are year-round residents of the park's brush and prairie habitats (Hayes 2004), and are one of the few top-level predators in the park. Coyotes are extremely adaptable, and are able to exist in (or near) urban areas; the habitat in PAAL is no exception, as farms and urban areas surround both units of the park.

Photo 17. Coyote (NPS Photo).

The size of adult coyotes varies by gender (males are typically larger) and geographic region, but an average adult coyote has a body length of about 1-1.5 m (3.28-4.92 ft) (Hall and Kelson 1959, Bekoff and Gese 2003). Coyotes are opportunistic predators, and prey species will vary depending on fluctuations in prey base abundance (Windberg and Mitchell 1990, Bekoff and Gese 2003). In southern Texas, coyotes have been observed preying upon rabbits, rodents, fruit, insects, and carrion (TPWD 2012).

Coyotes are active throughout the day, although they tend to be most active during crepuscular hours (Gese et al. 1989); the hours of peak activity may vary depending on the season or levels of human disturbance (Gese et al. 1989, Kitchen et al. 2000). Coyotes in urban habitats exhibit different periods of activity, as their peak periods of activity are almost exclusively during twilight and nighttime hours (Andelt 2012).

Coyotes are a territorial species and typically remain within their territory throughout the year. The size of a home territory is dependent upon food availability, habitat, season, and social organization (Laundre and Keller 1984, Gese et al. 1988, Bekoff and Gese 2003). In some regions (e.g., the Greater Yellowstone Ecosystem), coyotes exhibit high levels of social organization; however, in populations where the year-round food source is comprised of rodent species, coyotes tend to be solitary outside of the breeding season (USFS 2012).

When food and habitat availability are at sustainable levels, approximately 60-90% of adult females will produce litters during the breeding season (Knowlton 1972, Gese et al. 1989, Knowlton et al. 1999). When food and habitat availability are unusually high, up to 75% of yearling coyote females will produce litters (Chapman and Feldhamer 1982). The gestation period lasts approximately 63 days, and the average litter size ranges from four to six pups. Juvenile coyotes will disperse from their home den at around 6-9 months, although in some instances juveniles have been observed dispersing after their second year (USFS 2012).

Measures

- Population density
- Distribution

Reference Conditions/Values

The reference condition for coyotes was identified as the coyote population at the location of PAAL around the time of the Battle of Palo Alto (1846). Although very few data are available for this time period, this reference condition is in line with the management priorities for PAAL.

Data and Methods

Few studies have documented the health or status of coyotes in PAAL. The studies that do exist are primarily biological inventories of the park, and only address the presence/absence of species. During a 1993 inventory, Richard and Richardson (1993) observed coyotes and evidence of coyotes (e.g., scat) in the park. Hayes (2004) documented coyotes throughout the survey and indicated that coyotes were year-round residents of the park. Neither of these inventories provided estimates of population densities or distribution. Coyotes have been occasionally observed in PAAL during annual Texas tortoise surveys (Robert Woodman, GULN Ecologist, written communication, 22 October 2012). These surveys have been conducted from November 2008 – present. All observations and inventories took place only at the Palo Alto park unit; the Resaca de la Palma unit was not acquired by the park until 2011.

Current Condition and Trend

<u>Population Density</u>

No current estimate of population density exists for coyotes in PAAL. Density in coyote populations is largely dependent upon food and habitat availability. PAAL is a small park (1,376 ha [3,400 ac]), and it is likely that only a few coyotes would be in the park at a given time (Garza, phone communication, 29 June 2012).

Coyotes are observed infrequently in the park. When coyotes are observed at PAAL, it is typically after a coyote has been flushed from cover during mowing activities; maintenance workers at the Resaca de la Palma park unit have observed a solitary coyote on multiple occasions (Garza, phone communication, 29 June 2012). Hayes (2004) and Richard and Richardson (1993) both documented coyotes and evidence of coyotes in PAAL, but did not provide estimates of population density.

The lack of coyote observations is not necessarily indicative of a low population density, as coyotes are most active during periods when PAAL staff are not on site (e.g., dawn, dusk, and nighttime hours). Rolando Garza (phone communication, 29 June 2012) reported that coyote scat is observed frequently in the park, and that it is very likely that coyotes are often present in the park, but are not observed by visitors or staff.

<u>Distribution</u>

Similar to population density, there has been no research investigating coyote distribution in PAAL. With the small size of the park, it is likely that coyotes are confined to the brush and prairie habitats (Hayes 2004). There is adequate vegetative cover in the park for coyotes, and those that have been observed at the PAAL site were often foraging near grassy areas along the edges of densely covered brush areas (Garza, phone communication, 29 June 2012). With the ever-increasing urbanization around the Brownsville, Texas area, coyotes likely have a narrow home range in the PAAL area. While the distribution of coyotes in the Resaca de la Palma site is unknown, the unit's small size and urban environment is unlikely to support a consistent coyote territory.

Threats and Stressor Factors
PAAL staff identified several threats and stressors to the coyote population in the park. Among these stressors, habitat loss and destruction was identified as one of the most significant threats to this species. In recent years, the greater Brownsville, Texas area has been growing rapidly, and the areas surrounding PAAL are being developed quickly for residential and commercial uses. While development activities experienced a lull beginning in 2009, activities have begun to increase again in recent years (Garza, phone communication, 29 June 2012). The urbanization of the area around PAAL will essentially transform PAAL into an "island" of natural habitat in an area otherwise surrounded by human development. While such activity could reduce the size and distribution of the coyote population in the areas surrounding PAAL, coyotes are an exceptionally adaptive species and could persist/thrive through such a period. In fact, PAAL may serve as a local refugium of sorts for coyotes, and may harbor a larger population than it previously has.

Disease is a natural threat to coyote populations across their range. Bekoff and Gese (2003) summarized many of the known diseases that affect coyotes, including: canine parvovirus, canine distempter, canine infectious hepatitis virus, the plague bacterium (*Yersinia pestis*), and tularemia (*Francisella tularensis*). Coyotes may also carry rabies (Bekoff and Gese 2003) and a variety of ecto- (e.g., fleas, ticks, lice) and endo-parasites (e.g., flukes, tapeworms, heartworms), all of which may result in disease for the coyote (Gier and Ameel 1959, Gier et al. 1978, Bekoff and Gese 2003).

Drought is also a threat to the coyote population in the PAAL area. Not only do periods of drought remove many sources of water for coyotes, but these periods also affect availability of prey for coyotes. Starvation during crashes of prey sources may be a substantial mortality factor for coyotes across their range (Bekoff and Gese 2003).

Most studies of coyote mortality identify human activity as the leading cause of death in adult coyotes (Davison 1980, Tzilkowski 1980, Windberg et al. 1985, Gese et al. 1989, Windberg 1995). One of the major human threats to coyotes is collisions with vehicles while crossing roadways. While Rolando Garza (phone communication, 29 June 2012) indicated that observations of coyote road-kill carcasses are relatively rare, the urbanization and increasing traffic in the area of the park represents a potential threat to the coyote population in PAAL.

Data Needs/Gaps
An investigation into the current coyote population density and distribution is needed for PAAL. Without this information, an assessment of current condition is not possible. The reference condition for this component is likely to remain unknown, and a comparison of PAAL density/observations to the density of nearby populations could be used in future condition

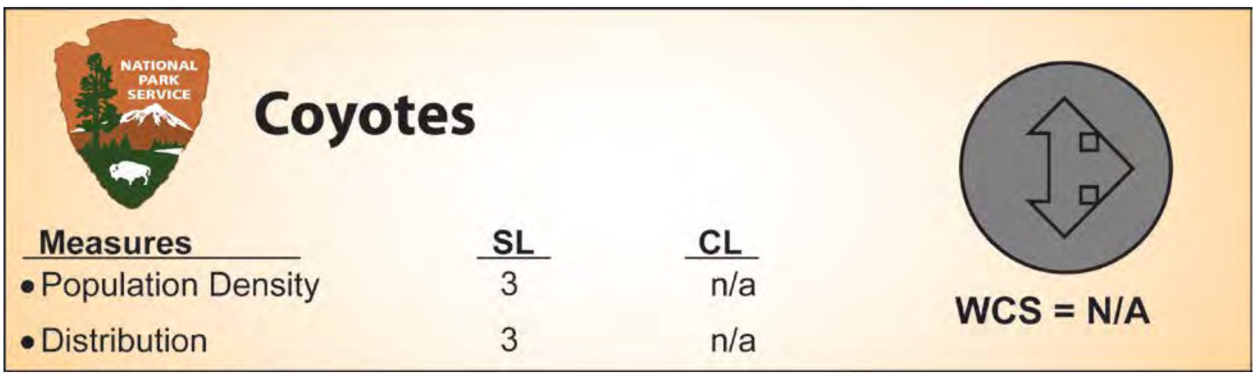
assessments. Density estimates for both PAAL and the surrounding areas are needed for this to be possible.

<u>Overall Condition</u>

Population Density
The project team defined the *Significance Level* for population density as a 3. However, due to the lack of data regarding this measure, a *Condition Level* was not assigned.

Distribution
The project team defined the *Significance Level* for distribution as a 3. No data exist for coyote distribution in PAAL, and a *Condition Level* was not assigned to this measure.

Weighted Condition Score
Information regarding the coyote population at PAAL is not available at this time. Without detailed information regarding the population density and distribution of coyotes in the PAAL area, a *Weighted Condition Score* cannot be assigned.



Sources of Expertise
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Robert Woodman, GULN Ecologist

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4.7 Collared Peccary

Description

The collared peccary (*Pecari tajacu*) is a medium-sized mammal that occurs in western and southern Texas (Photo 18). It is highly adaptable and can be found in a variety of habitats, including tropical to arid climates, and is also an opportunistic feeder (NPS 2012). The species can survive in arid climates by feeding on succulent plants, rather than depending on watering holes for hydration. The vegetation found in PAAL is characteristic of collared peccary habitat. Prickly pear (*Opuntia* sp.), found throughout the park, is an important source of food for the collared peccary (Gongora et al. 2011); however, their diet may also include mesquite beans, a variety of fruits, seeds, bulbs, and insects (NPS 2012).

Photo 18. Collared peccary in Big Bend National Park, Texas (NPS photo).

Texas, New Mexico, and Arizona make up the northern most extent for the collared peccary (Zervanos et al. 1972, NPS 2012). Although considered important to the ecology of the PAAL landscape, this mammal is observed infrequently in the park. Population density and distribution are core metrics identified by the park to assess current condition for the collared peccary population.

Measures

- Population density
- Distribution

Reference Conditions/Values

The reference condition for collared peccaries was identified as the collared peccary population at the location of PAAL around the time of the Battle of Palo Alto (1846). However, no information is available regarding the population at this time. According to one of the earliest reports on Texas wildlife (Bailey 1905), collared peccaries were common in southern Texas around the turn of the century.

Data and Methods

Few studies have documented the population density or distribution of collared peccaries in PAAL. The studies that do exist are primarily general biological inventories of the park, and only address the presence/absence of species rather than density or population distribution. During the first biological inventory of PAAL, Richard and Richardson (1993) documented the presence of collared peccary in the park. NPS (2013) mentions the probable presence of collared peccaries in the park.

Current Condition and Trend

Population Density

There are no data regarding collared peccary population density in PAAL. Without an established monitoring program, this measure cannot be assessed.

Distribution

There are also no data regarding the distribution of collared peccary in PAAL. Without regular surveys, this measure cannot be assessed.

Threats and Stressor Factors

PAAL staff identified several threats and stressors to the collared peccary population in the park. Among these stressors are habitat loss and fragmentation, competition with exotic species for food and habitat, drought, and hunting pressure from outside the park. If urbanization were to continue in the area, vehicle strikes could become another threat to collared peccaries in PAAL.

In recent years, the greater Brownsville, Texas area has been experiencing rapid growth, and the areas surrounding PAAL are experiencing increased residential and commercial development. While development activities experienced a lull beginning in 2007, they have begun to increase again in recent years (Garza, phone communication, 29 June 2012). The urbanization of the area around PAAL will essentially transform the park into an “island” of natural habitat in an area otherwise surrounded by human development. Such activity would likely reduce the size and distribution of the peccary population in the PAAL area.

Exotic species competition is a threat to collared peccary population density in PAAL. Feral hogs and peccaries do not necessarily compete for water resources (pigs require standing water whereas peccaries can feed on prickly pear which acts as their water supply) (Gabor and Hellgren 2000), but pigs may degrade the native habitat. According to Gabor and Hellgren (2000), there was an inverse correlation between invading pigs and peccary density. Peccary density is positively correlated with habitat quality; this means that the presence of feral pigs, which may decrease habitat quality, would subsequently negatively impact peccary density. Other exotic animals, such as nilgai, may alter habitat, causing habitat quality to decline (Garza, written communication, 21 February 2013).

Drought is also a major stressor. Not only do periods of drought remove many sources of water for collared peccaries, but these periods also affect availability of a diversity of food sources. Prolonged intake of only prickly pear for more than four days can cause gastrointestinal imbalances (e.g., diarrhea) in collared peccaries (Shiveley 1979). According to Lochmiller et al. (1985), the nutritional stress brought on by drought can also lead to decreased testosterone levels, which may adversely affect breeding activity in male peccaries.

Hunting pressure outside of the park is another threat to the collared peccary population in the PAAL area. According to Bodmer and Sowls (1993), overhunting is one of the factors that has resulted in a fragmented peccary population. Collared peccaries are hunted not only for their meat but for their hides as well (Gongora et al. 2011).

Data Needs/Gaps

An investigation into the current collared peccary population density and distribution is needed for PAAL. Without this information, an assessment of current condition is not possible. Data regarding collared peccary take from hunting may provide some insight into the status of the species in the area.

Overall Condition

Population Density

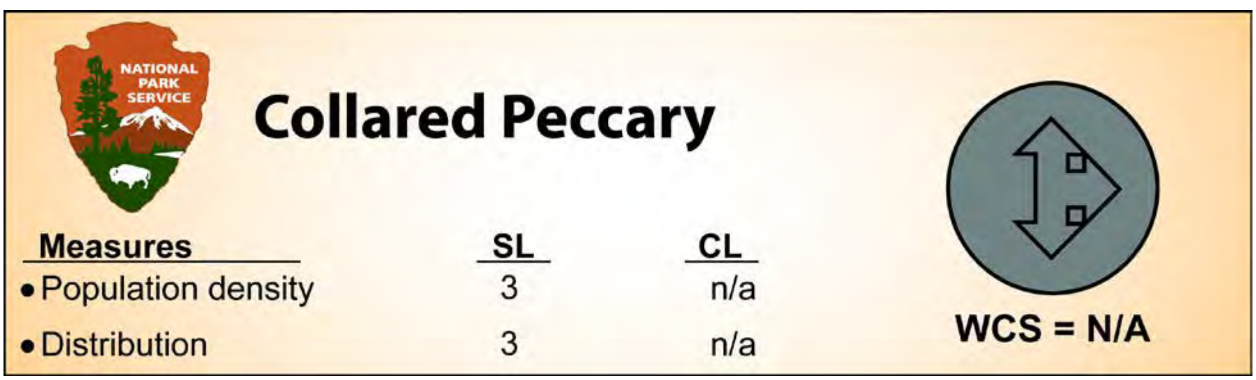
The project team defined the *Significance Level* for population density as a 3. There are no data for population density of collared peccaries in PAAL. Because of this data gap, a *Condition Level* was not assigned for this measure.

Distribution

The project team defined the *Significance Level* for distribution as a 3. There are also no data for distribution of collared peccaries in PAAL. Therefore, a *Condition Level* was not assigned for this measure.

Weighted Condition Score

A *Weighted Condition Score* was not calculated for collared peccary in PAAL due to a lack of current data for all measures.



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Rolando Garza, PAAL Archeologist and Integrated Resource Manager

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4.8 Wild Cats

Description

PAAL is one of the few places in Texas that provides potential habitat for four native wild cat species: the bobcat, the mountain lion (*Puma concolor stanleyana*), the ocelot (*Leopardus pardalis*), and the jaguarundi (*Felis yagouaroundi cacomitli*) (Figure 8). The dense Tamaulipan brushlands that are found along the lomas and higher elevations in PAAL likely provide the most suitable habitat for these species. However, grazing and extensive drainage of the heavy clay soils in the park have reduced the extent and density of these brushlands, leaving only fragmented brushland habitat available (Laack 1994). Because of habitat alterations, the distribution of these cat species is limited (Harveson et al. 2004), and observations in the park have become a rare occurrence. Behind the coyote, wild cats likely serve as a primary predator of native rodents and small mammals, and their presence in the PAAL may help to regulate prey populations.

Figure 8. Home ranges of the jaguarundi and the ocelot in Texas; the bobcat and mountain lion are considered to be widespread across Texas (modified from TPWD 2003).

The bobcat is a widely distributed species across the state of Texas, and favors areas of mixed and open cover, as well as dense shrublands (De Oliveira et al. 2010, TPWD 2012a). While bobcats occur in the same areas as ocelots and jaguarundi, they occupy a unique microhabitat that allows the species to overlap home ranges (De Oliveira et al. 2010). Bobcats range in size from 47.5-125 cm (18-49 in) (Sparano 1998), and prey on small rodent species and rabbits (TPWD 2012a). In Texas, bobcats are considered a non-game species and have no closed hunting season (TPWD 2012b).

The mountain lion (also referred to as cougar, puma, panther, and catamount) is a widely distributed wild cat species that ranges from Canada to South America (TPWD 2008). The mountain lion was abundant across Texas prior to human settlement, but human developments, persecution, and habitat loss restricted the species' range (TPWD 2008). Sightings of mountain lions are rare in the PAAL region, but isolated observations have been reported in the past 20 years. Mountain lions are the largest of the wild cat species in Texas, with the average male measuring 2 m (7 ft) in length, and weighing between 45-68 kg (100-150 lbs). Prey species of the mountain lion are also larger, as deer make up the primary food source for the species (McKinney 1996). Other prey species include collared peccary, livestock, and various small mammals (McKinney 1996). Much like bobcats, mountain lions are considered a non-game species in Texas, and have no closed hunting season (TPWD 2012b).

Both the ocelot and the jaguarundi are federally listed as endangered species, with the ocelot listed in 1972 (USFWS 1972) and the jaguarundi in 1976 (USFWS 1976). The ocelot is the larger of these two species, with an average length of 76-104 cm (30-41 in) and an average weight of 15-30 lbs (Campbell 2003). Ocelots prey on small rodents and rabbit species, and depend on dense cover for both den sites and foraging.

Ocelots were once widely distributed across Texas, but by the 1800s, populations began to experience significant population declines as brushland habitats were cleared for human developments and farming (Farmer 1992). Farmer (1992) reports that in 1992, only 1,618 ha (4,000 ac) of suitable ocelot habitat existed in Cameron County (where PAAL is located), and that the estimated Texas ocelot population was approximately 80-120 individuals. As of February 2010, the ocelot population in Texas had dropped to below 50 individuals (USFWS 2010).

Only two small ocelot populations are known to exist in Texas, with one population occurring on private land in Willacy County, and the other population in the chaparral habitat of nearby LANWR, approximately 32 km (20 mi) from PAAL (Campbell 2003, Sternberg and Mays 2011). In 1991, Laack (1991) estimated the ocelot population in LANWR to be 30-35 individuals. By 2009, the LANWR ocelot population was estimated to be as low as 8-10 individuals (Sternberg and Mays 2011). USFWS (2010) estimates that the total number of ocelots in the two south Texas populations is below 25 individuals.

The jaguarundi (Photo 19) is an elusive, smaller cat, typically slightly larger than a domestic cat (*Felis catus*), weighing approximately 3-10 kg (7-22 lbs) (Campbell 2003). Habitat requirements of the jaguarundi are poorly studied in south Texas, although jaguarundis are thought to occupy similar habitats as the ocelot (favoring dense brushlands). Campbell (2003) indicates that jaguarundi are likely more tolerant of open areas (e.g., pastures, farmland, grasslands) compared to the ocelot.

Photo 19. Jaguarundi (USFWS photo).

Sightings of the jaguarundi are extremely rare in south Texas, and most reported observations turn out to be domestic cats and not jaguarundi. The last confirmed specimen or sighting of a jaguarundi in south Texas occurred in April 1986 when a road-kill jaguarundi was recovered in Cameron County by TPWD (USFWS 1990). Prior to the collection of this specimen, the last confirmed jaguarundi sighting was in 1969 in Willacy County (USFWS 1990). Despite the long period between observations, it is still possible that transient jaguarundi may occur in PAAL.

Measures

- Species abundance and diversity
- Distribution

Reference Conditions/Values

The reference condition for wild cats was identified as the wild cat population at the location of PAAL around the time of the Battle of Palo Alto (1846), although the condition of the wild cat population during the battle is poorly documented.

Data and Methods

Few studies have documented the presence of wild cats within PAAL, and no studies or accounts of the cat population during the time of the battle exist. Farmer (1992) conducted the first natural resource survey in PAAL in 1992. While little information regarding wild cats was presented in this report, it did identify the ocelot and jaguarundi as two species that likely are present in the park during different periods of the year. Farmer (1992, p. 21) described the habitat of the two cat species as "brushy edged drainage ditches north of the battlefield site" and that the jaguarundi would likely make greater use of the park's grasslands than the ocelot would.

Laack (1994) conducted the park's only feline detection survey in 1994. This project investigated the use of PAAL by wild cats; previous monitoring in the area indicated that ocelots had been tracked to within 6.4 km (4 mi) of the park's northern border (Laack 1994). Using photo traps and tomahawk live traps, Laack (1994) recorded all species of wild cats trapped from 18 November 1994 to 3 December 1994. During the survey, two bobcats were captured in the live traps, and numerous photographs of bobcats were recorded; no ocelots or jaguarundis were recorded.

In 2002, Hayes (2004) conducted a biological inventory of the birds, fish, and mammal species present in PAAL. Five different field methodologies were used to survey mammals (Sherman live traps, trip cameras, ultrasonic detectors, mist netting, and Havahart live traps). The only wild cat species observed during the sampling efforts was a bobcat, although the authors indicate that suitable habitat does exist for the jaguarundi.

Photo 20. Ocelot kittens photographed in 2010 by a remote camera in Laguna Atascosa National Wildlife Refuge (USFWS photo).

Current Condition and Trend

<u>Species Abundance</u>

No current information exists that documents the abundance of wild cats in PAAL; the last intensive feline survey in the park was in 1994 (Laack 1994). As a non-game species, bobcats can be harvested with no established season or bag limit. Because of this, harvest statistics are not available, although Rolando Garza (phone conversation, 9 August 2012) indicates that bobcat tracks are frequently observed in the park. There have been no confirmed jaguarundi sightings in Texas since 1986 (USFWS 1990).

Nearby LANWR, located 32 km (20 mi) from PAAL, is home to one of two known ocelot populations in Texas, and monitoring/survey efforts are ongoing in the refuge. Much like the rest of the species' range, ocelot numbers in LANWR have been declining in recent years, and remote cameras have been set up in the refuge to document the presence of the cats. While the current sex ratio of the population in LANWR is unknown, reproduction has occurred in recent years; in 2010, trip cameras installed in the refuge photographed two ocelot kittens (Photo 20). In an effort to more accurately track the population size, several ocelots in LANWR have been radio-collared (Photo 21). Results of the monitoring identified 13 ocelots in the refuge, with potentially 12 unidentified ocelots in or around the refuge (USFWS 2011). These numbers are much lower than the estimated LANWR population size in 1991, which was 30-35 individuals (Laack 1991).

Photo 21. Radio collared ocelot in Laguna Atascosa National Wildlife Refuge (USFWS photo taken by a remote camera in the refuge).

Mountain lion observations are scarce in extreme southern Texas, and no surveys or estimates of population abundance exist. However, in March 2011, a male mountain lion was documented on a remote trip camera in LANWR (Photo 22). This sighting was the first of a mountain lion in this region in over a decade.

Photo 22. Mountain lion recorded by a remote sensor camera in LANWR, March 2011 (USFWS photo).

In PAAL, Rolando Garza (phone conversation, 9 August 2012) documented evidence of a large wild cat in early January 2011. Measurements of the tracks in the photograph indicate that they are likely that of a mountain lion; both the stride length and the width of the individual tracks were too large to be that of any other wild cat species in the area (Photo 23, Figure 9).

Photo 23. Photograph of a wild cat track, likely a mountain lion, in PAAL in early January 2011. The track measures approximately 4 inches in width (Photograph taken by Rolando Garza, PAAL).

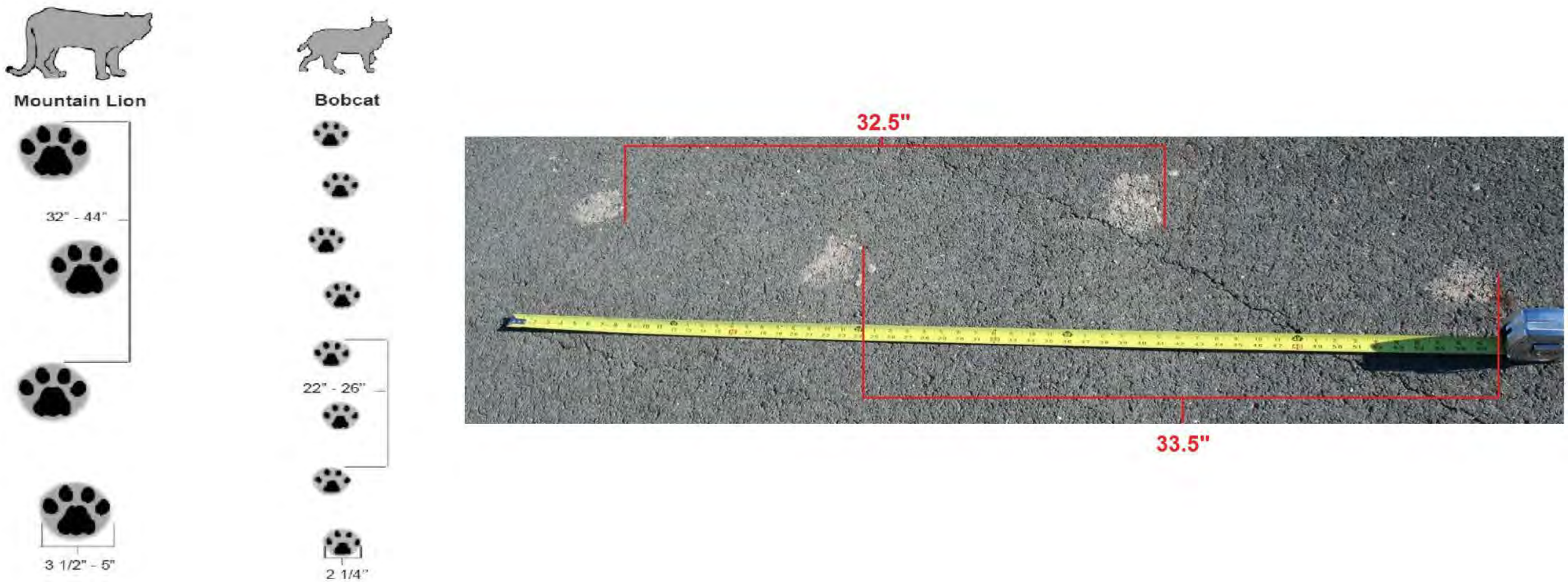


Figure 9. On left, field identification characteristics of mountain lion and bobcat (modified from MFWP 1999). On right, track marks likely from a mountain lion in PAAL. Measurements are in inches and are approximate (Photograph taken by Rolando Garza, PAAL).

Distribution

The distribution of wild cat species in PAAL has not been documented. Of the wild cats potentially present in the PAAL area, the bobcat has the least specific habitat requirements. Bobcats occupy a variety of habitats, ranging from dense shrublands to open areas of light cover (De Oliveira et al. 2010, TPWD 2012a). Because of their broad habitat requirements, bobcat distribution across the park is likely to be wider, and not associated with a specific locality or set of locations.

Mountain lions were once widely distributed across Texas. However, human activities largely restricted the species' range to rugged and isolated mountainous areas (McKinney 1996). TPWD uses mountain lion mortality information (rather than population estimates) to determine the distribution of mountain lions across the state. There have been no mountain lion mortalities reported in Cameron County since the reports began in 1983, although data are only current through 2005 (Figure 10) (TPWD 2008). This may indicate that the mountain lion's distribution does not include PAAL; however, the 2011 track evidence in PAAL (Figure 9, Photo 23) combined with the confirmed sighting in LANWR (Photo 22) suggests that, at a minimum, transient mountain lions may exist near the park. Landowners near (and within the legislative boundary of the park) indicate that mountain lions have been observed in the area in recent years (Garza, written communication, 13 June 2013). No surveys or harvest statistics exist for this region/species, so the actual distribution cannot be estimated at this time.

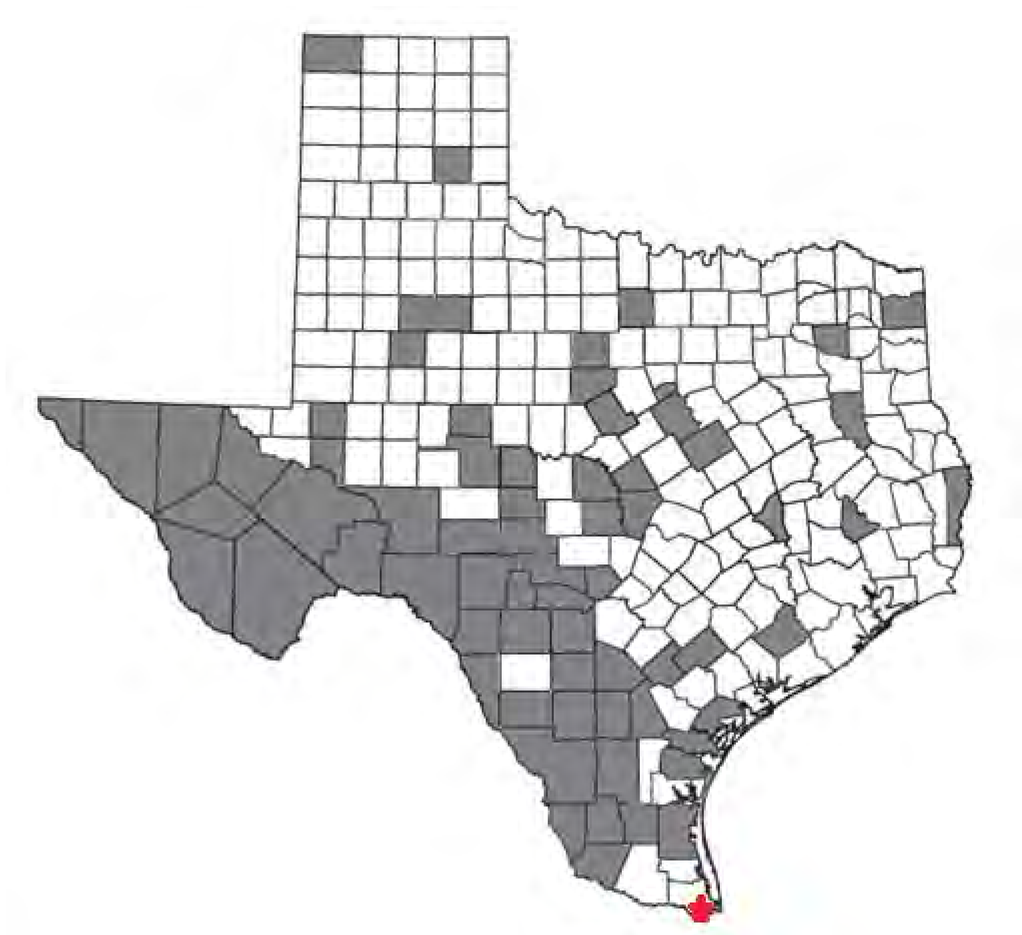


Figure 10. Mountain lion mortalities recorded in Texas, 1983-2005 (image reproduced from TPWD 2008). Shaded areas represent counties where mountain lion mortalities have been documented, and the red star indicates the location of PAAL.

Unlike the bobcat, ocelots have very specific habitat requirements. USFWS (2010) reports that ocelots require habitats with very dense vegetation with a canopy cover >75%. The shrub layer in optimal ocelot habitat needs to have 95% cover (USFWS 2010). These habitats are sparse in south Texas, as Tewes and Everett (1986) reported less than 1% of optimal habitat remains in the Lower Rio Grande Vvalley. Ocelot distribution in the PAAL area is probably limited to the LANWR region, and any ocelots that could occur in the park would likely be transients from that population (Garza, phone conversation, 9 August 2012).

The distribution of the jaguarundi is not well known in south Texas. Jaguarundi habitat is thought to be similar to ocelot habitat, although Campbell (2003) indicates that the jaguarundi may be more likely to occupy open areas such as grasslands and pastures. Since no observations have been recorded in south Texas in over 20 years, it is unlikely that this species' current distribution includes PAAL.

It is likely that the Tamaulipan brushland habitat in PAAL provides the best habitat for the wild cats in the area. A detailed discussion of this habitat and its distribution in the park is provided in Chapter 4.2 of this document.

Threats and Stressor Factors

The major threats facing the wild cats in the PAAL region (as identified by park staff) include habitat loss and fragmentation, vehicle collisions, and potential competition amongst other cat species and feral hogs (Garza, written communication, 13 June 2013). Habitat loss and fragmentation are the primary threats to wild cats in southern Texas (USFWS 2010). Over 95% of the ocelot's required habitat (dense shrubs/thornscrub) has been lost in the Lower Rio Grande Valley. The jaguarundi requires a similar habitat to that of the ocelot, and the conversion of this habitat to agriculture and range land may explain the lack of confirmed sightings in the PAAL region. Human development in the area surrounding PAAL could drive any transient wild cats in the area into the park, although this is speculation at this time (Garza, phone conversation, 9 August 2012).

All of the native cats in the PAAL area also have home ranges that extend into Mexico. Connectivity between wild cat populations across the international border is extremely limited, as border barrier development and human presence on the boundary make migration across the border almost impossible (USFWS 2010). The concern over connectivity is especially relevant to the south Texas ocelot population. Ocelot populations in southern Texas are fragmented and are limited to only a few regions.

Dispersal from established populations is limited by a lack of continuous habitat, and by road infrastructure in these areas. Road mortality among dispersing wild cats is a major concern in Texas. The only confirmed jaguarundi in the last 20 years was a road kill individual collected by TPWD (USFWS 1990). Wild cats in the PAAL area face heavy traffic at times, as Texas State Highway 550 and Farm to Market Road 1847 are in close proximity to the park.

Data Needs/Gaps

No data exist for the abundance or distribution of wild cats in PAAL. Without this information, a current assessment of condition cannot be made. A baseline survey of the bobcat population in the park (which is likely the only resident wild cat species) could help provide managers with vital information regarding population size and habitat use. Continued monitoring for potential transient ocelots, mountain lions, or jaguarundi is also needed.

Overall Condition

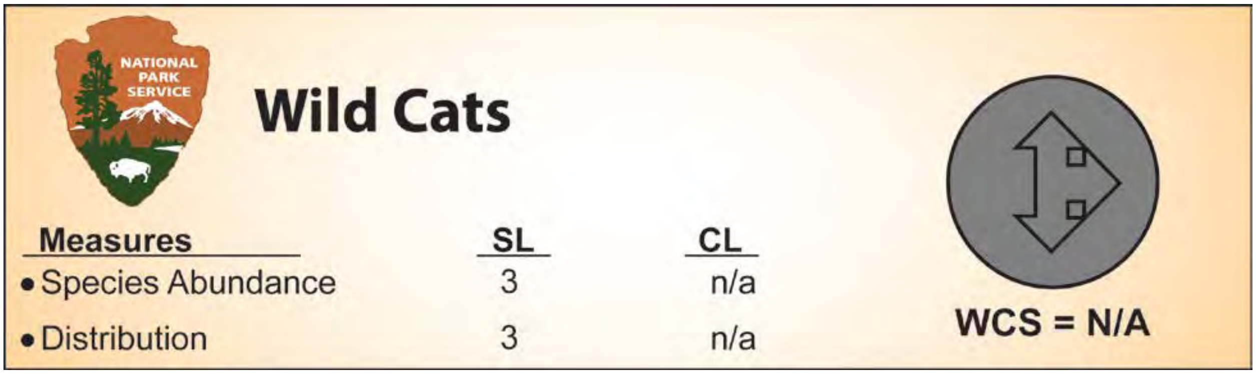
Species Abundance

The project team defined the *Significance Level* for species abundance as a 3. However, no data exist for wild cat abundance in PAAL. Bobcats are likely to exist in the park, and ocelots are present in the nearby LANWR, but no formal study or inventory has documented the abundance of wild cats in the park. Because of this, a *Condition Level* was not assigned to this measure.

