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Final Report

Legacy Demonstration of Technologies and Methodologies Relevant to Military Natural Resources Conservation

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The purpose of this demonstration has been to acquaint Department of Defense personnel with new technology and methods that will provide useful information about natural resources management and that can reduce the interference to military training that is caused by traditional field data gathering methods. The technologies described in this volume can simultaneously enhance military readiness and compliance with natural resources management policies.

The central feature of the demonstration is the integration of wildlife ratio-tracking via the Argos-Trios satellite system with natural resources survey and mapping in geographic information systems. Four military installations were the focus of the demonstration. Each installation has received our computing softwar, map layers, and wildlife locations data relevant to the demonstration, thus providing them abilities for further analyses of existing information and capabilities to add new information.

The studies conducted in conjunction with this project were demonstrations only, not rigorous scientific investigations. The resulting data should be treated as such. However, this demonstration project has proven the utility of remote, satellite-based data gathering technologies and methods for military natural resources conservation and management.

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Legacy Resource Management Program project #9550100, "Legacy Demonstration of Technologies and Methodologies Relevant to Military Natural Resources Conservation," FINAL REPORT.

CCRT FINAL FY1996/1997 LEGACY REPORT

Legacy Demonstration of Technologies and Methodologies Relevant to Military Natural Resources Conservation

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Throughout this report are references to Service Argos Location Classes (LC). These refer to the relative accuracy of the estimated locations (latitude and longitude) derived from the Argos system. Service Argos classifies its location estimates according to the following scheme:

Location Class (LC)

Class	Estimated Accuracy in Latitude and Longitude
3	<= 150 meters
2	<= 350 meters
1	<= 1000 meters
0	> 1000 meters
A and B	no estimate of location accuracy
Z	invalid location

CONTENTS

LEGACY DEMONSTRATION OF TECHNOLOGIES AND METHODOLOGIES RELEVANT TO MILITARY NATURAL RESOURCES CONSERVATION

BIOTELEMETRY BACKGROUND: Conventional biotelemetry systems, developed in the 1950s and 1960s, use directional receiving antennas to locate radio transmitters. Such systems have enabled field biologists to relocate previously captured and radio-tagged animals to study their natural history. Conventional biotelemetry systems, however, are typically restricted to small geographic areas accessed on foot, from automobiles, or by aircraft. Moreover, these systems generally require several personnel in the field at the same time in order to triangulate the location of the radio-tagged subject animal.

SATELLITE BIOTELEMETRY BACKGROUND: In 1981, the U.S. Army Edgewood Research Development and Engineering Center (ERDEC) recognized the shortfalls of conventional radio-transmitter biotelemetry systems and initiated a program with the Johns Hopkins University Applied Physics Laboratory (JHUAPL) to investigate the potential of developing small platform transmitter terminals (PTTs) to be mounted on animals and tracked via satellites. The program was designed to provide a capability that could track migratory birds and other widely ranging wildlife species anywhere on Earth. A miniature, satellite-received transmitter that is light enough to be carried on the backs of birds was first developed in the mid–1980s. The transmitters, or PTTs, are located and tracked by the French-U.S., Argos satellite system, which is capable of tracking mobile organisms anywhere on the face of the Earth with an accuracy of ± 150 meters out to 3 km (depending on the angle of the satellite and the quality of the PTT transmission). Since the inception of the program, miniaturization has led to the commercialization and fielding of transmitters that weigh less than 20 gm and can interface with an array of sensors. From the beginning, use of radio tagging has always been based on careful consideration of the effects of the transmitters on animal behavior and bird flight.

BEGINNING IN FY94, the Defense Department's Legacy Resource Management Program (Legacy) and Strategic Environmental Research and Development Program (SERDP) funded related projects (1) to demonstrate recently developed, satellite-based biotelemetry technologies on military bases (Legacy), and (2) to develop new capabilities to enhance existing systems (SERDP). These projects were planned and executed in parallel. The overall purpose of the joint Legacy/SERDP effort has been to develop, demonstrate, promote, and improve satellite tracking and remote monitoring systems for resource management and conservation on military lands. The four 1996 Legacy field demonstrations (described in this report), along with our Partners in Flight activities (also described herein), have produced extremely comprehensive tracking and monitoring databases for the target organisms. We incorporate this tracking and monitoring information into geographic information systems (GIS) to map animal movements in relation to habitat types, geo-political boundaries, vegetation cover, geomorphology, water resources, military land use activities, and many other geographically discrete data sets. In this way, we are providing valuable (and often previously unattainable) resource management information to military land managers. This system can also support near real-time monitoring and analysis of animal movements and behavior in relation to military land use activities to enhance research of cause and effect relationships between military activities and wildlife ecology.

THROUGH SUPPORT FROM LEGACY, we demonstrated commercially available satellite platform transmitter terminals (PTTs) on the four military bases mentioned below. We also applied numerous PTTs to certain migratory bird species throughout North America.

- Dugway Proving Ground (DPG), Utah encompasses 1,300 square miles southwest of Salt Lake City. DPG houses the U.S. Army Research, Development, Test, and Evaluation (RDT&E) Command's Chemical, Biological, and Radiological Weapons School, as well as a U.S. Air Force Flight Test Center. DPG activities include the testing of chemical agents, pathogens, and toxins, now conducted in sealed containment chambers (rather than open air testing as in the past). Other activities at DPG include Army Reserve and National Guard component maneuver training. We successfully tracked and monitored via satellite Pronghorn (a big game species) and wild Horses. Military land managers must provide habitat for and minimize environmental disturbance on these species. Our systems provided information about the movements of these animals remotely, without impacting military activities. Otherwise, the same data would have to be gleaned from field studies on foot, from trucks, or from low-flying aircraft (which would require a high level of coordination with military activities). We also satellite tracked several Ferruginous and Swainson's Hawks in the vicinity of DPG to assess potential effects from military activities.

- Naval Air Station Fallon (NASF), Nevada is centrally located among highly productive wetland and lake habitats that include Walker Lake, Stillwater National Wildlife Refuge, Pyramid Lake, and the Lahontan Reservoir. NASF houses the naval fighter weapons school (TOPGUN), the carrier airborne early warning weapons school, and is the only naval facility providing advanced integrated carrier air wing strike training. NASF also hosts realistic electronic warfare flight training, air to ground and air to air weapons delivery, special weapons delivery, and enemy evasion tactics. Aircraft stationed at NASF include F/A–18, F–14, A–6, F–5, and helicopters. Military aircraft from the Navy, Air Force, Marine Corps, and Nevada Air National Guard train at NASF. We successfully tracked and monitored via satellite 7 White Pelicans in the vicinity of the NASF and its associated training ranges. These wetland habitats surrounding the air station and military operating areas harbor large populations of White Pelicans and other bird species that **pose a significant threat of bird-aircraft collisions.** Altitude information derived from miniature pressure transducers on the PTTs was gathered and used in a single dimension soaring model to predict pelican flight time, location, and altitude to help predict times of high flight in relation to military aircraft travel.

- The Idaho Army National Guard Orchard Training Area (OTA), Idaho is centrally located within the 758,000 acre Snake River Birds of Prey National Conservation Area (SRBOPNCA). The OTA houses an Air National Guard A–10 Air Wing and is currently the third largest National Guard training facility in the U.S. The OTA hosts regular armored vehicle training, live fire and laser training with M1–Abrams tanks, and combined tank and helicopter maneuvers with live fire. During the summer months, the OTA serves as the Annual Training Site for the Idaho, Montana, and Oregon Army National Guard units that constitute the 116th CAV BDE, as well as other units from around the country. During the winter, most activity is concentrated in the northern portions of the OTA, where year-round schools are conducted by the Combat Vehicle Transition Training Team for National Guard Units from all over the country. The Idaho Army National Guard is directed by Congress to manage for the protection of one of the densest population of raptors in the U.S. in the SRBOPNCA. We successfully demonstrated simultaneous tracking of golden eagles and military vehicles as a method to study possible training effects on animal movements. Ferruginous Hawks (sensitive species designation) were also tracked via satellite in conjunction with the Deployable-Force-on-Force Instrumented Range System (DFIRST) to demonstrate the feasibility of integrating automated military tracking systems with natural resource management technology. We also tracked four Swainson's Hawks via satellite from the OTA as part of a larger, transcontinental migration study in conjunction with Partners in Flight.

- White Sands Missile Range (WSMR), New Mexico is the military's largest all-overland test range in the Western hemisphere. Within WSMR are the San Andres National Wildlife Refuge, White Sands National Monument (National Park Service), and Joranda Experimental Range (U.S. Department of Agriculture and U.S. Forest Service). WSMR houses the U.S. Army Research, Development, Test, and Evaluation (RDT&E) Command for weapons and space systems, and components. Between 1945 and 1989, a total of 38,029 missile firings were completed at WSMR, including the world's first atomic explosion at the Trinity site on July 16, 1945. We successfully tracked and monitored Oryx (an introduced African antelope) via satellite on the WSMR to help military land managers comply with National Park Service and New Mexico Game and Fish requirements for managing this exotic species. Management of this species has proven to be difficult for military land managers because of the Oryx's preference for remote, rugged terrain. In addition, Oryx habits on WSMR raise concerns of its potential effects on adjacent natural systems off-base. Continuing work on Oryx will employ the new, SERDP developed GPS PTTs to track these animals to an accuracy of ±100 meters throughout the 2+ million acre WSMR installation.

- In conjunction with Partners in Flight, we successfully developed a methodology and study protocol for application of satellite tracking to Tundra Peregrine Falcons (*Falco peregrinus tundrius*, a formerly threatened neotropical migrant) and Swainson's Hawks (*Buteo swainsoni,* declining population) using the smallest available transmitters (20 gm) that interface with the Argos satellites. Peregrines frequent military bases across North America, while Swainson's Hawks inhabit military lands throughout the western U.S. and Canada. In fact, we pioneered the application of space-based technology for the study of Neotropical migratory birds.

    1. In conjunction with Partners in Flight, we have applied dozens of commercially available 27gm and 20gm platform transmitter terminals (PTTs) since the autumn of 1993 to migrating Tundra Peregrine Falcons along the coasts of Maryland and Virginia and the gulf coast of Texas. PTTs were also applied in Peregrine breeding areas of Greenland and Eastern Canada. In only a few years,

these transmitters, tracked via the Argos System, have provided more data on Peregrine Falcon migratory patterns than the past 25 years of conventional field studies and leg band returns. We are now learning exactly where these birds travel, where they stop along their trek, and what threats may exist to their survival along the way. This research continues a tradition of DoD contributions to the recovery of endangered species, and in the case of peregrines, a wide-ranging species that occurs on military lands and training areas across the continent. Results of this work have appeared in scientific publications and have been featured in radio and television news programs. This coverage and interest reveals the power of these advanced technology applications to collect valuable information on a globally distributed, transcontinental migrant. Our work with the Tundra Peregrine Falcon is continuing to assist in the identification of key migratory and Neotropical habitat to support a wide variety of avian species common to both North and South America. This information will enable conservationists to identify key migratory and wintering habitats and to monitor these areas for the conservation of avian biodiversity.

2. Also in conjunction with Partners in Flight, our DoD sponsored Legacy project contributed significantly to radio-tracking of Swainson's Hawks (SWHA) with satellite-based technology during 1995 and 1996. We monitored their distribution on and off military installations in the western U.S., where their numbers had been diminishing at an alarming rate for unknown reasons. The Swainson's Hawk is listed as a species of concern by five states and the Bureau of Land Management, and as a special emphasis species by the U.S. Forest Service. Nesting population declines had been reported over much of the hawks' range, including Dugway Proving Grounds. With no obvious reason for this decline, scientists postulated that problems along migration routes or on wintering areas were responsible. SWHAs were marked with PTTs near the Idaho Army National Guard Orchard Training Area, Dugway Proving Ground, near Navy land holdings in Oregon, and the Rocky Mountain Arsenal (now a Fish and Wildlife Service refuge) in Colorado, as well as several provinces in Canada. The locations of these hawks were monitored on their North American breeding grounds, Argentinean wintering grounds, and along migration routes. In January of 1996, scientists visited different areas indicated by the satellite derived location data. They counted over 4,000 dead SWHA, killed as an apparent side effect of pesticide applications to croplands, and they believed the actual mortality numbers may have exceeded 20,000. Since adults represented nearly 90% of the dead birds and the entire Canadian SWHA population is estimated between 20–40,000 pairs, this loss represented a serious threat to the survival of the species. It turned out that this catastrophic population decline resulted from the use of a toxic organophosphate pesticide, recently brought into use on the pampas of Argentina where these hawks winter in communal roosts. Through the use of remote tracking and monitoring technology, this environmental problem was identified and, within 18 months, remedied through collaborative government and private sector management and education. Keeping this raptor off the endangered species list probably saved

millions of federal dollars by avoiding costly large-scale research and recovery programs and related habitat management activities in North America. This application of wildlife tracking via satellite is a perfect demonstration of the unique advantage this technology can provide in the study of a wide-ranging species.