Distribution

The distribution measure for this component was assigned a *Significance Level* of 3. No data exist for this measure in PAAL, and a *Condition Level* could not be assigned at this time.

Weighted Condition Score
Information regarding the wild cat population at PAAL is not available at this time. Without detailed information regarding the species abundance and distribution of wild cats in the PAAL area, a *Weighted Condition Score* cannot be assigned.



Sources of Expertise
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4.9 Native Rodents

Description

PAAL provides diverse habitats and ground cover for four native rodent species: the southern plains woodrat, the white-footed mouse, the hispid cotton rat, and the Mexican ground squirrel (*Spermophilus mexicanus*; Photo 24) (NPS 2013). These rodent species occupy specific habitat types within the park. The southern plains woodrat, the white-footed mouse, and the Mexican ground squirrel tend to occupy habitats that are dominated by cacti (family Cactaceae), mesquite, and brush species (Davis and Schmidly 1997). These habitats provide ample ground and aerial cover from predators, and are in close proximity to food sources. The hispid cotton rat occupies grassland habitats that are dominated by bluestem (genus *Andropogon*) and cordgrass/spartina (genus *Spartina*) (Davis and Schmidly 1997).

Photo 24. Mexican ground squirrel in PAAL (photo by Rolando Garza, PAAL).

The diet of the native rodent species varies depending on food availability and the rodent species that is foraging. For example, the hispid cotton rat feeds primarily on plant material, whereas the Mexican ground squirrel has a meat-dominated diet (Davis and Schmidly 1997). While the Mexican ground squirrel prefers to scavenge on carrion, it does forage on mesquite, Johnsongrass, and agrito (*Mahonia trifoliolata*) leaves when they are abundant (Davis and Schmidly 1997). The southern plains woodrat and white-footed mouse have diets dominated by prickly pear cacti, mesquite pods, seeds, and insect species (Davis and Schmidly 1997).

The Coues' rice rat (*Oryzomys couesi*) is a state-threatened species in Texas, and is typically found near marshes and aquatic grasses near shorelines (TPWD 2012). While the Palo Alto battlefield site is not home to large sources of water or aquatic species, the Resaca de la Palma site may provide suitable habitat. This species has not been observed during an inventory, nor has it been identified on the certified mammal list for the park (NPS 2013). However, it is possible that PAAL may be home to the Coues' rice rat during certain periods of the year.

While the native rodent species of PAAL are small and often not observed by visitors, they make up an important component of the park's ecosystem. These rodents serve as the primary food source for many avian and reptilian species; monitoring of the native rodent species in the park would likely provide managers with a broad indication of the current state of the PAAL ecosystem.

Measures

- Species abundance and diversity
- Distribution

Reference Conditions/Values

The reference condition for native rodents was identified as the native rodent population at the location of PAAL around the time of the Battle of Palo Alto (1846). However, no historic information regarding the native rodent population during the time of battle is available. Future analyses of condition could use more recent inventories or surveys as a baseline for comparison.

Data and Methods

Few studies have documented the health or status of the native rodents in PAAL. The studies that do exist are primarily biological inventories of the park, and only address the presence/absence of species. During the first biological inventory of PAAL, Richard and Richardson (1993) documented the presence of Mexican ground squirrels and southern plains woodrats in the park.

In 2002, Hayes (2004) conducted an inventory of PAAL. This inventory sought to create an annotated list for at least 90% of the bird, fish, and mammal species that were expected to occur in the park. Small mammal surveys were conducted using Sherman live traps set up on a line extending at least 50 m (164 ft). Traps were placed 10 m (33 ft) apart, and were baited with a combination of peanut butter, wild birdseed, and raisins (Hayes 2004). In some instances, the small mammal traps attracted large snakes (Photo 25), which may have affected the capture rate. The inventory identified only two native species of rodents, the southern plains woodrat and the hispid cotton rat; a list of species identified was submitted to the NPS to update NPSpecies.

Photo 25. Western diamondback rattlesnake near a small mammal trap (photo from Hayes 2004).

Current Condition and Trend

Species Abundance and Diversity

No current estimates of species abundance or diversity exist for the native rodents in PAAL. While no data have been collected regarding rodent species abundance, the NPS certified species list identifies four native rodent species as residents of the park (NPS 2013). An intensive inventory of the park has not occurred since 2002 (Hayes 2004), and the species diversity of the park may be greater than reported by NPS (2013). Richard and Richardson (1993) noted that the Coues' rice rat might be found in the park during certain periods of the year. Without data that are more recent, an assessment of the current condition is not possible at this time.

Distribution

To date, no studies have investigated the distribution of native rodent populations within PAAL.

Threats and Stressor Factors

PAAL staff identified several threats and stressors to the native rodent population in the park. Of the stressors identified, habitat loss and destruction was one of the most significant threats to this group of species. The city of Brownsville, Texas has experienced a period of rapid growth over the past two decades. Development (both residential and commercial) in the areas surrounding PAAL has begun to increase in recent years (Garza, phone communication, 29 June 2012). This urbanization will likely transform PAAL into an "island" of natural habitat in an area otherwise surrounded by urban development; the native rodent habitat in the area would be greatly fragmented if such an event were to occur.

The rodent population of PAAL (both the native and non-native rodent species) serves as the primary prey base for many other species in the park. Species in the park that are primary predators of rodents include raptors (e.g., aplomado falcon, Harris's hawk), reptiles (e.g., western diamondback rattlesnake, Great Plains rat snake [*Pantherophis emoryi*]), and coyotes. Robert Woodman (written communication, 30 August 2013) indicated that Texas indigo snakes were frequently observed in and around woodrat dens during Texas tortoise sampling efforts, perhaps indicating that indigo snakes were a primary predator for the park's woodrat population. While predation is a natural threat to rodents, periods of high predation (especially during breeding) could temporarily alter the size of the rodent population in the park.

Drought is a major threat to all of the natural resources in PAAL. Not only do periods of drought remove many sources of water for the native rodents in PAAL, but these periods also affect availability of food for rodents. Drought may reduce forage items such as seeds, leaves, or insects, and could lead to starvation for many resident rodents in the park. Hayes (2004) noted that periods of drought also led to a source of bias in their inventory of PAAL in 2002. Because the surveys took place during a period of drought, many species in the park did not have a source of surface water. Drought likely results in lower than expected observation rates for many rodent species in PAAL.

Another threat to the native rodent population of the park is the presence and associated disturbance caused by feral hogs. Martha Segura, GULN Coordinator, indicates that there have been direct observations of destruction of woodrat nests by hogs (Segura, written communication, 15 November 2012). Robert Woodman (written communication, 30 August 2013) supported this observation, and also indicated that similar den disruption events were observed in 2013. A substantial increase in the feral hog population of the park could dramatically affect the reproductive rates of the native rodents in the park.

<u>Data Needs/Gaps</u>

An investigation into the current native rodent population's species abundance, diversity, and distribution is needed for PAAL. Without this information, an assessment of current condition is not possible.

<u>Overall Condition</u>

Species Abundance and Diversity

The project team defined the *Significance Level* for species abundance and diversity as a 3. However, due to the lack of data regarding this measure, a *Condition Level* was not assigned.

Distribution

The project team defined the *Significance Level* for species distribution as a 3. No data exist for native rodent distribution in PAAL, and a *Condition Level* was not assigned to this measure.

Weighted Condition Score

Information regarding the native rodent population at PAAL is not available at this time. Without detailed information regarding the population abundance, diversity, and distribution of native rodents in the PAAL area, a *Weighted Condition Score* cannot be assigned.

Native Rodents

Measures	SL	CL
• Species Abundance and Diversity	3	n/a
• Distribution	3	n/a

WCS = N/A

Sources of Expertise

Rolando Garza, PAAL Archeologist and Integrated Resource Manager

Martha Segura, GULN Coordinator

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4.10 Butterflies

Description

Butterflies are ecological indicators of habitat health, which makes them an important part of the PAAL ecosystem. Their sensitivity to environmental change (e.g., habitat loss or fragmentation, climate change) has been the subject of scientific studies worldwide. Change has become evident in butterfly species migration patterns and habitat extent (Parmesan et al. 1999, Walther et al. 2002). Butterflies are also important pollinators and prey for other wildlife, particularly birds (BCE 2008).

Photo 26. Gulf fritillary (*Agraulis vanilla*), a common Texas butterfly (NABA photo by G. Quintanilla).

Many species of butterflies are known to inhabit and migrate through southern Texas. PAAL supports an expanse of natural vegetation that may provide habitat for a variety of butterfly species. Species recorded in Cameron County include butterflies from the following families: swallowtails (Papilionidae), hairstreaks and blues (Lycaenidae), brush-footed butterflies (Nymphalidae, Photo 25), and skippers (Hesperiidae) (Quinn 2010). The manfreda giant-skipper (*Stallingsia maculosa*), a species endemic to Texas, is considered to be one of the rarest butterflies in the state (Quinn 2010). The climate and vegetation of PAAL are characteristic of this butterfly's habitat; it can be found in moist and dry areas and prefers mesquite shrubland (Quinn 2007).

Measures

- Species abundance and diversity
- Distribution

Reference Conditions/Values

The ideal reference condition for PAAL butterflies is the population supported in the natural habitat around the time of the historic battle (1846). However, no information on butterflies is available from this time. One of the earliest available reports on butterflies in the area comes from a 1948 field season summary in the Lepidopterists' Society newsletter, which reports species that were abundant, "about average", or scarce in the Rio Grande Valley that year (Stallings 1948). The species referenced in that summary are presented in Table 20. It is important to note that this table is based on the observations of three groups of collectors during one field season and is not intended to be a comprehensive species list for the time period.

Table 20. Butterfly species observed in the Rio Grande Valley in 1948 and their relative abundance (Stallings 1948).

Abundant	Average	Scarce
great purple hairstreak	giant white	ornythion swallowtail
clytie ministreak	soldier	polydamus swallowtail
cyna blue	Mexican bluewing	ruby-spotted swallowtail
ceraunus blue	Walker's metalmark	white-angled sulphur
tawny emperor	gray ministreak	yellow-angled sulphur
	two-barred flasher	laviana white-skipper
	mimosa skipper	violet-patched skipper
	potrillo skipper	xami hairstreak
	empress leilia	lantana scrub-hairstreak

Data and Methods

The North American Butterfly Association (NABA) has created an abridged species checklist for PAAL (Quintanilla and Hanson 2008) and an annotated species list for the Lower Rio Grande Valley of south Texas (Quinn 2010). No studies or surveys of butterfly populations have been conducted specifically within PAAL.

Current Condition and Trend

Species Abundance and Diversity

Butterfly species abundance and diversity has not been studied within PAAL. NABA created a checklist of approximately 150 species that visitors may observe at PAAL (Quintanilla and Hanson 2008, Appendix C). However, the species on this checklist have not been officially confirmed within the park, and the list is not all-inclusive; many other species may also occur in the park. Additional potential species can be found on NABA's annotated species list for the Lower Rio Grande Valley of south Texas, which contains over 230 species (Quinn 2010, Appendix C). This list also provides some general information on species abundance in the region.

Photo 27. Western pygmy-blue (*Brephidium exile*) (NABA photo by G. Quintanilla).

Distribution

The distribution of butterflies within PAAL has not been studied.

Threats and Stressor Factors

Threats to the park's butterflies include habitat loss, drought, extreme weather events such as hurricanes, and exotic fire ants (*Solenopsis* sp.). Many species are also vulnerable due to host specificity, as their larvae rely on a specific plant species for food (e.g., monarchs [*Danaus plexippus*] and milkweed [*Asclepias* spp.]) (NWF 2011).

Habitat loss and fragmentation are perhaps the greatest threat to butterfly populations worldwide (ScienceDaily 2008, NWF 2011). Open habitats preferred by butterflies, such as grasslands and savannas, have particularly declined over time since they are relatively easy to convert for agriculture or development (NWF 2011). In recent years, the area around Brownsville, Texas, has been growing rapidly, and many of the areas around PAAL are being developed for residential and commercial uses. The urbanization of the area around PAAL will essentially transform PAAL into an island of natural habitat in an area otherwise surrounded by human development. Predation of eggs and larvae by exotic fire ants may also be impacting butterflies in Texas (Calvert 1999).

Drought conditions and extreme weather events, which are predicted to increase with global climate change, can seriously impact butterfly populations (Gilbert 1985, Achenbach 2011). Droughts often reduce production of plants that provide food for both caterpillars and adult butterflies, causing mortality or triggering risky migrations (Gilbert 1985). Droughts can also increase the likelihood of wildfires, which further reduce the vegetation available for butterflies. In addition, increased temperatures due to global warming may lengthen the growing season for plants, causing them to flower and go to seed earlier in the year. If butterfly life cycles or migration patterns do not change, they may "get out of sync" with their host plants and be unable to find enough food to survive (NWF 2011).

Data Needs/Gaps

Very little is known about PAAL's butterfly population. A formal list documenting the species that occur in the park does not exist. While some species abundance information is available for the greater Lower Rio Grande Valley region (Quinn 2010), butterfly abundance has not been studied in the park specifically. The distribution or other ecological aspects of the park's butterfly populations also have not been investigated.

Overall Condition

Species Abundance and Diversity

The project team defined the *Significance Level* for species abundance and diversity as a 3. Little information is available regarding the butterfly species that occur within PAAL. Therefore, a *Condition Level* could not be assigned.

Distribution

The project team defined the *Significance Level* for distribution as a 3. Since the distribution of butterflies within PAAL has not been studied, a *Condition Level* was not assigned for this measure.

Weighted Condition Score

A *Weighted Condition Score* could not be determined due to a lack of data. The condition and trend of butterflies at PAAL is unknown.

Butterflies

Measures	SL	CL
• Species abundance & diversity	3	n/a
• Distribution	3	n/a

WCS = N/A

Sources of Expertise

Rolando Garza, PAAL Archeologist and Integrated Resource Manager

Dale McPherson, Southeast Region NRCA Coordinator

Mark Spier, PAAL Superintendent

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4.11 Amphibians

Description

Amphibians act as key indicator species as they are especially susceptible to ecological changes due to their permeable skin (Smith and Keinath 2007). Toxins absorbed through an amphibian's skin can quickly spread throughout the ecosystem, as amphibians are important prey for many species (Smith and Keinath 2007).

Photo 28. Coastal plain toad (*Incilius nebulifer*) observed in PAAL (Photo from Duran 2004).

Six species of amphibians are present in PAAL (Couch's spadefoot, coastal plain toad [*Incilius nebulifer;* Photo 28], Great Plains narrowmouth toad [*Gastrophryne olivacea*], Mexican treefrog, Rio Grande leopard frog, and spotted chorus frog) and all of these species are native anurans (frogs or toads) (Duran 2004, NPS 2013). According to Cooper et al. (2004), the black-spotted newt (*Notophthalmus meridionalis*) and the lesser siren (*Siren intermedia*) could also be present in the park if annual rainfall increased and standing water in the park became more permanent. The dry, saline environment of the park creates a harsh habitat for amphibians and may be the reason for low numbers (Cooper et al. 2004). Amphibians typically rely on moist habitats and require water sources for reproduction (Dayton 2005). Most of the known species in PAAL have been observed near the resacas and holding tanks (Cooper et al. 2004).

Measures

- Species abundance and diversity
- Distribution

Reference Conditions/Values

An ideal reference condition for amphibians was identified as the population of herpetofauna at the location of PAAL around the time of the Battle of Palo Alto (1846). The earliest published survey of amphibians in west Texas is Bailey's 1905 "Biological Survey of Texas". This survey describes species occurrence by zone (PAAL is located in the lower austral zone [Figure 11]) and does not provide diversity or distribution information specific to the area that is now PAAL. Since there are no other sources that

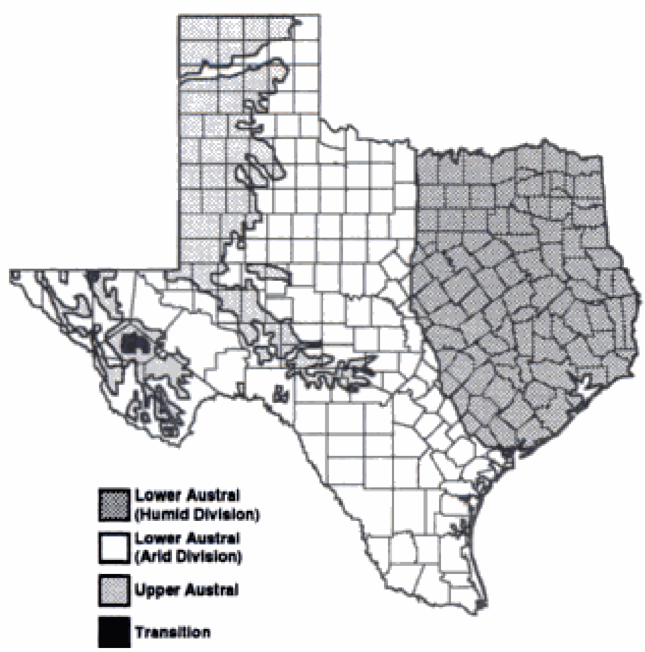


Figure 11. Bailey's life zones of Texas (Schmidly 2002).

provide adequate historical information on the park's amphibians between 1846 and park establishment, the species and distribution information in Bailey (1905) will serve as a "potential species list" for this assessment.

It is important to note that the land, hydrology, and vegetation in the PAAL region have been modified by continual human use since the time of the historical battle. This has likely had a significant impact on amphibian habitat in the park, and this ideal reference condition may no longer be an achievable management goal (Woodman, written communication, January 2010). PAAL has experience substantial water management, drainage, and lowered water tables in the years following the reference condition period. This has resulted in a drier surface and a more arid landscape than in 1846. Therefore, the more recent information presented in this report may serve as a suitable baseline or reference condition for future assessments.

Data and Methods

Farmer (1992) conducted a natural resource survey of PAAL. The survey includes a list of T & E species, including amphibians that are possibly present in PAAL. Farmer's (1992) survey breaks the study area into three habitats; brushland, salt prairie, and wetland.

Richard and Richardson (1993) conducted a biological inventory of PAAL in 1993. They focused on vegetative associations, but also noted faunal species present.

Judd and McNeely (2002) conducted an amphibian survey of PAAL in 2001. Trapping methods included 30.5 m (100 ft) of drift fence and 5 gallon pitfall traps that were placed near two resacas. The drift fence and pitfall trap surveys were conducted every month for a year. Three visual surveys were also conducted on rainy nights.

Duran (2004) conducted an inventory of reptiles and amphibians in PAAL between 2002 and 2003. Major sampling efforts focused on the borrichia prairie, coastal prairie/sacatal, and Tamaulipan thornscrub/mesquite habitats, which are displayed in Plate 10. Trapping methods included drift-fence arrays and cover boards, while visual and auditory surveys were also conducted. All observations were documented using GPS units and are displayed in Plate 11.

Current Condition and Trend

Species Abundance and Diversity

There are a total of six anuran species present in PAAL (NPS 2013). Table 21 displays the six species that are identified on the NPS Certified Species List as confirmed in the park as well as two species, the Rio Grande chirping frog (*Eleutherodactylus cystignathoides campi*) and the lesser siren (*Siren intermedia*), which NPS (2012) identifies as possibly present. All species within Table 21 are native species to the PAAL region.

Table 21. Amphibians that are present or possibly present in PAAL (NPS 2013). Species scientific names were updated if necessary using the Integrated Taxonomic Information System (ITIS).

Scientific Name	Common Name	Occurrence
Incilius nebulifer	coastal plain toad	Present in Park
Eleutherodactylus cystignathoides campi	Rio Grande chirping frog	Probably Present
Gastrophryne olivacea	Great Plains narrowmouth toad	Present in Park
Pseudacris clarkii	spotted chorus frog	Present in Park
Lithobates berlandieri	Rio Grande leopard frog	Present in Park
Scaphiopus couchii	Couch's spadefoot	Present in Park
Siren intermedia	lesser siren	Probably Present
Smilisca baudinii	Mexican treefrog	Present in Park

According to Farmer (1992), there are four T & E amphibians that may occur in PAAL: the black-spotted newt, Rio Grande lesser siren (*Siren intermedia texana*), white-lipped frog (*Leptodactylus fragilis*), and Mexican treefrog. The black-spotted newt, Rio Grande lesser siren, and white-lipped frog are Texas state-listed endangered species, while the Mexican treefrog is listed as threatened in the state. These species were not confirmed in PAAL, but were said to be possibly present if ephemeral or permanent ponds existed (Farmer 1992).

Richard and Richardson (1993) documented six anuran species in PAAL, including the Couch's spadefoot, Rio Grande chirping frog (*Syrrhophus cystignathoides campi*), coastal plain toad, spotted chorus frog, Great Plains narrow-mouthed toad, and Rio Grande leopard frog. The only two anuran species found in woodland habitat, away from the resacas, were the coastal plain toad and Couch's spadefoot (Richard and Richardson 1993).

Judd and McNeely (2002) documented one anuran during their survey, the coastal plain toad. During the survey, the two resacas located in the park were dry, which was a major factor, considering amphibians depend on a local water source to survive and breed.

Duran (2004) compiled amphibian species counts from observations, trapped specimens, and museum records. The coastal plain toad was the most common of the six species documented, while the Mexican treefrog was the least abundant amphibian species in the survey. Duran (2004) observed the spotted chorus frog 10 times during the course of the PAAL survey. However, nine of the 10 observations of the spotted chorus frog were audio records. Duran (2004) also noted that during the inventory there were dry conditions, which could account for the lack of observations due to species being inactive. Table 22 displays the compiled amphibian species counts from Duran's (2004) herpetofauna inventory of PAAL.

Table 22. Amphibians present in PAAL during 2003 herpetofauna inventory (Duran 2004).

Common Name	Number of Observations
coastal plain toad	25
Great Plains narrowmouth toad	18
spotted chorus frog	10
Rio Grande leopard frog	5
Couch's spadefoot	12
Mexican treefrog	2

Distribution

Duran (2004) documented locations of amphibians that may provide some insight into a relative distribution in PAAL. Locations were limited within the park; some species were only observed two or three times whereas other species were located several times. The coastal plain toad was recorded in locations near all three trap sites in three different vegetative habitats. Spotted chorus frogs were only observed in a dry resaca in the central area of the park, and Mexican tree frogs were only found near the western edge of PAAL. The Rio Grande leopard frog was found in the center of the park in and near the trap placed in Tamaulipan brush habitat, and one was observed on the western edge of PAAL. The Couch's spadefoot and Great Plains narrowmouth toad were observed near the center of the park, to the western edge of the park and in the northwestern section of the park. Plate 11 displays the recorded locations of amphibians in PAAL.

GULN staff has observed seemingly abundant populations of Rio Grande leopard frogs and chorus frogs in the park's resacas during wetter seasons/years (Woodman, written communication, 30 August 2013). Numerous coastal plain toads have also been observed by GULN staff during Texas tortoise sampling in the park.

Threats and Stressor Factors

Feral hogs, a non-native species, are a major a threat to amphibian populations. Feral hogs have been known to negatively affect native wildlife including amphibians (Ditchkoff and West 2007). Amphibians rely on the park's resacas for breeding; feral hogs frequent these resacas, which disrupts breeding activity (Woodman, written communication, January 2010). Feral hogs not only cause habitat loss by foraging on native vegetation, but they also directly prey upon herpetofauna (Jolley et al. 2010), and disrupt the native ecosystem by their wallowing and rooting behavior.

A natural stressor such as drought, which is common in PAAL, affects amphibian populations. Due to the region's arid climate and altered hydrology, the resacas no longer sustain permanent standing water. The arid climate and infrequent rain events cause stress to amphibians, especially because amphibians in the PAAL ecosystem depend on ephemeral pools created by large rain events for breeding (Dayton et al. 2004).

Urbanization and the development of agricultural areas in lands surrounding the park have caused habitat loss and disturbance for amphibians. The growing rates of road use also increase the risk of vehicle strikes (Cushman 2005). The region's land and vegetation has been drastically altered by drainage and water diversion due to urban and agricultural development. This has caused PAAL land to become drier with little to no permanent standing water. The current limited habitat can be further reduced by drought conditions (Woodman, written communication, January 2010).

Data Needs/Gaps

There are limited data on amphibians in PAAL. The Duran (2004) inventory describes the abundance, diversity, and possible distribution of the species observed, but it is now outdated. A more current study and long-term monitoring of amphibians are needed to assess any trends within the park.

Overall Condition

PAAL is home to a small variety of amphibians due to the lack of permanent standing water. All of the amphibians known to inhabit the park are native species. However, due to the fact that there have been no annual herpetological surveys in the park, a quantitative condition evaluation of amphibians in PAAL cannot be completed at this time. While the NPS has a record of confirmed species in the park (NPS 2013), this does not include estimates of species abundance or distribution, which were two of the NPS-specific measures for amphibians in PAAL. Annual monitoring of the populations in the park will allow for a more accurate assessment of these parameters.

Species Abundance and Diversity

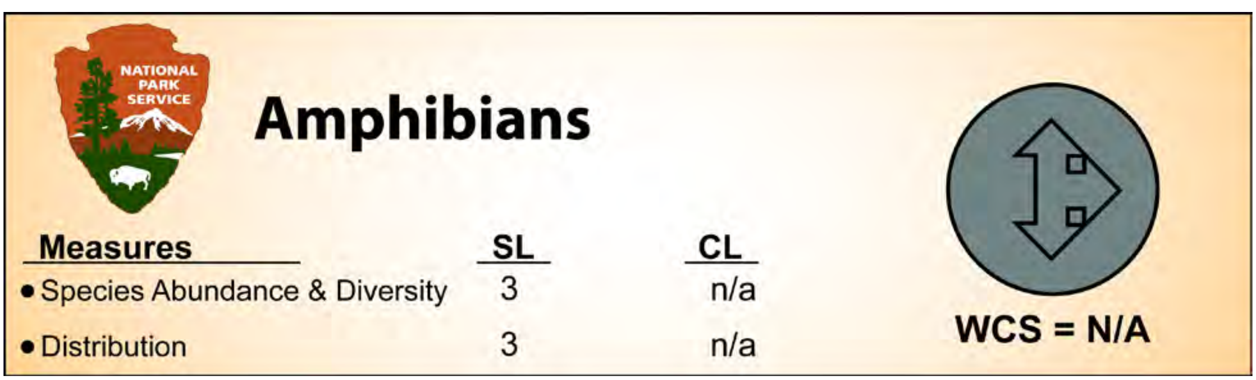
The project team defined the *Significance Level* for species abundance and diversity as a 3. Duran (2004) provides information regarding species abundance and diversity; however, the study is outdated. NPS (2013) provides a current list of species diversity, but has no measurements of abundance. Because of this data gap, it was not possible to assign a *Condition Level* at this time.

Distribution

The project team defined the *Significance Level* for distribution as a 3. There are limited current distribution data for PAAL. Long-term monitoring and full access to the park is necessary to complete a more accurate inventory and to aid in management. Because of this data gap, a *Condition Level* was not assigned.

Weighted Condition Score

A *Weighted Condition Score* for amphibians in PAAL was not assigned because both of the measures had unknown *Condition Levels*.



Sources of Expertise
Rolando Garza, PAAL Archeologist and Integrated Resource Manager

Robert Woodman, GULN Ecologist

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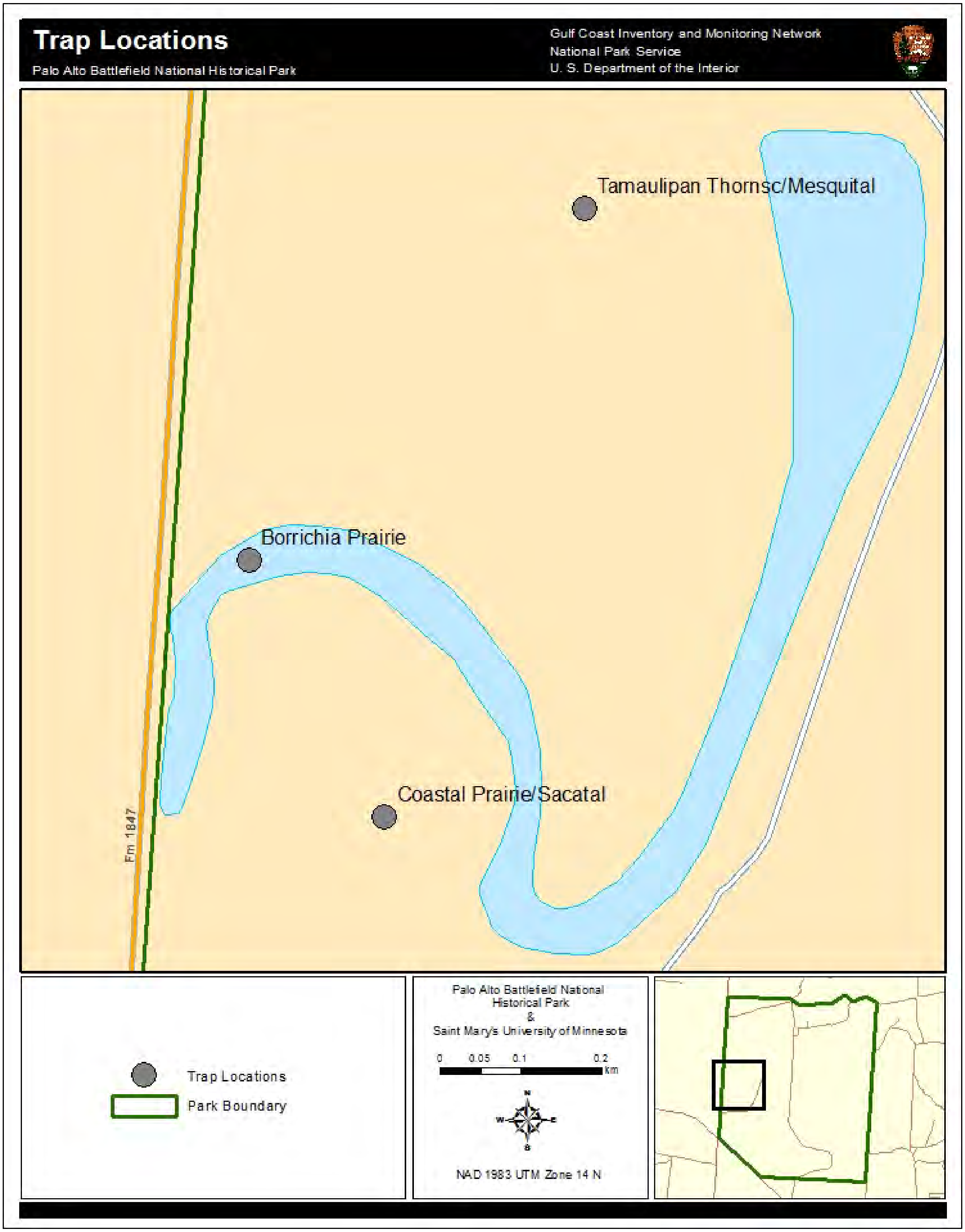


Plate 10. Locations of traps set during a reptile and amphibian inventory by Duran (2004) in PAAL between 2002 and 2003.

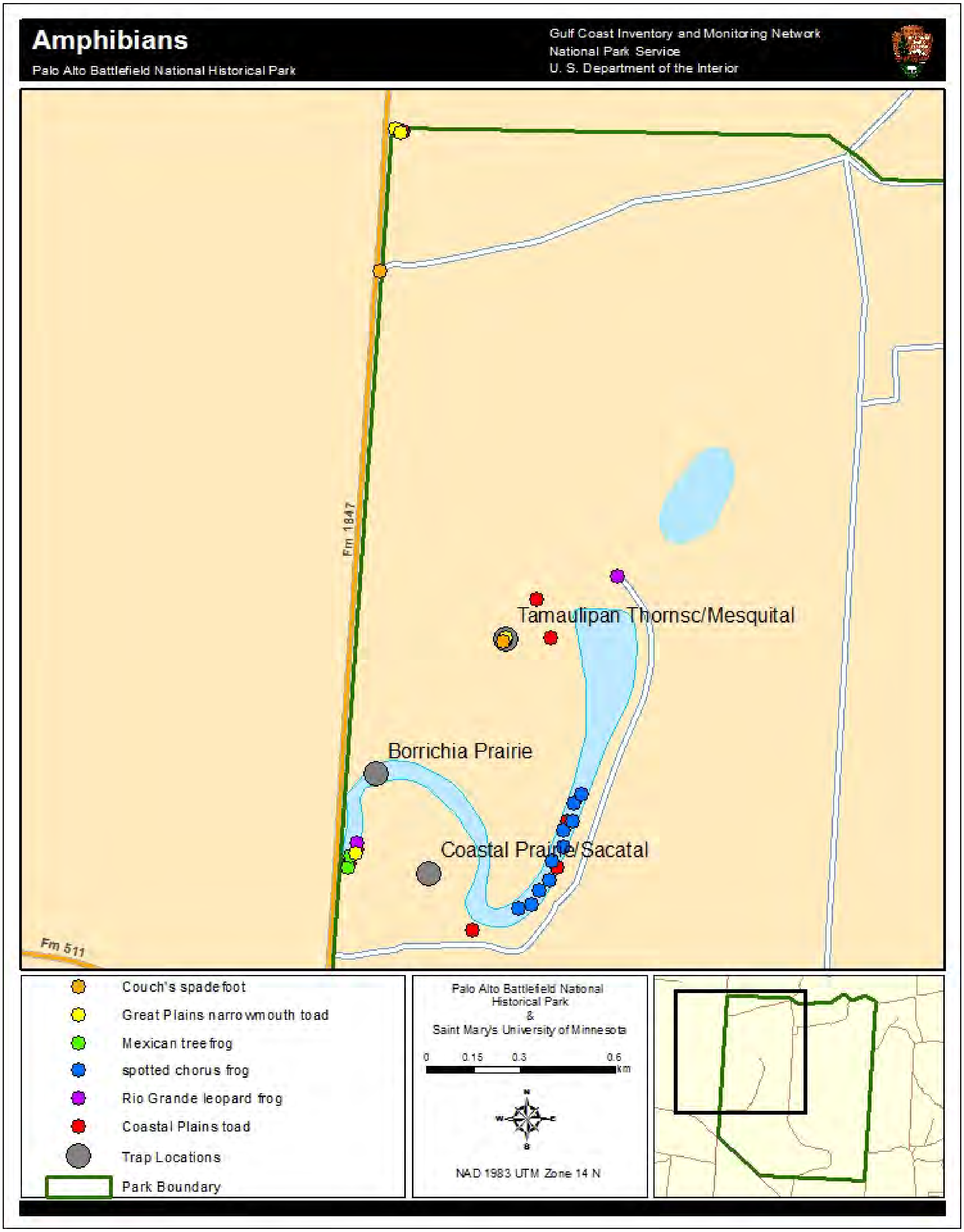


Plate 11. Locations of amphibians observed and trapped during a reptile and amphibian inventory by Duran (2004) in PAAL between 2002 and 2003.

4.12 Reptiles

Description

PAAL provides habitat for a number of reptiles, including snakes, lizards, turtles, and tortoises. Snakes are the most diverse reptile group in PAAL, with 14 species documented in the park (NPS 2013). There are also four lizard species documented in PAAL (NPS 2013). Three turtle species are found in PAAL, including one non-native species, the red-eared slider (*Trachemys scripta*), as well as one species of tortoise, Berlandier's tortoise (also known as the Texas tortoise). Reptiles are an important part of the ecosystem's food chain because some species serve as both predators and prey (ESI 2011). Reptiles may also play a role in seed dispersal and act as pollinators (TPWD 2012).

Photo 29. Plains black-headed snake (Tantilla nigriceps) (USFWS photo).

Measures

- Species abundance and diversity
- Species distribution

Reference Conditions/Values

An ideal reference condition for reptiles was identified as the population of herpetofauna at the location of PAAL around the time of the Battle of Palo Alto (1846). The earliest published survey of reptiles in west Texas is Bailey's 1905 "Biological Survey of Texas". This survey describes species occurrence by zone (PAAL is located in the lower austral zone [Figure 12]) and does not provide diversity or distribution information specific to the area that is now PAAL. Since there are no other sources that provide adequate historical information on the park's reptiles between 1846 and park establishment, the species and distribution information in Bailey (1905) will serve as a "potential species list" for this assessment.