THROUGH SUPPORT FROM SERDP, we have developed a Global Positioning System (GPS) PTT, new meteorological sensors, as well as an acoustic sensor that will be small enough to be integrated into a PTT to perform a variety of functions. As a result, a new, more capable generation of satellite tracked PTTs will soon be available for deployment. Advanced sensors in new PTTs will include a digital audio capture system (an acoustic sensor with pattern recognition software) and sensors to provide temperature, absolute vapor pressure (humidity), and atmospheric pressure. A miniature video camera can be added, and other sensors are also possible. Additionally, accelerometers are now being added to our PTTs to gather information relating to an animal's changes in speed and/or direction. Such information can be used, in conjunction with our developmental acoustic sensor, to infer possible animal reactions to known or assumed external stimuli, such as human generated noise (including aircraft overflights, sonic booms, single event noise, rocket launches, artillery fire, ground vehicle noise, small arms fire). Such a sensor could also be used to ascertain wingbeat frequency from birds to infer such important factors as power consumption and body weight, which are necessary to predict and forecast bird flight dynamics. The use of accelerometers to evaluate avian flight dynamics may play an important role in the development of predictive forecast models for avifauna. We are currently refining our models to evaluate and predict avian flight in relation to military and commercial aircraft traffic.

The new GPS PTTs will provide location estimates to within $\pm$ 100 m, which represents a quantum leap forward in the application of radio-telemetry to wildlife science. GPS readings can be collected according to a pre-programmed schedule to dramatically increase the number of positions that are possible (via satellite) and to enhance our ability to derive important facts regarding species range and habitat use. The acoustic sensor is designed to recognize animal vocalizations, thus allowing more thorough remote study of animal behaviors, species interrelationships, and microhabitat components of an animal's range. The acoustic sensor can also be programmed to monitor and record anthropogenically generated sounds in conjunction with the organisms' response. This capability enhances the study of cause and effect relationships by relating animal responses to discrete military activities.

CONCLUSION: Advanced biotelemetry capabilities that incorporate the latest innovations in microelectronics, GIS, remote sensing, and computer modeling offer great promise in helping to define and characterize human effects on species and ecological communities and to identify strategies to ensure their sustainability in the face of expanding human enterprise. Where military natural resource management issues have a direct impact on readiness, these capabilities (existing and developmental) can provide solutions quickly, at low cost, and with minimal interruption to military land use activities.

Purpose/Need: The process of natural resource management and planning begins with a thorough inventory and description of a natural systems' flora and fauna. This information is critical for the development and implementation of effective integrated natural resource management plans. Such plans, in turn, allow land managers, such as the U.S. Department of Defense, to maintain biodiversity, conserve natural resources, and comply with applicable environmental laws and regulations in concert with mission requirements. A central component of effective planning and management is the acquisition of thorough scientific information of: (1) highly mobile species (such as migratory birds); (2) rare, elusive, sensitive, threatened, or endangered species (as well as candidate species); (3) species of concern or otherwise special management species (such as exotics or big game species); and (4) animals that frequent inaccessible habitats or extremely rugged terrain. This process can be difficult and expensive. Complicating matters on military lands, field data gathering efforts often interrupt or conflict with ongoing land-use activities, such as military, mission-related material test/evaluation, troop training, or ground maneuvers. Advanced information gathering technologies—such as wildlife radio-tracking via satellites—provide sophisticated, state-of-the-art, methods to acquire otherwise difficult, expensive, or unattainable data. And these methods create little or no interference with ongoing ground activities.

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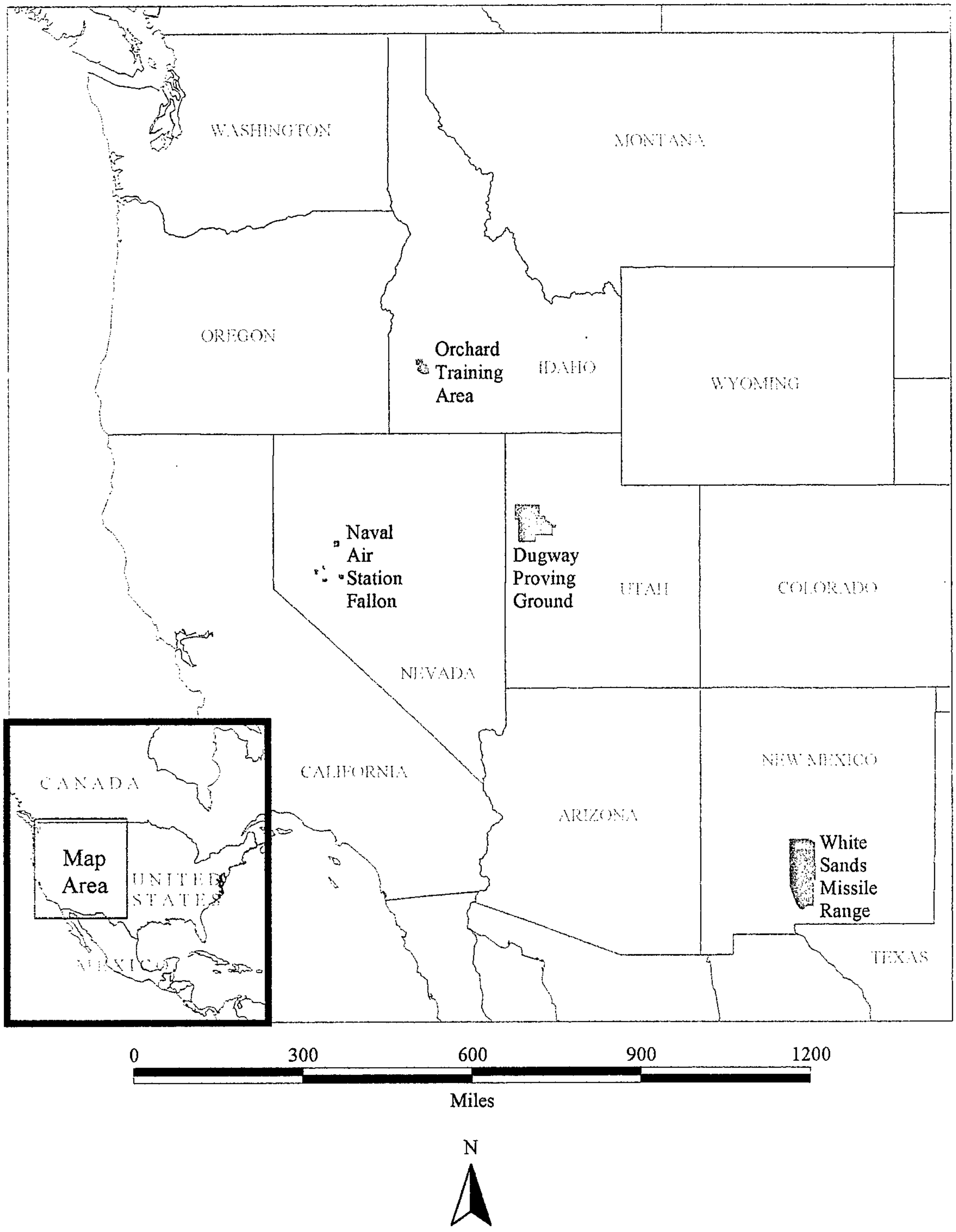
Partners: U.S. Department of Interior, U.S. Geological Survey Biological Resources Division, Boise State University (BSU), the University of Maryland Baltimore County (UMBC) Center for Conservation Research & Technology (CCRT), Pennsylvania State University (PSU), Johns Hopkins University Applied Physics Laboratory (JHUAPL), U.S. Fish and Wildlife Service, National Park Service, Naval Surface Warfare Center – Dahlgren Division, Bristol University (UK), Partners in Flight.

Recommendations/Lessons Learned: The U.S. military has already reached the conclusion that in order to effectively manage its natural resources in pursuit of maximum training and operational flexibility, it must take a holistic, ecosystem management approach. It is hoped that such an approach will help to identify and remedy natural resource management issues before they affect mission readiness. The SERDP Program has supported the development of new, advanced satellite telemetry hardware and sensors, while the Legacy Program has supported the demonstration and implementation of existing technologies on pilot military bases. Through support from these programs, we are defining the cutting edge of remote tracking and monitoring capabilities. And most importantly, we are using these advanced systems and the resulting data to provide comprehensive analyses and new approaches to pressing wildlife management concerns, as well as to applied operational and safety issues such as aircraft bird strike avoidance.

These technology-based systems are now poised to foster the early integration of military mission planning activities with critical natural resource information. And we stand ready to employ these tools to provide comprehensive research protocols, methods, hardware, and systems to enable planners and managers to meet military and environmental requirements quickly, cost effectively, with accurate information, and with minimal interruption to regular base activities.

The systems we have developed (and are continuing to refine) and their utility as tools for resource management and conservation continue to be defined and advanced, and the potential applications are practically limitless. Our recommendation to military planners and natural resource managers would be to consider using these technology tools – in conjunction with GIS, remote sensing, and computer modeling – as a means of quickly gathering critical ecological information regarding wildlife movements, natural history, and behavior in conjunction with potential military training and testing impacts, endangered species consultations, and proactive ecosystem management planning on military lands.

Military Installations Involved in Legacy Demonstration



Legacy Demonstration of Technologies and Methodologies Relevant to Military Natural Resources Conservation

INTRODUCTION

In accordance with items 1, 2, 3, 4, 7, and 9 of the stated Legacy Legislative Purposes, the Center for Conservation Research & Technology (CCRT) has demonstrated the use of remote sensing and positioning systems, and the use of telemetry via satellites integrated with geographic information systems (GIS), to resolve natural resource management and conservation issues. These issues involve Threatened and Endangered species, Neotropical migrants (Partners in Flight Program), and other species of wildlife directly affecting the missions and readiness of DoD installations. Also, CCRT has demonstrated the use of stored data and data repositories as sources of information and as methods by which data can be made readily available for future use.

CCRT has based this project on three (3) established technologies: geographic information systems (GIS), the Global Positioning System (GPS), and radio-telemetry via satellites. Telemetry via satellites operates through the Service Argos system. The system is a cooperative venture among the Centre National d'Etudes Spatiales (CNES, France), the National Aeronautics and Space Administration (NASA, USA), and the National Oceanic and Atmospheric Administration (NOAA, USA). The basic system consists of: (1) platform transmitter terminals (PTTs) mounted on the objects/animals to be tracked, (2) Argos onboard receivers and processors carried by NOAA satellites in low polar orbits, and (3) Service Argos data processing centers in Toulouse, France and Landover, Maryland. Operation begins when the PTT transmits a signal, including data from sensors aboard the PTT, to the satellite receiving and processing package. Service Argos downlinks processed data to the centers for additional computing of the PTT location, using principles of the Doppler shift. Computed locations and sensor data are then distributed to users.

Satellite telemetry has been employed to study seasonal movements of species of raptors, water birds, land and marine animals, many on a worldwide basis. Using this technology, we have conducted a study of wintering golden eagles in relation to land use in the Snake River Birds of Prey National Conservation Area (SRBOPNCA). Here, resident birds are joined by migrants on the military Orchard Training Area (OTA). Satellite telemetry was used to document both the local use areas and migratory tracks of these eagles. Data were then analyzed and displayed using GIS software. We also have used telemetry via satellites and GIS to analyze and display the movements of peregrine falcons as they migrate from their arctic nesting grounds to the southern hemisphere and back. These two examples demonstrate how animals can be studied and data acquired regardless of international boundaries or the remoteness of the area.

GIS software contains powerful geographic data processing tools that can edit, manipulate, manage, analyze, and display cartographic and associated attribute information. GIS technology, originally developed by the DoD, is now used by various commercial, scientific, and defense industries to create and analyze topographical and spatial relationships to make informed business, research, disaster preparedness, and resource management decisions.

GPS is a space-based system incorporating a constellation of earth orbiting satellites. This DoD developed and administered system triangulates a position of a receiver using precise time and position information broadcast from satellites. GPS receivers are used for air, marine, and land navigation and to accurately locate ground positions, including habitat which, in turn, is needed to interpret digital satellite images such as LANDSAT. During our demonstration, GPS receivers were carried into the field to locate targeted individuals for observation, habitat measurement, and verification of locations in relation to jurisdictional boundaries.

Four military installations were chosen representing Army, Navy, and Army National Guard. These were: Dugway Proving Ground, Utah; Naval Air Station Fallon, Nevada; the Orchard Training Area, Idaho; and White Sands Missile Range, New Mexico. The training and testing missions of these installations create a variety of resource management problems that can be addressed by technologies and methodologies of this demonstration. Our demonstration also included Neotropical migratory birds, the management of which has implications for military operations, and to which the DoD provides support through the multi-agency Partners in Flight Program.

DUGWAY PROVING GROUND, UTAH

INTRODUCTION

PURPOSE

Wildlife biologists at Dugway Proving Ground (DPG) are charged with the management of native species of wildlife and of feral horses, which are protected as part of America's heritage by the Wild Horse Act. This Legacy demonstration provided remote technology for tracking and monitoring animals that pose significant challenges to field biologists; for example, pronghorn and feral horse. In addition to these large mammals, we tracked two species of avian predators, the Swainson's hawk and ferruginous hawk. Information collected about land use and respective jurisdictional boundaries crossed by these species can be applied to make decisions regarding range carrying capacity, allowable take via hunting (pronghorn), and numbers of horses to offer for adoption through the Bureau of Land Management (BLM) "adopt a horse" program. Other management decisions regarding military training in areas used heavily by these species are made easier once animal land use and habitat requirements are more fully understood. This Legacy project demonstrated the utility of tracking animals via space-based systems, which enable the monitoring of sensitive wildlife species without disturbance by "on the ground" conventional observation and telemetry techniques. Additionally, the monitoring of wildlife species using satellite-based technology was not impeded due to training schedules, material testing procedures, or areas closed to human traffic due to the presence of unexploded ordinance or sensitive military operations.

BACKGROUND

DPG is located 104 km southwest of Salt Lake City, Utah (Fig. I-1). The approximate center of DPG is 40° 10' north latitude and 113° 14' west longitude. DPG covers 324,857 hectares (1,300 square miles) and includes mountains, valleys, and a large, flat, sparsely vegetated area that extends westward into the southern reaches of expansive salt flats of the Great Salt Lake Desert. In 1941, the Chemical Warfare Service (CWS) determined that it needed a large-scale chemical and biological warfare testing area. With increased population growth near the U.S. Army's Edgewood Arsenal, MD, and because of restrictions on various testing there, the CWS surveyed the western U.S. for a new location to conduct its tests. DPG was officially established 12 February 1942, and testing commenced in the summer of that year. During World War II, DPG tested toxic agents, flame throwers, chemical spray systems, biological warfare weapons, antidotes for chemical agents, and protective clothing. In October 1943, DPG established biological warfare facilities at an isolated area within DPG (Granite Peak). DPG was slowly phased out after W.W.II, becoming inactive during August 1946. The base was reactivated during the Korean War and in 1954 was confirmed as a permanent Department of Army installation. In October 1958, DPG became home to the U.S.

Army Chemical, Biological, and Radiological (CBR) Weapons School, which moved from the U.S. Army Chemical Center, MD. Today DPG continues its role in the testing of chemical agents, pathogens, and toxins, now conducted in sealed containment chambers (rather than open air testing as in the past). Other activities at DPG include Army Reserve and National Guard component maneuver training, and U.S. Air Force Flight Test Center.

Four species of animals were chosen for study at DPG. Two species were ungulates, feral horses (*Equis caballus*) and Pronghorn (*Antilocapra americana*); and 2 species were raptors, ferruginous hawks (*Buteo regalis*) and Swainson's hawks (*Buteo swainsoni*).

The feral horse bloodlines in this region are thought to be animals lost from ranches and not from Spanish origins. These horses average 1.5 meters in height at the withers and weigh an estimated average of 340 kg. In cooperation with the Bureau of Land Management (BLM), DPG assists in the management of feral horses, ensuring sustainable use of available natural resources while promoting overall fitness of the feral horse population. DPG must also maintain adequate habitat parameters for native wildlife populations.

Pronghorns are ruminants that measure approximately one meter at the shoulder and 1.5 meters in length. Average mass is approximately 40 kg. DPG includes an important winter range and some year round habitat for pronghorn.

The ferruginous hawk was previously listed as a Category 2 species for potential listing as threatened or endangered under the Endangered Species Act. The ferruginous hawk is a large western buteo with a range in mass from 977 to 1,194 grams (males), and from 1,501 to 1,866 g (females). The average length is 58 cm, with a wingspan of 135 cm. Nest sites include rock outcrops, hillsides, trees, or cliff-sides. Ferruginous hawks primarily prey on mammals, ranging from mice and voles to ground squirrels and full-grown jackrabbits.

Localized declines have made the Swainson's hawk, a Neotropical migrant, a species of concern throughout its range. Extensive southward migration to the Pampas region of Argentina and colonial roosting has made it vulnerable to agricultural pesticides, particularly organophosphates. The Swainson's hawk nests in trees throughout the western United States. The average size is 53 cm in length and wingspan is 132 cm. Mass ranges from an average of 725g (males) to 1,150 g (females).

Specific objectives of the Legacy demonstration:

Feral Horse and pronghorn:

- Track via satellite and conventional telemetry to obtain location estimates of radio marked pronghorns and horses.
- Determine seasonality of habitat use.
- Identify pronghorn and horse ranges and distribution.
- Demonstrate the accuracy of satellite-derived locations.
- Use GIS to display locations of pronghorn and feral horses in relation to jurisdictional boundaries; relate movements to features such as topography, vegetation, and water; and identify habitats that might be affected by training or testing.

Swainson's hawk (SWHA) and ferruginous hawk (FEHA):

- Track via satellite to determine breeding use areas at DPG.
- Track movements along migration pathways and locate winter use areas.
- Use GIS to display bird movements relative to breeding areas, migration routes, and winter use areas; and relate bird movements to habitat, and military installations and activities.

PRODUCTS

- Breeding area use map of each individual bird overlayed on BLM 1:100,000 land use coverage: FEHA: 3rd wk Mar. - 4th wk Jul.; SWHA: 3rd wk Apr. - 4th wk Jul.
- Migration route of each raptor tracked (Sept. – Nov. 15).
- Winter use area of each raptor tracked.
- Seasonal movements of each ungulate on BLM land use coverage during the following time frames: Nov. – Feb., Sept. – Oct., Mar. – Apr.

METHODS

STUDY AREA

DPG is located within the Great Salt Lake Desert, a subdivision of the Bonneville Basin, which is also part of the Great Basin Desert. The Bonneville Basin was once covered by the Pleistocene freshwater of Lake Bonneville, which deposited sediments on the salt covered flats that may reach depths of 610 meters. The old lakebed is categorized as cold desert or as Intermountain Sagebrush province. Elevations range from a low of approximately 1,400 meters to a high at nearby Ibapah peak of 3,684 meters. The topography within DPG contains broad valleys separated by north south trending mountain ranges. There are several isolated mountains. Most mountain ranges here were formed in a sequence of folding and block activity. Lava flows are visible in the majority of the ranges, but some (such as Granite Mountain) have granitic intrusions. The broad valley floors are filled with alluvium from the nearby mountains, resulting in distinctive physiographic features, such as piedmont slope (bajada) and nearly level basin floors. Pleistocene glaciers created Lake Bonneville, which resulted in gravel beaches, deltas, gravel bars, lake plains, and shorelines. These lake bed features are still visible in the area.

Habitat in the vicinity is characterized by salt desert vegetation (pickleweed, shadscale, gray molly, greasewood, budsage, juniper brush) interspersed with barren salt flats, along with stabilized and active dunes. Non-native plants such as cheat grass and Russian thistle are invading DPG at a fast pace. Cheat grass is estimated to cover 11.4% of DPG and (if present expansion continues) estimates indicate it could cover 25% of DPG by the year 2025.

The climate is arid as mountain ranges surrounding the Great Basin deplete moisture from storm systems. Most moisture enters the Great Basin from the south. Average annual rainfall for DPG is less than 17 cm. Temperature extremes range from 43°C to - 31°C, with an average maximum range of 18°C and minimum +3°C.

CAPTURE AND RADIOMARKING

Pronghorn/Horses

Permits were supplied by John Martin of DPG and included federal permit PRT-22710 and Utah state license "4BAND1985." Pronghorn were captured for radio marking via the use of a netgun shot from a helicopter (Helicopter Wildlife Management, Salt Lake City, Utah). This work was carried out under the direction of Ageiss Environmental, Inc., of Denver, CO. Tagging of pronghorn was completed quickly. Animals were sexed, aged, and a 35 ml blood sample was drawn for analysis of contaminants. Radio transmitters were attached via neck collars.

Platform Transmitter Terminals (PTTs) were attached to pronghorn using canvas and butyl rubber collars. Collars also included a conventional VHF transmitter using 172 MHz. Package mass averaged a total of 745 grams. Power output was 500 mW. The PTT included 4 electronic sensors: temperature, battery voltage, activity, season count. Three seasons were used to program the PTT duty cycle, two for operation seasons and one to turn off transmissions at the end of the demonstration. The duty cycle was programmed for: 8 hours on (i.e., transmitting) and 24 hours off (from March through July), then on for 8 hours every 6 days during August and September. From October through December the PTTs again operated 8 hours on, 24 hours off. Comparisons were made between a sample of conventional radio tracking location estimates and satellite received location estimates.

Capture and marking of feral horses occurred with cooperation by the BLM, DPG, BSU, and Ageiss Environmental Inc. Feral horses were herded by helicopter to catch pens and controlled in a squeeze-chute while being tagged. Only female horses were radio marked with PTTs, because males are more often engaged in fighting, which could destroy or damage radio collars. Horses were sexed and aged by BLM personnel, and healthy mares aged between two and five years old were selected for attaching PTT collars. Also, a 35 ml blood sample was obtained for analysis of contaminants.

Platform Transmitter Terminals (PTT) were attached to feral horses using canvas and butyl rubber collars, which included a conventional VHF transmitter using 172 MHz. The package mass averaged 745 grams, the PTT transmitted at 500 mW and included 4 sensors (i.e., battery voltage, activity, temperature, and season count). The 3 seasons included two for operation seasons and one to turn off the PTT. The duty cycle was 8 hours on, 24 hours off from March through July, then on for 8 hours every 6 days during August and September. From October through December the PTTs operated 8 hours on, 24 hours off.

Ferruginous hawks/Swainson's hawks

Surveys for hawks were conducted at DPG and beyond in suitable habitat until nest sites were found. There were few ferruginous hawk nests in the vicinity of DPG. Several sites that were visited offered evidence that the young had been predated by mammals or other avian predators and that the adults had dispersed. Only one rest site was occupied by 15 June 1996 (Table Mountain). The only occupied Swainson's hawk nests detected near DPG were found in the vicinity of Grantsville and Tooele. Because there were few nesting attempts made by these species within DPG, we marked subjects that were as close as possible to DPG. This allowed us to develop information on these species to help determine breeding use areas near DPG, to describe the period when the hawks leave the DPG area, and to track movements along migration pathways and to locate winter use areas.

We trapped adult ferruginous hawks in May and June 1996. We placed traps near habitual perches, along regularly used flight paths, and within view of the nest. We targeted capture during mid brood-rearing (young 2 - 5 weeks old), when adults were likely to be tenacious and not abandon their young. We instrumented all captured ferruginous hawks with 33g backpack packages (approximately 30g PTT and 3g harness). We took the following morphological measurements of each individual (if possible): mass (g), wing chord (mm), wingspan (mm), footpad (mm), bill depth (mm), hallux length (mm), and culmen length (mm). Each captured hawk was banded with a USFWS band on the right leg (unless previously banded).

Swainson's hawk nest sites were surveyed for breeding activity in early May. Breeding adults were captured using dho-gazas with great-horned owls as lures, and/or bal-chatri traps with gerbils as bait. Each captured individual was radio-tagged with a 33g PTT in a backpack configuration. Measurements taken included: mass (g), wing chord (mm), and footpad (mm). Additionally, the bottom half of the rectrices were painted with a non-toxic, quick dry paint to facilitate observations of individuals. We took the following morphological measurements of each individual (if possible): mass (g), wing chord (mm), wing span (mm), footpad (mm), bill depth (mm), hallux length (mm), and culmen length (mm). Each captured hawk was banded with a USFWS band on the right leg (unless previously banded). A total of four raptors (1 FEHA and 3 SWHA) were outfitted with satellite PTTs attached by a Teflon ribbon body harness. Each PTT had a Power output of 150 mW. The units included 4 sensors, temperature, battery voltage, activity, and season count. We programmed 3 seasons: two for operation cycles, and one to turn the unit off. We used the following duty cycle: 8 hours on, 20 hours off through 1 August, then 8 hours on, 84 hours off, turning off in December.

MONITORING

Field biologists from Ageiss Environmental made visual observations on a regular basis and plotted locations of radio marked pronghorn. One full-time and one half-time biologist were employed during 1996 and 1997 to track 22 pronghorn (included three with PTTs) and 18 feral horses (included three with PTTs). The VHF transmitter on the large mammal PTT collars enabled DPG staff or contractors to: verify PTT coordinates through triangulation or homing; locate the animal in case of PTT failure; and locate the animal if the motion sensor indicated mortality. Field biologists from Ageiss Environmental made visual observations on a regular basis and plotted locations of radio marked pronghorn and horses.

Data from the PTTs were relayed to Legacy researchers every 4 days. These data were visually inspected using ArcView GIS and forwarded to interested collaborators. Home ranges (90% convex polygons) were calculated with RANGESV software using Argos location estimates of location classes 0 – 3.

RESULTS

CAPTURE, REDIOTAGGING, AND MONITORING

Pronghorn

Pronghorn capture and radio marking occurred on 12 March 1996. A total of 19 conventional collars and three satellite received PTTs were attached to four mature male and eighteen mature female pronghorn. Captured Pronghorn were earmarked with colored tag, and the following data recorded: age, sex, general health, and capture location. A 35 ml blood sample was also drawn.

According to Steve Boyle, Ageiss has continued intensive ground tracking of radio-marked pronghorn, with one full-time and one half-time biologist averaging 2.2 relocations of each marked pronghorn per week. Information obtained by visual observations included plots of pronghorn locations, noting range habitat, association with other animals, weather, date, and time.

A total of 1,466 location estimates (includes location classes 3-Z) were received from the 3 pronghorns tagged with PTTs from about 12 March through December 1996. This is an average of 12.8 locations per animal per week. Animal ID# 5720 provided 512 location estimates, ID# 5723 provided 441 location estimates and ID # 5725 provided 513 location estimates (see Table I-1).

Table I-1: Numbers of Argos location estimates per PTT.