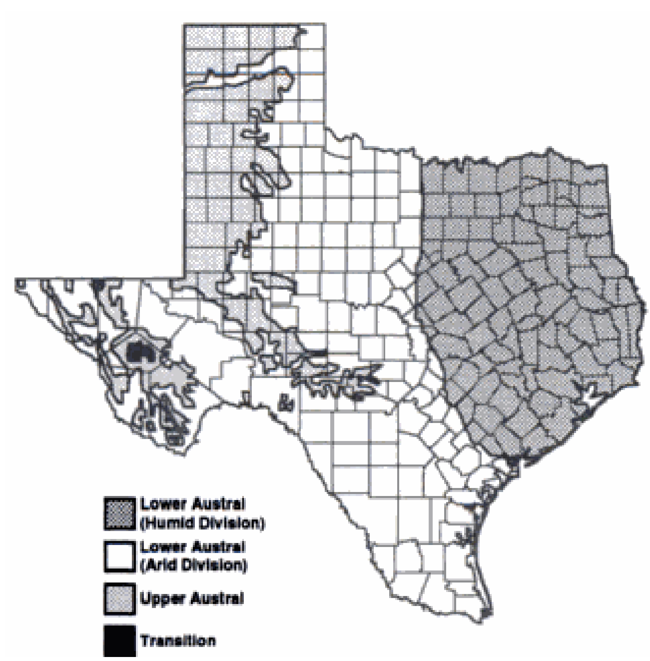


Figure 12. Bailey's life zones of Texas (Schmidly 2002).

It is important to note that the land, hydrology, and vegetation in the PAAL region have been modified by continual human use since the time of the historical battle. This has likely had a significant impact on reptile habitat in the park, and this ideal reference condition may no longer be an achievable management goal (Woodman, written communication, January 2010). Therefore, the more recent information presented in this report may serve as a suitable baseline or reference condition for future assessments.

Data and Methods

Duran (2004) conducted an inventory of the reptiles and amphibians in PAAL from 2002 to 2003. Duran (2004) sampled three sites in PAAL, with major sampling efforts focusing on the borrichia prairie, coastal prairie/sacatal, and Tamaulipan thornscrub/mesquite habitats, which are displayed in Plate 12. Trapping methods used in Duran (2004) included drift-fence arrays and coverboards, while observation methods employed were visual and auditory surveys. All observations were documented using GPS units. Sampling efforts occurred over a short period of time and cannot be considered as quantitative distributional efforts.

Current Condition and Trend

Species Abundance and Diversity

According to NPS (2013), there are 21 snakes, lizards, turtles, and tortoise species present in PAAL. However, Duran (2004) only observed 16 reptile species, all of which were native to the area. Table 23 displays the NPS Certified reptile species list, which includes all reptile species that have been confirmed as present in PAAL; this list does not include the regal black-striped snake (*Coniophanes imperialis*), which NPS (2013) noted as being possibly present in PAAL. The NPS list also includes the yellow mud turtle and Texas spiny softshell turtles (*Apalone spinifera emoryi*); however, these two species are less common during dry periods.

Table 23. Reptile species found in PAAL, as documented by NPS (2013).

Scientific Name	Common Name
Apalone spinifera emoryi	Texas spiny softshell turtle
Cnemidophorus gularis gularis	Texas spotted whiptail
Coluber constrictor oaxaca	Mexican racer
Crotalus atrox	western diamondback rattlesnake
Drymarchon melanurus erebennus	Texas indigo snake
Gopherus berlandieri	Texas tortoise
Kinosternon flavescens	yellow mud turtle
Masticophis flagellum testaceus	western coachwhip
Masticophis spp.	whipsnake spp.
Masticophis schotti ruthveni	Ruthven's whipsnake
Nerodia rhombifer	diamondback water snake
Elaphe guttata emoryi	Great Plains rat snake
Phrynosoma cornutum	Texas horned lizard
Pituophis catenifer sayi	bullsnake
Salvadora grahamiae lineata	Texas patch-nosed snake
Sceloporus olivaceus	Texas spiny lizard
Sceloporus variabilis marmoratus	rose-bellied lizard
Sonora semiannulata taylori	Taylor's ground snake
Tantilla nigriceps	plains black-headed snake
Thamnophis proximus orarius	Gulf Coast ribbon snake
Trachemys scripta elegans	red-eared slider

Duran (2004) documented 16 reptile species in PAAL. The total number of observations was recorded for each species documented, and some reptiles were more commonly observed than others. During Duran's (2004) inventory, the most common species in PAAL were the rose-bellied lizard (*Sceloporus variabilis marmoratus*), Texas horned lizard, Texas spotted whiptail, and Texas spiny lizard (*Sceloporus olivaceus*). The Texas horned lizard and Texas tortoise are both listed as threatened species in the state of Texas. Species rarely seen by Duran (2004) were plains black-headed snake (*Tantilla n. nigriceps*), Taylor's ground snake (*Sonora semiannulata taylori*), western coachwhip (*Masticophis flagellum testaceus*), Texas indigo snake (*Drymarchon melanurus erebennus*), and the yellow mud turtle. Table 24 displays the number of observations of all reptile species documented during Duran's herpetofauna inventory of PAAL. However, it is important to note that reptile survey results may be influenced by sampling methods (e.g., drift fences, coverboards, pitfall traps) and timing. Certain reptiles may be too large to fit under coverboards or may simply avoid them for unknown reasons. Some reptile species are seasonal and can only be found in the park at certain times of year (Woodman, written communication, January 2013), while other species may be present in the park if adequate rains keep standing water in nearby resacas (Duran 2004). According to NPS staff, the reptiles seen most frequently in PAAL are the rose-bellied lizard, rattlesnakes, and the Texas tortoise (Woodman, written communication, January 2013).

Table 24. Reptile species documented by Duran (2004) during a herpetofauna inventory of PAAL.

Scientific Name	Common Name	Number of Observations
Cnemidophorus gularis gularis	Texas spotted whiptail	26
Coluber constrictor oaxaca	Mexican racer	8
Crotalus atrox	Western diamondback rattlesnake	9
Drymarchon melanurus erebennus	Texas indigo snake	1
Gopherus berlandieri	Texas tortoise	10
Kinosternon flavescens	Yellow mud turtle	2
Elaphe guttata emoryi	Great Plains rat snake	7
Phrynosoma cornutum	Texas horned lizard	38
Pituophis catenifer sayi	Bullsnake	1
Masticophis flagellum testaceus	Western coachwhip	2
Masticophis schotti ruthveni	Ruthven's whipsnake	6
Salvadora grahamiae lineata	Texas patch-nosed snake	4
Sceloporus olivaceus	Texas spiny lizard	14
Sceloporus variabilis marmoratus	Rose-bellied lizard	167
Sonora semiannulata taylori	Taylor's ground snake	2
Tantilla nigriceps	plains black-headed snake	2

Species Distribution

As part of the park-wide reptile inventory, Duran (2004) also recorded the locations of reptile observations in PAAL. The inventory alone cannot provide complete species distributions within PAAL due to the lack of a quantitative distributional sampling design. This data is baseline information that can be used to develop a monitoring strategy, which could later provide species distributions within PAAL. Plate 13 displays the locations of the species observed during the inventory.

Threats and Stressor Factors

PAAL staff identified many threats to the reptile population of the park. Some of these threats include land use outside of the park, habitat loss, and climate change.

Climate change is an increasing concern for reptiles in PAAL. Increasing temperatures and drier climates cause stress on both plants and animals due to reduced water availability in already semi arid regions (Araujo et al. 2006). According to Araujo et al. (2006), reptiles have slow dispersal rates, and increasing aridity due to climate change may cause ranges to contract.

Habitat loss can be a major stressor to reptiles. Fragmentation and removal of habitat in the areas surrounding the park have been caused by the increasing rate of land development and conversion. The park, however, acts as a closed habitat island for herpetofauna (Woodman, written communication, January 2010). The current habitat patches may be a stable environment for the reptiles that reside in the park if the vegetation and landscape remain unchanged (Woodman, written communication, January 2010).

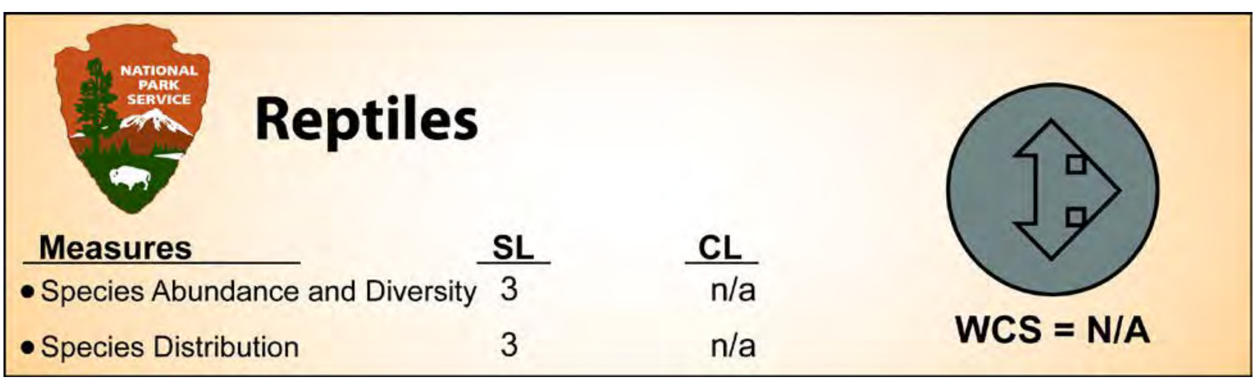
Data Needs/Gaps
Very little information is available that characterizes reptile population parameters in PAAL. Duran (2004) documented baseline information such as annotated checklists of herpetofauna and locations of reptiles found during the inventory. However, this inventory occurred over a short period of time and is nearly a decade old. Current and long-term annual or biannual monitoring efforts would provide information necessary to determine trends in population sizes or diversity, and species distribution. Annual monitoring of the populations in the park will allow for a more accurate assessment of these parameters. GULN is currently conducting limited monitoring of surface-active reptile abundance at three locations in the park; however, no results have yet been published.

Overall Condition
A number of species of snakes, lizards, and turtles have been documented in PAAL; however, very little information characterizing reptile populations is currently available. While the NPS has a record of confirmed species in the park, this list does not allow for estimates of abundance or distribution parameters. Thus, it is not possible to assess the condition of reptiles in PAAL at this time.

Species Abundance and Diversity
The project team defined the *Significance Level* for species abundance and diversity as a 3. The NPS Certified reptile species list for PAAL includes 21 reptiles (NPS 2013). However, the most recent abundance and diversity data for reptiles in the park is nearly a decade old. Because of this data gap, a *Condition Level* for this measure was not assigned.

Species Distribution
The project team defined the *Significance Level* for species distribution as a 3. There are no current available data characterizing the distribution of reptiles in PAAL. Therefore, it is not possible to assign a *Condition Level* for this measure.

Weighted Condition Score
A *Weighted Condition Score* for reptiles in PAAL was not assigned because both of the measures had unknown *Condition Levels*.



Sources of Expertise
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Robert Woodman, GULN Ecologist

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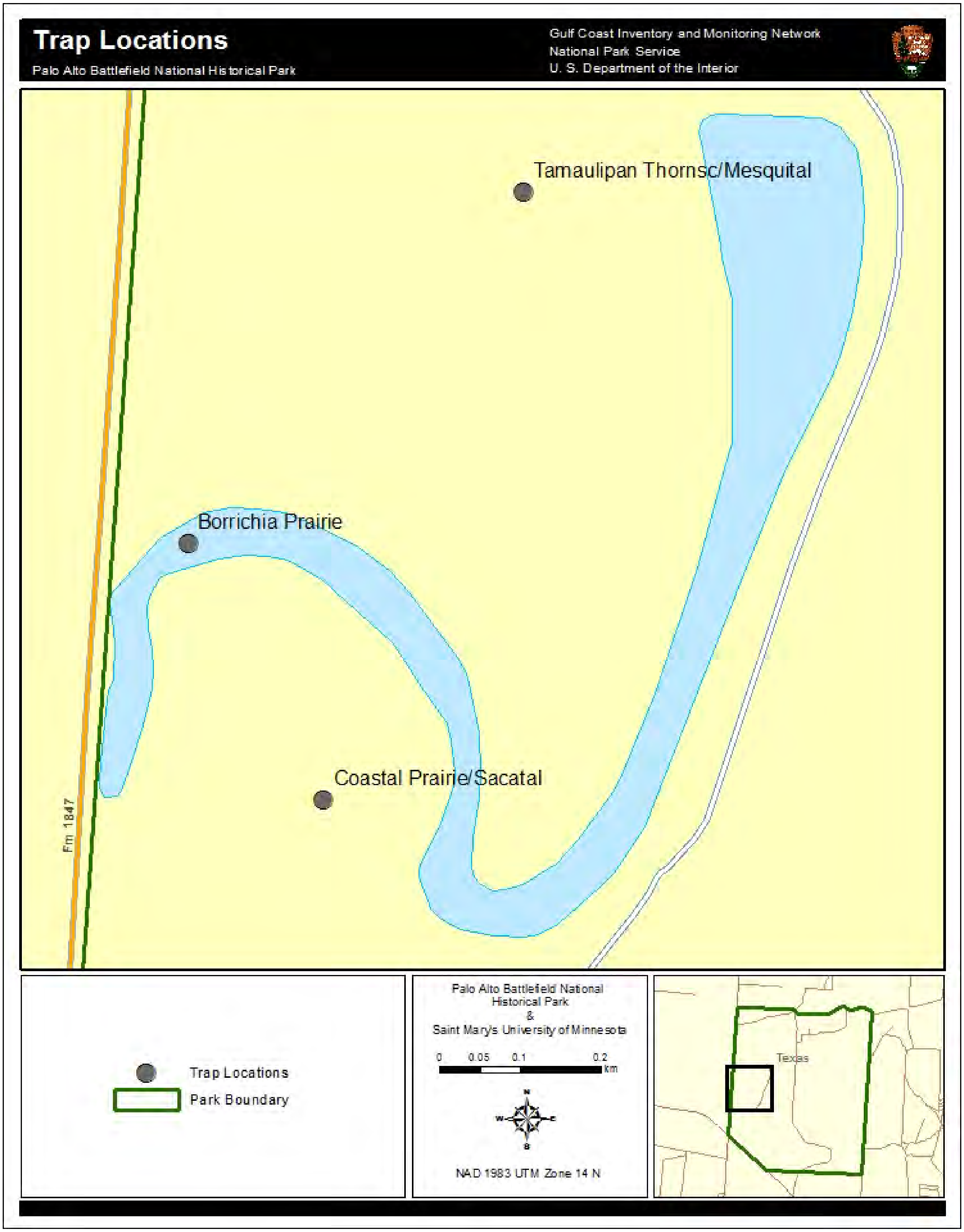


Plate 12. Locations of traps set during a reptile and amphibian inventory by Duran (2004) in PAAL between 2002 and 2003.

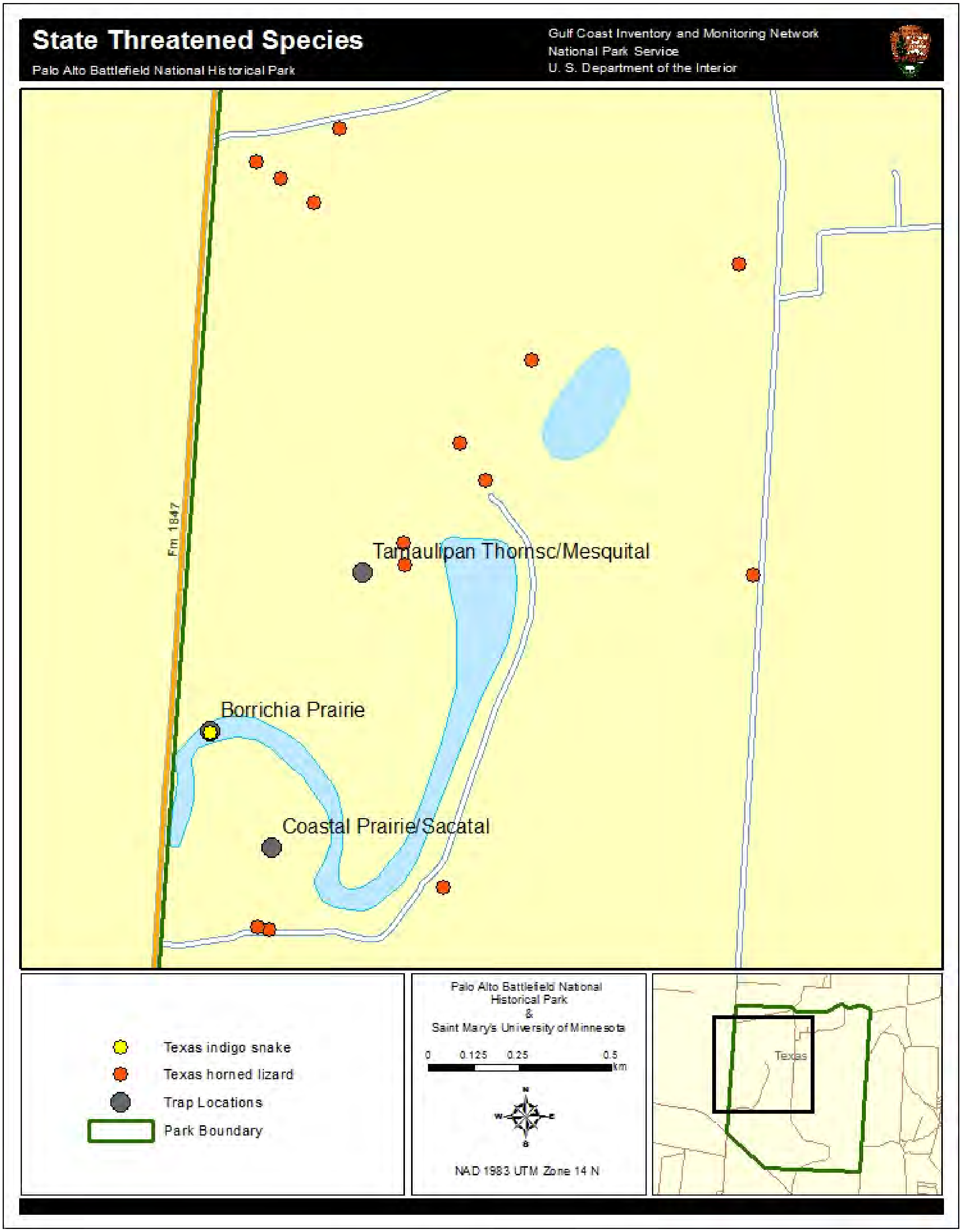


Plate 13. Locations of reptiles observed and trapped during a reptile and amphibian inventory by Duran (2004) in PAAL between 2002 and 2003.

4.13 Texas Tortoise

Description

The Texas tortoise (*Gopherus berlandieri*; Photo 30) is the smallest member of the *Gopherus* genus in North America. This small species is the most sexually dimorphic of the four *Gopherus* species (Judd and Rose 1983, Hellgren et al. 2000). It reaches its most northern limit in southern Texas, where it is state listed as threatened species (TPWD 2012).

Photo 30. Texas tortoise (Photo by Duran 2004).

Vegetation in PAAL is characteristic of Texas tortoise habitat, which allows the park to support a small population of the species. According to Duran (2004), Texas tortoises are fairly common in the park. During Duran (2004)'s study in 2002 and 2003, there were eight known tortoise locations in PAAL, including mesquital or thornscrub habitat (Duran 2004). Park staff at PAAL decided that the core measures needed to assess and monitor this species are population density and distribution, age class structure, and sex ratio.

Measures

- Population density and distribution
- Age class structure
- Sex ratio

Reference Conditions/Values

A reference condition has not been established for Texas tortoise in PAAL. The most comprehensive description of reptiles in the park comes from an inventory by Duran (2004).

Data and Methods

Duran (2004) conducted an inventory of reptiles and amphibians in PAAL, as well as two other GULN parks, during 2002 and 2003. Duran (2004) sampled three different sites, one each in borrichia prairie, coastal prairie/sacatal, and Tamaulipan thornscrub/mesquite habitats. Trapping methods included drift-fence arrays and coverboards; other observation types were visual encounters and auditory surveys. Observations were linked with GPS points to display relative distribution in the study area. Plate 14 displays the trap locations, as well as recorded Texas tortoise observations.

Bracewell and Woodman (2011) created a habitat model for Texas tortoise in PAAL. The model displays likely tortoise habitat by locating areas in the park that fit habitat requirements, such as mesquite ridges, prickly pear vegetation, and open canopy habitats away from the salt prairie. Field observations were also made, and tortoise locations were documented using GPS units.

Current Condition and Trend

<u>Population Density and Distribution</u>

Duran (2004) encountered eight tortoises during the survey. According to Duran (2004), the Texas tortoise was fairly common during the survey in mesquite and thornscrub vegetation (Photo 31). Seven tortoises were in Tamaulipan thornscrub/ mesquite habitats, and one was located in borrichia prairie.

Photo 31. A Texas tortoise in its burrow under prickly pear cactus in PAAL (NPS photo).

Bracewell and Woodman (2011) conducted a mark and recapture survey as part of an ongoing effort coordinated by the GULN. The 2011 survey documented as many as 50 tortoise locations in PAAL. The tortoise population seemed to be most dense in the southwestern section of the park; however, several tortoises were observed in the northwestern section of the park. Most of the observations were found in the “likely habitat” the model predicted, which consists of mesquite lomas with open canopy vegetation. The Twin Ridges are an exception to the model; at least five tortoises were found in a small area here (Bracewell and Woodman 2011).

Surveys have taken place in the years following Bracewell and Woodman (2011); however, the data are not yet published. Robert Woodman (written communication, 30 August 2013) indicates that the PAAL tortoise data summary report is currently in draft form, and will be ready for publication as a NPS NRDS report in late 2013. This report will summarize tortoise summaries from 2008-2013. Below is a brief summary of this unpublished report's findings regarding density and distribution in PAAL:

- 157 tortoises were named and marked (tortoises were collected and assigned an ID number during biannual sampling from May 2008 – Present). Each tortoise has an initial GPS-located encounter point;

- 330 tortoise encounters were recorded between May 2008 and May 2013. Each encounter had time, date, tortoise ID, weight, and GPS location recorded;

- Recaptures-per-tortoise ranged from 0-6;

- Tortoises were observed at Twin Ridges from 2008-2011, but no observations have been made since 2011 and researchers believe the site has dried out and lost necessary vegetation cover;

- Estimated density of tortoises in "better habitat" may be quite comparible to those reported in research literature, although this has not yet been analyzed in the PAAL data;

- Current density estimates suggest that there are over four tortoises per hectare in PAAL, and that the estimated home ranges of tortoises in the area are as small as 1 ha or less.

Age Class Structure
At the time of publication, there are limited data regarding tortoise age class structure in PAAL. Similar to the previous measure, data related to age class structure will be part of the yet to be published NPS NRDS report for PAAL. Mark-recapture based population estimates indicate that the 93 ha (230 ac) of "better habitat area" in PAAL may harbor 905 individuals that are age 12+ (Woodman, written communication, 30 August 2013). Further discussions of age class structure will be available in the NRDS report when it becomes available.

Sex Ratio
Similar to the age class structure measure, there are limited data regarding the sex ratio of the tortoise population in PAAL available at this time. However, Robert Woodman (written communication, 30 August 2013) provided some preliminary data from the yet to be published NPS NRDS report for PAAL. Tortoise surveys from 2008-2013 found that the sex structure in 136 adults that were aged $\geq$12 was 48% male to 52% female. The continued GULN monitoring efforts, combined with the upcoming NRDS report for the park, will provide greater detail on this measure and will allow for a future assessment of condition in the coming years.

Threats and Stressor Factors
Threats to the PAAL Texas tortoise population, as identified by park staff, include land use outside of the park, habitat loss, and feral hogs.

Urbanization and growing agricultural practices outside the park threaten the Texas tortoise. Habitat is lost or fragmented when native brushland is cleared for new housing, roadways, and farms. According to Thode (1999), the Rio Grande Valley is one of the fastest growing areas for urbanization and agriculture in Texas. Increased highway traffic has also caused mortality to tortoises crossing roads, and growing numbers of agricultural plots separate tortoise populations with fencing, leading to population bottlenecks (Thode 1999). However, it is likely that urbanization and land changes outside of the park will only affect the extra-PAAL tortoise population (Woodman, written communication, 30 August 2013). Robert Woodman has expressed the notion that PAAL may actually be gaining tortoise habitat (supported by the substantial increase in brush habitat in the park observed by aerial images of 1940 and present). If PAAL continues to be drained and continues to see brush development and recruitment, it may be a reasonable conclusion that "better habitat" is increasing in the park (Woodman, written communication, 30 August 2013).

Feral hogs, a non-native species, may be a direct and indirect threat to the Texas tortoise in PAAL. Feral hogs have been known to negatively affect native wildlife through habitat loss and depredation. Feral hogs cause habitat loss by foraging on native vegetation (Jolley et al. 2010). Feral hogs not only cause habitat loss, but they have also been observed preying on eggs and adult Texas tortoises in Texas (Taylor and Hellgren 1997, as cited by Jolley 2007).

Data Needs/Gaps

Little information is available regarding the Texas tortoise population in PAAL. Duran (2004) describes a possible distribution within the park. However, the survey is outdated. Bracewell and Woodman (2011) data and model are current but not long-term. The GULN has continued the tortoise surveys in the park and monitors the park's population two times a year (Segura, written communication, 29 March 2013). However, the results of these surveys were not available at the time of this document's publication. Annual monitoring of tortoise density, distribution, age class structure, and sex ratio of tortoises in the park is necessary to make a more accurate assessment of these parameters, and GULN monitoring should continue in order to create a robust data set for this component.

Overall Condition

The condition assignments for the measures in this component did not factor in the recent data from the NPS NRDS document that is currently in press. The data from that document will likely provide necessary information that would better facilitate a *Condition Level* assignment. The condition of this component will likely need to be re-evaluated when that document has been published.

Population Density and Distribution

The project team defined the *Significance Level* for population density and distribution as a 3. Bracewell and Woodman (2011) data and model display the locations of Texas tortoise during the recent survey, but more information and further surveys are needed to identify any trends. Due to the lack of data regarding this measure, a *Condition Level* was not assigned.

Age Class Structure

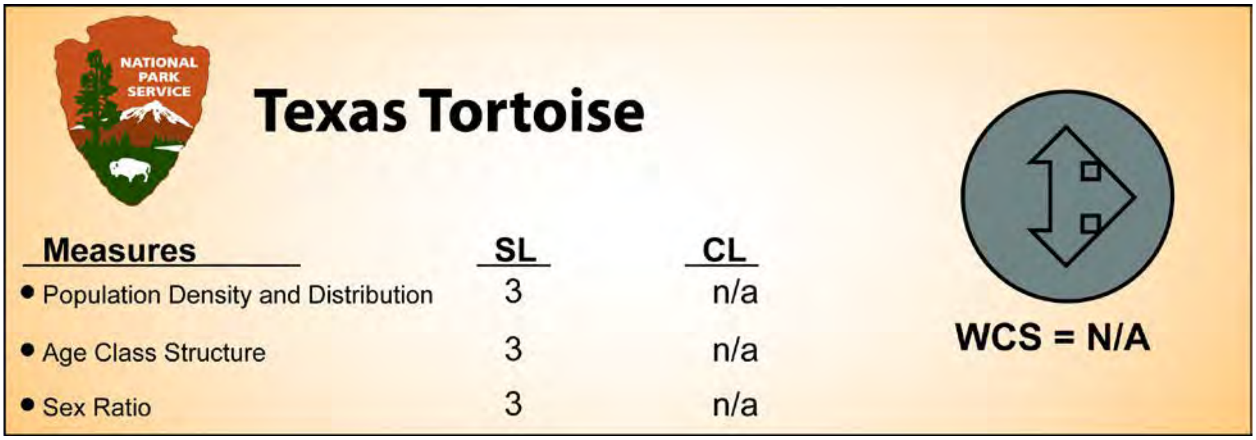
The project team defined the *Significance Level* for age class structure as a 3. There are no available data characterizing the age class structure of Texas tortoise in PAAL. Because of this data gap, a *Condition Level* was not assigned for this measure.

Sex Ratio

The project team defined the *Significance Level* for sex ratio as a 3. There are no available data characterizing the sex ratio of Texas tortoise in PAAL; therefore, a *Condition Level* was not assigned for this measure.

Weighted Condition Score

A *Weighted Condition Score* was not assigned for the Texas tortoise in PAAL because all of the measures had unknown *Condition Levels*.



Sources of Expertise

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Robert Woodman, GULN Ecologist

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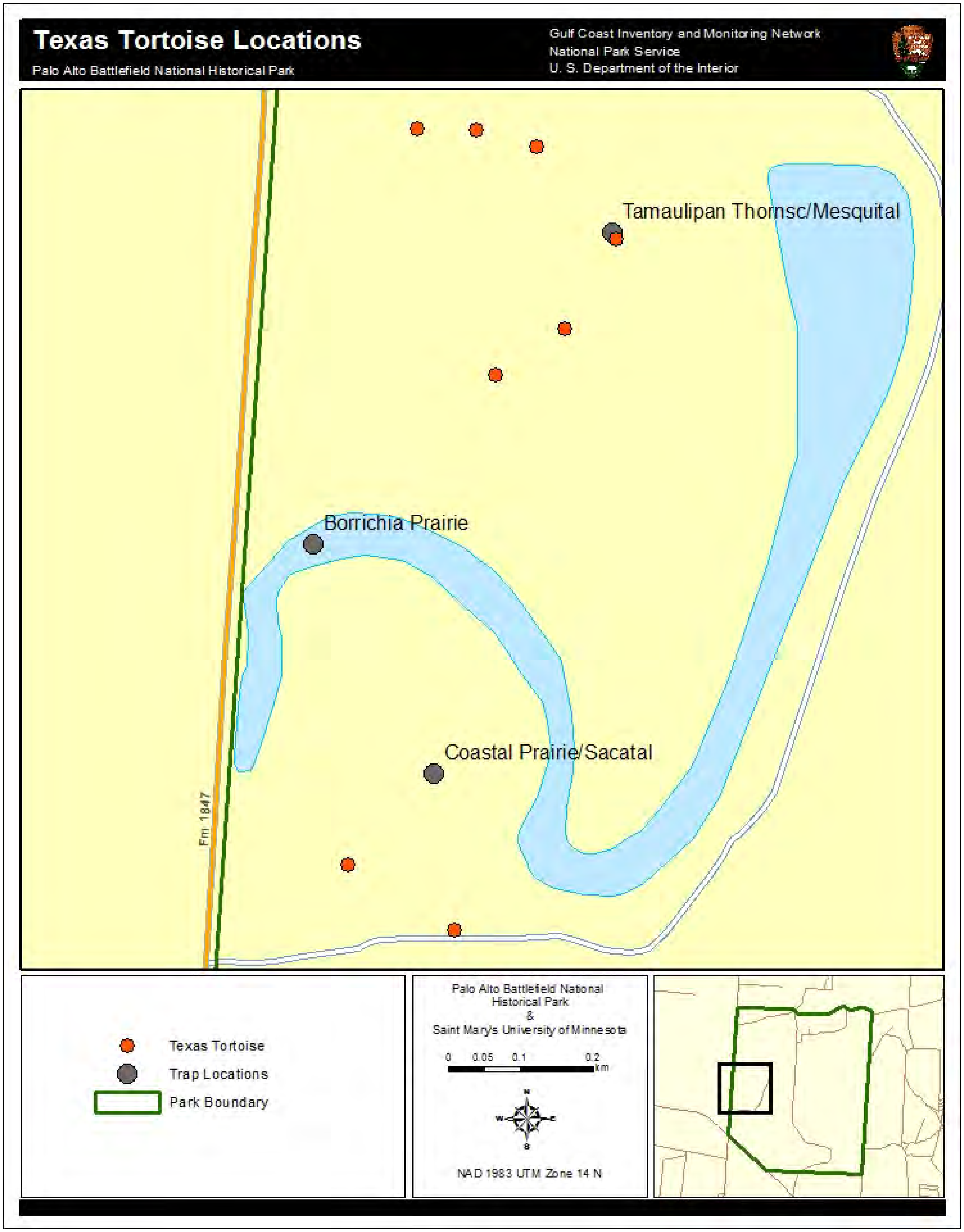

Plate 14. Locations of tortoises encountered in PAAL during the 2002-2003 reptile and amphibian inventory by Duran (2004).

4.14 Air Quality

Description

Air pollution can significantly affect natural resources and their associated ecological processes. Consequently, air quality in parks and wilderness areas is protected and regulated through the 1916 Organic Act and the Clean Air Act of 1977 (CAA) and the CAA's subsequent amendments. The CAA defines two distinct categories of protection for natural areas, Class I and Class II airsheds. Class I airsheds receive the highest level of air quality protection as offered through the CAA; only a small amount of additional air pollution is permitted in the airshed above baseline levels. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas and allow for moderate development (EPA 2008a). PAAL is designated as a Class II airshed.

Measures

- Atmospheric deposition of nitrogen
- Atmospheric deposition of sulfur
- Ozone concentration
- Particulate matter ($PM_{2.5}$)
- Visibility

Atmospheric Deposition of Nitrogen and Sulfur:

Nitrogen and sulfur oxides are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2008b). While in the atmosphere, these emissions form compounds that may be transported long distances and settle out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia) (EPA 2008b, NPS 2008). Atmospheric deposition can be in wet (i.e., pollutants dissolved in atmospheric moisture and deposited in rain, snow, low clouds, or fog) or dry (i.e., particles or gases that settle on dry surfaces as with windblown dusts) form (EPA 2008b). Deposition of sulfur and nitrogen can have significant effects on ecosystems including acidification of water and soils, excess fertilization or increased eutrophication, changes in the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water, and vegetation (NPS 2008, reviewed in Sullivan et al. 2011a and 2011b). The native vegetation in the arid and semi-arid plant communities in PAAL may be sensitive to excess nitrogen and acidic deposition (Sullivan et al. 2011c, 2011d).

Ozone

Ozone occurs naturally in the earth's atmosphere where, in the upper atmosphere, it protects the earth's surface against ultraviolet radiation (EPA 2008b). However, it also occurs at the ground level (i.e., ground-level ozone) where it is created by a chemical reaction between nitrogen oxides and volatile organic compounds (VOCs) in the presence of heat and sunlight (NPS 2008). Ozone is also one of the most widespread pollutants affecting vegetation and human health in the U.S. (NPS 2008). Considered phytotoxic, ozone can cause significant foliar injury and growth effects for sensitive plants in natural ecosystems (EPA 2008a, NPS 2008). Specific effects include reduced photosynthesis, premature leaf loss, and reduced biomass, and prolonged exposure can increase vulnerability to insects and diseases or other environmental stresses (NPS 2008). At high concentrations, ozone can aggravate respiratory and cardiovascular diseases in humans, reduce lung function, cause acute respiratory problems, and increase susceptibility to respiratory infections (EPA 2008b, EPA 2010a); this could be a concern for visitors and park staff engaging in aerobic activities in the park, such as hiking.

Particulate Matter (PM) and Visibility:
Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets suspended in the atmosphere. Fine particles ($PM_{2.5}$) are those smaller than 2.5 micrometers in diameter (EPA 2009). Particulate matter largely consists of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2008a, EPA 2009). Fine particles are a major cause of reduced visibility (haze) in many national parks and wildernesses (EPA 2010b). $PM_{2.5}$ can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries, and/or vehicles react with air (EPA 2009, EPA 2010b). Particulate matter either absorbs or scatters light. As a result, the clarity, color, and distance seen by humans decreases. Water in the atmosphere causes particles like nitrates and sulfates to expand, increasing their light-scattering efficiency (EPA 2010b). $PM_{2.5}$ is also a concern for human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2008b, EPA 2009, EPA 2010b). Short-term exposure to these particles can cause shortness of breath, fatigue, and lung irritation (EPA 2008b, EPA 2009).

Reference Conditions/Values
The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks, based on the current National Ambient Air Quality Standards (NAAQS), ecosystem thresholds, and visibility improvement goals (NPS 2010a). Table 25 shows the air quality index values used to assess air quality in national parks. Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Ozone condition is based on the NAAQS standard of 75 parts per billion (ppb) (an annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years). Visibility conditions are assessed in terms of a Haze Index, a measure of visibility, termed deciviews, that is derived from calculated light extinction and represents the minimal perceptible change in visibility to the human eye (NPS 2010a). Finally, NPS ARD recommends the following values for determining air quality condition (Table 25). The “good condition” metrics may be considered the reference condition for PAAL.

Table 25. National Park Service Air Resources Division air quality index values (NPS 2010a).

Condition	Ozone concentration (ppb)	Wet Deposition of N or S (kg/ha/yr)	Visibility (dv*)
Significant Concern	≥76	>3	>8
Moderate Condition	61-75	1-3	2-8
Good Condition	≤60	<1	<2

*a unit of visibility proportional to the logarithm of the atmospheric extinction (TCEQ 2012); one deciview represents the minimal perceptible change in visibility to the human eye.