	SWHA			Feral Horse			Pronghorn			FEHA	
	5697	5698	19196	5700	5710	5739	5720	5723	5725	19185	ALL
LC											
3	0	1	5	9	12	1	40	31	41	3	143
2	3	7	9	36	32	2	48	35	55	13	240
1	9	7	33	82	52	4	77	49	90	42	445
0	28	58	64	125	133	16	182	139	186	93	1024
A	12	18	33	94	54	8	78	106	78	32	513
B	9	21	33	67	62	12	83	78	61	28	454
Z	2	4	4	10	0	2	4	3	2	10	41
Total	63	116	181	423	345	45	512	441	513	221	2860

Argos Location Classes (LC) = Estimated Accuracy in Latitude and Longitude

LC 3	<= 150m
LC 2	<= 350m
LC 1	<= 1000m
LC 0	> 1000m
LC A and B	no estimate of location accuracy
LC Z	invalid location

DPG is still in the process of ground-truthing and digitizing habitat layers in their GIS. Once this is accomplished animal location estimates acquired via satellite can be integrated to learn about animal use in relation to actual habitat, elevation, and topography. Until that is accomplished the location estimates are presently displayed to identify land use by pronghorn relating to jurisdictional boundaries, association with available water sources, and spatial association with horses.

Location estimates collected from pronghorns marked with PTTs indicated movement between DoD-managed lands at DPG and lands managed by BLM. The majority of locations show that these marked pronghorn utilized DPG along the east-central portion of the installation, with forays off DPG onto BLM land. Further analysis of GIS vegetation layers combined with roadways likely will show that pronghorn are utilizing young cheatgrass and annual forbs along roadways in this region. Vegetation along roadways receives more moisture and heat (during late winter and spring), therefore it greens faster than vegetation in roadless areas, attracting pronghorn to forage along roadways. Roadway maintenance includes the mowing of road shoulders, which stimulates grass and forb growth (Steve Boyle, pers. comm.). Pronghorn location estimates were plotted using "Ranges" to determine average size of home range. We used location estimates with estimated error of less than 1,000 m to create 90% convex polygons to quantify and display land use by pronghorn. The pronghorn wearing PTT ID# 5720 used an average of 5,942 hectares and had a core use area located due north of Ditto, primarily on DPG. This animal was occasionally detected on BLM property north of DPG. Location estimates did not measurably vary by season. PTT ID# 5723 used a similar range location as 5720 and had a 90% convex polygon of 8,791 hectares. During the winter months (Nov. – Feb.) this pronghorn was detected southeast of its primary core use area, directly north of Ditto. The pronghorn tagged with PTT ID # 5725 had a core use area entirely within DPG, primarily north of Ditto. The average size of its 90% convex polygon was 7,407 hectares. During September and October it was frequently detected near Ditto. See maps, figures I-1 through I-4.

Feral Horses

In collaboration with the BLM, 24 feral horses were captured on 3 June 1996 using a helicopter to herd the selected horses to a funnel and catch pen. Three females were tagged with PTT collars that were also equipped with conventional VHF transmitters.

According to Steve Boyle, Ageiss conducted ground tracking of radio-marked horses, with one full-time and one half-time biologist averaging 2.2 relocations of each marked horse per week. Ageiss biologists plotted horse locations, noting range habitat, association with other animals, weather, date, and time.

A total of 813 location estimates were received via satellite from the 3 PTTs attached to horses. ID#5700 received 423 location estimates, averaging 18 locations per week. ID# 5710 received 345 location estimates, averaging 14 locations per week. ID# 5739 received 45 location estimates, averaging 1 locations per week, but we did not receive this PTT after 21 June 1996. We calculated 90% convex polygon ranges using location estimates with an estimated error of less than 1,000 m. Horse PTT ID# 5700 had a 90% core use area of 4,729 hectares located primarily on BLM property, northeast of Baker. It was less frequently detected within DPG, but never near Baker or south of Burns or Stark Road. Location estimates were consistent throughout the year, with no seasonal use variations detected. Horse PTT ID # 5710 had a 90% core use area entirely within DPG, located due north of Ditto. A 90% convex polygon use area averaged 5,873 hectares. No seasonal use patterns were detected, as location estimates were consistently located within the core use area for the entire year. Horse PTT ID# 5739 failed prematurely. While it was functioning, we could determine a 90% convex polygon use area for this horse of 3,245 hectares, located on the northeast border of DPG. Several location estimates were on BLM property near DPG. See Table I-1 and maps in Fig. I-5 through I-8.

Ferruginous hawks/Swainson's hawks

There were very few nesting attempts by raptors in the vicinity of DPG in 1996. Trapping attempts for ferruginous hawks were made at Terra (10 km east of Dugway) and also at the south end of the Tooele Army Depot, both without success. An adult male from a nesting territory known as Table Mountain was captured and radio-tagged with a 30 gram PTT on 15 June 1996. He was part of a pair that successfully bred, raising 3 young that were nearly fledged by the capture date. This radiomarked individual stayed in the Dugway area until 26 June 1996 (Fig. I-9). He moved through the northwest corner of Colorado and remained in south central Wyoming until 26 October 1996. He returned to eastern Utah by 2 November and moved onward to the Sevier Desert area where he stayed from 5 November through 27 January 1997. Then he moved to the eastern edge of central Nevada. He departed there 28 February 1997 and moved eastward to the Uinta Mountain Range, from where we received the last transmission on 3 March 1997, some 15 miles east of Kamas, Utah.

A total of three Swainson's hawks were tagged with 30 gram PTTs, the first on 6 September 1996, the second on 7 September 1996 and the third, on 8 September 1996. All were adult females and thought to be successfully nesting in the vicinity of Tooele and Grantsville, Utah. All three Swainson's hawks followed a similar pathway southward to Argentina. Migration south began in the third week of September. They were detected in the southeastern corner of Utah by the end of September, continuing across New Mexico into Texas, following the Texas Mexico border, continuing along the coastal plains of Mexico, and passing Verracruz by mid-October (Fig. I-10). By the third week in October all three individuals had arrived in Panama. Then they entered Colombia, where they migrated along the eastern slope of the Andes mountains. These birds passed east of Iquitos, Peru and traveled through the Selvas region of Brazil, and through central Bolivia, with all individuals entering northern Argentina by the second week in November. They continued southward and east to arrive in the Pampas region of Argentina by mid-November (Fig. I-11). All three stayed within this heavily agriculturalized region, the major crops being sunflowers and alfalfa.

An international group of scientists studied Swainson's hawks in this area during 1995 and 1996. Researchers documented colonial roosts, with hundreds (sometimes thousands) of Swainson's hawks roosting in trees planted by resident farmers and ranchers. Swainson's hawks foraged for grasshoppers, where they also became vulnerable to applications of organophosphates used by farmers to reduce insect pests. In some cases Swainson's hawks came in direct contact with the pesticides as they were sprayed, or they ingested insects that were recently sprayed. Organophosphates act quickly in the body and in this case killed thousands of Swainson's hawks in farm fields. Large numbers of dead hawks also were discovered at roost sites (B. Woodbridge and M. Fuller, pers. comm.).

Because Swainson's hawks marked with PTTs helped this international team of researchers delineate the winter use area of Swainson's hawks in the Pampas of Argentina, steps were taken to limit the use of organophosphates by local farmers through a voluntary program carried out by the chemical suppliers and local authorities. Area farmers were able to substitute another product that proved to be less harmful to hawks in place of the pesticide (i.e., monocrotophos) affecting Swainson's hawks (M. Kochert, pers. comm.).

No mortalities of Swainson's hawks were reported for the 1996/1997 winter period. All three of the Swainson's hawks tagged at DPG began a northward migration by mid-March and followed the same pathway that they had used the previous autumn. All three birds were detected in Mexico during April and arrived in New Mexico by the first week of May. The tagged birds had returned to the breeding use areas by mid-May. An effort was made to recapture and remove the PTTs from these birds. All three radio-marked individuals attempted to breed. Two PTTs were recovered from birds that successfully fledged young. The third bird was on territory, but no young were observed, and trapping efforts failed.

Year-round information collected on Swainson's hawks provides valuable insight for DPG base natural resource managers. It would be difficult to assess the management success for a species that spends most of the year on migration and in winter use areas. These types of movements expose this species to a wide array of threats that military installations cannot manage. This case in particular demonstrates the need to fully understand the natural history and potential problems a species is exposed to.

Counts and percentages of location estimate quality or location class (LC) are shown in Table I-1. Horse and pronghorn PTTs had the same power output (500 mW) and similar duty cycles and performed equally well, with 25.9% (horse) and 24.4% (pronghorn) of location estimates falling into the best LC categories (1-3). The 30g units used for Swainson's and ferruginous hawks also had the same power output of 150mW. Performance for the three PTTs used for Swainson's varied widely. ID# 5697 was thought to have failed, but when the unit was recovered we found that the antennae was removed. This PTT recorded the fewest locations due to this damage. PTT ID# 5698 provided 116 location estimates, and PTT ID# 19196 provided 181 location estimates. The ferruginous hawk PTT ID# 19185 provided 221 location estimates over a 9-month period, averaging about 6.1 location estimates per week.

DISCUSSION

The utility of tracking wide-ranging animals via satellite received telemetry was clearly illustrated for all species involved in this study. Within the DPG environs, "remote" tracking provided location estimates according to the established duty cycles of the PTTs regardless of: (1) weather conditions, (2) animal location within roadless or sensitive military areas, (3) darkness, or (4) expertise level of conventional radio trackers and observers. When ground-truthed by conventionally acquired locations, satellite received locations were confirmed to accurately document the movements, interactions, and range use of pronghorn and horses (Fig. I-1 through I-8). This location data will assist managers to understand seasonal use of the various parts of DPG and, where necessary, better plan military use within these areas to avoid disturbing the animals. Further, the PTT location data document the distribution of pronghorn and horse ranges within the various jurisdictional boundaries of DoD, State of Utah, and BLM managed lands. Location estimates can help managers relate animal movements to features such as topography, vegetation, and water as soon as these features are incorporated into DPG's GIS. Finally, by marking a sample of herd members of both horse and pronghorn, managers can identify habitats used by these animals that might be affected by military training and testing. Location estimates of marked individuals could also help managers to determine what areas are not used by sensitive species. This would allow for better scheduling and use of land for military activities, which would reduce potential conflicts between DoD and wildlife.

GIS was successfully used to display bird movements along migration pathways and winter use areas. GIS was instrumental in relating bird movements to land use and to military installations, along with other landowners and activities. We hoped to compare horse and pronghorn locations collected via satellite with those obtained by conventional telemetry. There were few occasions when ARGOS satellites and Ageiss biologists collected data at the same time. We reviewed both data sets for comparable data and found only 18 that fell within the same 24-hour period (Table I-2). These "matches" indicate that tracking via satellite can be used to document the general areas of use of individuals, thus avoiding the cost and potential disruption resulting from sending field personnel out on a regular basis.

Table I-2

Topography	Hour Difference	Linear Error (ft)
Mountain Basin or Canyon	7.64	10914.75
Mountain Basin or Canyon	-7.49	584.69
Foothill_Terrace	6.29	3768.17
Foothill_Terrace	-3.82	1519.65
Foothill_Terrace	-0.47	2960.84
Foothill_Terrace	8.03	2942.75
Foothill_Terrace	-20.74	1020.62
Foothill_Terrace	-5.86	4706.69
Foothill_Terrace	0.93	782.08
Foothill_Terrace	14.67	872.98
Foothill_Terrace	14.86	5303.61
Foothill_Terrace	-6.05	1639.67
Playa	2.21	857.12
Playa	6.33	1056.94
Playa	-4.56	297.50
Playa	4.59	1142.51
Stable Dune	0.40	1135.88
Alluvial Mountain Margin	-0.12	2905.22
Alluvial Mountain Margin	14.26	2131.88
Alluvial Mountain Margin	-4.32	4068.87

This Legacy demonstration has clearly shown that year round tracking of sensitive species is possible via satellite-based telemetry. The information acquired can be used to help guide land managers' decisions to assist the DoD maintain mission readiness without sacrificing the needs of wildlife and their respective habitat.

MANAGEMENT IMPLICATIONS

Remote tracking and monitoring via satellite cannot replace visual observations and conventional radio telemetry to characterize and describe the behavior of animals, or to document productivity in a marked individual. In some cases both methods are best used together. Used alone, satellite-received telemetry is excellent for tracking animals over vast landscapes or migratory distances. Conventional telemetry is most effective for tracking animals that do not range far, and/or those that occur where travel by roadways is easily accomplished.

The GIS capability at DPG is steadily improving, and progress continues to ground-truth various data layers that will enhance interpretation of animal location estimates. Meanwhile, there remain complications in converting GIS layers presently displayed in GRASS to use in ARCINFO applications.

RECOMMENDATIONS

While the 1995-96 tracking efforts have provided baseline information on horses and pronghorn, conditions within the range can vary dramatically. Droughts can affect available forage and water sources; heavy snowfall accumulations can force these animals to seek food and shelter in areas not otherwise used in milder winters. Therefore, it is desirable that a sample of these species continue to be tracked via satellite to determine present day use of the range and for planning military activities.

The ecology of sensitive species like Swainson's hawks and ferruginous hawks living in the DPG area is poorly understood. Both species have been proposed as candidates under the Endangered Species Act. In the case of Swainson's hawks, tracking with satellite telemetry allowed scientists to learn of organophosphate-induced mortality that occurred in Argentina. It was discovered that tens of thousands of Swainson's died in 1995 alone. This most certainly affected local populations throughout the breeding range in North America. This fact illustrates the need to understand the entire life cycle of the species under study. If we had only studied Swainson's hawks on the breeding ground, we would not have found the causes for widespread regional declines. Declines might have erroneously been attributed to breeding ground conditions, thus triggering a series of expensive, potentially disruptive studies and management actions. Tracking via satellite allowed an international effort to address the problem, thus reducing or eliminating mortality caused by organophosphates. If mortalities had continued unabated, we might have seen this species added to the Endangered Species List by the turn of the century or sooner. While the cost-savings in avoiding such an action is incalculable, preventing endangered species listings undoubtedly saves a tremendous amount of money, human resources, and training time at military installations.

ACKNOWLEDGEMENTS

At DPG, we thank John Martin, the Chief of the Conservation–Preservation Division, biologist Scott Bates, and GIS Analyst James A. Mikkelson for technical and logistical support. Ageiss Environmental, Inc. biologist, Steve Boyle, and Brigham Young University graduate student, Shelly Kramer, provided valuable participation in fieldwork associated with this project. Shelly also made valuable observations that aided in recovery of PTTs from Swainson's hawks.

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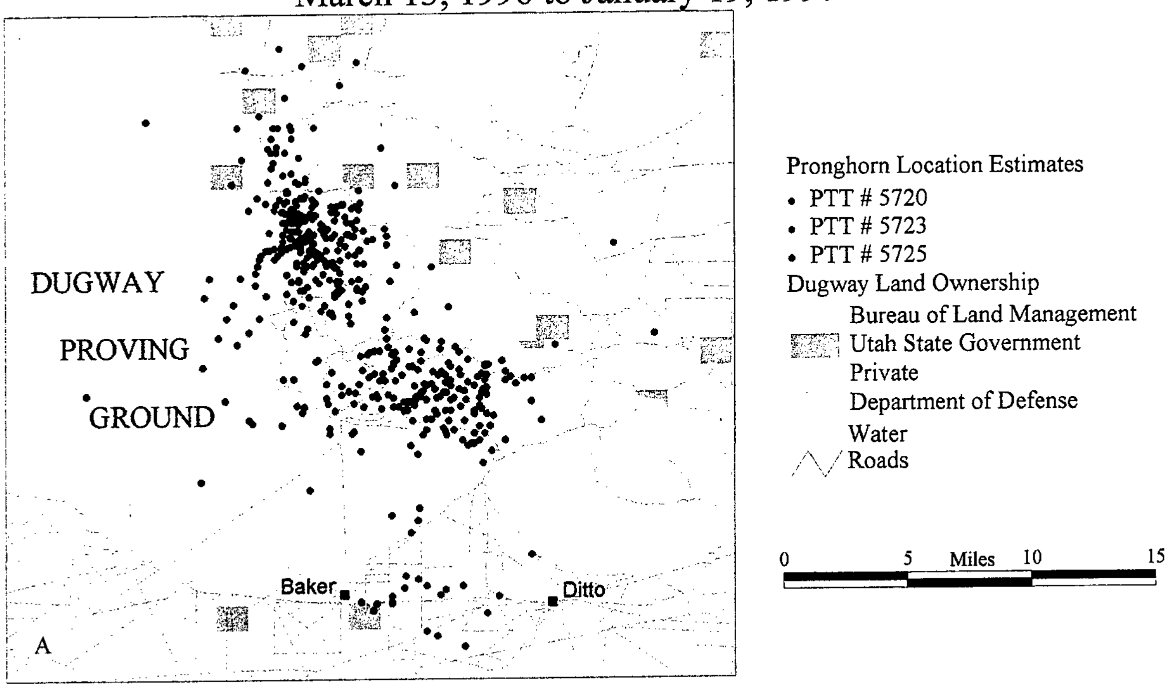
Pronghorn Location Estimates

Dugway Proving Ground, Utah

March 13, 1996 to January 19, 1997



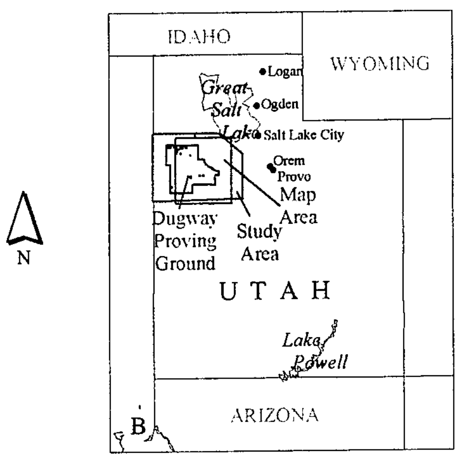
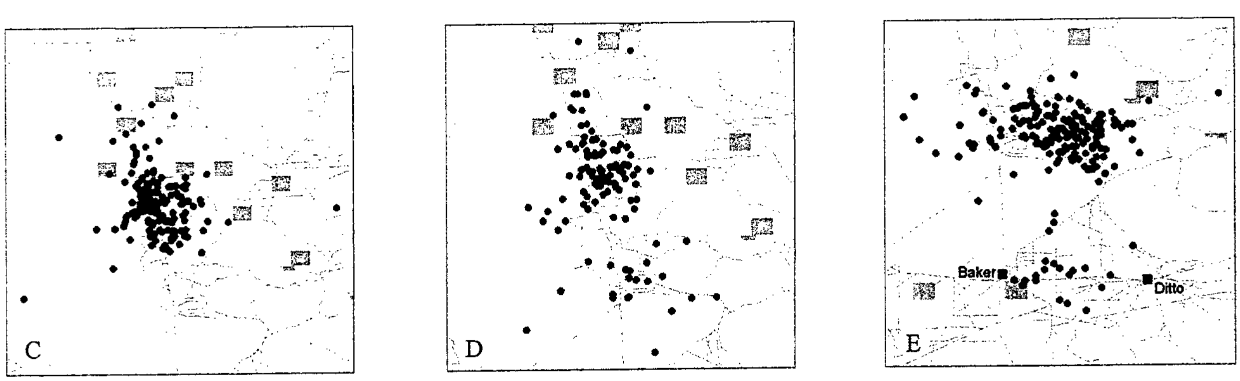


Figure I-1. Pronghorn Location Estimates and Reference Information

A. Dugway land ownership and all Pronghorn location estimates.

B. Reference.

C, D, E. Individual Pronghorn location estimates (PTT #s 5720, 5723, and 5725, respectively). Note the proximity to roadways, where Pronghorn are possibly utilizing young cheatgrass and annual forbs.



Pronghorn - PTT # 5720

Home Range Information

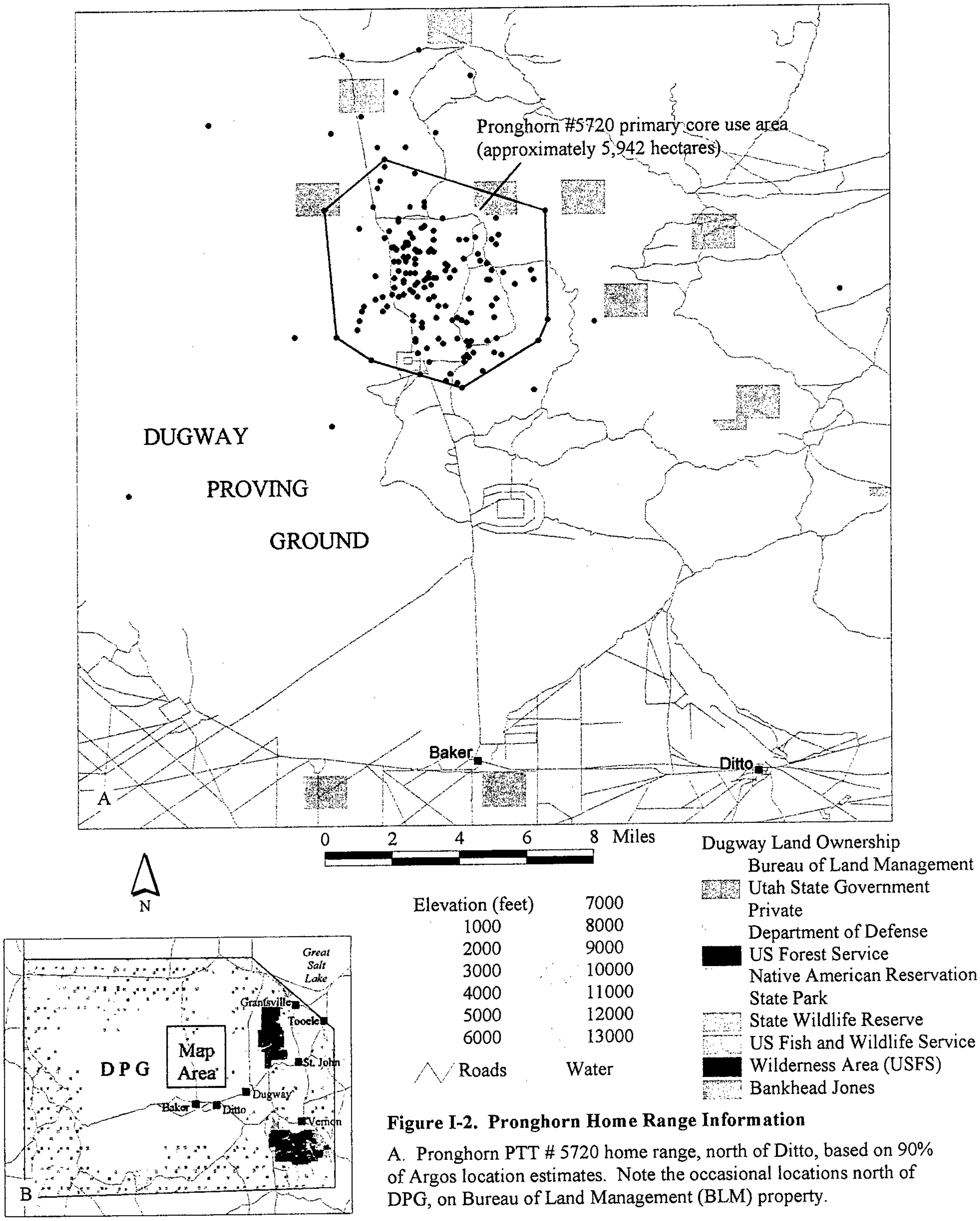


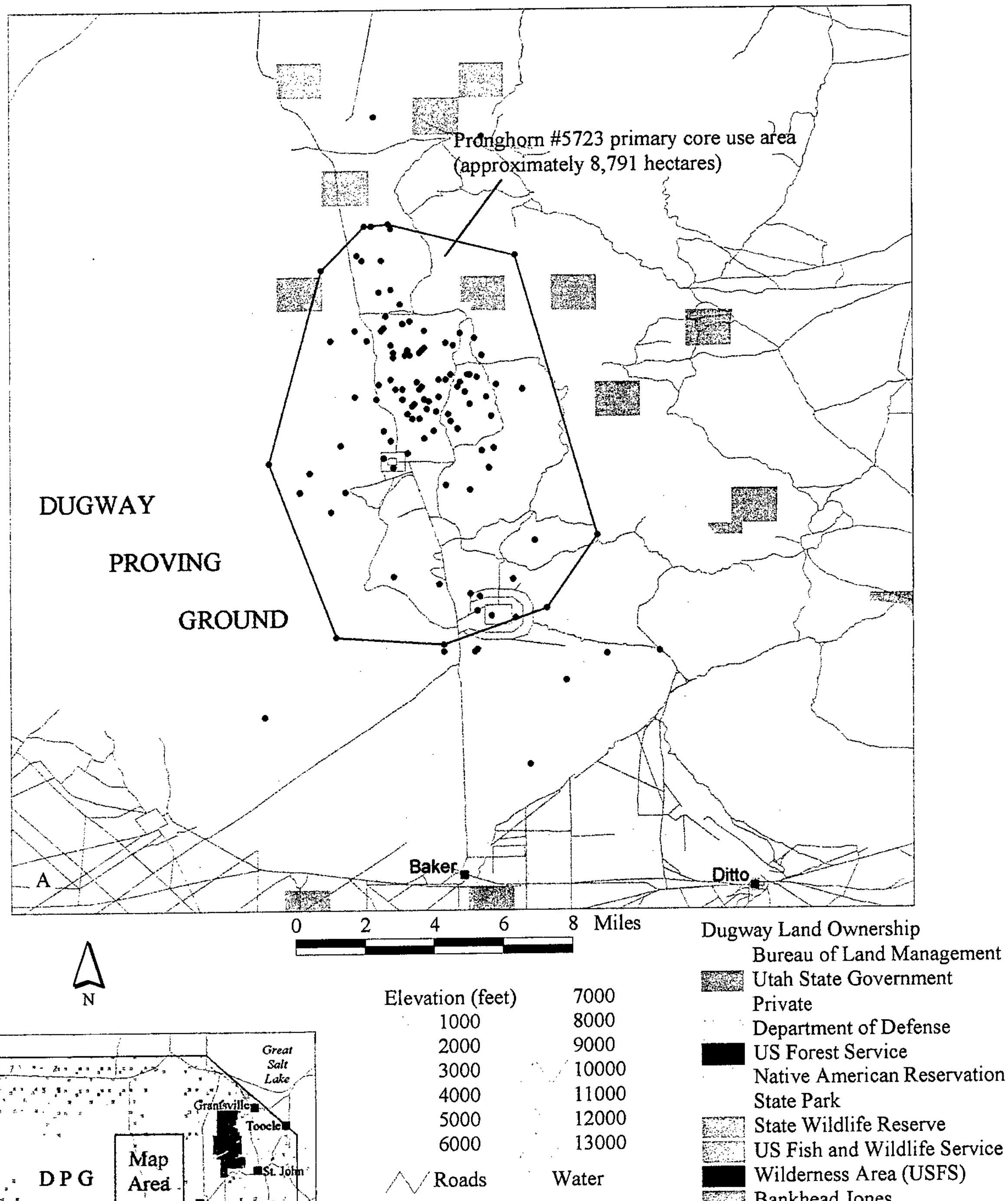
Figure I-2. Pronghorn Home Range Information

A. Pronghorn PTT # 5720 home range, north of Ditto, based on 90% of Argos location estimates. Note the occasional locations north of DPG, on Bureau of Land Management (BLM) property.