Data and Methods

Monitoring in the Park

There is no active on-site monitoring of air quality parameters at PAAL.

NPS Data Resources

Although data on air quality parameters are not actively collected within park boundaries, data collected at several regional monitoring stations for various parameters can be used to estimate air quality conditions in PAAL. NPS ARD provides estimates of ozone, wet deposition of nitrogen and sulfur, and visibility that are based on interpolations of data from all air quality monitoring stations operated by NPS, EPA, various states, and other entities, averaged over the most recent 5 years (2006-2010). These estimates are available from the Explore Air website (NPS 2012) and are used to evaluate air quality conditions. On-site or nearby data are needed for a statistically valid trends analysis, while a 5-year average interpolated estimate is preferred for the condition assessment. NPS (2010b) describes air quality conditions and trends in an annual report for over 200 park units, including PAAL.

Other Air Quality Data Resources

The National Atmospheric Deposition Program–National Trends Network (NADP) database provided annual average summary data for nitrogen and sulfur concentration and deposition in the southern coastal Texas region. Monitoring site TX39, located in Corpus Christi, Texas, is approximately 193 km (120 mi) north of PAAL. Although no longer operational, this site provided deposition data for the region from 2002 through 2006. Results from monitors located within 16 km (10 mi) from parks are generally considered to be representative of park conditions (Ellen Porter, NPS Air Resources Division Air Quality Specialist, phone communication, 25 October 2012). Data recorded at monitors beyond this distance from parks may represent regional conditions, but may not be representative of actual park conditions.

The EPA Air Trends database provides annual average summary data for ozone concentrations near PAAL. Monitoring site number 48-061-0006 is operated by the Texas Commission on Environmental Quality (TCEQ) and is located in Brownsville, Texas, approximately 8 km (5 mi) south of PAAL (EPA 2012). The Air Trends database also provided data for particulate matter concentrations ($PM_{2.5}$) from two monitoring sites in the region. The San Benito monitoring site (ID 48-061-2002), located approximately 18 km (11 mi) northwest of PAAL, collected data from January 1999 through August 2005. The Isla Blanca Park monitoring site (ID 48-061-2004), located approximately 32.3 km (20.1 mi) east of PAAL on the southern point of South Padre Island, Texas, has been actively collecting particulate matter data for the region since August 2005.

The Clean Air Status and Trends Network (CASTNet) provides summaries of the composition of nitrogen and sulfur deposition in various regions around the U.S. Similarly, the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program actively monitors visibility conditions in Class I airsheds across the U.S. However, the nearest CASTNet and IMPROVE monitoring sites are located in Big Bend National Park, approximately 740 km (460 mi) northwest of PAAL. The distance of these monitors from PAAL and the variations among terrain make it difficult to extrapolate data accurately; thus, data from these monitoring stations was not considered in this assessment.

Special Air Quality Studies

Sullivan et al. (2011a) assessed the relative sensitivity of national parks to the potential effects of acidification caused by acidic atmospheric deposition from nitrogen and sulfur compounds. The relative risk for each park was assessed by examining three variables: the level of exposure to emissions and deposition of nitrogen and sulfur; inherent sensitivity of park ecosystems to acidifying compounds (N and/or S) from deposition; and level of mandated park protection against air pollution degradation (i.e., Wilderness and Class I). The outcome was an overall risk assessment that estimates the relative risk of acidification impacts to park resources from atmospheric deposition of nitrogen and sulfur (Sullivan et al. 2011a). Using the same approach, Sullivan et al. (2011b) assessed the sensitivity of national parks to the effects of nutrient enrichment by atmospheric deposition of nitrogen. The outcome was an overall risk assessment that estimates the relative risk to park resources of nutrient enrichment from increased nitrogen deposition.

Current Condition and Trend

Atmospheric Deposition of Nitrogen and Sulfur

Five-year interpolated averages of total nitrogen (from nitrate and ammonium) wet deposition and total sulfur (from sulfate) wet deposition are used to estimate condition for deposition; using a 5-year average smoothes out annual variations in precipitation, such as heavy precipitation one year versus drought conditions in another. The current 5-year average (2006-2010) estimates total wet deposition of nitrogen in PAAL at 2.4 kg/ha/yr, while total wet deposition of sulfur is 2.2 kg/ha/yr (NPS 2012). Relative to the NPS ratings for air quality conditions (see Table 25 for ratings values), atmospheric deposition of both nitrogen and sulfur falls into the *Moderate Concern* category. However, several factors are considered when rating the condition of atmospheric deposition, including effects of deposition on different ecosystems (NPS 2010a). Based on the NPS process for rating air quality conditions, ratings for parks with ecosystems considered potentially sensitive to nitrogen or sulfur deposition typically are adjusted up one condition category. In general, arid and semi-arid ecosystems are considered to be sensitive to increased levels of nitrogen and sulfur, as acidification and nutrient enrichment can cause shifts in native species composition and allow encroachment of exotic species and grasses (reviewed in Sullivan et al. 2011a and 2011b). PAAL comprises arid and semi-arid vegetation communities, which may be at risk from increased deposition, particularly nitrogen. Thus, the condition for deposition of nitrogen and sulfur in PAAL may be considered of *Significant Concern*.

Figure 13 shows the annual average concentrations of sulfate, nitrate, and ammonium recorded in Corpus Christi, Texas, the NADP monitor nearest to PAAL (approximately 193 km [120 mi] north of the park).

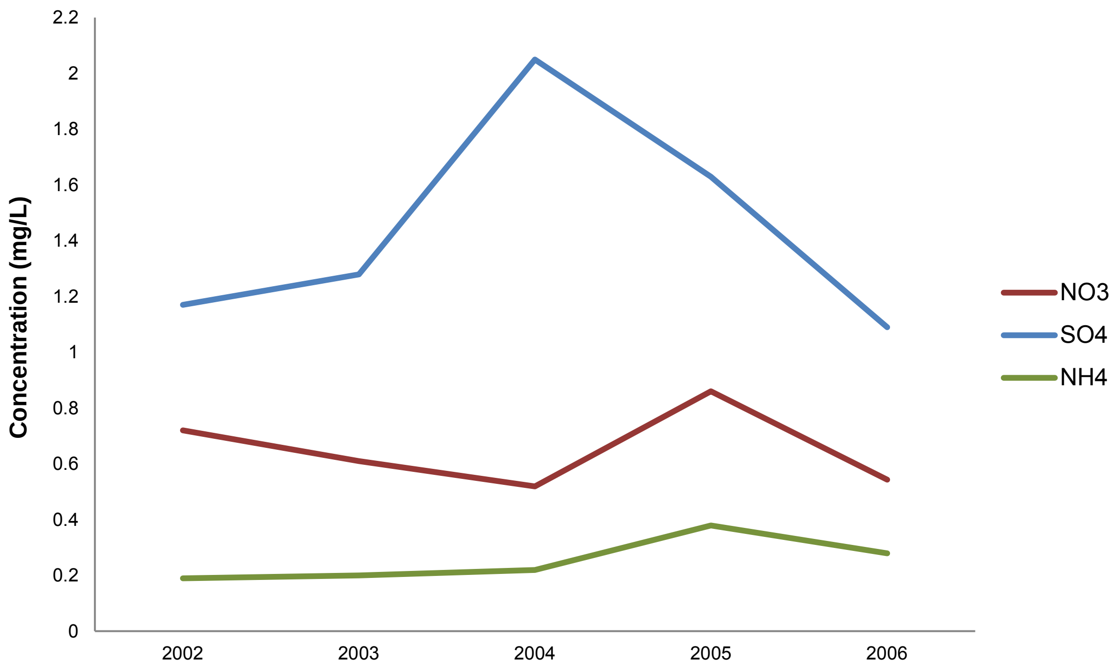

Figure 13. Annual average concentrations of sulfate (SO_4), nitrate (NO_3), and ammonium (NH_4) (mg/L) in Corpus Christi, Texas, 2002-2006 (NADP monitoring site TX39, located approximately 193 km north of PAAL) (Source: NADP 2012). Note: Ammonium (NH_4) is included because it adds significantly to total nitrogen deposition.

Relative risk of acidification and nutrient enrichment of ecosystems was assessed by examining exposure to nitrogen deposition and acidification, inherent sensitivity of park ecosystems, and mandates for park protection. Sullivan et al. (2011c) ranked PAAL as having moderate acidifying (nitrogen and sulfur) pollutant exposure, very low ecosystem sensitivity to acidification, and moderate park protection due to its Class II airshed status. The relative ranking of overall risk from acidification due to acid deposition was low relative to other parks (Sullivan et al. 2011c). In a separate examination, Sullivan et al. (2011b) used the same approach to assess the sensitivity of national parks to nutrient enrichment effects from atmospheric nitrogen deposition relative to other parks. PAAL was ranked as having moderate risk for nitrogen pollutant exposure, moderate ecosystem sensitivity, and moderate park protection mandates (Class II airshed). The relative ranking of overall risk of effects from nutrient enrichment from atmospheric nitrogen deposition was low relative to other parks (Sullivan et al. 2011d).

Ozone Concentration

The NAAQS standard for ground-level ozone is the benchmark for rating current ozone conditions within park units. In 2008, the standard was strengthened from 80 ppb to 75 ppb, based on the annual 4^{th} highest daily maximum 8-hour concentration, averaged over 3 years. The condition of ozone in NPS park units for trends reporting by NPS is determined by calculating the 5-year average of the fourth-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2010a). The current 5-year average (from 2006-2010) for PAAL indicates an average ground-level ozone concentration of 64.2 ppb (NPS 2012), which falls under the *Moderate Concern* category based on NPS guidelines. Trend analysis of data from 1999-2008 indicate ozone concentration to be of moderate concern with no statistically significant degradation or improvement in condition (NPS 2010b).

Ozone concentrations are monitored daily by the TCEQ in Brownsville, Texas, approximately 8 km (5 mi) south of PAAL. Figure 14 illustrates the annual fourth-highest daily maximum of 8-hour average concentrations. Results from monitors located within 16 km (10 mi) from parks are considered to be representative of park conditions (Porter, phone communication, 25 October 2012). Concentrations near PAAL have been relatively stable over the last 15 years, fluctuating between 60 and 70 ppb, and are well within the NAAQS standard protective of human health.

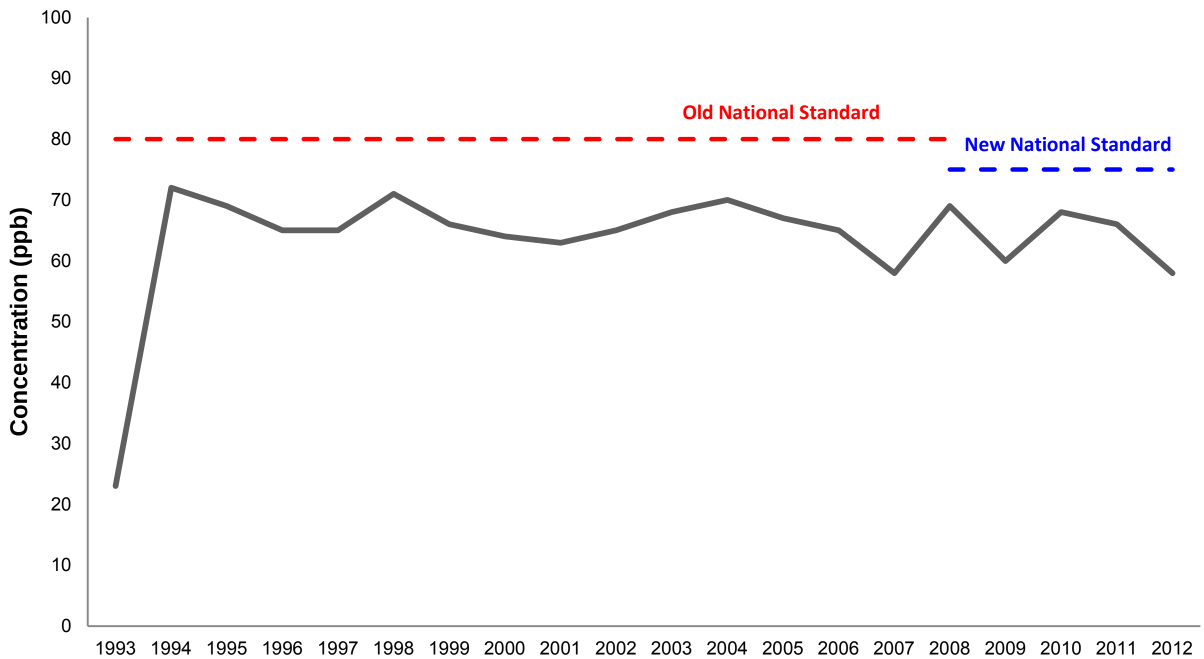

Figure 14. Annual 4th highest 8-hour maximum ozone (O_3) concentrations (ppb) near PAAL, 1993-2012 (Source: EPA 2012). Considerably lower concentrations in 1993 are due to limited data collection period (December only when the monitor came on line) and reflects only one month of ozone concentration data. Note: Site 48-061-0006 is the monitor located in Brownsville, Texas, approximately 8 km (5 mi) south of PAAL. Monitors located within 16 km (10 mi) of the park are considered representative of park conditions. Prior to 2008, the NAAQS ozone standard was 0.08 ppm (80 ppb) (shown in red); in March 2008, the standard was amended to 0.075 ppm (75 ppb) (shown in blue).

Kohut (2004) assessed ozone concentrations in the GULN and the risk of injury to plant species that are sensitive to sustained ozone exposure. Data from 1995-1999 indicate ozone concentrations in PAAL during this time frequently exceeded 60 ppb for a few hours each year and occasionally exceeded 80 ppb for a few hours each year. No year during observation experienced more than 3 hours in which concentrations exceeded 100 ppb; however, at these levels, it is possible for vegetation to sustain injury. Sensitive plant species begin to experience foliar injury when exposed to ozone concentrations of 80-120 ppb/hour for extended periods of time (8 hours or more); the levels of exposure experienced in PAAL are not likely to cause foliar damage (Kohut 2004). Overall, the frequently low soil moisture conditions in PAAL and the low levels of ozone exposure make the risk of foliar injury to plants low (Kohut 2004). No ozone sensitive plants have been identified in PAAL (Kohut 2004).

Particulate Matter ($PM_{2.5}$)

The NAAQS standard for $PM_{2.5}$ is a weighted annual mean of 15.0 µg/m^3 or 35 µg/m^3 in a 24-hour period over an average of 3 years (EPA 2010b). Data on average particulate matter concentrations, collected at two different monitoring stations in the PAAL region, are available from 2000 through 2012. Average annual $PM_{2.5}$ concentrations in the PAAL region have been relatively stable since 2000 (Figure 15). Although $PM_{2.5}$ concentrations in PAAL are well within the EPA standards for levels that are protective of human health; concentrations on the haziest days contribute to impaired visibility in the park.

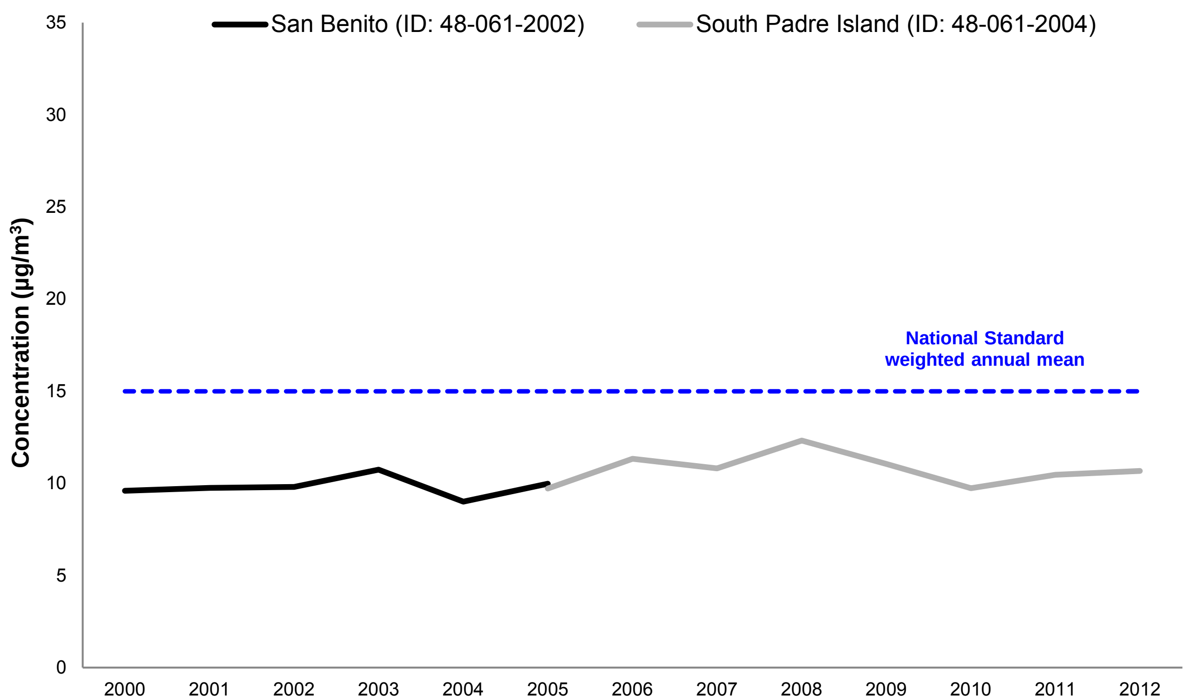

Figure 15. Annual particulate matter ($PM_{2.5}$) concentrations (weighted annual mean) near PAAL, 2000-2012 (EPA 2012). Note: San Benito monitoring site (ID 48-061-2002) is located approximately 18 km (11 mi) northwest of PAAL and the Isla Blanca Park monitoring site (ID 48-061-2004) is located approximately 32.3 km (20.1 mi) east of PAAL on the southern point of South Padre Island, Texas.

Visibility

Visibility impairment occurs when airborne particles and gases scatter and absorb light; the net effect is called “light extinction,” which is a reduction in the amount of light from a view that is returned to an observer (EPA 2003). In response to the mandates of the CAA, federal and regional organizations established IMPROVE in 1985 to aid in monitoring of visibility conditions in Class I airsheds. The goals of the program are to 1) establish current visibility conditions in Class I airsheds; 2) identify pollutants and emission sources causing the existing visibility problems; and 3) document long-term trends in visibility (NPS 2010b).

Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier.The most current 5-year average (2006-2010) estimates average visibility in PAAL to be 8.9 dv above average natural visibility conditions (NPS 2012). This falls into the *Moderate Concern* category for NPS air quality condition assessment.

The clearest and haziest 20% of days each year are also examined for parks (NPS 2012), and these are the measures used by states and EPA to assess progress toward meeting the national visibility goal. The most current 5-year average (2006-2010) estimates visibility at 8.7 dv on the 20% clearest days and 20.2 dv on the 20% haziest days (NPS 2012).

Threats and Stressor Factors

Park managers have identified a number of threats and stressors to air quality in PAAL. These include adjacent land use activities (e.g., particulate matter and smoke from agricultural burning), vehicle emissions from nearby highway/roads, development and emissions from nearby urbanized areas, air emissions carried on predominant winds from international sources, and emissions from nearby oil refineries and industrial plants located outside of Brownsville, near the boundaries of PAAL, and near the Gulf Coast.

Nitrogen deposition results from emissions of nitrogen oxides from vehicles, power plants, and other combustion sources, and ammonia from agricultural activities and fires. In ecosystems adapted to naturally low amounts of nitrogen, increased nitrogen deposition can alter plant communities and reduce diversity (Sullivan 2011b). Higher nitrogen levels favor certain plant species, like fast-growing invasive species, at the expense of native forbs and shrubs. Sulfur emissions and particulate matter often originate from such sources as coal-fired power plants, petroleum refining, and chemical processing operations, many of which are located in central, southern and coastal Texas, as well as northern Mexico. Prevailing seasonal winds may carry these emissions into PAAL.

Data Needs/Gaps

There are monitors in nearby Brownsville, Texas that provide particulate matter and ozone concentration data as both daily and annual average summaries. However, the nearest active NADP monitor that provides annual averages for nitrogen and sulfur deposition is located in Beeville, Texas, approximately 300 km (186 mi) north of PAAL. Likewise, the nearest CASTNet and IMPROVE sites, that monitor acid deposition and visibility respectively, are located in Big Bend National Park, over 700 km (434 mi) northwest of PAAL. Periodic or consistent monitoring of nitrogen and sulfur deposition and visibility would help managers better understand the local air quality condition in and around PAAL.

Overall Condition

Nitrogen Deposition

The *Significance Level* for atmospheric deposition of nitrogen was defined as a 3. Sullivan et al. (2011b, 2011d) and NPS (2010a) rate the arid and semi-arid ecosystems in PAAL as moderately sensitive to nutrient enrichment by nitrogen deposition. Current estimates for nitrogen deposition are considered to be of moderate to significant concern based on NPS criteria for rating air quality when factoring in the sensitivity of the ecosystem. However, no data are collected in or nearby PAAL to be able to understand local or regional deposition rates or trends over time. Deposition of nitrogen is currently of moderate concern (*Condition Level* = 2).

Sulfate Deposition
The *Significance Level* for atmospheric deposition of sulfate was defined as a 3. Sullivan et al. (2011a, 2011c) rate the sensitivity of arid and semi-arid ecosystems in PAAL to acidification by sulfur deposition and other acids as low. Current estimates for sulfate deposition fall into the moderate to significant concern category based on NPS criteria for rating air quality when factoring in sensitivity of the ecosystem. No data are collected in or nearby PAAL to be able to understand local or regional deposition rates or trends over time. Deposition of sulfate is of moderate concern (*Condition Level* = 2).

Ozone Concentration
The *Significance Level* for ozone concentration was also defined as a 3. Current average ground-level ozone concentrations fall into the moderate concern category based on NPS criteria for rating air quality. Likewise, trend analysis of data from 1999-2008 indicate ozone concentration to be of moderate concern but with no statistically significant degradation or improvement in condition (NPS 2010b). Annual average concentrations (1993 through 2012) indicate a stable trend that is well within EPA standards protective of human health. Kohut (2004) suggests concentrations rarely exceed 80 ppb each year and that dry soil conditions and overall low ozone exposure make risk of foliar injury to plants low. Therefore, the *Condition Level* for ozone concentration is a 1, of low concern.

Particulate Matter Concentration ($PM_{2.5}$)
The *Significance Level* for concentration of fine particulate matter ($PM_{2.5}$) was defined as a 3. $PM_{2.5}$ concentrations near PAAL are well within the EPA standards for levels that are protective of human health. However, it is likely that particulate matter on the haziest days contributes to impaired visibility in the park. The *Condition Level* for $PM_{2.5}$ is a 1, of low concern.

Visibility
The *Significance Level* for visibility was defined as a 3. Current visibility estimates for PAAL, derived from interpolated averages, fall into the moderate concern category based on NPS criteria. However, no data are collected at the park, and the nearest visibility monitor is over 700 km (430 mi) away, which makes it difficult to determine average visibility conditions in PAAL or any trends in visibility conditions. The *Condition Level* for visibility is unable to be determined.

Weighted Condition Score
The *Weighted Condition Score* for the air quality component is 0.500, indicating the condition is of moderate concern with a stable trend.

Air Quality

Measures	SL	CL
• Nitrogen deposition	3	2
• Sulfur deposition	3	2
• Ozone concentration	3	1
• $PM_{2.5}$ concentration	3	1
• Visibility	3	n/a

WCS = 0.500

Sources of Expertise

Ellen Porter, NPS Air Resources Division Air Quality Specialist

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4.15 Water Quality

Description

Water quality is a Vital Sign for parks in the GULN, including PAAL. Remnant oxbow lakes, or resacas, are some of the main surface water features in the park (Farmer 1992). There are no perennial surface water bodies in the main park unit of PAAL; the Resaca de la Palma unit of PAAL is bordered on three sides (north, east, and south) by the Resaca de la Palma, a remnant oxbow of the Rio Grande that is now used for flood control, water storage, wildlife habitat, irrigation, and adding aesthetics to the City of Brownsville (Photo 32).

In the main park unit, most resacas have filled in with sediment over time. Several agricultural or livestock tanks were excavated within the resacas to provide water for irrigation and livestock during times of farming and ranching. At present, these features will fill with and retain water after heavy rain events and tropical storms (Meiman 2006); however, this is only temporary. The ephemeral nature of available water in resacas provides little opportunity for aquatic life, such as fish, to establish and thrive.

Photo 32. Looking southeast over the Resaca de la Palma from the viewing platform at the Resaca de la Palma unit of PAAL (Photo by Shannon Amberg, SMUMN GSS).

Measures

- Temperature
- Total dissolved solids
- Dissolved oxygen
- pH
- Prevalence of fecal coliform
- Prevalence of heavy metals (mercury)
- Prevalence of nutrients (phosphates, nitrates)

Temperature

Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can temperature affect the ability of water to hold oxygen, but it also affects biological activity and growth within water systems (USGS 2010). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range for existence (USGS 2010). As temperature increases or decreases too far past this range, the number of species and individuals able to live there eventually decreases. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water, making them more toxic to aquatic life (USGS 2010).

Total Dissolved Solids

Total dissolved solids (TDS) represent the concentration of dissolved inorganic and organic matter in the water. Most TDS are inorganic salts including calcium, magnesium, carbonates, nitrates, chlorides, and sulfates (SDWF 2012). These make their way into waterways primarily through runoff. Sources of TDS often include erodible landscapes that deposit materials into waterways, mineral springs, and agricultural or urban runoff. The concentration of TDS affects the water balance in the cells of aquatic organisms (EPA 2012a); if the TDS are extremely low, an organism's cells will swell, and if the TDS are too high, an organism's cells will shrink. The TDS determines the ease of an organism's ability to remain in the water column (EPA 2012a). One way of measuring the presence of dissolved solids is through specific conductance of water, which is the measure of the ionic activity and content of water, or water's ability to conduct electricity. The higher the concentration of dissolved solids (calcium, various salts, magnesium, etc.), the higher the conductivity of the water will be. Specific conductance is presented here as a measure for understanding concentrations of dissolved solids in surface and ground waters near PAAL.

Dissolved Oxygen

Dissolved oxygen (DO) is critical for organisms that live in water. In order to survive, fish and zooplankton filter out or "breathe" dissolved oxygen from the water (USGS 2010). Oxygen enters water from the air, when atmospheric oxygen mixes with water at turbulent, shallow riffles in a waterway, or when released by algae and other plants as a byproduct of photosynthesis. As the amount of DO drops, it becomes more difficult for aquatic organisms to survive (USGS 2010). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than warm water (USGS 2010). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2010).

pH

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7 being neutral (USGS 2010). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2010). Chemicals in water can change the pH and harm animals and plants living in the water; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2010).

Fecal Coliform (*E. coli*)

Bacteria are a common natural component of surface waterways and are mostly harmless to humans. However, certain bacteria, specifically those found in the intestinal tracts and feces of warm-blooded animals, can cause illness in humans (USGS 2011a). Fecal coliform bacteria are a subgroup of coliform bacteria that, when used in monitoring water quality, can indicate if fecal contamination has occurred in a specific waterway. *Escherichia coli* (*E. coli*) is a specific species of bacteria that belongs to the larger group of coliform bacteria and is characterized by its ability to break down urease (an enzyme that breaks down urea into carbon dioxide and ammonia) (USGS 2011a). Thus, *E. coli* is a preferred indicator for determining if potential pathogens are present in freshwater resources. It is tested by counting colonies that grow on micron filters placed in an incubator for 22-24 hours. High concentrations of *E. coli* can cause serious illness in humans (USGS 2011a).

Heavy Metals

Mercury naturally occurs in the air, water, rocks, and soil; it can exist in a number of forms including elemental mercury or as inorganic or organic mercury compounds (EPA 2012b). Originating from coal combustion, waste incineration, mining activities, and natural sources such as volcanic eruptions that send mercury into the atmosphere, airborne mercury can eventually settle to the ground through precipitation, dust, or through gravity-induced deposition (EPA 2012c). Once deposited, it can accumulate in surface waters where, through microbial activity, it is converted to methylmercury, a neurotoxin that is biomagnified in the aquatic food web (EPA 2012c). Methylmercury can bioaccumulate in fish tissues and further affect birds and mammals that consume mercury-laden fish; methylmercury exposure in animals and birds can result in death, reduced fertility, slowed growth and development, and abnormal behavior (EPA 2012c). Human exposure to mercury can affect the nervous system and harm the brain, heart, kidneys, lungs, and immune system of humans (EPA 2012b).

Nutrients

Nutrients, such as nitrogen and phosphorus, are crucial in supporting healthy aquatic environments; however, elevated concentrations of these nutrients can negatively impact water quality and threaten the ability of plants and aquatic organisms to thrive (USGS 2013a). Nitrogen occurs naturally in the atmosphere and in soils and is deposited into surface waters through precipitation and runoff; nitrogen deposition is increased by human inputs such as sewage, fertilizers, and livestock waste (USGS 2013b). Nitrates can cause a host of water quality related problems when present in high concentrations including, but not limited to, excessive plant and algae growth, eutrophication, and depleted dissolved oxygen available to aquatic organisms (USGS 2013b). Nitrogen, when present as nitrate, in drinking water can be harmful to humans, particularly young children, and livestock (USGS 2013b). Phosphorus is commonly found in agricultural fertilizers, manure, organic wastes in sewage, and sometimes industrial effluent (USGS 2013b). In excess, phosphorus in water systems can increase the rate of eutrophication, encourage overgrowth of plants, deplete dissolved oxygen, and threaten fish and macroinvertebrate populations (USGS 2013b). Soil erosion is the primary contributor of phosphorus input into surface waters, in which enriched soils are deposited into waterways through runoff during heavy precipitation events (USGS 2013b).

Reference Conditions/Values

The reference condition for PAAL's water quality is the TCEQ water quality criterion considered to be protective of aquatic life and human recreation and bathing. Table 26 shows the standards for various surface water quality parameters set by the TCEQ.

Table 26. Texas Commission on Environmental Quality surface water quality standards for surface-water quality (TCEQ 2010).

Water Quality Measure	TCEQ Standard
Temperature	Maximum 95 °F (35 °C)
Total Dissolved Solids	1,500 mg/L
Dissolved oxygen (mg/L)	> 5.0 mg/L
pH	6.5 – 9.0
Fecal coliform	≤126 CFU/100 mL
Heavy metals (mercury)	2.4 μg/L (acute); 1.3 μg/L (chronic)
Nutrients (nitrates, phosphates)	N/A

Data and Methods

PAAL has limited surface water bodies within park boundaries. Those that exist in the main park unit are ephemeral ponds or abandoned resacas that hold water only for short periods of time after rain events. The Resaca de La Palma unit is bordered on the north, east, and south sides by the Resaca de la Palma, an oxbow of the Rio Grande that now transports water through Brownsville, Texas for various municipal uses. Data characterizing water quality of water transported through the Resaca de la Palma were not available. The Resaca de la Palma is used primarily for transporting irrigation water, catching water runnoff and water storage (during tropical storm and hurricane events), and aesthetics. It is not clear if the water is tested regularly for safe bathing or safe recreation standards.

There are several TCEQ water quality monitoring stations in and around Brownsville, Texas; however, no established TCEQ water quality monitoring stations are located within or in close enough proximity to PAAL to indicate current condition of water quality in the park.

In 2000, the NPS published results of surface-water quality data retrievals for PAAL using six EPA national databases: Storage and Retrieval (STORET) water quality database management system, River Reach File (RF3), Industrial Facilities Discharge (IFD), Drinking Water Supplies (DRINKS), Flow Gages (GAGES), and Water Impoundments (DAMS) (NPS 2000). The retrieval identified one active USGS stream gage and 19 water impoundments within the study area; however, no stations were located within the park boundary. Of 32,945 observations for various parameters collected at 21 monitoring stations operated by the NPS, USGS, EPA, and Texas Natural Resource Conservation Commission from 1959 to 1997, 39% were collected by the USGS from 1966 through 1997. Many of the monitoring stations represent either one-time or intensive single-year sampling efforts by the collecting agencies. Ten stations within the study area but outside of the park boundary yielded longer-term records that consisted of multiple observations for several water quality parameters. The stations yielding the longest-term records within the study area are: Rio Grande near Brownsville (PAAL0012); Rio Grande International Bridge at U.S. Route 77 at Brownsville (PAAL0015); Rio Grande at Brownsville (PAAL0018); Rio Grande at El Jardin Pumping Station (PAAL0011); Rio Grande River at Mission (PAAL0017); and 1232002 Laguna Madre Es Line 320 Site 02 (Brownsville Ship Channel)

(PAAL0009) (NPS 2000). However, even among these stations, no data observations were captured within park boundaries or upstream of the park (as there is no “upstream” of the park) (NPS 2000, Meiman 2006) (see Figure 16). Results are presented in this assessment, but they are interpreted with caution as it is not likely observations accurately reflect water quality conditions in the park when collected.

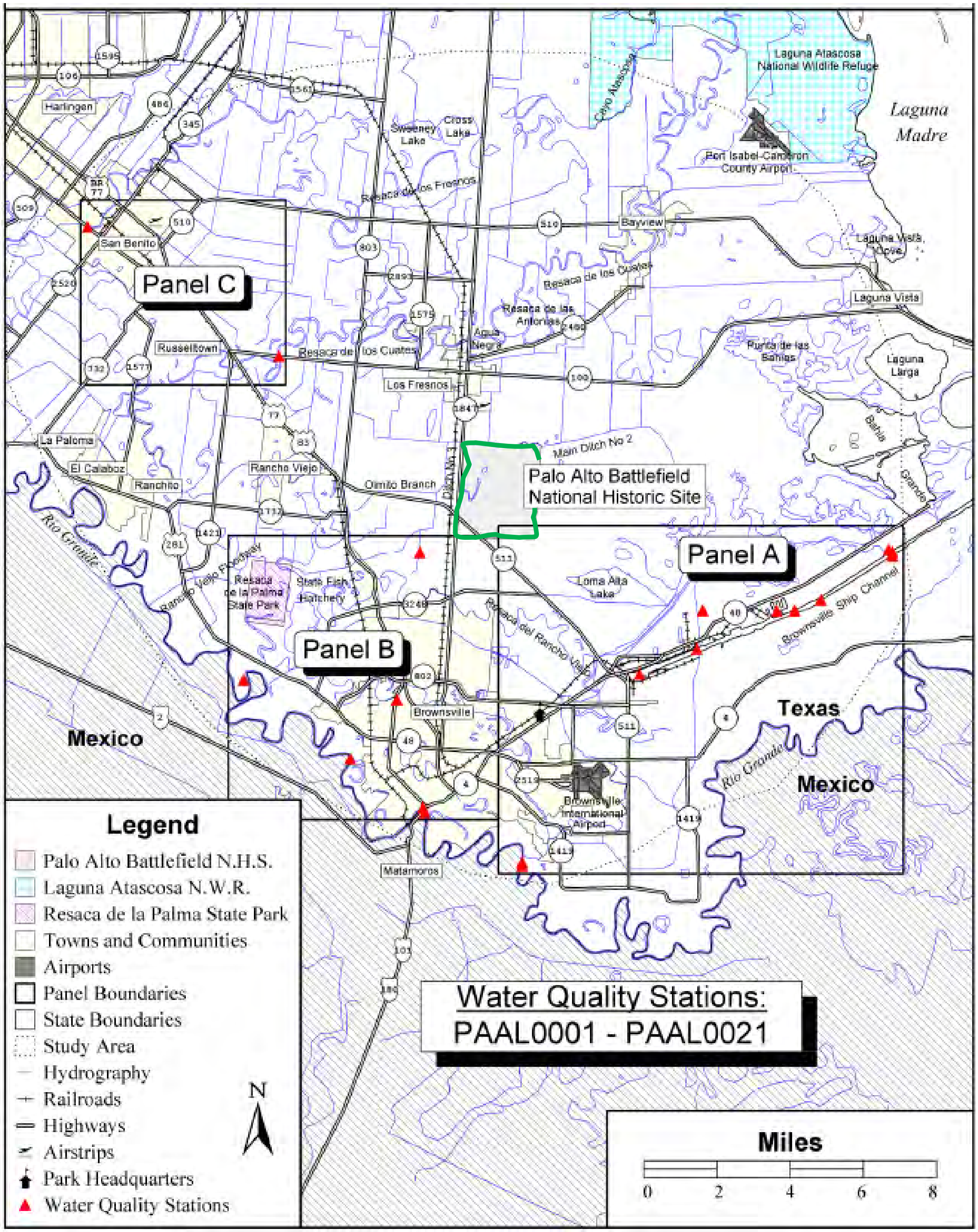

Figure 16. Water quality monitoring locations near PAAL identified in the NPS 2000 Baseline Water Quality Inventory (NPS 2000). The main unit of PAAL is outlined in green.

Farmer (1992) compiled a natural resources survey of PAAL, in which the water body features of the park and the surface and ground water quality of the area were described. Farmer (1992) reported that the quality of ground water in most of the area around PAAL was considered unsuitable for crop irrigation and did not meet state recommended drinking water standards. This summary discussed generally elevated levels of dissolved solids (mainly sodium, chloride, and sulfate) ranging from 1,000 to 5,000 mg/L, as well as high levels of nitrates and boron in area wells. The summary also indicated that groundwater under PAAL was considered moderately to highly saline (>3,000 mg/L). This summary did not offer insight into the condition of the measures of interest for this assessment, aside from some nutrients.

Meiman (2006) provides a short summary report detailing the hydrogeology of PAAL. This report summarized previous efforts to inventory and characterize water quality condition for the existing water bodies in the park, discussed water quality monitoring and research efforts, discussed associated land uses, and outlined various threats to water quality in the park. Meiman (2006) stated that the natural hydrogeology of the coastal plain has been altered to such a degree that the annual or semi-annual flooding that used to occur along the Rio Grande and Arroyo Colorado can no longer fill the resacas and ponds in PAAL. Any water accumulation that occurs in the resacas and ponds in PAAL was due to heavy rain events and tropical storms or, in the case of some ponds, recharged via pumping of water from a drainage ditch adjacent to the park boundary; consequently, any water retention in the park dries up within a few days.

Current Condition and Trend

Temperature

NPS (2000) reported that water temperature was measured 971 times at 12 monitoring locations in the study area from 1959 through 1997. None of the observations were characterized as exceeding the EPA water quality standard used in the NPS (2000) baseline inventory. However, since the inventory only provides a summary of the data queried rather than individual records, it is unclear how many observations would exceed the current TCEQ standard, a maximum of 35 °C (95 °F).

No other data or studies have documented temperature fluctuations in surface or ground waters in the area around PAAL.

Total Dissolved Solids

NPS (2000) did not report any observations of total dissolved solids; however, specific conductance was measured 629 times at 11 stations from 1959 through 1997. Observations of specific conductance in the study area ranged from 623 to 56,000 microsiemens/cm at 25 °C; mean values ranged from 1,168 to 52,571 microsiemens/cm at 25 °C. The highest conductance readings occurred at PAAL stations 0001, 0002, 0004, and 0009. Elevated conductivity indicates high concentrations of dissolved solids in the water source. These observations were not compared to a standard or threshold during the NPS (2000) inventory; thus, no exceedances were highlighted.

No other data or studies have documented total dissolved solids concentrations in surface or ground waters in the area around PAAL.

Dissolved Oxygen

NPS (2000) reported that dissolved oxygen concentrations were measured 841 times at 12 monitoring stations in the study area from 1960 through 1997. Eighty-six observations (10.2%) at seven monitoring locations were equal to or less than the 4 mg/L EPA threshold for protection of aquatic life. Most of these observations (95%) were reported from 1968 through 1980 at four locations: PAAL0001, PAAL0002, PAAL0004, and PAAL0009.

No other data or studies have documented dissolved oxygen concentrations in surface or ground waters in the area around PAAL.

pH

NPS (2000) reported that pH was measured 1,200 times at 12 monitoring locations in the study area from 1959 through 1997. Twenty observations (1.7%) at five monitoring locations were outside the acceptable pH ranges protective of freshwater (6.5 to 8.5 standard units) and marine aquatic life (6.5 to 9.0 standard units). Three monitoring locations were located along the Brownsville Ship Channel (PAAL0002, PAAL0004, and PAAL 0009) and two were located on the Rio Grande (PAAL0011 and PAAL0015).

No other data or studies have documented pH of surface or ground waters in the area around PAAL.

Indicator Bacteria (fecal coliform, *E. coli*)

NPS (2000) reported that fecal coliform concentrations were measured 404 times at six monitoring locations in the study area from 1972 through 1996. A total of 246 concentrations at five locations in the Rio Grande near Brownsville (PAAL0011, PAAL0012, PAAL0015, PAAL0016, and PAAL0020) equaled or exceeded the NPS Water Resources Division criterion for safe bathing (200 CFU/100 ml) between 1975 and 1996. Over half of these observations (55%) were reported at two locations near Brownsville (PAAL0011 and PAAL0012) from 1975 through 1996; the highest concentration measured 799,999 CFU/100 ml at PAAL0012 in August 1977. Note that the criterion used in the NPS (2000) inventory is less conservative than the current TCEQ standard of 126 CFU/100 ml; it is unclear how many additional observations would exceed the more conservative TCEQ standard for safe bathing.

No other data or studies have documented bacteria concentrations in surface or ground waters in the area around PAAL.

Presence of Heavy Metals (Mercury)

NPS (2000) reported that mercury concentrations were measured 132 times at nine monitoring locations in the study area from 1970 through 1996. Two concentrations, 2.3 µg/L recorded at PAAL0011 and 4.2 µg/L recorded at PAAL0018, exceeded the EPA drinking water criterion (2.0 µg/L); the observation at PAAL0018 also exceeded the 2.4 µg/L EPA criterion for acute freshwater. It is unclear what number of additional observations would exceed the more conservative TCEQ standard of 1.3 µg/L for drinking water (the acute freshwater standard is the same as EPA).

No other data or studies have documented concentrations of heavy metals in surface or ground waters in the area around PAAL.

Presence of Nutrients (nitrate and phosphate)

NPS (2000) reported that nitrate was measured 213 times at eight monitoring locations in the study area from 1959 through 1997. Phosphate was also measured 102 times at six monitoring locations in the study area from 1959 through 1997. Nitrate observations during this time ranged from 0.0 to 2.9 mg/L; mean values ranged from 0.0 to 0.166 mg/L across monitoring locations. Phosphate observations ranged from 0.0 to 3.7 mg/L; mean values ranged from 0.0 to 1.256 mg/L across monitoring locations. These observations were not compared to a standard or threshold during the NPS (2000) inventory; thus, no exceedances were highlighted.

Farmer (1992) reported briefly that boron and nitrate concentrations exist at high levels throughout the area around PAAL. High nitrate levels had been detected in wells less than 30 m (100 ft) deep and in localized areas in the region; it is believed that contamination from fertilizer use is the main cause of these high nitrate levels.

Threats and Stressor Factors

Despite no surface water quality data having been collected in PAAL as queried by NPS (2000), authors of the inventory suggest that surface waters in the area around the park were likely impacted by various human activities. These included contamination through agricultural and ranching operations, urban development (which is rapidly increasing around the park), municipal and industrial discharges, stormwater runoff into active creeks and resacas used to transport water in the region, marine traffic along the Brownsville Ship Channel, atmospheric deposition (contaminants in air emissions), and recreational use.

Meiman (2006) comments on the rapid development that is occurring and moving northward toward PAAL from the Brownsville city limits. Although the main park unit of PAAL has no perennial surface water resources, increased development and agricultural land uses could contribute to increased issues with ground water quality. Meiman (2006) highlights the shallow water table and sandy soils as factors that make the ground water aquifer more susceptible to various forms of contamination, including elevated levels of nutrients from fertilizer and livestock waste or elevated levels of toxic compounds or metals. For instance, prior to protection as a historic battlefield, the property was used for livestock grazing and several resacas were modified to be used as retention ponds for watering cattle. A cattle dip tank was created and filled with arsenic-based pesticide to treat cattle for fever tick. This tank has since been removed along with the contaminated soils.

Although occurring rarely, flooding (caused by heavy rain events or tropical storms) can bring contaminants into ponds and resacas via runoff from adjacent ranching and agricultural lands, as well as from the major roads that border the main unit of PAAL on two sides. Despite the water retention lasting for a short period of time, nutrients and other contaminants would be left behind in the soils following evaporation or drainage.

Data Needs/Gaps

Because surface water in the park is ephemeral, there has been no consistent monitoring of water quality parameters within the boundaries of the main park unit. The exception to this is the Resaca de La Palma, which is used to transport water through the City of Brownsville, Texas where it is eventually used for irrigation, storage and transport of runnoff, and aesthetics. Typically, water used for such purposes is tested regularly for compliance with EPA health thresholds, particularly if the water is to be used for drinking, bathing, or irrigation. PAAL managers do not monitor the waters that run through the Resaca de la Palma, as this is a municipal resource. However, data characterizing water quality adjacent to the Resaca de la Palma unit would help managers understand how riparian habitat and flora and fauna may be affected by certain water quality issues, such as impacts of high levels of pesticides or herbicides, bacteria concentrations, or heavy metal concentrations.

Overall Condition

Overall, past summaries of water quality in the area, particularly ground water quality, indicate elevated levels of nutrients, dissolved solids, some metals, and bacteria; however, none of the observations from the NPS (2000) baseline water quality inventory were actually collected in or upstream of the park. The ephemeral nature of the water features in the park makes it difficult to monitor water quality regularly. Thus, the lack of consistent monitoring data on basic water quality parameters renders it difficult to make definitive statements about current water quality conditions within PAAL.

Temperature

The project team defined the *Significance Level* for temperature as a 3. Due to the lack of available data from within park boundaries, a *Condition Level* was not assigned.

Specific Conductance

The *Significance Level* for specific conductance is a 3. Due to the lack of available data, a *Condition Level* was not assigned.

Dissolved Oxygen

The *Significance Level* for this measure is a 3. Due to the lack of available data, a *Condition Level* was not assigned.

pH

The project team defined the *Significance Level* for pH as a 3. Due to the lack of available data, a *Condition Level* was not assigned.

Indicator Bacteria (fecal coliform, E. coli)

The project team defined the *Significance Level* for indicator bacteria (fecal coliform, *E. coli*) as a 3. Due to the lack of available data, a *Condition Level* was not assigned.

Presence of Heavy Metals

The *Significance Level* for presence of heavy metals is a 3. Due to the lack of available data, a *Condition Level* was not assigned.

Presence of Nutrients

The project team defined the *Significance Level* for presence of nutrients as a 3. Due to the lack of available data, a condition level was not assigned.

Weighted Condition Score
A *Weighted Condition Score* for PAAL water quality could not be assigned due to a lack of available data.

Sources of Expertise
Joe Meiman, GULN Hydrologist

Mark Spier, PAAL Superintendent

Rolando Garza, PAAL Archeologist and Integrated Resource Manager

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4.16 Viewshed

Description

A viewshed is the area visible from a particular location. The National Park Service Organic Act (16 U.S.C. l) implies the need to protect the viewsheds of National Parks, Monuments, and Reservations. At PAAL, viewsheds are of particular importance because the primary reason for visitation to the historical site is to immerse one's self in the cultural history of the battlefield.

Photo 33. Viewshed from the PAAL boardwalk. Features in this photo include: A: Elevated area built for the HWY 550 overpass that spans Paredes Road, B: Overhead street light near HWY 550, C, D: Signs for the nearby toll road (photo by Rolando Garza, PAAL).

The PAAL viewshed is unique due to its small size and limited topographic relief (Photo 33). The vegetation at PAAL can be characterized by the translation of the park's name, "high stick". These high shrub/scrub areas can limit the PAAL viewshed (NPS 1997). According to NPS (1997), the park's viewshed is affected by any structure greater than 6 m (20 ft) tall that is located on either the south or west border. The NPS continues to work with city planners to minimize land development surrounding the park that could affect the park's viewshed. The protection efforts include discouraging incompatible development (e.g., multistory buildings, factories, warehouses) on the south and west sides of the park (NPS 1997). It should be noted that in 2008, protective zoning overlays that were put in place in the mid 1990s (following the construction of the Titan Tire plant) were modified to be less restrictive. Additionally, development plans for an industrial corridor along HWY 550 have been put in place with little or no input/consideration for the park (Spier, written communication, 24 June 2013).

The current viewshed is impaired by the presence of several man-made features outside the park. Examples of these features include highway overpasses and associated light towers, and the 18 m (60 ft) Titan Tire factory building façade (Photo 34). According to Mark Spier (written communication, 24 June 2013), if the proposed Tenaska natural gas power generating plant is constructed, two smokestacks (approximately 43 m [140 ft] tall) would be built and located approximately 2 km (1.2 mi) west of the park's visitor center. Natural factors also affect the PAAL viewshed, as the growth of tall brush limits the visible area of the viewshed at PAAL. However, in the near future the park plans on implementing a vegetation management plan with hopes of reducing brush height and restoring the cultural landscape of the core battlefield to the prairie vegetation that was present in 1846 (Spier, written communication, 24 June 2013).

Photo 34. The Titan Tire building façade, as viewed from the PAAL Overlook Trail parking lot (Photo by Mark Spier, PAAL).

Measures

- Change in land use cover type inside the park (internal viewshed)
- Change in land use cover type outside the park (external viewshed)

Reference Conditions/Values

The reference condition for this component is an unobstructed view similar to what would have been observed on the battlefield during the Battle of Palo Alto in 1846. Deviations from the historic reference condition (viewshed) are reported and analyzed here using GIS analyses and photo interpretation.

Data and Methods

PAAL staff identified seven priority observation points: Boardwalk, Living History Area, Mexican Line Trail, Overlook, Overlook Parking Lot, U.S. Line Trail, and Visitor Center (Garza, Spier, phone conversation, 2 April 2013). These locations were identified and documented by PAAL staff using a GPS unit. The GIS vector data created for this analysis resides in a file geodatabase that includes two feature classes: Viewshed_Points and Observation_Points. The Viewshed_Points feature class describes the points where popular viewing spots are located. Most of the observation points consist of only one point, but some locations (e.g., overlook, overlook parking lot boardwalk, visitor center) consist of several points. The photo point data collected supports the GIS data by enabling individuals to view the actual on-the-ground conditions. An internal and external viewshed were then created using ArcGIS to demonstrate change in land use cover change. Plate 15-Plate 21 display the individual viewshed analysis for each observation point, and Photo 35-Photo 41 are the respective views for each observation point from the cardinal directions. It should be noted that the visible viewshed threats are not as obvious and prominent in these photos as they are to the naked eye (Garza, written communication, 8 July 2013).

For each of these points or lines, a viewshed was calculated using ESRI's Spatial Analyst Viewshed Tool in ArcGIS 10.1, which requires point or polyline GIS data (representing the viewing location) and a Digital Elevation Model (DEM). For each of the observation points, a point shapefile was created for use with the Viewshed Tool. For line features, a polyline was created; the Viewshed Tool uses each vertex in the line to determine the viewshed of the feature as a whole. The DEM used for each observation point was mosaicked from the National Elevation Dataset (NED), which has a resolution of approximately 3 m (9.8 ft). A 1.8 m (5.9 ft) offset was applied to each observation point shapefile to account for average human height. The result of the operation is a theoretical viewshed layer that represents the visible area from a point without correcting for visibility factors (e.g., vegetation, smoke, humidity, heat shimmer, or curvature of the earth).

Current Condition and Trend

<u>Change in Land Use Cover Type Inside the Park (Internal Viewshed)</u>
Seven observation points were used to determine the internal viewshed of PAAL. The resulting total visible area from the observation points was 544 ha (1344 ac), about 40% of the park's total area. Most of the area not visible from these points is in the northern portion of the park (Plate 22).

The primary 2006 National Landcover Database (NLCD) landcover classes viewable within PAAL are Shrub/Scrub and Grassland/Herbaceous, at 21% and 6%, respectively (Table 27) (Fry et al. 2011). The Shrub/Scrub class is characterized by shrubs (the dominant vegetation) that are less than five meters in height. The canopy in this vegetation class accounts for 21% of the total vegetation. Vegetation included in this class are true shrubs, young trees (in early successional stage), and environmentally stunted trees (MRLC 2012). Graminoids dominate the Grassland/Herbaceous class. This herbaceous vegetation accounts for approximately 80% of the total vegetation in the landcover class. These areas "are not subject to intensive management such as tilling, but can be utilized for grazing" (MRLC 2012, p. 1). Plate 23 displays the viewable landcover composition in PAAL.

Table 27. 2006 NLCD viewable landcover composition in PAAL (Fry et al. 2011).

Landcover Class	Hectares	Percent Cover
Not Visible	885	65
Shrub/Scrub	283	21
Grassland/Herbaceous	88	6
Woody Wetlands	33	2
Emergent Herbaceous Wetlands	24	2
Developed, Low Intensity	18	1
Pasture/Hay	13	1
Cultivated Crops	9	1
Developed, Medium Intensity	5	<1
Barren land (rock/sand/clay)	5	<1
Developed, Open Space	1	<1
Deciduous Forest	<1	<1

Analysis of NLCD change data indicates very little change within the internal viewshed from 2001 to 2006; only about 27 ha (67 ac) changed over that time (approximately 5% of total visible area from the observation points) (Table 28). The change that did occur is likely due to succession from Grassland/Herbaceous to Shrub/Scrub class and the conversion of Shrub/Scrub to Cultivated Crops. Plate 24 displays the viewable landcover change in PAAL.

Table 28. Landcover classes reclassified in 2006 from previouse classification in 2001 within PAAL lands visible from the observation points.

New Landcover Class	Hectares
Unchanged/Not Visible	1,339
Shrub/Scrub	14
Cultivated Crops	9
Barren Land	2
Emergent Herbaceous Wetlands	1

Change in Land Use Cover Type Outside the Park (External Viewshed)

Similar to the internal viewshed, the external viewshed changed little between 2001 and 2006 according to the NLCD change product. Of the 2,995 ha (7401 ac) identified as visible from the viewpoints established for the park, approximately 189 ha (467 ac) experienced a change in classification (about 6%). A vast majority of this change (37 ha [91 ac]) was from Shrub/Scrub to Cultivated Crops. The Cultivated Crops landcover class includes

> …areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled (MRLC 2012, p. 1).

In relation to the park, about 48 ha (119 ac) of area changed to Cultivated Crops within 24 km (15 mi) of the park boundary (Plate 25). Forty-four ha (109 ac) of the visible area changed to developed area, with much of this developed area being the open space designation (i.e., area with a mix of constructed materials, less than 20% impervious surfaces, and mostly lawn-grass type vegetation [MRLC 2012]). Similar to within the park, the primary NLCD cover class in the external viewshed is Shrub/Scrub designation. Appendix D provides a complete listing of designation changes between 2001 and 2006.

Threats and Stressor Factors

Construction of the nearby highway overpass and associated light fixtures are a threat to the park's viewshed. The location of the overpasses and their associated light fixtures make them easily visible above the dense brush line (Garza, phone communication, 2 April 2013). Furthermore, a proposed plan to construct high voltage power lines along U.S. Highway 550 and Paredes Line Road (bordering the south and west boundaries of the park, respectively) will likely impact the park's viewshed. The height of the proposed power lines is estimated at 40 m (130 ft) (Spier, phone communication, 2 April 2013). Further away from the park (13 km [8 mi]), the cranes at the Brownsville Ship Channel are visible within the park on a clear day.

As previously mentioned, the abandoned Titan Tire factory (located just 0.8 km [0.5 mi] from the park) has an approximately 18 m (60 ft) tall facade that is visible from many locations within the park. Further away from the park (1.9 km [1.2 mi]), the smokestacks from a proposed natural gas power plant will likely be visible from the park. These smokestacks would be approximately 43 m (140 ft) (Spier, phone communication, 2 April 2013).

The expansion of Brownsville is another threat to the PAAL viewshed. Brownsville is located just south of the park in Cameron County. According to NPS (1997), the land surrounding the park may be characterized as industrial and/or modern development in the future, which may result in little remaining open and natural space; noise levels would increase, and air quality may decline (NPS 1997). Mark Spier indicated that a convenience store is likely to be developed near the park's southeast border, and that the signage and building would likely be seen from within the park (phone communication, 2 April 2013). It should be noted that businesses and advertising agencies are prohibited from constructing signage within 0.4 km (0.25 mi) of the park.

Data Needs/Gaps

Continued development of spatial data that explain landscape change will enable accurate and up-to-date viewshed assessments of the metrics examined in this analysis. Specifically, NLCD data from post-2006 is needed. Ideally, the results of the viewshed analyses completed with contemporary data could help park staff work with city planners to minimize the impact of surrounding development on the park's viewshed.

Overall Condition

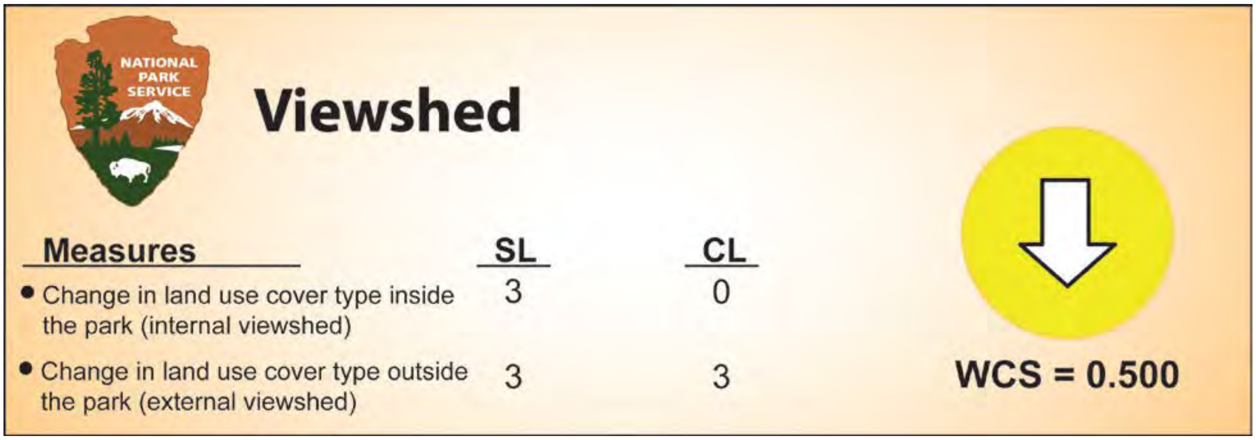
Change in Land Use Cover Type Inside the Park (*Internal Viewshed*)
The *Significance Level* for this measure is 3, indicating it is of high importance in determining the condition of the viewshed. Overall, little landcover change occurred within the internal viewshed from 2001 to 2006. The change that did occur is likely due to natural succession of vegetation; no change occurred that could be designated as anthropogenic. Therefore, the *Condition Level* of this measure is 0, indicating least concern.

Change in Land Use Cover Type Outside the Park (*External Viewshed*)
The *Significance Level* for this measure is also a 3. Similar to the internal viewshed, landcover change was minimal within the external viewshed of the park from 2001-2006. Change to developed cover classes was also minimal in the external viewshed. Some potential causes for concern include urban development and industrial infrastructure, such as the multistory buildings and smokestacks. In addition, because the external viewshed is not controlled by NPS, development that deteriorates the viewshed is possible.

It should be noted that the data used for the analysis are from 2001 to 2006. According to Mark Spier (written communication, 24 June 2013), 2006 was approximately when the external viewshed threats began to develop around the park. The beginning of these threats was the construction on the roadways adjacent to the park, and the threats have continued to the present time (2013) with subsequent and continuing developments in the park's general vicinity. As previous components have discussed, the natural landscape of PAAL is becoming an "island" surrounded by the expansion and development of the city of Brownsville; this component deals first hand with this issue. Development is one of the most critical threats that the park currently faces and will impact all resources in the park (Spier, written communication, 24 June 2013).

Replication of the analysis with more recent data (post-2006) is needed to more accurately describe condition. Even though landcover change (according to the NLCD) was minimal from 2001-2006, the recent construction around the park, and the opinion of park managers resulted in this measure being assigned a *Condition Level* of 3, indicating high concern.

Weighted Condition Score
The *Weighted Condition Score* for this component 0.500, indicating the component's condition is of moderate concern; the recent (and continued) developments around the park dictated a declining trend be assigned to this component.



Sources of Expertise
Rolando Garza, PAAL Archaeologist and Integrated Resource Manager

Mark Spier, PAAL Superintendant

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National Park Service (NPS). 1997. Palo Alto Battlefield National Historic Site, Texas: draft, general management plan, environmental assessment. U.S. Department of the Interior, Palo Alto Battlefield National Historic Site, Texas.

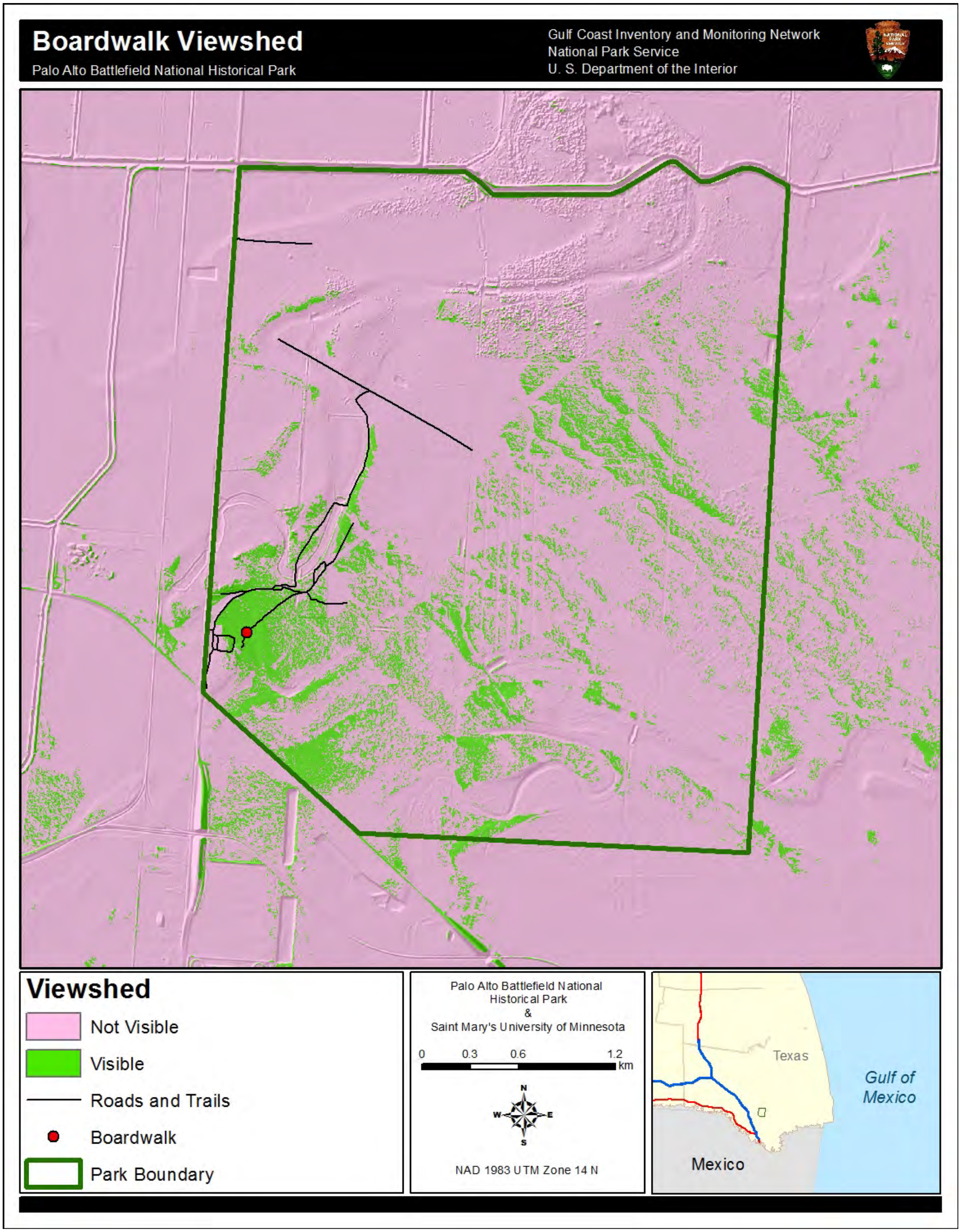


Plate 15. Viewshed analysis from the Boardwalk priority observation point in PAAL.

Photo 35. Photos taken from the Boardwalk for each cardinal direction (Photos by Rolando Garza, PAAL). It should be noted that the visible viewshed threats are not as obvious and prominent in these photos as they are to the naked eye.

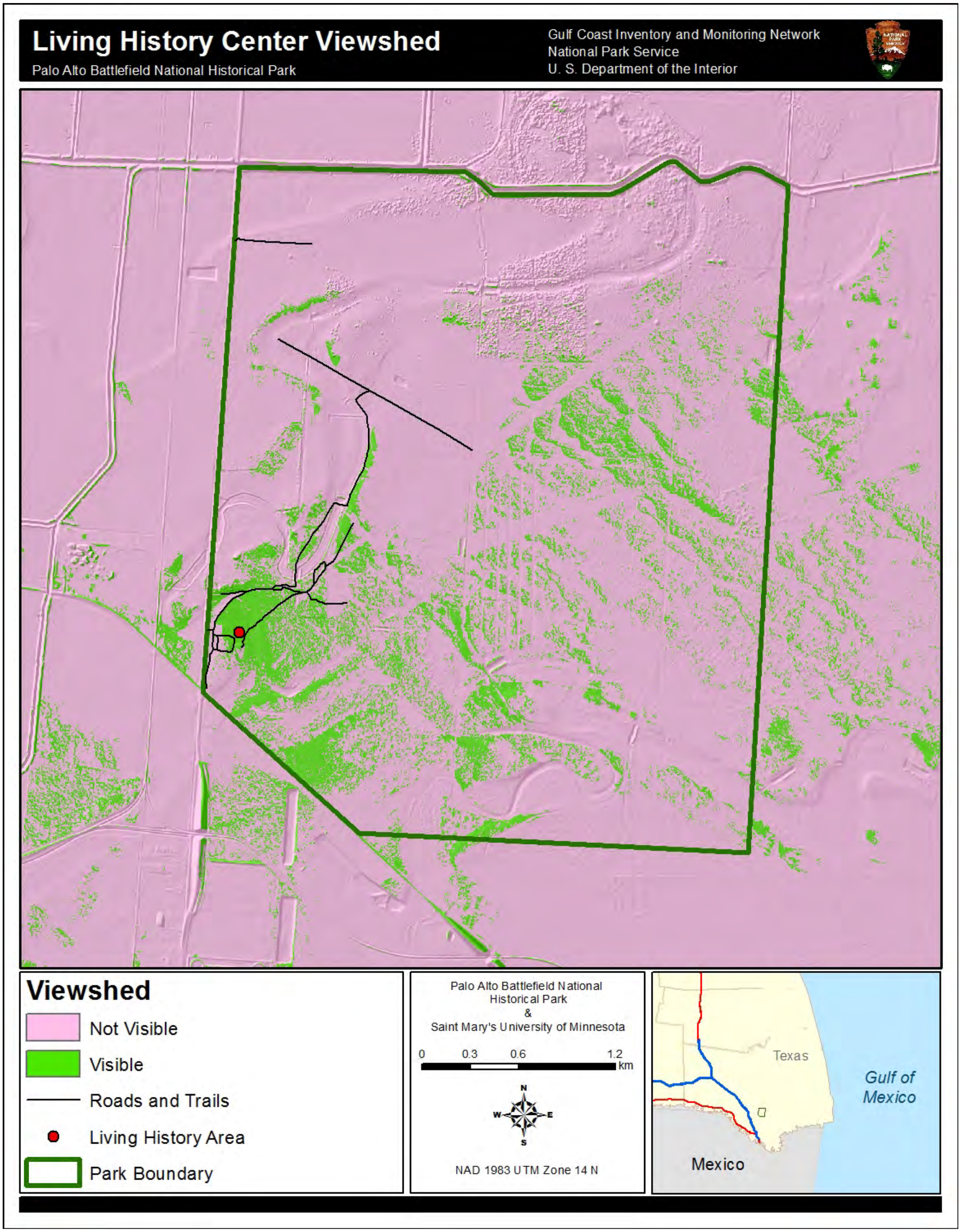


Plate 16. Viewshed analysis from the Living History Area priority observation point in PAAL.

Photo 36. Photos taken from the Living History Area for each cardinal direction (Photos by Rolando Garza, PAAL). It should be noted that the visible viewshed threats are not as obvious and prominent in these photos as they are to the naked eye.

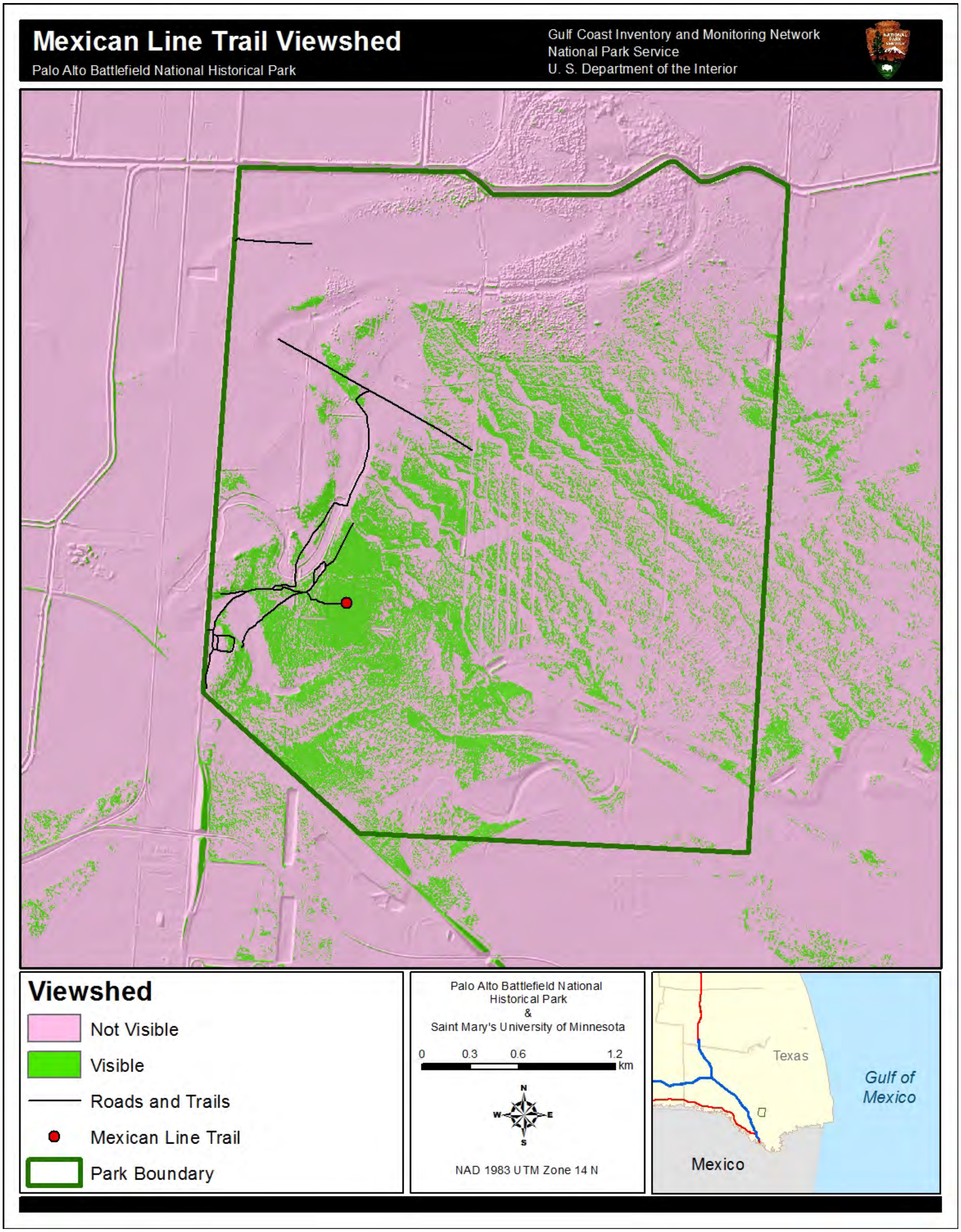


Plate 17. Viewshed analysis from the Mexican Line Trail priority observation point in PAAL.

Photo 37. Photos taken from the Mexican Line Trail for each cardinal direction (Photos by Rolando Garza, PAAL). It should be noted that the visible viewshed threats are not as obvious and prominent in these photos as they are to the naked eye.