B. Reference.

Pronghorn - PTT # 5723

Home Range Information



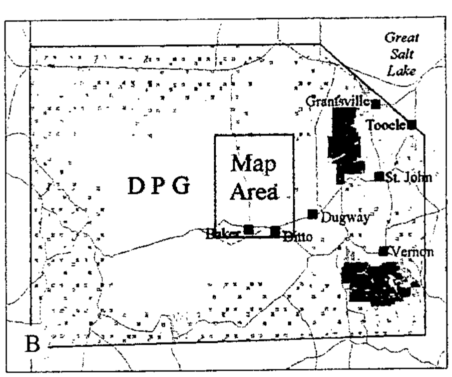


Figure I-3. Pronghorn Home Range Information

A. Pronghorn PTT # 5723 home range, north of Ditto, based on 90% of Argos location estimates. The locations southeast of the animal's primary core use area were during the winter months (Nov. - Feb.), possibly indicating seasonal variation in habitat use.

B. Reference.

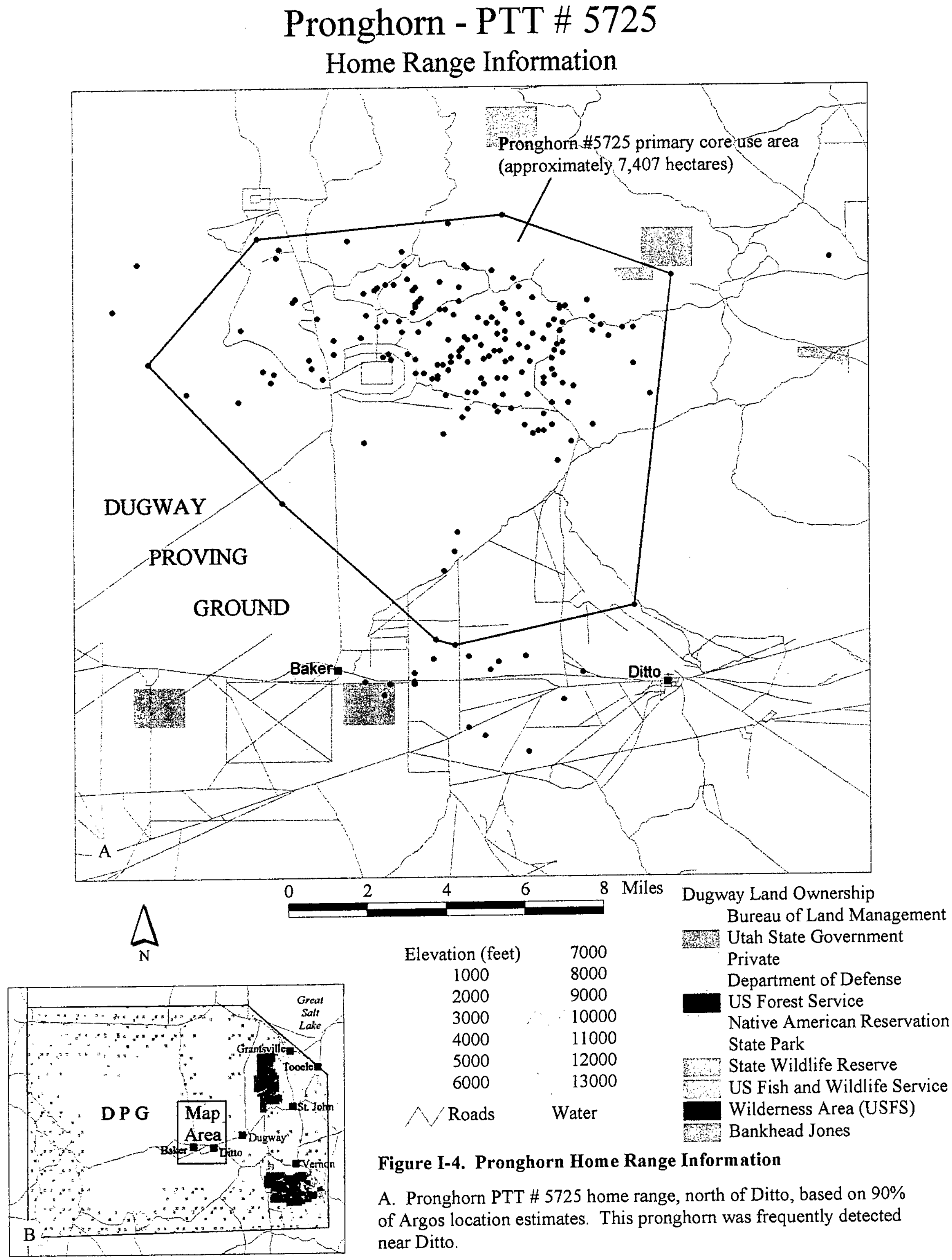


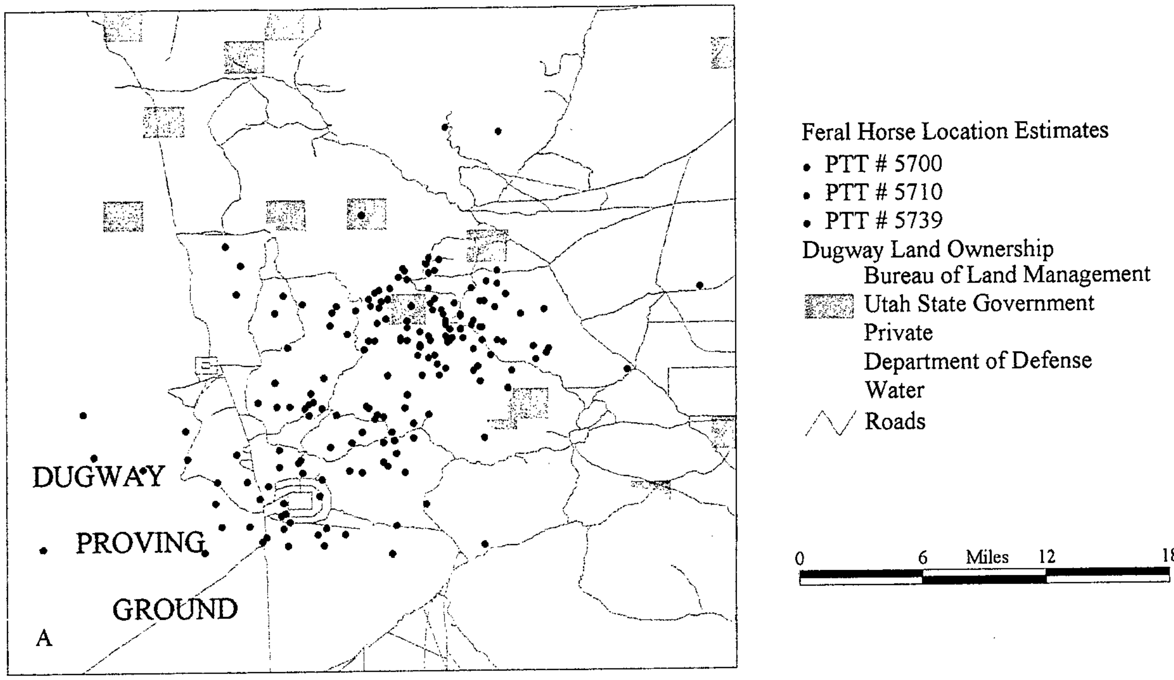
Figure I-4. Pronghorn Home Range Information

A. Pronghorn PTT # 5725 home range, north of Ditto, based on 90% of Argos location estimates. This pronghorn was frequently detected near Ditto.

B. Reference.

Feral Horse Location Estimates

Dugway Proving Ground, Utah
June 3, 1996 to January 24, 1997



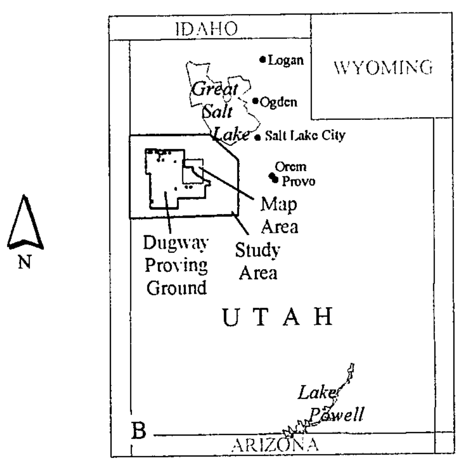


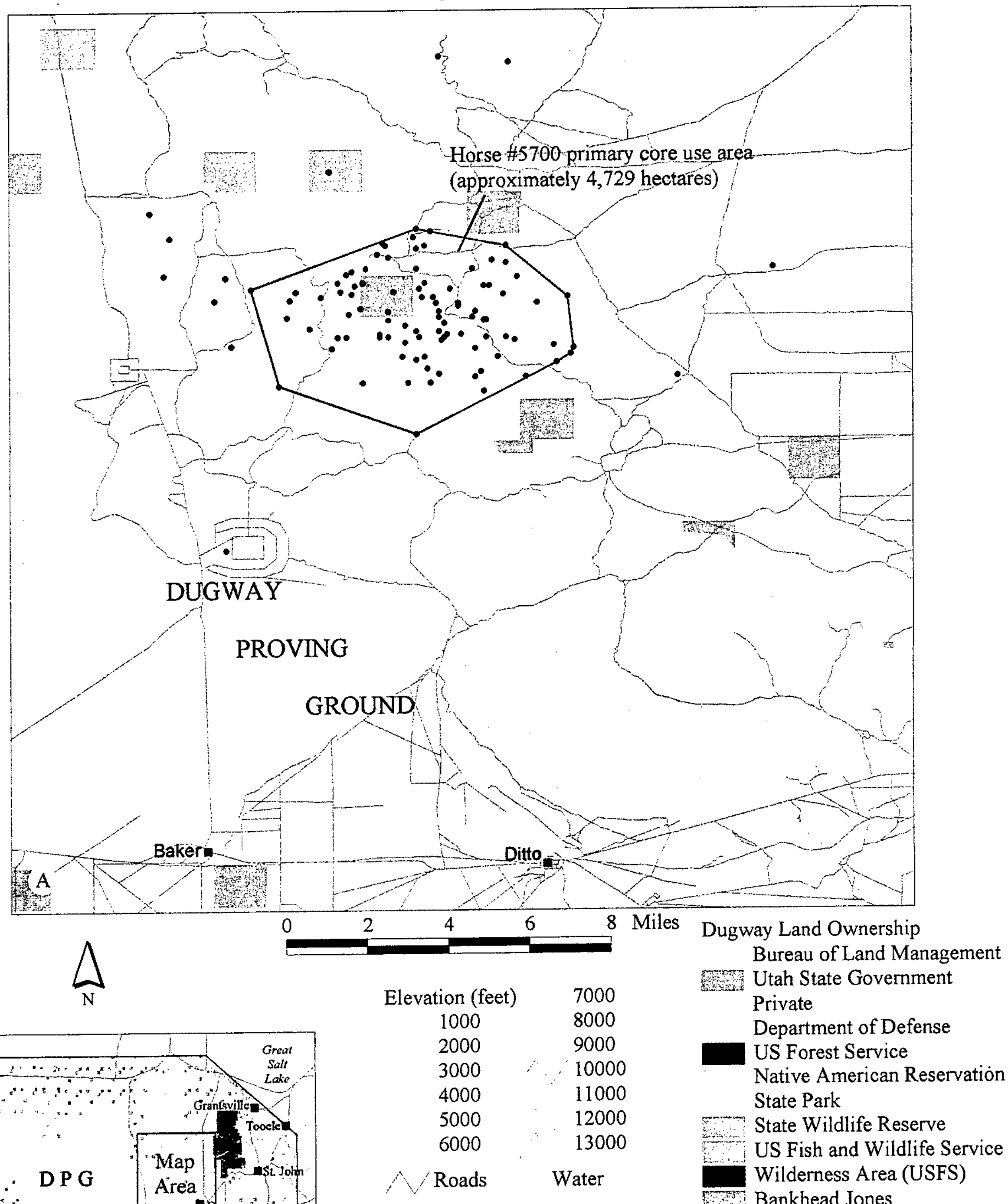
Figure I-5. Feral Horse Location Estimates and Reference Information