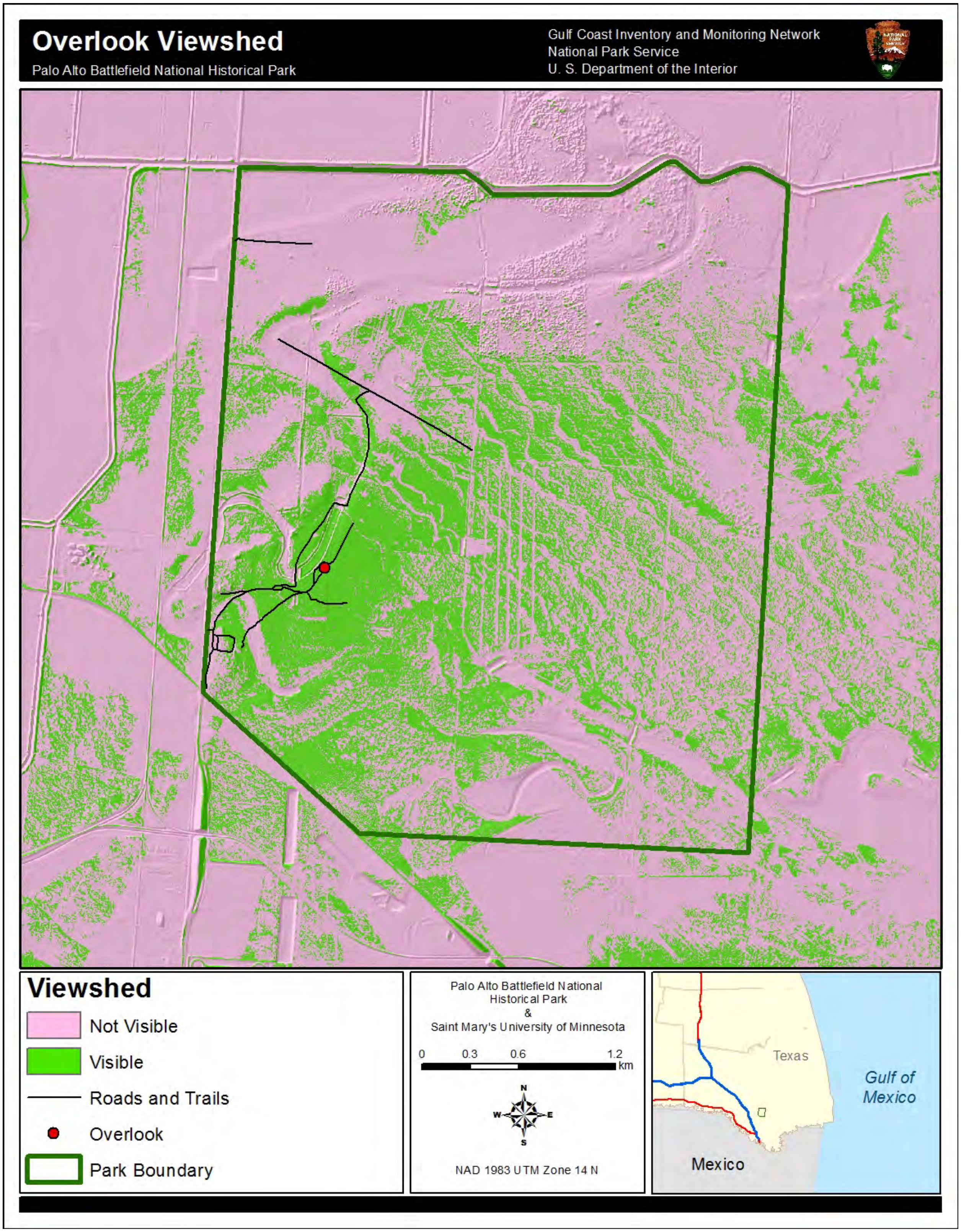


Plate 18. Viewshed analysis from the Overlook priority observation point in PAAL.

Photo 38. Photos taken from the Overlook for each cardinal direction (Photos by Rolando Garza, PAAL). It should be noted that the visible viewshed threats are not as obvious and prominent in these photos as they are to the naked eye.

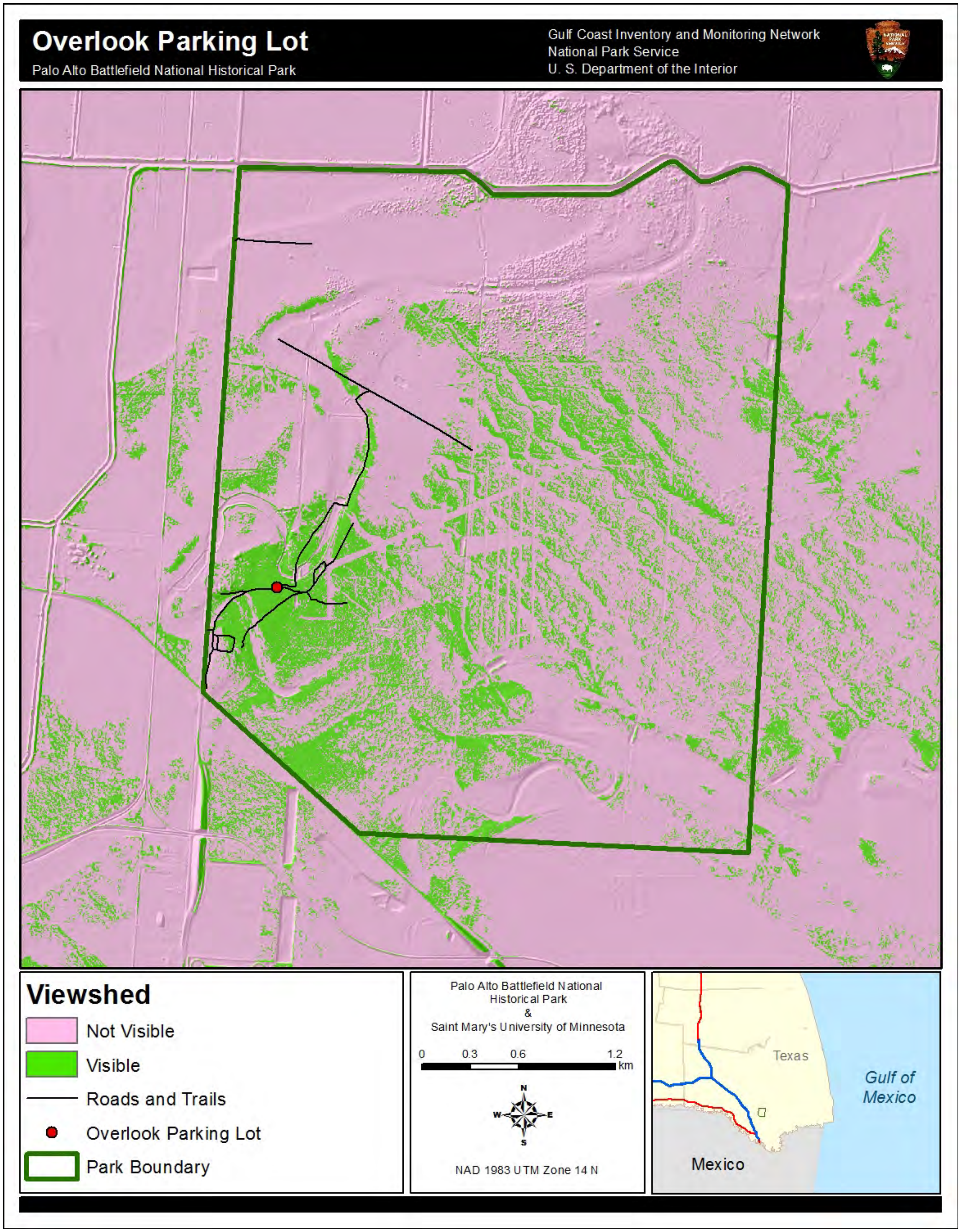


Plate 19. Viewshed analysis from the Overlook Parking Lot priority observation point in PAAL.

Photo 39. Photos taken from the Overlook Parking Lot for each cardinal direction (Photos by Rolando Garza, PAAL). It should be noted that the visible viewshed threats are not as obvious and prominent in these photos as they are to the naked eye.

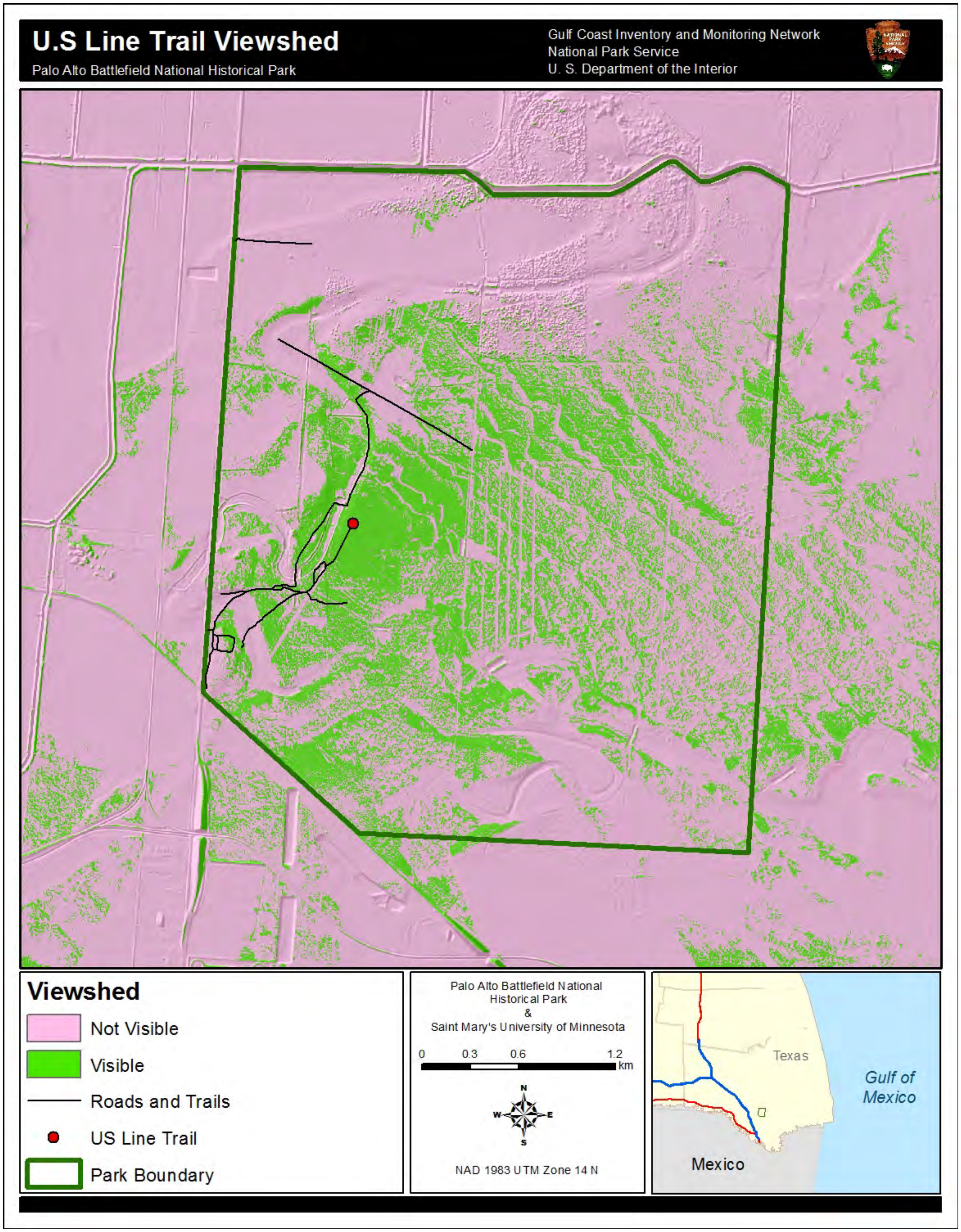


Plate 20. Viewshed analysis from the U.S. Line Trail priority observation point in PAAL.

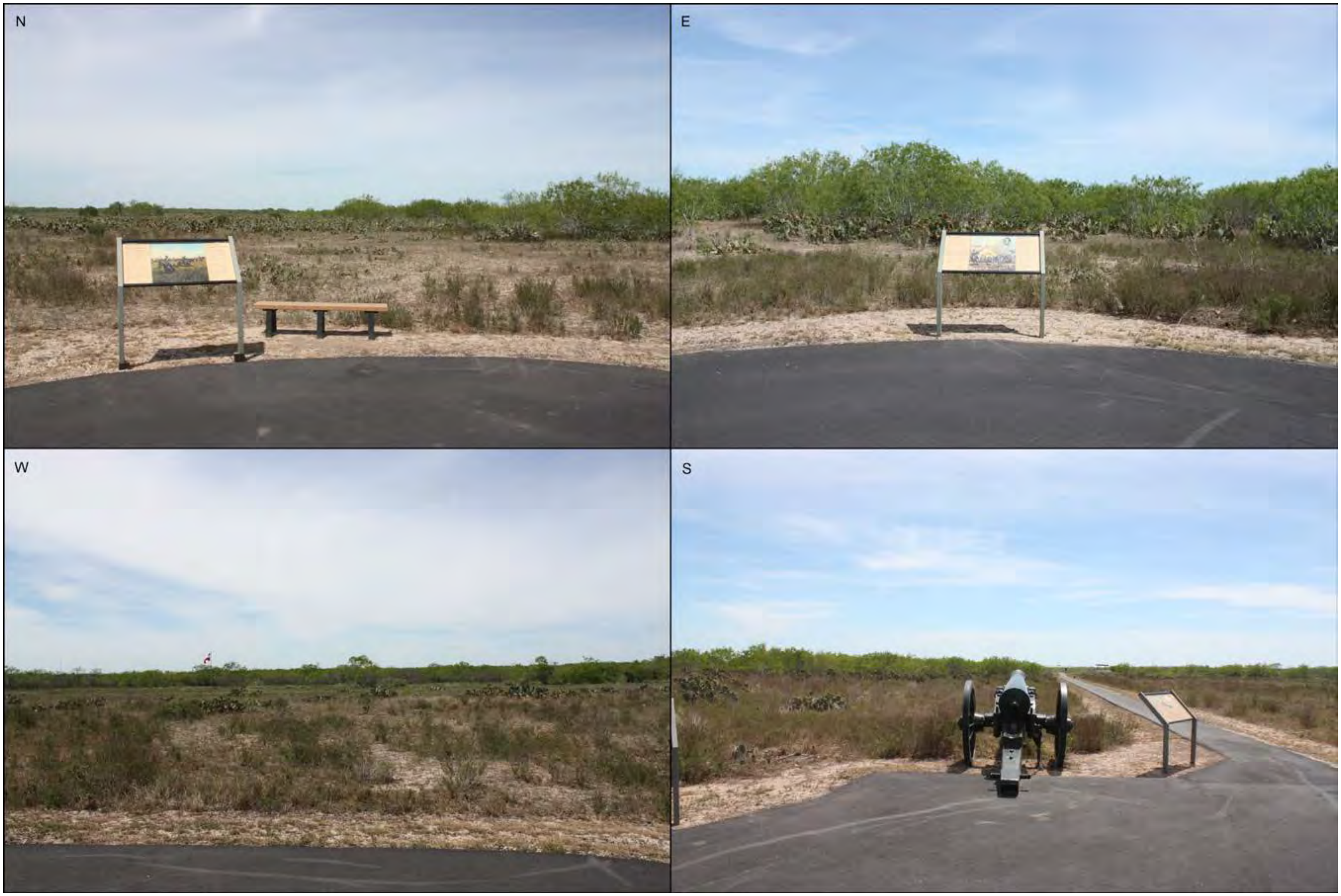


Photo 40. Photos taken from the U.S. Line Trail for each cardinal direction (Photos by Rolando Garza, PAAL). It should be noted that the visible viewshed threats are not as obvious and prominent in these photos as they are to the naked eye.

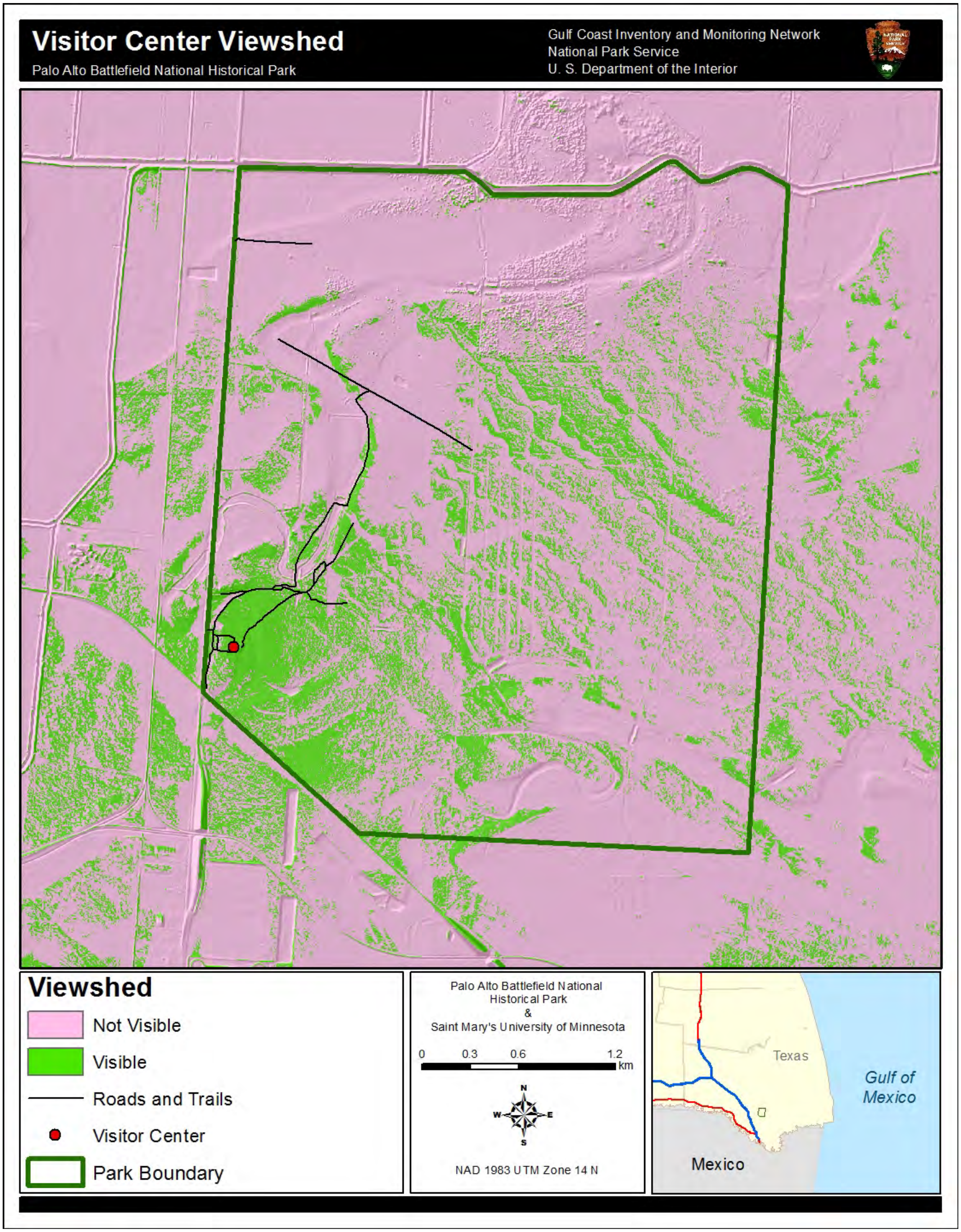


Plate 21. Viewshed analysis from the Visitor Center priority observation point in PAAL.

Photo 41. Photos taken from the Visitor Center for each cardinal direction (Photos by Rolando Garza, PAAL). It should be noted that the visible viewshed threats are not as obvious and prominent in these photos as they are to the naked eye.

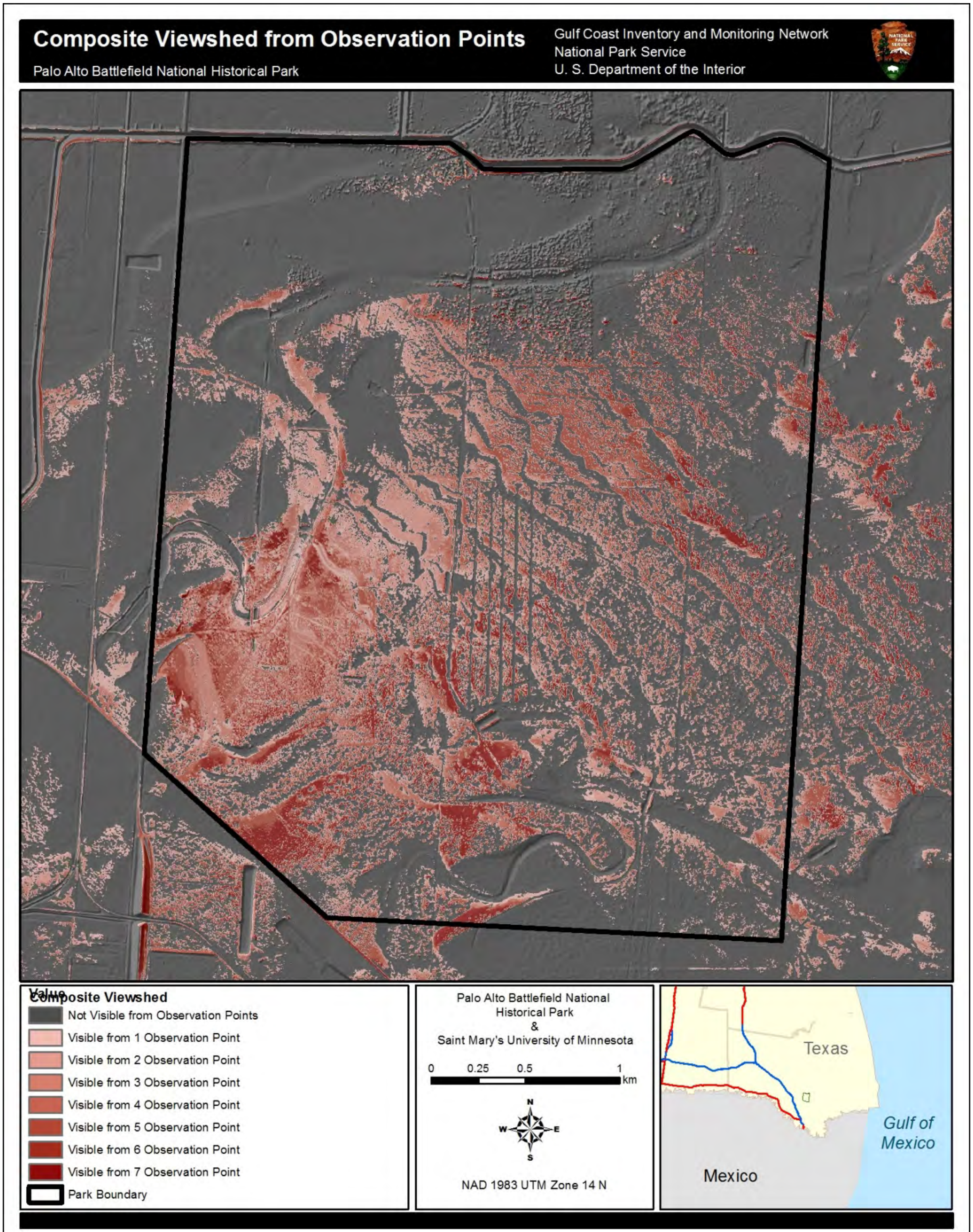


Plate 22. Composite viewshed analysis from the observation points in PAAL.

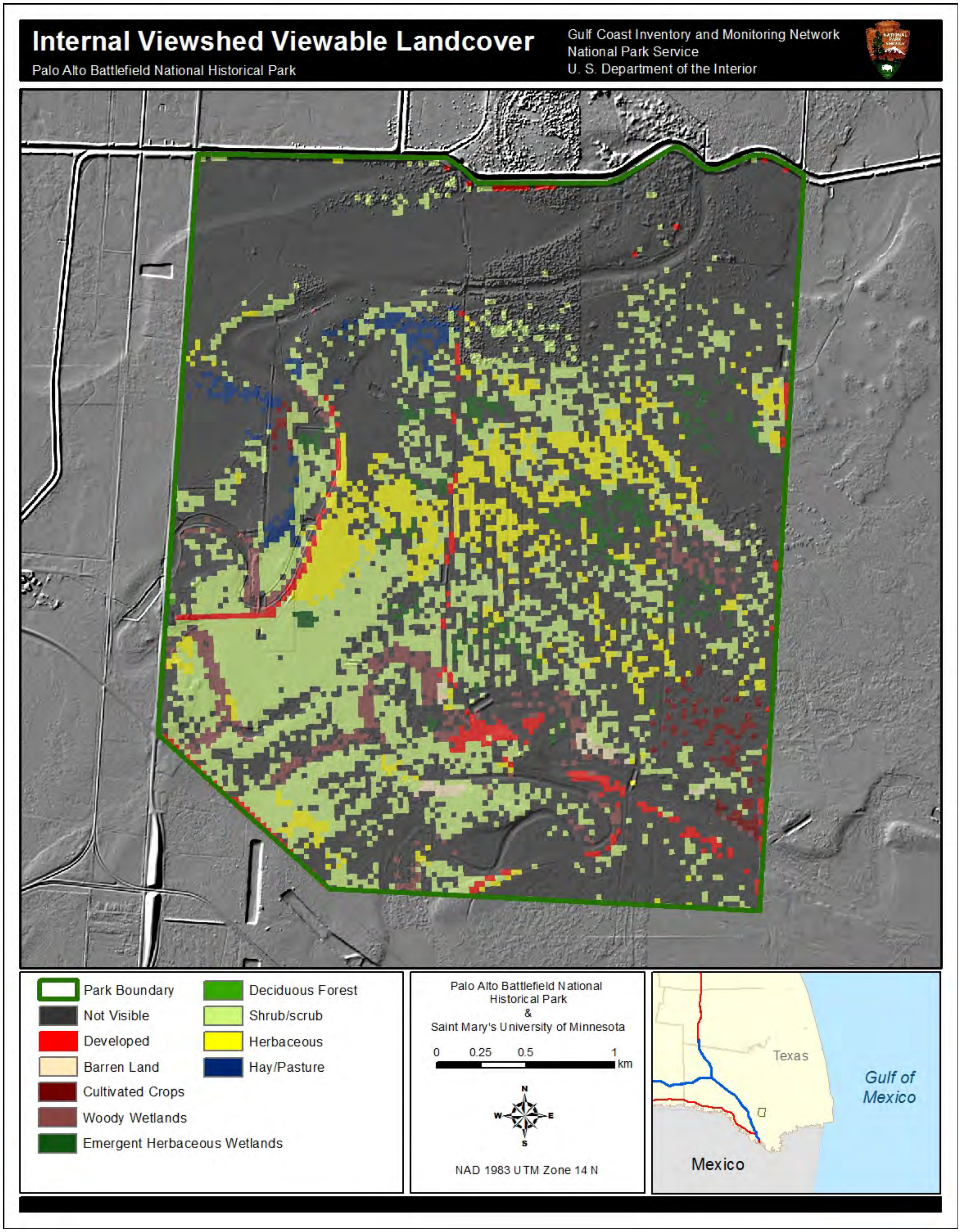


Plate 23. 2006 NLCD viewable landcover composition in PAAL (Fry et al. 2011).

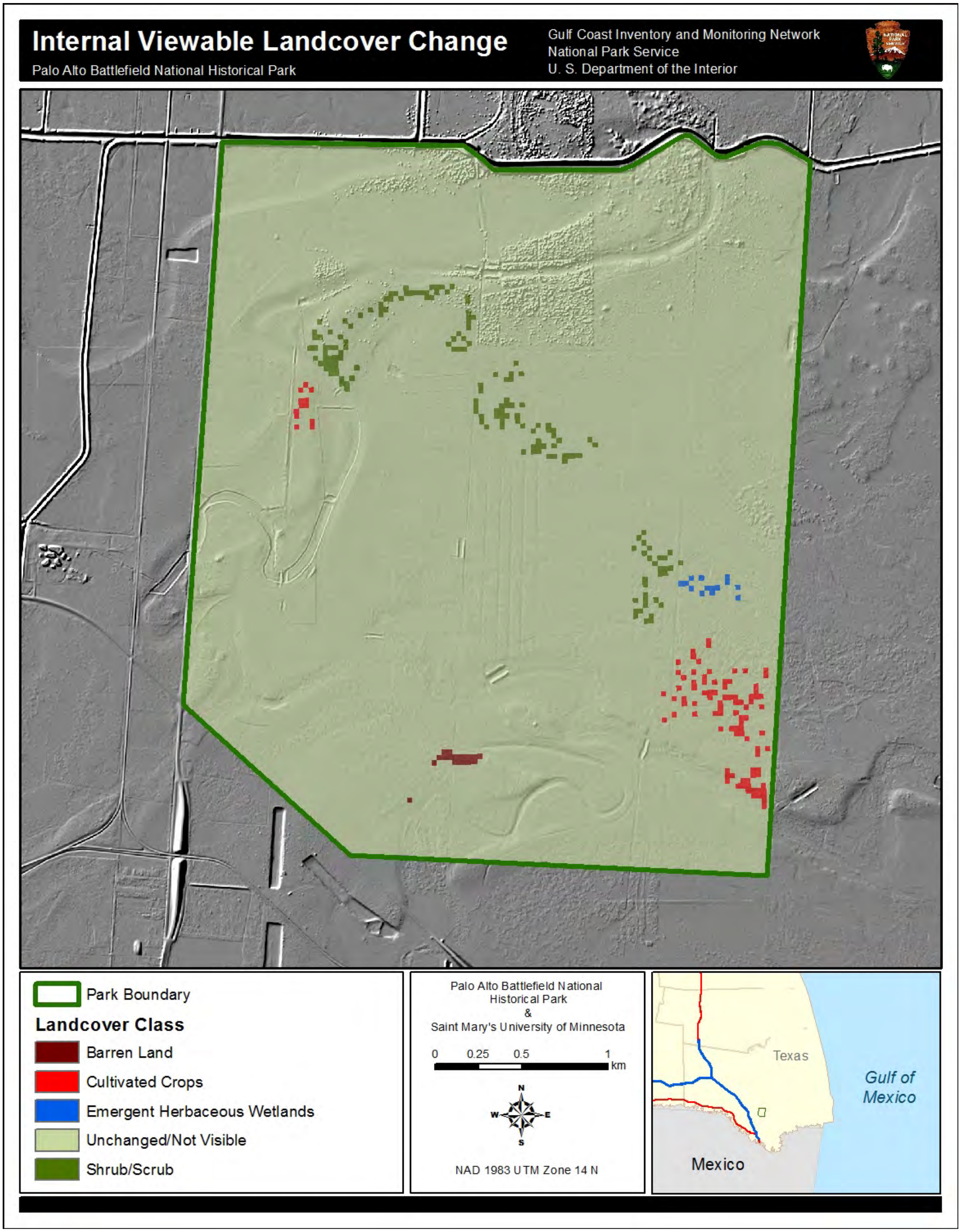


Plate 24. NLCD 2001 to 2006 change within PAAL lands viewable from the observation points (Fry et al. 2011).

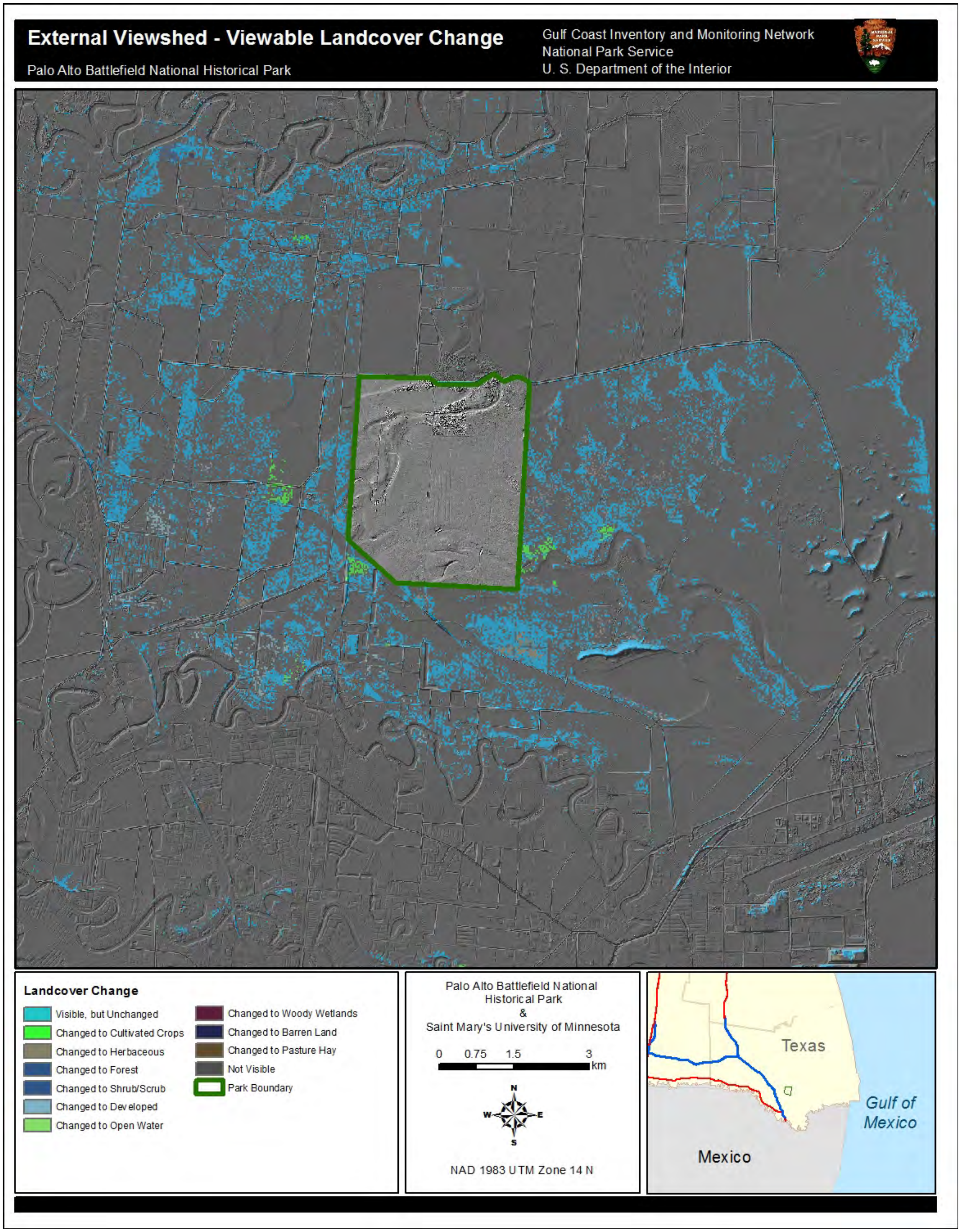


Plate 25. NLCD 2001 to 2006 change outside PAAL lands viewable from the observation points (Fry et al. 2011).

4.17 Soundscape

Description

The definition of soundscape in a national park is the total ambient sound level of the park, comprised of both natural ambient sound and human-made sounds (NPS 2000). The NPS's mission is to preserve natural resources, including natural soundscapes, associated with the national park units. Intrusive sounds are of concern to park visitors, as they detract from their natural and cultural resource experiences (NPS 2000). In addition, traffic or other human-caused noise sources can interrupt interpretive programs being held within a park. According to a survey conducted by the NPS, many visitors come to national parks to enjoy, equally, the natural soundscape and natural scenery (NPS 2000).

Noise can have two major impacts. Perceived noises can alter the quality of the soundscape as well as the behavior of visitors and wildlife. Noise also elevates ambient sound levels above the natural condition, and thereby reduces opportunities to hear the sounds of nature or cultural sounds. Many factors affect how visitors and wildlife perceive and respond to noise. Primary acoustical factors include the level, duration, and spectral properties of the noise, as well as the rate of occurrence and its diurnal or seasonal schedule. Non-acoustical factors, such as experience, expectations, and adaptability, play a role in how visitors and wildlife respond to noise.

Measures

- Occurrence of human-caused sound
- Natural ambient sound level

Reference Conditions/Values

A reference condition has not been defined for soundscape for PAAL. Establishing a reference condition is difficult, given the park's historic use as a battlefield, where loud gun shots, cannon blasts, and human-caused noises were frequent. Ideally, managers would like to minimize the impact of human sounds that would not have existed at the time of the historic battle (e.g., cars, airplanes, modern development).

Data and Methods

No soundscape data have been gathered at PAAL.

Current Condition and Trend

Occurrence of Human-Caused Sound

No data have been gathered on the occurrence of human-caused sound within or around PAAL.

Natural Ambient Sound Level

The natural ambient sound level is an estimate of what an acoustical environment might sound like without the contribution of anthropogenic sounds. It includes all physical and biological sounds regularly heard at a site. To date, no natural ambient sound level data have been collected at PAAL.

Threats and Stressor Factors

Threats to the park's soundscape include increasing noise from traffic (ground and air), adjacent land use, and human development. Roads form the western and southwestern boundary of PAAL and a major highway lies less than 5 km (3 mi) from the park's southwestern edge. Paredes Line Road on the western boundary has been expanded from a two-lane to a four-lane highway within the past 5 years (Spier, written communication, October 2012). GULN sampling crews that have visited the park regularly since 2008 have noted increased traffic and machinery noise over time (Woodman, written communication, October 2012). A railroad runs just outside the park's western border. The park is also just over 10 km (6.2 mi) from the Brownsville International Airport and lies under one of its major approach routes (Spier, written communication, October 2012). Urban sprawl from Brownsville, TX, is also a concern (Cooper et al. 2004). Two industrial parks were recently established less than 2.5 km (1.5 mi) from the park's south and southwestern boundaries (Garza, written communication, October 2012).

Data Needs/Gaps

To date, no soundscape data have been gathered at or around PAAL. Baseline data collection is needed to identify natural and human-caused sounds and sound levels heard in the park. This will help managers mitigate any potential impacts from these sounds and provide data for comparison in the future to identify any changes or trends in soundscape. Additionally, park management is interested in studying the potential impacts of traffic noise on wildlife (Cooper et al. 2004).

Overall Condition

Occurrence of Human-Caused Sound

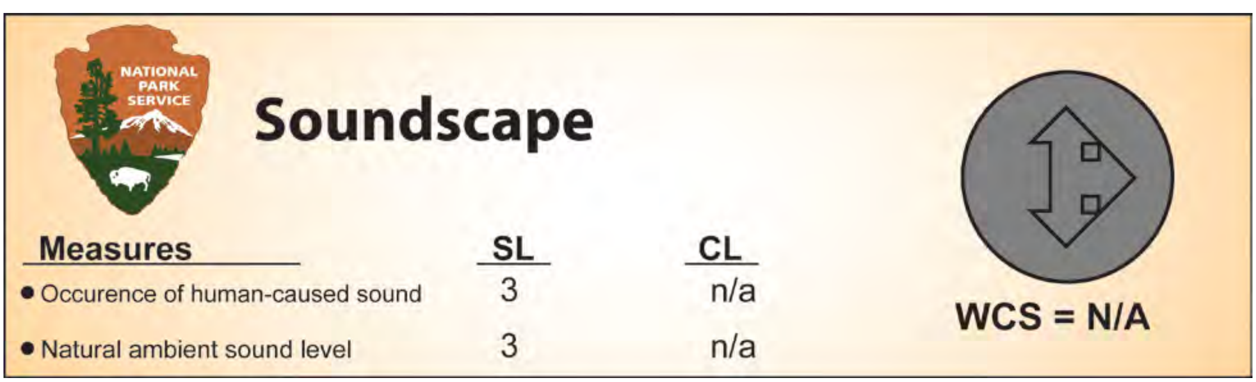
The project team defined the *Significance Level* for occurrence of human-caused sound as a 3. However, since no soundscape data have been gathered in the park, a *Condition Level* could not be assigned.

Natural Ambient Sound Level

The project team defined the *Significance Level* for natural ambient sound level as a 3. No data are available for this measure, so a *Condition Level* could also not be assigned.

Weighted Condition Score

Since a *Condition Level* was not assigned for either of this component's measures, a *Weighted Condition Score* could not be calculated. The overall condition of PAAL's soundscape is unknown with an unknown trend.



Sources of Expertise

Rolando Garza, PAAL Archeologist and Integrated Resource Manager

Robert Woodman, GULN Ecologist

Mark Spier, PAAL Superintendent

Literature Cited

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National Park Service (NPS). 2000. Directors Order #47: Soundscape preservation and noise management. http://www.nps.gov/policy/DOrders/DOrder47.html (accessed 17 September 2012).

4.18 Dark Night Skies

Description

A natural lightscape is a place or environment characterized by the natural rhythm of the sun and moon cycles, clean air, and of dark nights unperturbed by artificial light (NPS 2012). The NPS directs each of its units to preserve, to the greatest extent possible, these natural lightscapes (NPS 2006). Natural cycles of dark and light periods during the course of a day affect the evolution of species and other natural resource processes such as plant phenology (NPS 2006, 2012). Several wildlife species require darkness to hunt, hide their location, navigate, or reproduce (NPS 2012). In addition to the ecological importance of dark night skies, park visitors expect skies to be free of light pollution and allow for star observation.

Measures

During site visits, the NPS Night Sky Team (NST) collects data for a suite of measures in order to define the current condition of dark night skies in a park unit. While the NST has not visited PAAL, the suite of measures that they would use on a visit includes:

- Sky luminance over the hemisphere in high resolution (thousands of measurements comprise a data set), reported in photometric luminance units (V magnitudes per square arc second or milli-candela per square meter) or relative to natural conditions, often shown as a sky brightness contour map of the entire sky. V magnitude is a broadband photometric term in astronomy, meaning the total flux from a source striking a detector after passing through a "Johnson-Cousins V" filter. It is similar to the "CIE photopic" broadband function for wavelengths of light to which the human eye is sensitive (Bessell 1990);

- Integrated measures of anthropogenic sky glow from selected areas of sky that may be attributed to individual cities or towns (known as city light domes), reported in milli-Lux of hemispheric illuminance or vertical illuminance;

- Integration of the entire sky illuminance measures, reported either in milli-Lux of total hemispheric (or horizontal) illuminance, milli-Lux of anthropogenic hemispheric (or horizontal) illuminance, V-magnitudes of the integrated hemisphere, or ratio of anthropogenic illuminance to natural illuminance;

- Vertical illuminance from individual (or groups of) outdoor lighting fixtures at a given observing location (such as the Wilderness boundary), in milli-Lux;

- Visual observations by a human observer, such as Bortle Class and Zenithal limiting magnitude;

- Integrated synthesized measure of the luminance of the sky within 50 degrees of the Zenith, as reported by the Unihedron Sky Quality Meter, in V magnitudes per square arc second;

Reference Conditions/Values

The reference condition for dark night skies in PAAL is defined as the night sky visibility as observed on the historic battlefield. It can be hypothesized that the natural sky visibility during the historic battle (1846) had no anthropogenic influences, with the exception of the occasional campfire (Garza, email communication, 25 October 2012).

The NST defines reference condition in terms of sky luminance and illuminance at the observer's location from anthropogenic sources as follows:

> No portion of the sky background brightness exceeds natural levels by more than 200 percent, and the sky brightness at the Zenith does not exceed natural Zenith sky brightness by more than 10 percent. The ratio of anthropogenic hemispheric illuminance to natural hemispheric illuminance from the entire night sky does not exceed 20 percent. The observed light from a single visible anthropogenic source (light trespass) is not observed as brighter than the planet Venus (0.1 milli-Lux) when viewed from within any area of the park designated the naturally dark zone (Dan Duriscoe, NPS Night Sky Team, personal communication, 2011).

Achieving this reference condition for preserving natural night skies is well summarized in the NPS Management Policies (2006, p. 57) as follows in section 4.10:

> The Service will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light.

Implementing this directive in PAAL requires that facilities within the park and local communities around the park meet outdoor lighting standards that provide for the maximum amount of environmental protection while meeting human needs for safety, security, and convenience. This means that outdoor lights within the park:

- produce zero light trespass beyond the boundary of their intended use;
- be of an intensity that meets the minimum requirement for the task but does not excessively exceed that requirement;
- be of a color that is toward the yellow or orange end of the spectrum to minimize sky glow;
- be controlled intelligently, preventing unnecessary dusk to dawn bright illumination of areas.

Data and Methods
No data have been collected by the NPS in PAAL related to dark night skies.

Current Condition and Trend

Background for NPS Night Sky Team's Suite of Measures
While no data have been collected in PAAL, it is important to recognize that anthropogenic light in the night environment can be very significant, especially on moonless nights. Unshielded lamps mounted on tall poles have the greatest potential to cause light pollution, since light directly emitted by the lamp has the potential to follow an unobstructed path into the sky or the

distant landscape. This type of light spill has been called glare, intrusive light, or light trespass (Narisada and Schreuder 2004). The dark-adapted human eye will see these individual light sources as extremely bright points in a natural environment. These sources also have the potential to illuminate the landscape, especially vertical surfaces aligned perpendicular to them, often to a level that approaches or surpasses moonlight. The brightness of such objects may be measured as the amount of light per unit area striking a “detector” or a measuring device, or entering the observer’s pupil. This type of measure is called illuminance (Ryer 1997).

Illuminance is measured in lux (metric) or foot-candles (English). It is usually defined as luminous flux per unit area of a flat surface (1 lux = 1 lumen / m^2). However, different surface geometries may be employed, such as a cylindrical surface or a hemispheric surface. Integrated illuminance of a hemisphere (summed flux per unit area from all angles above the horizon) is a useful, unbiased metric for determining the brightness of the entire night sky. Horizontal and vertical illuminance are also used; horizontal illuminance weights areas near the Zenith are much greater than areas near the horizon, while vertical illuminance preferentially weights areas near the horizon, and an azimuth of orientation must be specified.

Direct vertical illuminance from a nearby anthropogenic source will vary considerably with the location of the observer, since this value varies as the inverse of the square of the distance from light source to observer (Ryer 1997). Therefore, measures of light trespass are usually made in sensitive areas (such as public campgrounds).

Anthropogenic light which results in an upward component will be visible to an observer as “sky glow”. This is because the atmosphere effectively scatters light passing through it. The sky is blue in daytime because of Rayleigh scattering by air molecules, which is more effective for light of shorter wavelengths. For this reason, bluish light from outdoor fixtures will produce more sky glow than reddish light. Larger particles in the atmosphere (aerosols and water vapor droplets) cause Mie scattering and absorption of light, which is not as wavelength-dependent and is more directional. When the air is full of larger particles, this process gives clouds their white appearance and produces a whitish glow around bright objects (e.g., the sun and moon). The pattern of sky glow as seen by a distant observer will appear as a dome of light of decreasing intensity from the center of the city on the horizon. As the observer moves closer to the source, the dome gets larger until the entire sky appears to be luminous (Garstang 1989).

Light propagated at an angle near the horizon will be effectively scattered and the sky glow produced will be highly visible to an observer located in the direction of propagation. Predictions of the apparent light dome produced by a sky glow model demonstrate this (Luginbuhl et al. 2009). Light reflected off surfaces (e.g., a concrete road or parking area) becomes visible light pollution when it is scattered by the atmosphere above it, even if the light fixture has a “full cutoff” design and is not visible as glare or light trespass to a distant observer. For this reason, the intensity and color of outdoor lights must be carefully considered, especially if light-colored surfaces are present near the light source.

Light domes from many cities, as they appear from a location within Joshua Tree National Park, are shown in Figure 17 and Figure 18, as a grayscale and in false color. This graphic demonstrates that the core of the light dome may be tens or hundreds of times brighter than the extremities. A logarithmic scale for sky luminance and false color are commonly used to display monochromatic images or data with a very large dynamic range, and are used extensively in reports of sky brightness by the NST.

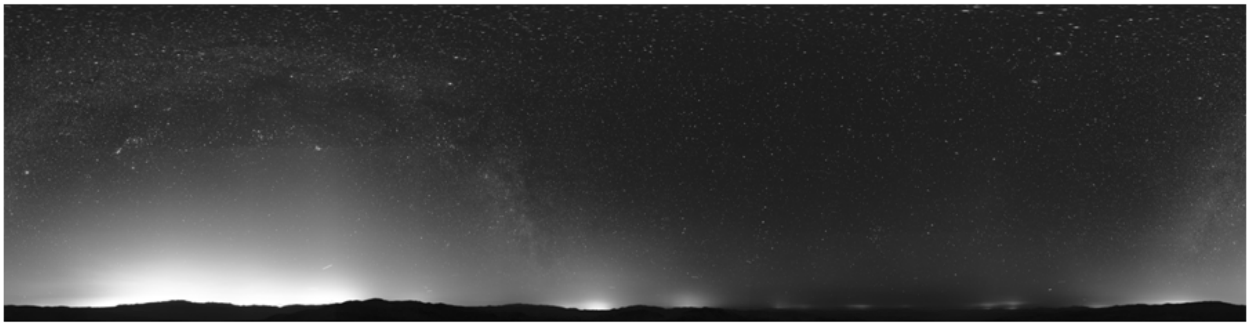


Figure 17. Grayscale representation of sky luminance from a location in Joshua Tree National Park (Figure provided by Dan Duriscoe, NPS Night Sky Team).

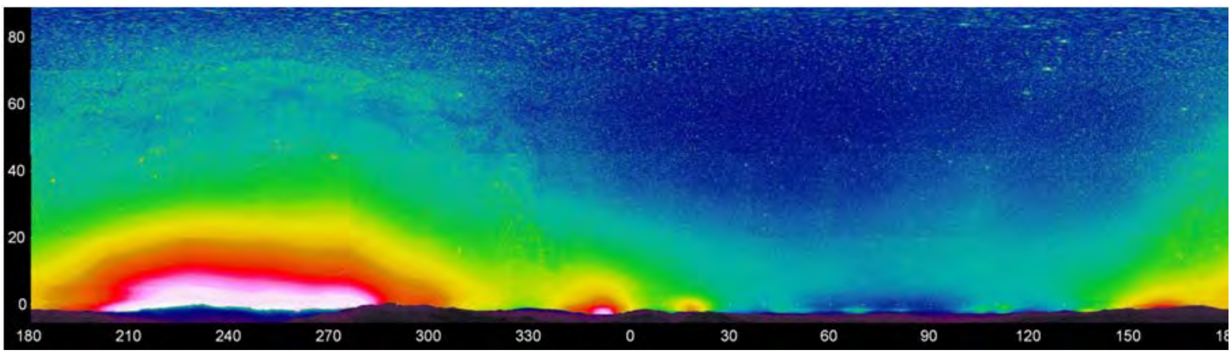


Figure 18. False color representation of Figure 1 after a logarithmic stretch of pixel values (Figure provided by Dan Duriscoe, NPS Night Sky Team).

The brightness (or luminance) of the sky in the region of the light domes may be measured as the number of photons per second reaching the observer for a given viewing angle, or area of the sky (such as a square degree, square arc minute, or square arc second). The NST utilizes a digital camera with a large, dynamic range, monochromatic charge-coupled device (CCD) detector and an extensive system of data collection, calibration, and analysis procedures (Duriscoe et al. 2007). This system allows for the accurate measurement of both luminance and illuminance, since it is calibrated on standard stars that appear in the same images as the data and the image scale in arc seconds per pixel is accurately known. Sky luminance is reported in astronomical units of V-magnitudes per square arc second, and in engineering units of milli-candela per square meter. High resolution imagery of the entire night sky reveals details of individual light domes that may be attributed to anthropogenic light from distant cities or nearby individual sources. These data sets may be used for both resource condition assessment and long-term monitoring.

Figure 17 and Figure 18 contain information on natural sources of light in the night sky as well as anthropogenic sources. The appearance of the natural night sky may be modeled and predicted in terms of sky luminance and illuminance over the hemisphere, given the location, date, time, and the relative brightness of the natural airglow (the so-called "permanent aurora" which varies in intensity over time) (Roach and Gordon 1973). The NST has constructed such a model, and uses it in analysis of data sets to remove the natural components. This results in a more accurate measure of anthropogenic sky glow (Figure 19). Figure 18 represents "total sky brightness" while Figure 19 displays "anthropogenic sky glow" or "net light pollution." This is an important distinction, especially in areas where anthropogenic sky glow is of relatively low intensity.

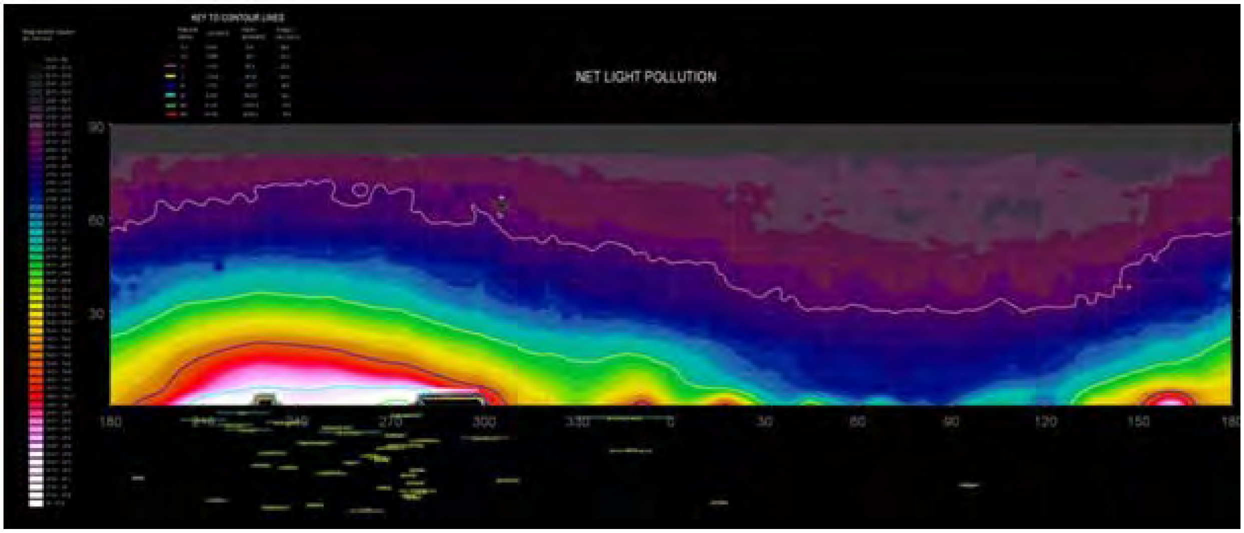


Figure 19. Contour map of anthropogenic sky glow at a location in Joshua Tree National Park, analogous to Figure 2 with natural sources of light subtracted (Figure provided by Dan Duriscoe, NPS Night Sky Team).

The accurate measurement of both anthropogenic light in the night sky and the accurate prediction of the brightness and distribution of natural sources of light allows for the use of a very intuitive metric of the resource condition - a ratio of anthropogenic to natural light. Both luminance and illuminance for the entire sky or a given area of the sky may be described in this manner (Hollan 2008). This so-called "light pollution ratio" is unitless and is always referenced to the brightness of a natural moonless sky under average atmospheric conditions, or, in the case of the NST data, the atmospheric conditions determined from each individual data set.

The reference conditions for anthropogenic sky luminance were identified as no more than 200 percent brighter than natural conditions in *any* area of the sky and no more than 10 percent brighter at the Zenith. These values correspond to light pollution ratios of 2.0 and 0.1, respectively. The NST has obtained values of 50-100 for this measure at the core of city light domes seen from several areas administered by the NPS, including Lake Mead National Recreation Area, Saguaro National Park, and Colorado National Monument (NPS Night Sky Team, unpublished data). This is because these NPS areas are very close to the cities of Las Vegas, Nevada; Tucson, Arizona; and Grand Junction, Colorado, respectively.

A quick and accurate method of quantifying sky brightness near the Zenith is the use of a Unihedron Sky Quality Meter. The Unihedron Sky Quality Meter is a single-channeled hand-held photometric device. A single number in magnitudes per square arc second is read from the front of the device after its photodiode and associated electronics are pointed at the Zenith and the processor completes its integration of photon detection. Because the meter is relatively inexpensive and easy to use, a database of measures has grown since its introduction (see http://unihedron.com/projects/darksky/database/index.php). The NST produces values from each data set as both a synthesized value derived from the high-resolution images and by hand held measures with a Unihedron Sky Quality Meter. The performance of the Sky Quality Meter has been tested and reviewed by Cinzano (2005). While fairly accurate and easy to use, the value it produces is biased toward the Zenith. Therefore, the robustness of data collected in this manner is limited to areas with relatively bright sky glow near the Zenith, corresponding to severely light polluted areas. While not included in the reference condition, a value of about 21.85 would be considered "pristine", providing the Milky Way is not overhead and/or the natural airglow is not unusually bright when the reading is taken.

Visual observations are important in defining sky quality, especially in defining the aesthetic character of night sky features. A published attempt at a semi-quantitative method of visual observations is described in the Bortle Dark Sky Scale (Bortle 2001). Observations of several features of the night sky and anthropogenic sky glow are synthesized into a 1-9 integer interval scale, where class 1 represents a "pristine sky" filled with easily observable features and class 9 represents an "inner city sky" where anthropogenic sky glow obliterates all the features except a few bright stars. Bortle Class 1 and 2 skies possess virtually no observable anthropogenic sky glow (Bortle 2001).

Another visual method for assessing sky quality is Zenithal Limiting Magnitude (ZLM), which is the apparent brightness or magnitude of the faintest star observable to the unaided human eye, which usually occurs near the Zenith. This method involves many factors, the most important of which is variability from observer to observer. A ZLM of 7.0-7.2 is usually considered "pristine" or representing what should be observed under natural conditions; observation of ZLM is one of the factors included in the Bortle Dark Sky Scale. Zenith Limiting Magnitude is often referenced in literature on the quality of the night sky, and is the basis for the international "Globe at Night" citizen-scientist program (see http://www.globeatnight.org/index.html). The NST has experimented with the use of this observation in predicting sky quality, and has found that it is a much coarser measure and prone to much greater error than accurate photometric measures over the entire sky. For these reasons, it is not included in the reference conditions section. .

Threats and Stressor Factors

Situated in close proximity to two major urban areas (Brownsville, Texas; Matamoros, Mexico), PAAL is subjected to high levels of anthropogenic light pollution. This light pollution comes from human developments on the land surrounding the park, and areas further away from the park (downtown Brownsville, Texas, and even further away from Matamoros, Mexico) also contribute light pollution. Many businesses have unobstructed lights that are orientated upwards, and these lights remain on even when the business's operating hours have passed. The Resaca de la Palma site is situated much closer to Brownsville, Texas, and is likely exposed to greater levels of light pollution than the Palo Alto site.

The park's urban location, coupled with its close proximity to Port Isabel, also results in high levels of traffic passing by the site, and at night, the lights from passing vehicles contribute to light pollution. Transportation infrastructure (i.e., street lights) has increased in size in the past decade, most notably the addition of an overpass at the nearby intersection of Texas State Highway 550 and Farm to Market Road. Several bright streetlights from this development are easily visible during both daylight and night time hours (Photo 42).

Photo 42. Streetlight (indicated by a black arrow) at the intersection of Texas State Highway 550 and Farm to Market Road. Photo was taken from the PAAL Visitor center looking south (Photo by Shannon Amberg, SMUMN GSS).

External light sources are not the only source of anthropogenic light pollution in PAAL, as several park lighting fixtures are in operation outside of business hours. The visitor center has a spotlight that shines on a replica U.S.-Mexican War cannon during all dark hours; this spotlight is used as a security device to help prevent vandalism and theft of the cannon and other interpretive pieces (Garza, personal communication, 25 October 2012). Other sources of light also exist in the park, as several lights are in place around the visitor center and the maintenance building.

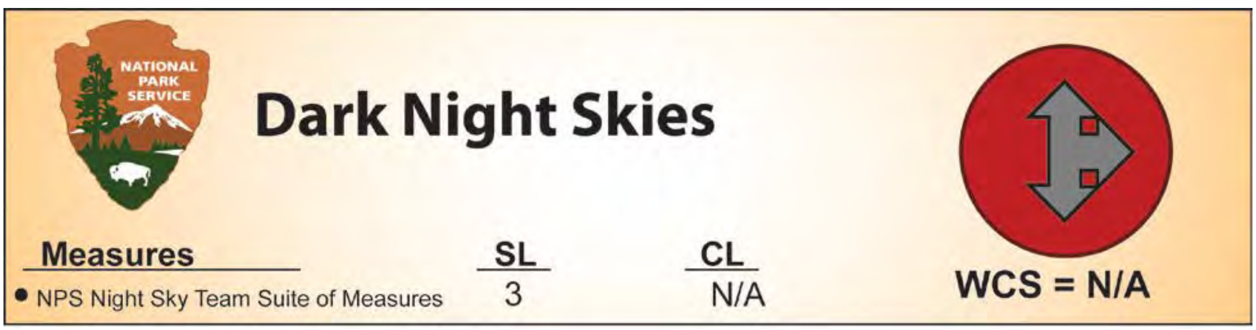
Currently, PAAL does not share an administrative boundary with any commercial development. However, Rolando Garza has described PAAL as an "island" in an otherwise urban environment; human development and associated lighting structures are beginning to surround the park (Garza, personal communication, 25 October 2012). As urbanization continues, the night skies of PAAL will likely continue to deteriorate, and management and legislative objectives may be needed to protect the deteriorating integrity of the resource.

Data Needs/Gaps

There has been no collection of baseline data at PAAL in regards to dark night skies. Without this data, an assessment of the condition of the night skies cannot be completed. A visit from the NST would allow for measurements of the entire sky brightness condition. Measurements should occur on a periodic basis, about once every 5 years, with the highest point in the park serving as the preferred observing site, in order to track external threats.

<u>Overall Condition</u>
During scoping meetings, the PAAL NRCA team assigned the NPS Night Sky Team's suite of measures a *Significance Level* of 3. Despite the lack of available data, it is likely that the current condition of dark night skies is threatened due to the urbanization of the areas surrounding PAAL. While a current trend cannot be assigned to this resource due to the lack of recent data, the level of concern for this resource is believed to be high, which is why a red circle was assigned to this resource. A visit from the NPS NST would provide baseline dark night sky measurements and would allow for a more accurate depiction of current condition and trend for PAAL.

Weighted Condition Score
Because SMUMN GSS could not assign *Condition Levels* to the component, no *Weighted Condition Score* was assigned. However, because of the threats from nearby communities, infrastructure (e.g., highway lights, city lights), and future developments, park managers have experessed high levels of concern for this component. Because of this, a red condition graphic, indicating high concern, was applied to this component.



Sources of Expertise
National Park Service Night Sky Team members Dan Duriscoe, Chad Moore, Teresa Jiles, Jeremy White, and Robert Meadows

Rolando Garza, PAAL Archeologist and Integrated Resource Manager

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Chapter 5 Discussion

Chapter 5 provides an opportunity to summarize assessment findings and discuss the overarching themes or common threads that have emerged for the featured components. The data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also addressed is how condition analysis relates to the overall natural resource management issues of the park.

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps exist for most key resource components assessed in this NRCA. Table 29 provides a detailed list of the key data gaps by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 29. Identified data gaps or needs for the featured components in PAAL.

Component	Data Gaps/Needs
Open Prairie Community	➢ Research is needed into the extent and rate of woody encroachment in the park ➢ Investigation into the usefulness of fire in controlling the woody plant encroachment ➢ Invasive plant surveys would be helpful to determine if these species are present in the undisturbed prairie communities, and if they are affecting the native species composition in these areas
Tamaulipan Brushland	➢ Little is known about the succession or conversion rates of grasslands transitioning to brushland in South Texas ➢ An invasive plant survey would help managers to determine if these species are present in the park's brushlands and if they are affecting native species ➢ A survey of the brushlands in the Resaca de la Palma unit is needed
Resaca Wetland & Riparian Community	➢ Data that pertain to the soil moisture and soil redox potential in the park are needed ➢ Information regarding the frequency and duration of inundation events in the wetlands of the park would be useful to park managers (although this will be difficult to obtain) ➢ An updated native plant survey is needed to determine if any native species have been lost due to hydrological changes or non-native displacement
Breeding Birds	➢ Continuation of the annual breeding bird surveys are needed to analyze and detect potential long-term trends. The establishment of additional breeding surveys (or expansion of existing surveys) would also be useful, especially on the eastern portion of the park ➢ Utilization of the eBird Kiosk data is needed so that park managers have a more accurate, year-round data source for bird observations in the park
Raptors	➢ A raptor nesting survey would provide managers with a more accurate description of the nesting raptors in the park ➢ Annual aplomado falcon breeding surveys are needed to track productivity and abundance trends in this endangered species
Coyotes	➢ A survey that investigates the coyote density and distribution in the park is needed in PAAL

Table 29. Identified data gaps or needs for the featured components in PAAL (continued).

Component	Data Gaps/Needs
Collared Peccary	➢ Very few, if any, studies have documented the density and distribution of collared peccaries in the park. This type of data is needed in order for managers to accurately assess the current status of these animals in the park
Wild Cats	➢ No data exist regarding wild cat abundance or distribution in the park, and a baseline survey for the feline species found in the park is needed
Native Rodents	➢ An investigation into the current native rodent population's species abundance, diversity, and distribution is needed in PAAL
Butterflies	➢ A formal certified species list that identifies the butterflies that are known to occur in the park is not available ➢ A survey that documents the butterfly abundance in the park, as well as the distribution of butterflies in the park is needed
Amphibians	➢ There are limited data available for amphibians in the park, and a contemporary survey of amphibians in the park is needed
Reptiles	➢ There are limited data available for reptiles in the park, and a contemporary survey of reptiles in the park is needed
Texas Tortoise	➢ Continuation of the GULN Texas tortoise monitoring is needed to determine long-term trends in the PAAL population ➢ Expansion of the GULN monitoring to include density, distribution, age class structure, and sex ratio of tortioses would greatly help managers to better gauge the health of the population
Air Quality	➢ No monitoring of air quality occurs within the PAAL boundaries. Periodic or consistent monitoring of the identified parameters would help managers to better understand the local air quality in and around the park
Water Quality	➢ Because surface water in the park is ephemeral, there has been no consistent monitoring of water quality parameters within the boundaries of the main park unit ➢ Data characterizing water quality adjacent to the Resaca de la Palma unit are needed
Viewscape	➢ Continued development of spatial data (specifically NLCD data post-2006) that explain landscape change will enable accurate and up-to-date viewshed assessments
Soundscape	➢ No soundscape data has been collected in the park. Soundscape monitoring in the park is needed to identify baseline levels of natural and human-caused sounds ➢ A study investigating the potential impacts traffic noise has on wildlife was proposed in Cooper et al. (2004), a study of this kind could be useful to park managers, especially with the threat of more nearby developments
Dark Night Skies	➢ Night sky measurements completed by the NPS Night Sky Team are needed at PAAL to establish baseline sky brightness values for the park. This will be especially important as new structures and lights are erected near the park

Many of the park's data needs involve the establishment of an annual monitoring program, as many of the park's components have either outdated data or no data at all. Several of the components analyzed in this report had outdated data, and did not have data that facilitated long-term trend analyses.

The park's vegetative communities are in need of an updated survey, as well as an investigation into the extent of non-native species in these areas. The park's wildlife components are all in need of contemporary data, although the GULN has begun annual bird surveys in the park during the winter and breeding seasons. Very few studies have expanded upon the early inventories and surveys (e.g., Richard and Richardson 1993, Cooper et al. 2004) that were completed in the park near the end of the 1990s. Being located at the periphery of several native cats' home ranges, a survey of the native cats in the park would be very useful to park managers. The Texas tortoise population is the most frequently monitored wildlife species in the park, as the GULN surveys the population in PAAL annually. Expansion of this survey could help to better understand the density, distribution, and age class structure of this species in the park.

The components that describe environmental quality (i.e., air and water quality, viewscape, soundscape, and dark night skies) are in need of expanded monitoring efforts. No monitoring of air quality occurs within PAAL boundaries, and water quality monitoring (in regards to basic water quality parameters) has not occurred consistently in the park. Data used in the viewshed component is current only through 2006; with the expansion of Brownsville, TX, it will be important for park staff to obtain more recent NLCD data. A replication of the viewshed analysis using contemporary data will be highly useful for park managers, as the park's viewshed continues to be threatened by human development surrounding the park. No data exist for the dark night skies or soundscape components.

5.2 Component Condition Designations

The conditions assigned to each resource component presented in Chapter 4 are presented in Table 30 (definitions of condition graphics are located in Figure 20 following Table 30). It is important to remember that the graphics represent simple symbols for the overall condition and trend assigned to each component. Because the condition of a component (as represented by the symbols in Table 30) is based on a number of factors and an analysis of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information.

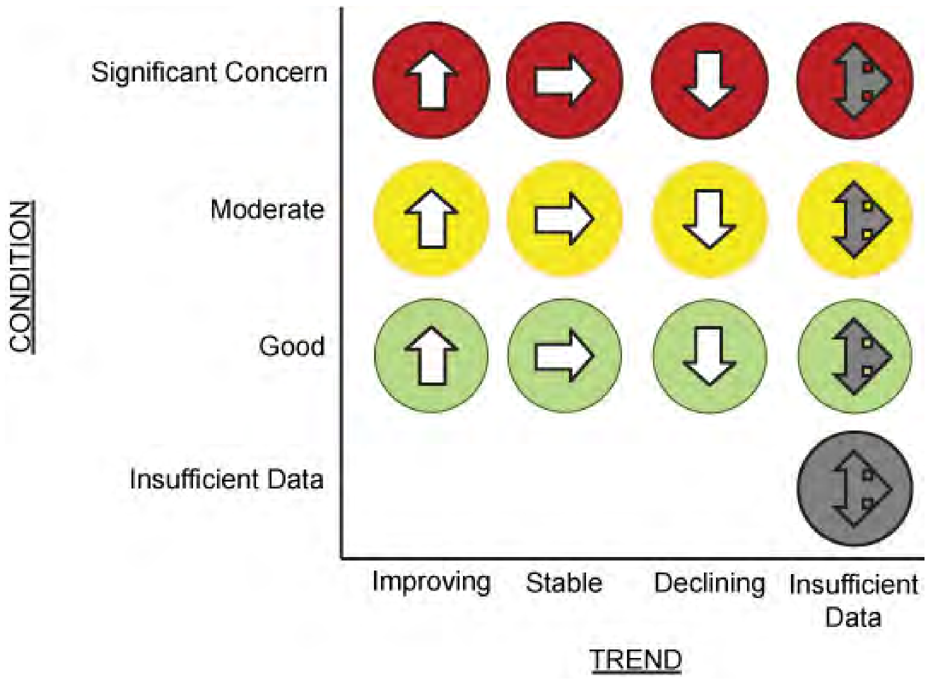


Figure 20. Symbols used for individual component assessments with condition or concern designations along the vertical axis and trend designations along the horizontal.

Table 30. Summary of current condition and condition trend for featured NRCA components. Higher Weighted Condition Scores indicate higher concern.

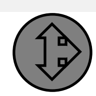
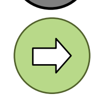
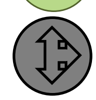
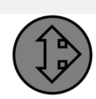
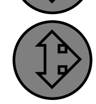
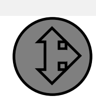
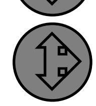
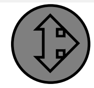
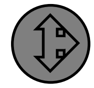
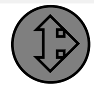
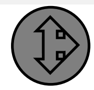
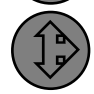
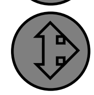
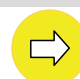
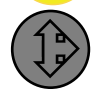
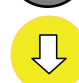
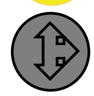
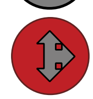
Component	WCS	Condition
Biological Composition		
Ecological communities		
Open Prairie Community	N/A	
Tamaulipan Brushland	0.333	
Resaca Wetland & Riparian Community	N/A	
Birds		
Breeding Birds	N/A	
Raptors	N/A	
Mammals		
Coyotes	N/A	
Collared Peccary	N/A	

Table 30. Summary of current condition and condition trend for featured NRCA components. Higher Weighted Condition Scores indicate higher concern (continued).

Component	WCS	Condition
Mammals		
Wild Cats	N/A	
Native Rodents	N/A	
Insects		
Butterflies	N/A	
Herptiles		
Amphibians	N/A	
Reptiles	N/A	
Texas Tortoise	N/A	
Environmental Quality		
Air quality	0.500	
Water quality	N/A	
Viewshed	0.500	
Soundscape	N/A	
Dark night skies	N/A	

For the four featured components with available data and fewer data gaps, assigned conditions varied. The Tamaulipan brushlands component was the only component to be considered of low concern. Two components related to environmental quality were deemed to be of moderate concern: air quality and viewshed. Dark night skies was the only component of high concern, primarily due to the rapid encroachment of the city of Brownsville, recent developments near the park, and the park's proximity to two very large cities (Brownsville, TX; and Matamoros, Mexico).

5.3 Park-wide Condition Observations

Despite the great variety in vegetation and physical features within PAAL's boundaries, many of the resources discussed in this report are interrelated and share similar management concerns (e.g., data gaps, threats from outside the park).

Native Vegetation Communities
The native vegetation communities of PAAL (represented in this report by the prairie, brushland, and wetland communities) are vital resources for the park, providing habitat for wildlife and performing critical ecological functions. These communities are also among the most visible ecological resources to park visitors. Due to a lack of comparable data over time (either historic information or current data for comparison), condition could not be assessed for two of the selected vegetative communities: open prairie community, and the resaca wetland and riparian community.