A. Dugway land ownership and all Feral Horse location estimates.

B. Reference.

Horse - PTT # 5700

Home Range Information



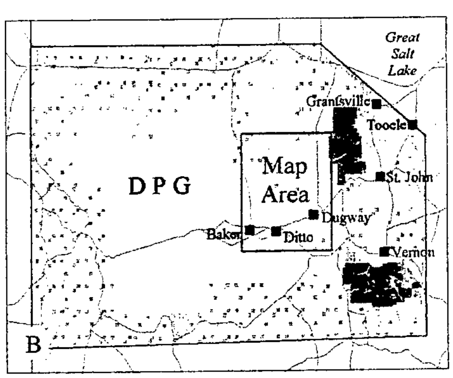
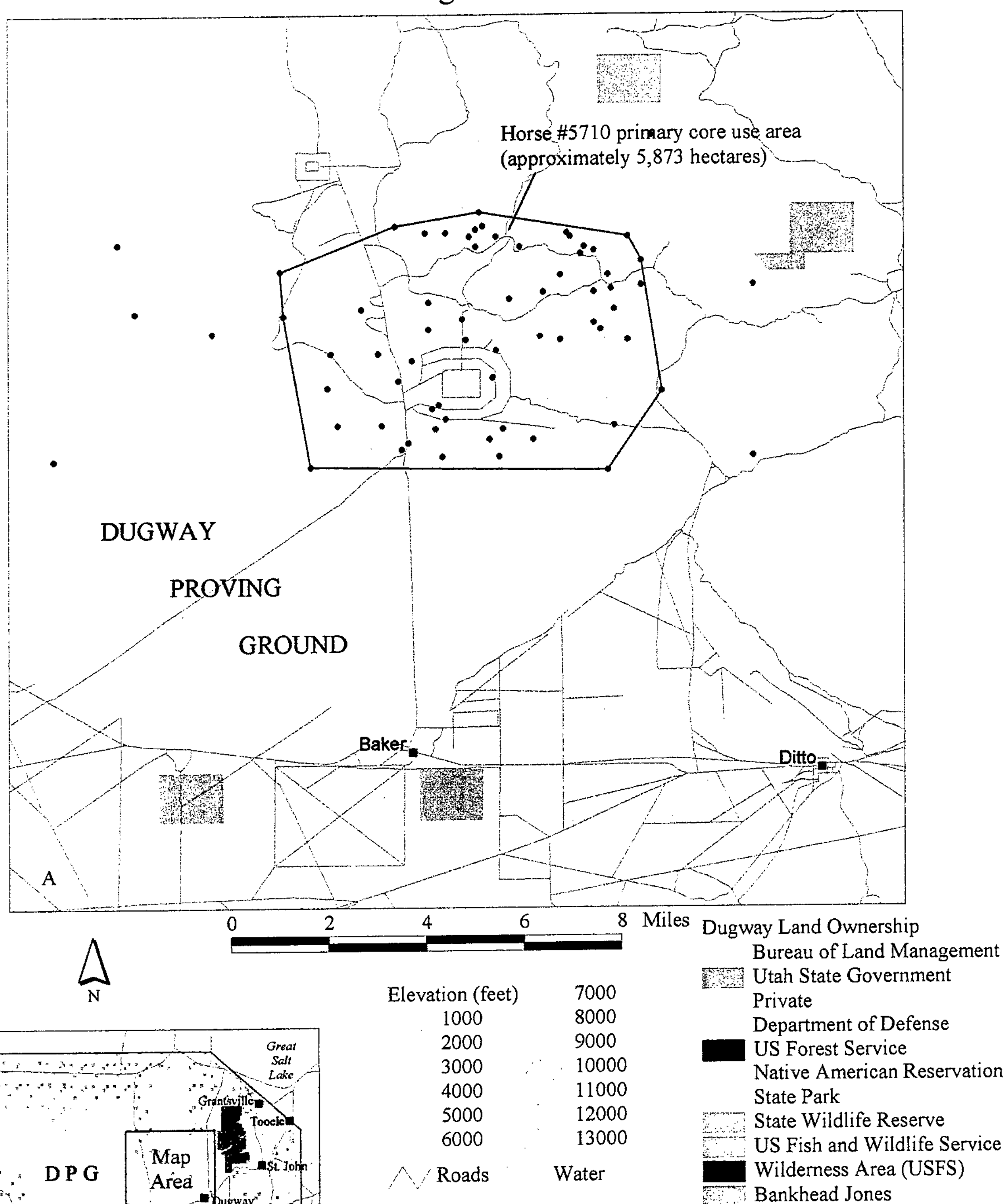


Figure I-6. Horse Home Range Information

A. Horse PTT # 5700 home range, northeast of Baker, based on 90% of Argos location estimates.

B. Reference.

Horse - PTT # 5710
Home Range Information



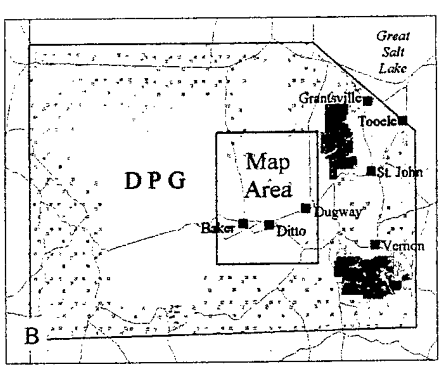
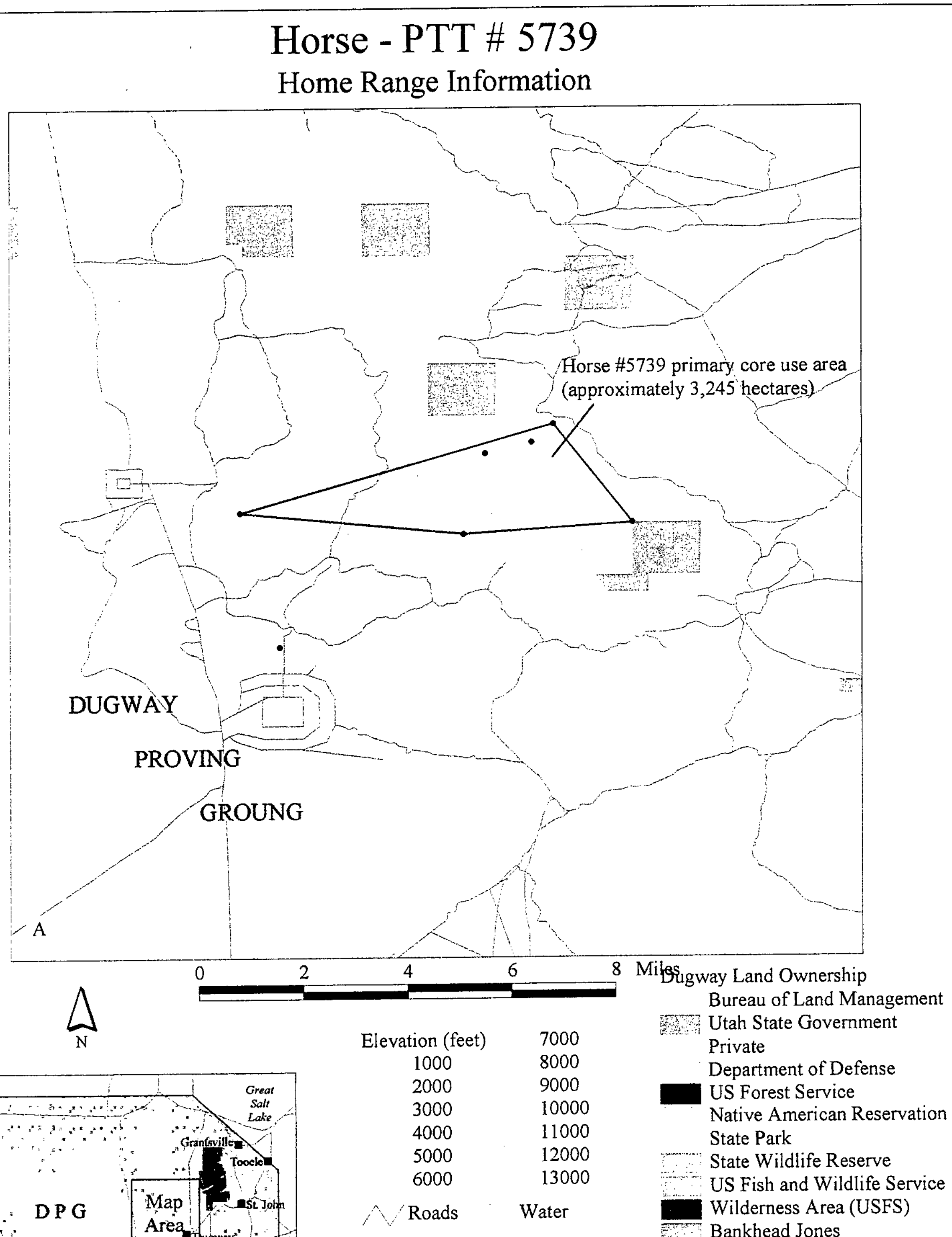


Figure I-7. Horse Home Range Information

A. Horse PTT # 5710 home range, north of Ditto, based on 90% of Argos location estimates.

B. Reference.



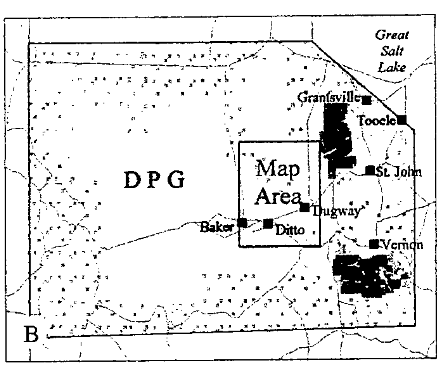


Figure I-8. Horse Home Range Information

A. Horse PTT # 5739 home range, based on 90% of Argos location estimates. Few locations were received because collar ceased operating prematurely.