The open prairie community was lacking data that pertained to species richness and the ratio of native to non-native species in the park. The two measures that had enough data to summarize and analyze trends (extent of woody species coverage, and extent of grassland species coverage), were deemed to be of high concern. Managers have indicated that the expansion of woody species into the native grasslands is of high concern, and that this encroachment needs to be monitored in the future. The resaca wetland and riparian community component had insufficient data for all measures except for the extent of wetland and riparian communities (which was determined to be of moderate concern).

Tamaulipan brushlands were the vegetative community that could be assessed, and was considered of low concern with a stable trend. The native species diversity in the park's brushlands appears to be relatively high, and despite being reduced when compared to the 1846 battlefield, the areal extent of Tamaulipan brushlands has expanded since 1934.

Other Biotics
The wildlife species that were featured as NRCA components included breeding birds, raptors, coyotes, collared peccary, wild cats, native rodents, butterflies, amphibians, reptiles, and the Texas tortoise. Due to a lack of recent data for comparison to historic information, condition and trend could not be determined for any of the wildlife components. Many of these components have had very little monitoring done since the early surveys and inventories completed in the park during the 1990s. The notable exception is the Texas tortoise, which has had recent surveys conducted by the GULN. The GULN has also begun winter and breeding land bird surveys in the park, which should help to characterize the health of the bird components in the park.

Environmental Quality
Environmental quality is important in maintaining healthy functioning ecosystems. The health of terrestrial and aquatic organisms in parks can be substantially affected by the condition of air and water quality. The park's air quality is currently of moderate concern with a stable trend. Nitrogen and sulfate deposition are a potential issue, due to the sensitivity of arid and semi-arid ecosystems to acidification and/or nutrient enrichment from these pollutants; these measures were both determined to be of moderate concern.

The ephemeral nature of the water features in the park makes it difficult to monitor water quality regularly. Thus, the lack of consistent monitoring data on basic water quality parameters renders it difficult to make definitive statements about current water quality conditions within PAAL. Because of this, a current condition for this resource was not assigned.

The park's viewshed is currently of moderate concern, with little land use change (e.g., conversion for development) occurring within the park. However, the last decade has seen dramatic increases in developments outside of the park, very near the park's administrative boundary. Monitoring will be needed in the coming years to track the developments in the areas visible from within the park's boundaries. Condition could not be determined for soundscape because of little or no available data, although this component is of concern to managers due to the expansion of Brownsville, TX, and the energy and highway developments located near the park. The dark night skies component had limited data, but park managers expressed that the recent developments around the park (e.g., lights near the highway overpass) were severe enough to designate the current condition as one of significant concern.

Park-wide Threats and Stressors

Several threats and stressors influence the condition of multiple resources throughout PAAL. These include the presence of exotic plants and animals, extreme weather events (e.g., hurricanes, drought), habitat loss and human development, and nearby energy developments (specifically nearby power lines, power plants, and wind farms).

Exotic plant species are a threat to all of the park's vegetation communities, as they can out-compete native plants and alter ecological processes such as fire regime and nutrient cycling (Brooks and Pyke 2001, Reiser et al. 2012). There have been 21 exotic plant species recorded in PAAL, and exotic plants make up approximately seven percent of the park's plant population (NPS 2013). The exotic plants in the park are found primarily on disturbed sites, and have the potential to spread into the more "natural" communities and outcompete the native species.

PAAL is also home to several exotic species of animals, which range in size from the very large nilgai (100-288 kg [220-630 lbs]) to the small fire ant (genus *Solenopsis*; 2-6 mm). Regardless of size, these species are destructive to the native landscape of PAAL, and affect both the natural and cultural resources of the park. Nilgai, the largest exotic mammal in the park, were introduced in Texas as an exotic game species and subsequently established populations in southern Texas. Nilgai frequent the grasslands of the park and are diet generalists, meaning they can eat grasses or can shift to browse when grass becomes unavailable. This species has the potential to cause overgrazing on native rangelend ecosystems, and can cause disruption of the balance within natural plant communities.

Feral hogs are a significant threat to the park, as their behavior affects the natural plant and animal communities in the park and the archeological record that exists some 30 cm (12 in) below the soil. In some areas of the park, the vascular plant communities have been destroyed or heavily altered by the hogs' rooting behavior. The hogs in the park can also out-compete native mammals (such as coyotes or wild cats) for food and other habitat-related resources.

While PAAL is home to a substantial native rodent population (see Chapter 4.9), there are also exotic rodent species present in the park, namely the black and Norway rats. The Norway rat is the more common of the two exotic species, but both species have the potential to outcompete native rodent species for food, burrows, and other resources.

Hurricanes and tropical storms strike the Gulf coast of Texas at an average rate of 0.67 storms per year, or approximately two storms every 3 years. Most of these weather events occur between late spring and early fall, with prime storm activity occurring from August through October (Weise and White 1980). When wind velocities reach 119 km/hr (74 mi/hr), tropical storms become categorized as hurricanes; the most severe hurricanes have sustained winds in excess of 322 km/hr (200 mi/hr) (Weise and White 1980). Such strong winds can cause significant changes to the park's vegetation communities, and can inundate many of the dry resaca beds. During storm events, vegetation can be uprooted and large amounts of sand can be displaced inland (Weise and White 1980). An equally destructive force is the tidal storm surge that accompanies hurricanes. These surges expend tremendous energy, causing erosion and transporting and depositing huge amounts of coastal sediment in the process (Weise and White 1980). PAAL is less than 24 km (15 mi) from the Gulf, and while storm surges may not reach as far inland as the park, heavy rain and winds are likely to inundate areas of the park and result in significant vegetation damage.

Brownsville, Texas has grown rapidly over the last 20 years, and residential and commercial developments around PAAL have especially increased in recent years (Garza, personal communication, 29 June 2012). This process of urbanization will likely result in a transformation of the natural landscape of the PAAL area, and PAAL may become an "island" of natural habitat in an area surrounded by urban structures. Energy developments around the park, particularly wind and other alternative energy plants, have also grown rapidly. The development of wind and alternative energy necessitates the creation of high-tension power lines around the developments. Recently, a plan was approved to install high-tension 345 kV power lines along the U.S. Highway 550/511 corridor that borders the park along the south and east. The installation of these power lines will likely be accompanied by high levels of anthropogenic disturbance (machinery, noise, lights), and an increased risk for animal mortality (specifically in bird collisions and electrocutions).

Overall Conclusions

PAAL is a very unique and diverse park that supports a variety of unique ecological communities, landscapes, and wildlife. The diversity in PAAL's communities ranges from the Tamaulipan brushlands (that are only found in south Texas and northeastern Mexico), to the resaca wetlands and riparian communities. Visitors to PAAL have the opportunity to view wildlife ranging in size from the very small native rodents, to the very large non-native nilgai. PAAL is also unique in that many of the resources currently present in the park are similar to what Mexican and American soldiers would have observed during the Battle of Palo Alto in 1846.

This assessment serves as a review and summary of available data and literature for featured natural resources in the park. The information presented here may serve as a baseline against which any changes in condition of components in the future may be compared. Unfortunately, many of the components analyzed here were not assigned an overall condition due to data gaps; some of these needs are being addressed by recently implemented GULN monitoring programs, which will provide valuable information for condition assessment in the near future. In order for PAAL managers to better understand the health, integrity, and trends of these valuable resources, additional research is needed for the specified components identified in this document.

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Appendix A. Native plant species documented in the Tamaulipan brushlands by Richard and Richardson (1993) and in the brush-grasslands vegetative zone by Lonard et al. (2004).

Scientific name	Common name	Richard and Richardson 1993	Lonard et al. 2004
Dyschoriste crenulata	wavyleaf snakeherb	x	x
Elytraria bromoides	wheatspike scalystem		x
Justicia pilosella	Gregg's tube tongue	x	x
Ruellia nudiflora var. *runyonii*	Runyon's wild petunia	x	x
Stenandrium dulce	sweet shaggytuft		x
Phaulothamnus spinescens	snake-eyes, devilqueen	x	x
Celosia nitida	West Indian cock's comb		x
Cynanchum barbigerum	swallow-wort		x
Acourtia runcinata	stemless desertpeony		x
Chromolaena odorata	crucita, Jack in the bush		x
Fleischmannia incarnata	pink thoroughwort		x
Ambrosia psilostachya	Cuman or western ragweed	x	
Symphyotrichum divaricatum	southern annual saltmarsh aster	x	
Bidens laevis	smooth beggartick	x	
Borrichia frutescens	sea oxeye	x	
Clappia suaedifolia	fleshy clapdaisy	x	
Erigeron tenellus	Rio Grande fleabane	x	
Evax verna	spring pygmycudweed	x	
Florestina tripteris	sticky florestina	x	
Gutierrezia texana	Texas snakeweed	x	
Rayjacksonia phyllocephala	camphor daisy	x	
Parthenium hysterophorus	Santa Maria feverfew	x	
Trixis inula	tropical threefold	x	
Thymophylla pentachaeta	fiveneedle pricklyleaf, parralena		x
Thymophylla tenuiloba var. *treculii*	Trecul's pricklyleaf	x	x
Isocoma drummondii	Drummond's goldenbush		x
Senecio ampullaceus	groundsel, Texas ragwort		x
Simsia calva	bush sunflower	x	x
Verbesina microptera	Texas crownbeard		x
Wedelia texana	hairy wedelia		x
Ebenopsis ebano	Texas ebony	x	x
Dalea scandens	low dalea	x	x
Dalea pogonathera var. *walkerae*	Walker prairie clover	x	
Desmanthus virgatus	wild tantan	x	
Leucaena pulverulenta	great leadtree, tepeguaje		x
Parkinsonia aculeata	retama		x
Prosopis glandulosa	honey mesquite	x	x
Prosopis reptans var. *cinerascens*	tornillo	x	
Rivina humilis	rougeplant	x	x
Condalia hookeri	Brazilian bluewood	x	x
Karwinskia humboldtiana	coyotillo	x	x
Ziziphus obtusifolia	lotebush	x	x
Castela erecta	goatbush	x	x
Melochia pyramidata	angle-pod broomweed, pyramidflower		x
Celtis pallida	spiny hackberry	x	x
Phoradendron tomentosum	Christmas mistletoe		x
Yucca treculeana	Spanish dagger	x	x
Nothoscordum bivalve	crowpoison		x
Tillandsia baileyi	reflexed airplant		x
Tillandsia recurvata	small ballmoss	x	x
Bouteloua trifida	red grama		x
Chloris ×subdolichostachya	shortspike windmill grass		x
Digitaria pubiflora	Carolina crabgrass		x
Leptochloa dubia	green sprangletop		x

Scientific name	Common name	Richard and Richardson 1993	Lonard et al. 2004
Pappophorum vaginatum	whiplash pappusgrass		x
Trichloris pluriflora	multiflower false Rhodes grass		x
Tridens eragrostoides	lovegrass tridens		x
Acanthocereus tetragonus	barb-wire cereus, triangle cactus	x	x
Cylindropuntia leptocaulis	Christmas cactus, tasajillo	x	x
Echinocactus texensis	devil's head, horse crippler	x	x
Echinocereus pentalophus	ladyfinger cactus	x	x
Mammillaria heyderi	Heyder's pincushion cactus	x	x
Opuntia engelmannii	Engelmann pricklypear	x	x
Thelocactus setispinus	miniature barrel cactus	x	x
Koeberlinia spinosa	allthorn	x	x
Maytenus phyllanthoides	mangle-dulce, Florida mayten	x	x
Schaefferia cuneifolia	desert yaupon	x	x
Hypericum pauciflorum	fewflower St. Johnswort	x	x
Dichondra micrantha	Asian ponysfoot		x
Evolvulus alsinoides var. *angustifolius*	slender dwarf morning glory, ojo de vibora	x	x
Evolvulus sericeus	silver dwarf morning-glory	x	
Lenophyllum texanum	Texas stonecrop	x	x
Ibervillea lindheimeri	Lindheimer's globeberry	x	x
Jatropha cathartica	Berlandier's nettlespurge,	x	x
Jatropha dioica	leatherstem	x	x
Salvia coccinea	scarlet or blood sage	x	x
Teucrium cubense	germander	x	x
Abutilon trisulcatum	anglestem abutilon		x
Bastardia viscosa	viscid bastardia		x
Acleisanthes obtusa	Berlandier's trumpets	x	x
Forestiera angustifolia	narrowleaf forestiera	x	x
Phemeranthus aurantiacum	orange fameflower		x
Zanthoxylum fagara	lime pricklyash, colima	x	x
Sideroxylon celastrinum	saffron plum, la coma		x
Leucophyllum frutescens	cenizo	x	x
Capsicum annuum	chilipiquin		x
Lantana urticoides	West Indian shrubverbena		x
Lantana achyranthifolia	brushland shrubverbena, desert lantana	x	x
Aloysia gratissima	whitebrush	x	x
Glandularia bipinnatifida var. *bipinnatifida*	Dakota mock vervain	x	
Verbena canescens	gray vervain	x	
Verbena halei	Texas vervain	x	
Lycium berlandieri	Berlandier's wolfberry		x
Cooperia sp.	rainlily	x	x
Callisia micrantha	small-flowered roseling	x	x
Bothriochloa laguroides subsp. *torreyana*	silver beardgrass		x
Buchloe dactyloides	buffalograss		x
Digitaria californica	Arizona cottontop		x
Enteropogon chlorideus	buryseed umbrellagrass		x
Panicum hallii var. *filipes*	filly panicum	x	x
Setaria leucopila	Plains bristlegrass		x
Tridens albescens	white tridens		x
Tridens texanus	Texas tridens		x
Sporobolus pyramidatus	Madagascar dropseed	x	
Sporobolus virginicus	seashore dropseed	x	
Heliotropium angiospermum	scorpion's-tail	x	
Lepidium austrinum	southern pepperwort	x	
Billieturnera helleri	coppery false fanpetals	x	
Malvastrum americanum	Indian Valley false mallow	x	
Rhynchosida physocalyx	buffpetal	x	
Oenothera speciosa	pinkladies	x	

Scientific name	Common name	Richard and Richardson 1993	Lonard et al. 2004
Plantago rhodosperma	redseed plantain	x	
Portulaca pilosa	kiss me quick	x	
Portulaca umbraticola	wingpod purslane	x	
Cissus trifoliata	sorrelvine	x	

Appendix B. The number of bird species in PAAL and the studies which have identified their presence.

Scientific Name	Common Name	NPS (2013)	Farmer (1992)	Richard and Richardson (1993)	Hayes (2004)	NPS (2012)
Anas fulvigula	mottled duck	X		X		
Dendrocygna autumnalis	black-bellied whistling-duck	X		X	X	X
Ardea alba	great egret	X		X	X	X
Ardea herodias	great blue heron	X		X	X	
Bubulcus ibis	cattle egret	X		X	X	
Egretta caerulea	little blue heron	X		X		
Egretta thula	snowy egret	X		X		
Egretta tricolor	tricolored heron	X		X		X
Nyctanassa violacea	yellow-crowned night heron	X		X	X	
Charadrius vociferus	killdeer	X		X	X	X
Charadrius wilsonia	Wilson's plover	X		X		
Himantopus mexicanus	black-necked stilt	X		X	X	
Larus atricilla	laughing gull	X		X	X	X
Sterna antillarum	least tern	X		X		
Podilymbus podiceps	pied-billed grebe	X		X		
Tachybaptus dominicus	least grebe	X		X		
Eudocimus albus	American white Ibis, white ibis	X		X		
Plegadis chihi	white-faced ibis	X	X	X		
Columbina passerina	common ground dove	X		X	X	X
Leptotila verreauxi	white-tipped dove	X		X		
Zenaida asiatica	white-winged dove	X		X		
Zenaida macroura	mourning dove	X		X	X	X
Ceryle torquata	ringed kingfisher	X			X	
Ortalis vetula	plain chachalaca	X		X	X	
Crotophaga sulcirostris	groove-billed ani	X		X	X	
Geococcyx californianus	greater roadrunner	X		X		
Colinus virginianus	northern bobwhite	X		X	X	X
Rallus elegans	king rail	X		X		
Rallus longirostris	clapper rail	X		X		
Eremophila alpestris	horned lark	X		X		
Cardinalis cardinalis	northern cardinal	X		X	X	X
Cardinalis sinuatus	pyrrhuloxia	X		X		X

Scientific Name	Common Name	NPS (2013)	Farmer (1992)	Richard and Richardson (1993)	Hayes (2004)	NPS (2012)
Guiraca caerulea	blue grosbeak	X			X	X
Passerina cyanea	indigo bunting	X			X	X
Passerina versicolor	varied bunting	X			X	
Corvus cryptoleucus	Chihuahuan raven	X		X		
Aimophila botterii texana	Texas Botteri's sparrow	X	X	X	X	X
Aimophila cassinii	Cassin's sparrow	X			X	X
Ammodramus savannarum	grasshopper sparrow	X			X	
Arremonops rufivirgatus	olive sparrow	X	X	X		X
Chondestes grammacus	lark sparrow	X		X	X	X
Carpodacus mexicanus	house finch	X			X	
Hirundo rustica	barn swallow	X			X	
Progne subis	purple martin	X		X		
Agelaius phoeniceus	red-winged blackbird	X		X	X	X
Icterus bullockii	Bullock's oriole	X				
Molothrus aeneus	bronzed cowbird	X		X	X	X
Molothrus ater	brown-headed cowbird	X			X	X
Quiscalus mexicanus	great-tailed grackle	X		X	X	X
Sturnella magna	eastern meadowlark	X		X	X	X
Lanius ludovicianus	loggerhead shrike	X	X	X	X	X
Mimus polyglottos	northern mockingbird	X		X	X	X
Toxostoma curvirostre	curve-billed thrasher	X		X	X	X
Toxostoma longirostre	long-billed thrasher	X		X		X
Passer domesticus	house sparrow	X			X	
Campylorhynchus brunneicapillus	cactus wren	X		X		X
Thryomanes bewickii	Bewick's wren	X		X	X	
Myiarchus tyrannulus	brown-crested flycatcher	X		X	X	X
Pitangus sulphuratus	great kiskadee	X		X	X	X
Tyrannus couchii	Couch's kingbird	X		X	X	X
Tyrannus forficatus	scissor-tailed flycatcher	X		X	X	X
Vireo griseus	white-eyed vireo	X		X	X	X
Melanerpes aurifrons	golden-fronted woodpecker	X		X	X	X
Picoides scalaris	ladder-backed woodpecker	X		X	X	X
Chordeiles acutipennis	lesser nighthawk	X		X		
Chordeiles minor	common nighthawk	X		X	X	

Scientific Name	Common Name	NPS (2013)	Farmer (1992)	Richard and Richardson (1993)	Hayes (2004)	NPS (2012)
Nyctidromus albicollis	common pauraque	X		X		X
Egretta rufescens	reddish egret		X			
Mycteria americana	wood stork		X			
Camptostoma imberbe	northern beardless-tyrannulet		X			
Pachyramphus aglaiae	rose-throated becard		X			
Setophaga pitiayumi	tropical parula		X			X
Geothlypis trichas insperata	Brownsville yellowthroat		X			
Icterus graduacauda	Audubon's oriole		X			
Icterus cucullatus	(Sennett's) hooded oriole		X			
Columbina inca	Inca dove			X		
Coccyzus americanus	yellow-billed cuckoo			X		X
Baeolophus atricristatus	black-crested titmouse					X
Amphispiza bilineata	black-throated sparrow					X
Thryothorus ludovicianus	Carolina wren					X
Sturnus vulgaris	European starling					X
Cairina moschata	muscovy duck					X
Vanellus vanellus	northern lapwing*					X
Auriparus flaviceps	verdin					X
Numenius phaeopus	whimbrel*					X
Polioptila caerulea	blue-gray gnatcatcher					X
Spizella passerina	chipping sparrow					X
Spiza americana	dickcissel					X
Spinus psaltria	lesser goldfinch					X
Number of Species Observed		**67**	**12**	**58**	**42**	**48**

*represents a species observed during NPS (2012) surveys that is likely not a breeding species

Appendix C. Butterfly species checklist for the lower Rio Grande valley (RGV) in south Texas (Quinn 2010). Species listed as "possible" or only found in a county other than Cameron are not included here. Species on the abridged checklist for PAAL (Quintanilla and Hanson 2008) are in bold.

Scientific name	Common name	Notes
Swallowtails (Papilionae)		
Battus philenor	**pipevine swallowtail**	
Papilio cresphontes	**giant swallowtail**	
Battus polydamas	**polydamas swallowtail**	
Papilio ornythion	**ornythion swallowtail**	rare
Papilio polyxenes asterius	**black swallowtail**	
Papilio anchisiades	**ruby-spotted swallowtail**	
Eurytides philolaus	dark kite-swallowtail	Cameron County
Papilio thoas	thoas swallowtail	
Papilio astyalus	broad-banded swallowtail	rare
Papilio pilumnus	three-tailed swallowtail	rare
Papilio garamas abderus	magnificent swallowtail	one record: Cameron County
Papilio rogeri pharnaces	pink-spotted swallowtail	rare
Whites (Pierinae)		
Appias drusilla	**Florida white**	near coast
Ganyra josephina	**giant white**	uncommon
Pontia protodice	**checkered white**	uncommon
Pieris rapae	cabbage white	rare
Ascia monuste	**great southern white**	common
Melete lycimnia isandra	common melwhite	
Itaballia demophile	cross-barred white	
Anthocharis midea	falcate orange-tip	rare
Sulphurs (Coliadinae)		
Colias eurytheme	**orange sulphur**	occasional
Anteos maerula	**yellow-angled sulphur**	occasional
Phoebis agarithe	**large orange sulphur**	common
Eurema boisduvaliana	**Boisduval's yellow**	rare
Eurema lisae	**little yellow**	common
Nathalis iole	**dainty sulphur**	uncommon
Zerene cesonia	**southern dogface**	common
Phoebis sennae	**cloudless sulphur**	common
Kricogonia lyside	**lyside sulphur**	
Eurema mexicana	**Mexican yellow**	uncommon
Eurema salome	Salome yellow	Cameron/Hidalgo Counties
Eurema nise	**mimosa yellow**	common
Eurema dina	Dina yellow	Cameron/Hidalgo
Anteos clorinde	**white-angled sulphur**	occasional
Phoebis philea	**orange-barred sulphur**	occasional
Eurema daira	**barred yellow**	rare
Eurema proterpia	**tailed orange**	uncommon
Eurema nicippe	**sleepy orange**	uncommon
Hairstreaks (Theclinae)		
Atlides halesus	**great purple hairstreak**	occasional
Arawacus sito	fine-lined stripe-streak	
Rekoa palegon	gold-bordered hairstreak	
Rekoa stagira	smudged hairstreak	
Strymon melinus	**gray hairstreak**	
Strymon alea	**Lacey's scrub-hairstreak**	
Calycopis isobeon	**dusky-blue groundstreak**	
Chlorostrymon simaethis	**silver-banded hairstreak**	uncommon
Satyrium favonius	oak hairstreak	rare
Cyanophrys longula	mountain greenstreak	
Strymon rufofusca	**red-crescent scrub- hairstreak**	occasional
Strymon bebrycia	red-lined scrub-hairstreak	rare
Strymon istapa	**mallow scrub- hairstreak**	common
Strymon cestri	tailliess scrub-hairstreak	rare

Scientific name	Common name	Notes
Ministrymon clytie	**clytie ministreak**	
Ministrymon azia	gray ministreak	rare
Callophrys xami	**xami hairstreak**	Brownsville
Oenomaus ortygnus	aquamarine hairstreak	Brownsville
Parrhasius moctezuma	Mexican-M hairstreak	
Strymon yojoa	**yojoa scrub- hairstreak**	south Texas
Strymon bazochii	**lantana scrub- hairstreak**	occasional
Electrostrymon sangala	ruddy hairstreak	rare
Eumaeus childrenae	superb cycadian	
Allosmaitia strophius	strophius hairstreak	rare
Evenus regalis	regal greatstreak	
Pseudolycaena damo	sky-blue greatstreak	
Atlides polybe	black-veined greatstreak	
Blues (Polyommatinae)		
Brephidium exile	**western pygmy-blue**	common
Zizula cyna	**cyna blue**	rare
Leptotes cassius	**cassius blue**	rare
Hemiargus ceraunus	**ceraunus blue**	common
Leptotes marina	**marine blue**	uncommon
Hemiargus isola	**Reakirt's blue**	common
Everes comyntas	eastern tailed-blue	rare
Metalmarks (Riodinidae)		
Calephelis nemesis	**fatal metalmark**	common
Lasaia sula	**blue metalmark**	
Calephelis nilus	**rounded metalmark**	common
Calephelis rawsoni	Rawson's Metalmark	few
Melanis pixe	**red-bordered pixie**	
Caria ino	**red-bordered metalmark**	S. Texas
Emesis emesia	curve-winged metalmark	Cameron County
Apodemia walkeri	Walker's metalmark	rare
Snouts (Libytheinae)		
Libytheana carinenta	**American snout**	abundant
Heliconians & fritillaries (Heliconiinae)		
Agraulis vanillae	**gulf frittilary**	common
Heliconius charithonius	**zebra heliconian**	
Dione moneta	**Mexican silverspot**	rare
Euptoieta claudia	**variegated frittilary**	common
Dryas julia	**Julia heliconian**	
Dryadula phaetusa	banded orange heliconian	rare
Euptoieta hegesia	**Mexican frittilary**	
Brush-footed (Nymphalidae)		
Chlosyne theona	**theona checkerspot**	
Chlosyne janais	**crimson patch**	occasional
Microtia elva	elf	Cameron County
Dymasia dymas	tiny checkerspot	Brownsville
Phyciodes texana	Texan crescent	common
Phyciodes tulcis	**pale-banded crescent**	
Phyciodes tharos	**pearl crescent**	common
Vanessa cardui	**painted lady**	widespread
Vanessa annabella	west coast lady	Hidalgo/Cameron
Junonia genoveva	**tropical buckeye**	along coast
Chlosyne lacinia	**bordered patch**	
Chlosyne definita	**definite patch**	PAAL/Kleberg
Chlosyne endeis	banded patch	Rare
Texola elada	**elada checkerspot**	
Phyciodes graphica	**vesta crescent**	
Anartia fatima	**banded peacock**	ocassional
Polygonia interrogationis	**question mark**	uncommon
Vanessa atalanta	**red admiral**	

Scientific name	Common name	Notes
Anartia jatrophae	**white peacock**	
Phyciodes phaon	**phaon crescent**	
Vanessa virginiensis	**American lady**	
Junonia coenia	**common buckeye**	
Adelpha fessonia	**band-celled sister**	
Dynamine dyonis	**blue-eyed sailor**	
Diaethria anna	Anna eighty-eight	
Diaethria astala	navy eighty-eight	
Mestra amymone	common mestra	
Hamdryas februa	**gray cracker**	rare
Epiphile adrasta	**common banner**	Willacy County
Biblis hyperia	**red rim**	rare
Hamadryas guatemalena	**Guatemalan cracker**	Starr/Hidalgo/Cameron
Hamadryas amphinome	red cracker	Cameron County
Historis odius	Orion cecropian	
Smyrna blomfildia	Blomfild's beauty	rare
Smyrna karwinskii	Karwinski's beauty	Brownsville
Myscelia ethusa	**Mexican bluewing**	forested area
Eunica monima	dingy purplewing	rare
Eunica tatila	Florida purplewing	Less common
Siproeta stelenes	**malachite**	
Marpesia chiron	many-banded daggerwing	rare
Marpesia petreus	**ruddy daggerwing**	
Anaea troglodyta	**tropical leafwing**	common in woodlands
Anaea andria	**goatweed leafwing**	rare
Anaea eurypyle	pointed leafwing	
Asterocampa celtis	**hackberry emperor**	uncommon
Doxocopa pavon	**pavon emperor**	rare
Asterocampa leilia	**empress leilia**	
Doxocopa laure	**silver emperor**	rare
Asterocampa clyton	**tawny emperor**	
Opsiphanes sp.	owlet	
Cyllopsis gemma	**gemmed satyr**	Brownsville
Hermeuptychia sosybius	**Carolina satyr**	
Dircenna klugii	Klug's clearwing	Brownsville
Danaus plexippus	**monarch**	
Danaus gilippus	**queen**	abundant
Danaus eresimus	**soldier**	
Skippers (Hesperiidae)		
Phocides polybius	**guava skipper**	
Chioides zilpa	**zilpa longtail**	rare
Urbanus proteus	**long-tailed skipper**	common
Urbanus procne	**brown longtail**	common
Urbanus doryssus	White-tailed longtail	rare
Cabares potrillo	**potrillo skipper**	
Pellicia arina	**glazed pellicia**	uncommon
Eantis tamenund	**sickle-winged skipper**	
Erynnis horatius	**Horace's duskywing**	rare
Pyrgus albescens	**white checkered-skipper**	
Heliopetes domicella	**Erichson's white- skipper**	rare
Heliopetes sublinea	**east-Mexican white- skipper**	
Proteides mercurius	**mercurial skipper**	rare
Phocides belus	beautiful beamer	
Polygonus leo	hammock skipper	south Texas
Aguna asander	**gold-spotted aguna**	occasional
Urbanus dorantes	**dorantes longtail**	uncommon
Astraptes fulgerator	**two-barred flasher**	uncommon
Spathilepia clonius	**falcate skipper**	
Staphylus mazans	**mazans scallopwing**	south Texas
Staphylus ceos	golden-headed scallopwing	common in Texas/rare in RGV
Timochares rupifasciatus	**brown-banded skipper**	occasional

Scientific name	Common name	Notes
Erynnis tristis	**mournful duskywing**	uncommon
Pyrgus oileus	**tropical checkered- skipper**	common
Heliopetes laviana	**laviana white- skipper**	common
Celotes nessus	**common streaky- skipper**	southwest Texas
Chioides catillus	**white-striped longtail**	common
Aguna claxon	**emerald aguna**	
Aguna metophis	tailed aguna	
Urbanus teleus	**teleus longtail**	uncommon
Urbanus evona	turquoise longtail	
Achalarus toxeus	**coyote cloudywing**	uncommon
Achalarus jalapus	jalapus cloudywing	rare
Cogia calchas	**mimosa skipper**	
Chiomara asychis	**white-patched skipper**	
Erynnis funeralis	**funereal duskywing**	common
Pyrgus philetas	**desert checkered- skipper**	
Heliopetes macaira	**Turk's cap white- skipper**	uncommon
Pholisora catullus	**common sootywing**	uncommon
Vidius perigenes	**pale-rayed skipper**	Cameron county
Lerema accius	**clouded skipper**	abundant
Hylephila phyleus	**fiery skipper**	abundant
Atalopedes campestris	**sachem**	abundant
Amblyscirtes celia	**Celia's roadside- skipper**	uncommon
Lerodea dysaules	**olive-clouded skipper**	
Panoquina ocola	**Ocola skipper**	common
Nyctelius nyctelius	**violet-banded skipper**	
Nastra julia	**Julia's skipper**	occasional
Decinea percosius	**double-dotted skipper**	rare
Polites vibex	**whirlabout**	abundant
Quasimellana eulogius	**common mellana**	occasional
Lerodea eufala	**eufala skipper**	uncommon
Calpodes ethlius	**Brazilian skipper**	
Panoquina sylvicola	**purple-washed skipper**	uncommon
Cymaenes odilia	**fawn-spotted skipper**	uncommon
Copaeodes minima	**southern skipperling**	common
Wallengrenia otho	**southern broken-dash**	common
Amblyscirtes nysa	**nysa roadside- skipper**	uncommon
Lerodea arabus	**violet-clouded skipper**	
Panoquina panoquinoides	**obscure skipper**	common
Panoquina evansi	**Evan's skipper**	
Carrhenes canescens	hoary skipper	rare
Xenophanes tryxus	glassy-winged skipper	rare
Systasea pulverulenta	Texas powdered-skipper	rare
Grais stigmaticus	hermit skipper	rare
Gesta invisa	false duskywing	Hidalgo/Cameron
Synapte malitiosa pecta	malicious skipper	common
Monca crispinus	violet-patched skipper	common in wet years
Perichares philetes	green-backed ruby-eye	rare
Rhinthon osca	osca skipper	Hidalgo/Cameron
Megthymus yuccae	yucca giant-skipper	
Stallingsia maculosa	manfreda giant-skipper	one of rarest in TX

Appendix D. NLCD cover class change (2001-2006) within PAAL external viewshed (gray indicates class with actual change).

Landcover_Change	Hectares	Percent Visible
Shrub/Scrub to Shrub/Scrub	1190	34
Grassland/Herbaceous to Grassland/Herbaceous	454	13
Cultivated Crops to Cultivated Crops	351	10
Emergent Herbaceous Wetlands to Em. Herb. Wetlands	347	10
Developed Low Intens. to Developed Low Intens.	262	7
Barren Land to Barren Land	205	6
Developed, Open Space to Developed, Open Space	126	4
Pasture/Hay to Pasture/Hay	125	4
Developed Med Intens. to Developed Med Intens.	117	3
Woody Wetlands to Woody Wetlands	112	3
Shrub/Scrub to Cultivated Crops	37	1
Developed Hgh Intens. to Developed Hgh Intens.	25	<1
Deciduous Forest to Deciduous Forest	18	<1
Grassland/Herbaceous to Emergent Herbaceous	14	<1
Grassland/Herbaceous to Shrub/Scrub	14	<1
Pasture/Hay to Shrub/Scrub	12	<1
Barren Land to Shrub/Scrub	11	<1
Cultivated Crops to Shrub/Scrub	11	<1
Shrub/Scrub to Evergreen Forest	10	<1
Shrub/Scrub to Developed, Open Space	8	<1
Grassland/Herbaceous to Cultivated Crops	7	<1
Pasture/Hay to Developed, Low Intensity	6	<1
Open Water to Open Water	6	<1
Shrub/Scrub to Developed, Low Intensity	5	<1
Pasture/Hay to Developed, Medium Intensity	5	<1
Shrub/Scrub to Barren Land	5	<1
Pasture/Hay to Developed, Open Space	5	<1
Shrub/Scrub to Deciduous Forest	3	<1
Cultivated Crops to Developed, Medium Intensity	3	<1
Shrub/Scrub to Developed, Medium Intensity	3	<1
Cultivated Crops to Developed, Low Intensity	3	<1
Shrub/Scrub to Grassland/Herbaceous	2	<1
Grassland/Herbaceous to Developed, Open Space	2	<1
Emergent Herbaceous Wetlands to Cultivated Crops	2	<1
Grassland/Herbaceous to Deciduous Forest	2	<1
Shrub/Scrub to Emergent Herbaceous Wetlands	2	<1
Grassland/Herbaceous to Developed, Low Intensity	2	<1
Cultivated Crops to Barren Land	2	<1
Shrub/Scrub to Pasture/Hay	2	<1

Landcover_Change	Hectares	Percent Visible
Grassland/Herbaceous to Barren Land	1	<1
Cultivated Crops to Developed, Open Space	1	<1
Barren Land to Emergent Herbaceous Wetlands	1	<1
Woody Wetlands to Cultivated Crops	1	<1
Evergreen Forest to Evergreen Forest	1	<1
Pasture/Hay to Barren Land	1	<1
Open Water to Cultivated Crops	1	<1
Grassland/Herbaceous to Developed, Med Intensity	1	<1
Barren Land to Mixed Forest	1	<1
Barren Land to Evergreen Forest	<1	<1
Mixed Forest to Mixed Forest	<1	<1
Barren Land to Grassland/Herbaceous	<1	<1
Deciduous Forest to Cultivated Crops	<1	<1
Shrub/Scrub to Mixed Forest	<1	<1
Grassland/Herbaceous to Evergreen Forest	<1	<1
Grassland/Herbaceous to Pasture/Hay	<1	<1
Pasture/Hay to Deciduous Forest	<1	<1
Cultivated Crops to Open Water	<1	<1
Cultivated Crops to Woody Wetlands	<1	<1
Emergent Herbaceous Wetlands to Barren Land	<1	<1
Open Water to Shrub/Scrub	<1	<1
Developed, Open Space to Developed, Med. Intens.	<1	<1
Developed, Open Space to Developed, High Intensity	<1	<1
Barren Land to Developed, Open Space	<1	<1
Barren Land to Cultivated Crops	<1	<1
Deciduous Forest to Grassland/Herbaceous	<1	<1
Mixed Forest to Developed, Low Intensity	<1	<1
Pasture/Hay to Developed, High Intensity	<1	<1
Woody Wetlands to Open Water	<1	<1
Woody Wetlands to Barren Land	<1	<1

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