B. Reference.

Ferruginous Hawk - PTT # 11985

Dugway Proving Ground - June 15, 1996 to June 27, 1997

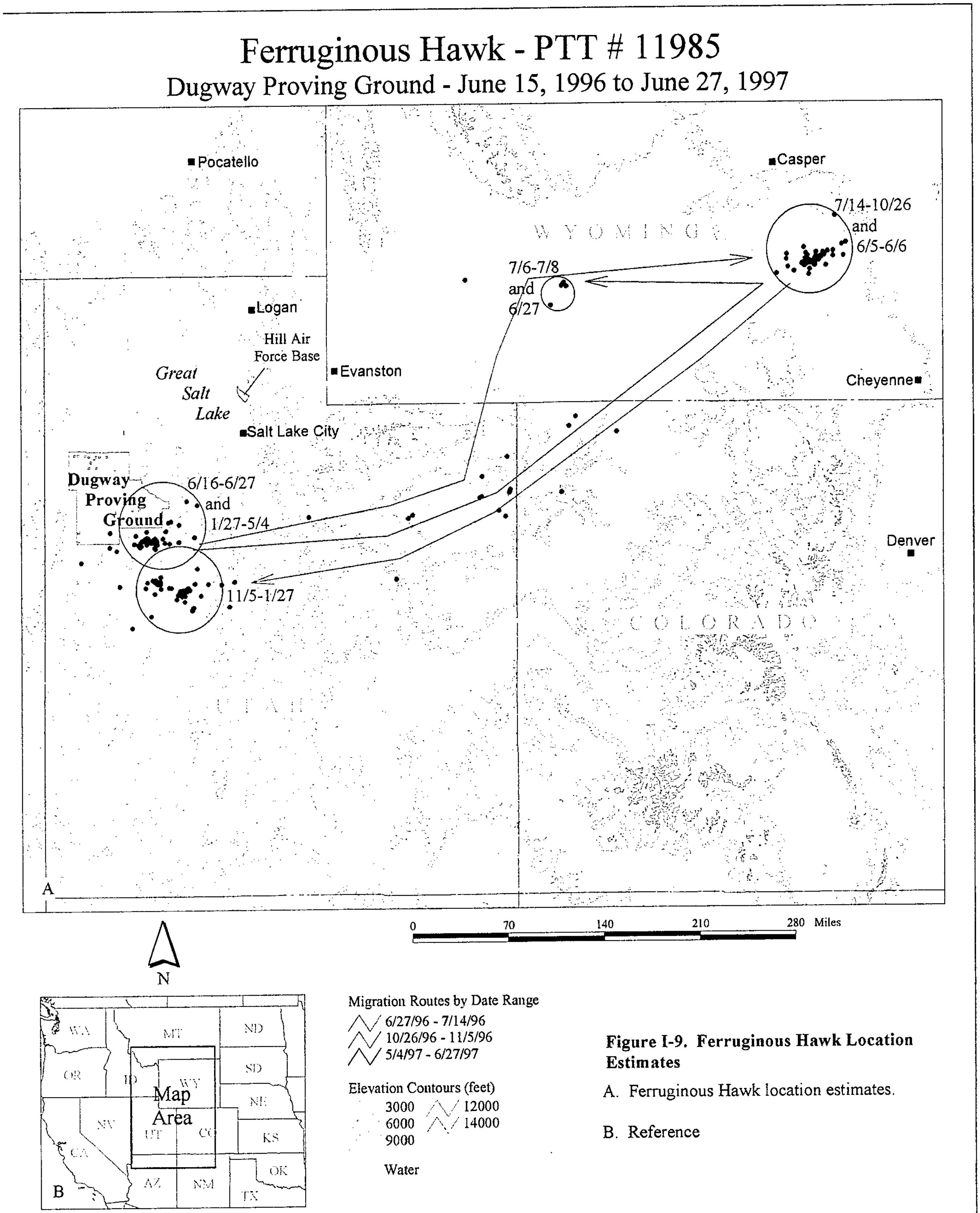


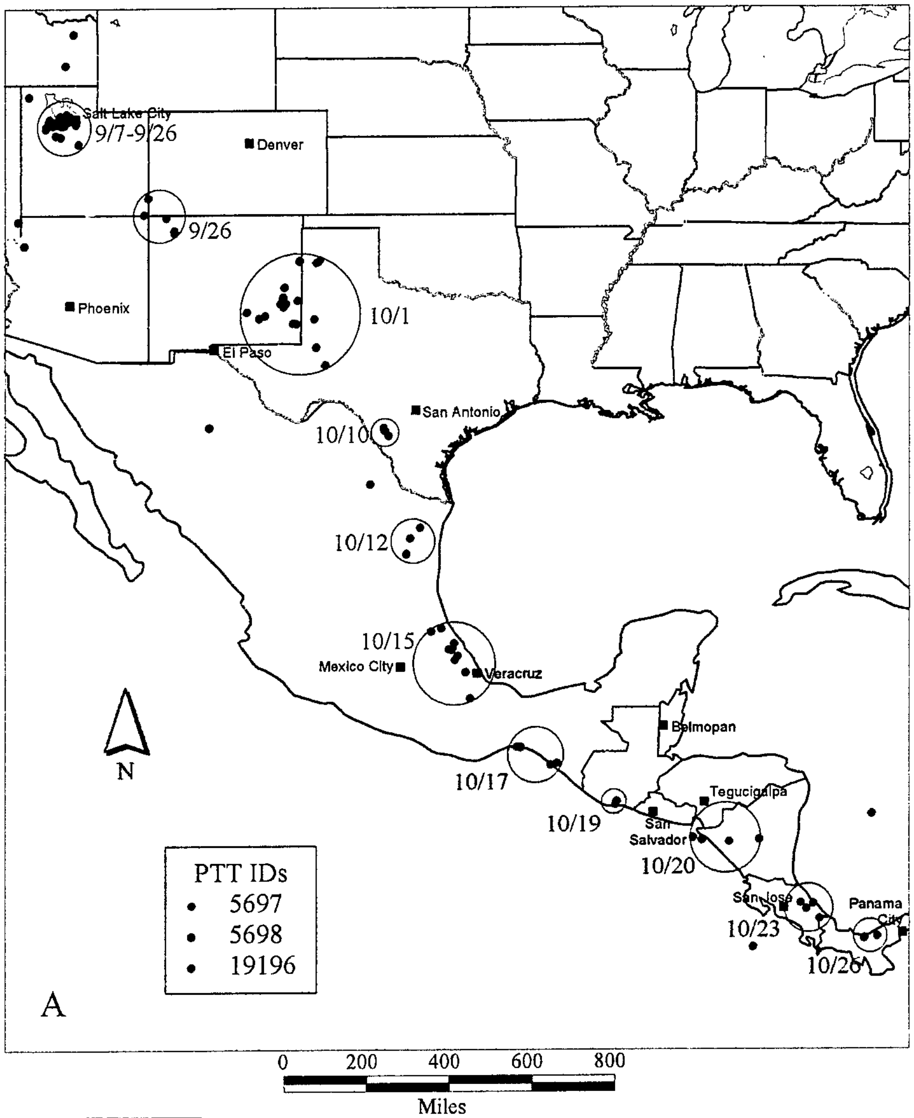
Figure I-9. Ferruginous Hawk Location Estimates

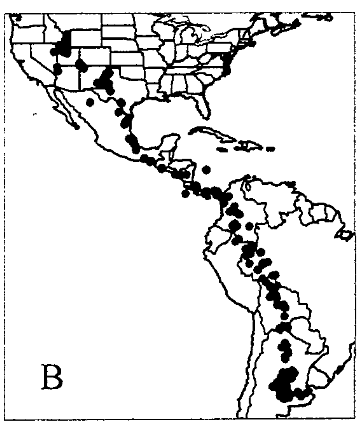
A. Ferruginous Hawk location estimates.

B. Reference

Swainson's Hawks - PTTs 5697, 5698, and 19196

September 6, 1996 to October 26, 1996
(first half of southward migration)





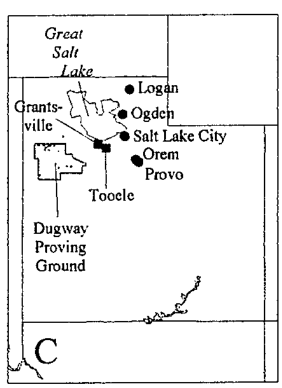


Figure I-10. Swainson's Hawks Migration Routes (first half)

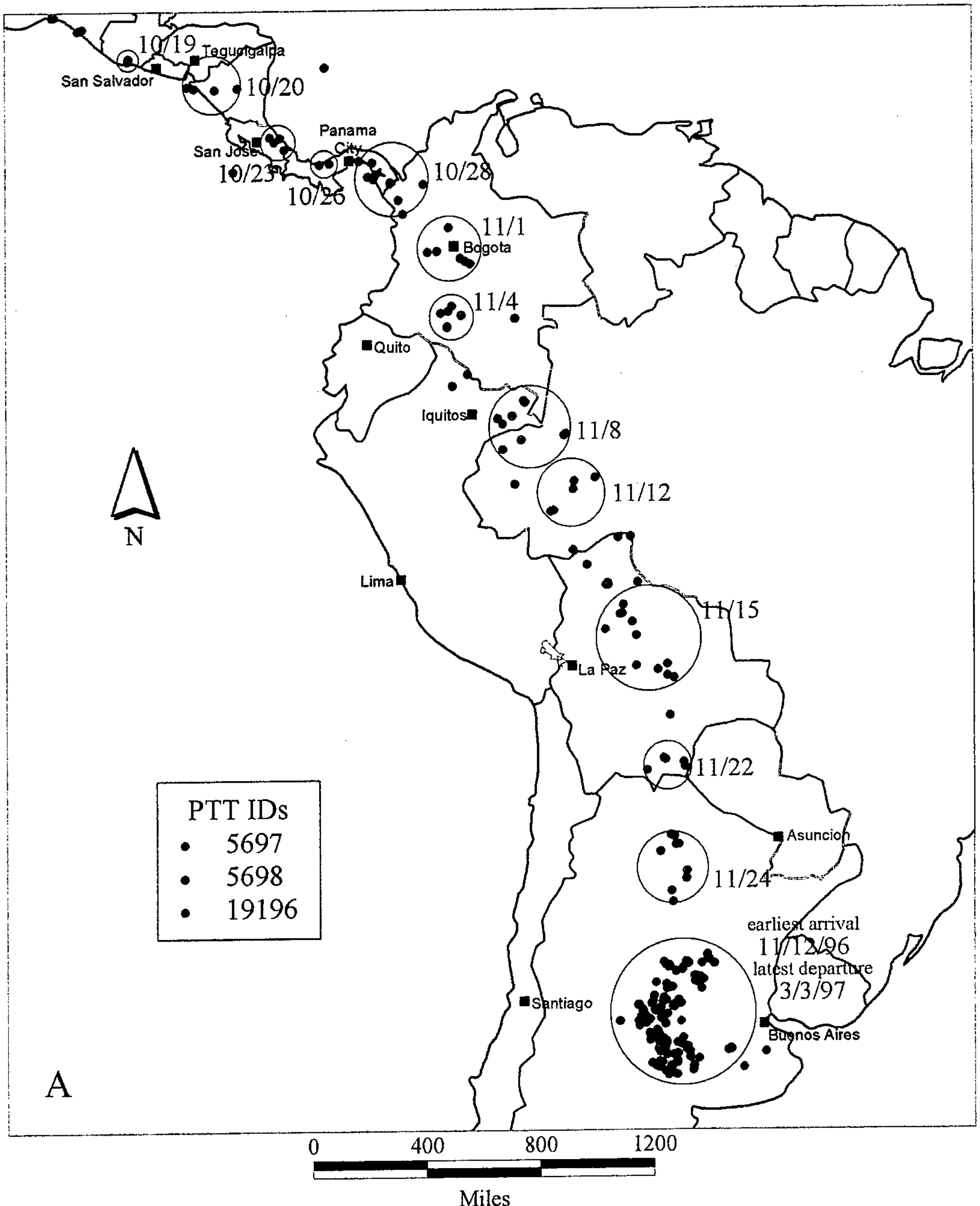
A. Swainson's Hawks location estimates from September 6, 1996 to October 26, 1996.

B. Location estimates from full southward migration. Same path was used for northward return. This full dataset runs from September 6, 1996 to August 5, 1997.

C. Reference. Transmitters were applied near Tooele and Grantsville, Utah.

Swainson's Hawks - PTTs 5697, 5698, and 19196

October 26, 1996 to March 30, 1997
(second half of southward migration)



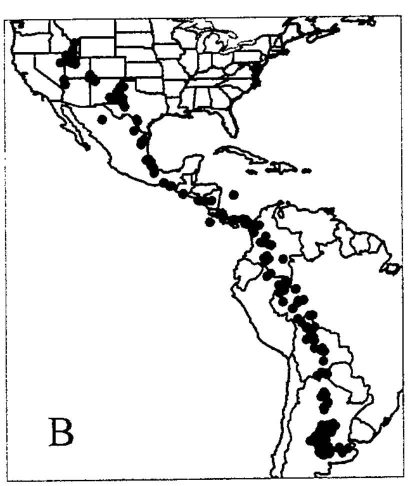


Figure I-11. Swainson's Hawks Migration Routes (second half)

A. Swainson's Hawks location estimates from October 26, 1996 to March 30, 1997.

B. Location estimates from full southward migration. Same path was used for northward return. This full dataset runs from September 6, 1996 to August 5, 1997.

NAVAL AIR STATION FALLON, NEVADA

INTRODUCTION

PURPOSE

The goal of this Legacy effort was to demonstrate the usefulness of radio tracking via satellites and the use of geographic information systems (GIS) to describe the movements of white pelicans over the large areas they use in the Lahontan Valley region near NASF.

BACKGROUND

Naval Air Station (NAS) Fallon is located in the Lahontan Valley of west-central Nevada, approximately 70 miles east of Reno and six miles southeast of the city of Fallon. The valley is a hydrologic basin of the lower Carson River, which includes the Lahontan Reservoir and extends to the Carson Sink. The area includes the city of Fallon (pop. 7,060), NAS Fallon, the Fallon Paiute-Shoshone Indian Reservation and Colony (pop. 970), Carson Lake, Fallon National Wildlife Refuge (NWR), and Stillwater Wildlife Management Area (WMA) and NWR..

Ancient Lake Lahontan reached its last high water mark (1,335 m elevation) around 13,000 years ago. Periodically, Lake Lahontan inundated most valleys of northwestern Nevada, including Lahontan Valley. As the climate became more arid, the lake alternately receded and advanced, finally leaving many smaller terminal lakes at the ends of the remaining river systems. A series of such shallow lakes, marshes and meadows formed at the terminus of the Carson River in Lahontan Valley. Waterfowl, marsh birds, shorebirds, and other wetland-dependent wildlife use the valley for migratory stopovers, and as wintering, foraging, and breeding grounds.

Stillwater WMA was established in 1948 and encompasses 90,650 ha, including over 16,187 ha of private inholdings. Within its boundaries are 31,363 acres designated in 1991 as Stillwater NWR. Historically, wetland acreage within Stillwater WMA totaled as much as 13,355 ha, but in recent drought years that number was reduced to several hundred ha. As of December 1995 the figure stood at around 4,452 ha. Carson Lake is a shallow marsh that once covered over 10,117 ha; in recent years it has varied in size from 769-3,035 ha. The approximately 7285-ha reserve of Fallon NWR was established in 1981. This site once boasted 10,522 ha of wetlands, but today exists as such only in extremely good water years and is normally a desolate salt flat. Only in 1991 did Stillwater begin to acquire any water rights. Until then, these traditional wetlands received only the scant precipitation, return flows from irrigated fields, excess runoffs in the wettest of years, and water purchased by the United States Fish and Wildlife Service (USFWS). As of May 1997, Stillwater had acquired 3,915,071 m^3 of water rights in an ongoing process.

The area's wildlife populations are impressive, with peaks of 12,000 tundra swans (*Cygnus* *columbanius*), 10,000 geese (*Branta spp.*), 30,000 American white pelicans (*Pelecanus erythrorhynchos*), 70 bald eagles (*Haliaeetus leucocephalus*), and over 350,000 ducks. In addition, thousands of shorebirds and wading birds use the wetlands, including black-necked stilts (*Himantopus mexicanus*), American avocets (*Recurvirostra americana*), long-billed dowitchers (*Limnodromus scolopaceus*), long-billed curlews (*Numenius americanus*), Wilson's phalaropes (*Phalaropus tricolor*), white-faced ibis (*Plegadis chihi*), herons, and egrets. The managers of the lands in the Lahontan Valley face challenges to conserve habitat for these birds and other natural resources.

NAS Fallon, approximately 13 miles southwest of Stillwater WMA, was established as an Army airfield during World War II. The airfield was deactivated for several years after the war, and was reactivated in 1951 as a Navy Auxiliary Air Station. During the 1950's the facility was used jointly by the Navy and Air Force, and the runway was extended to provide the station with the longest runway at a Naval Air Station. Construction of new airfield structures during the 1970's and 1980's added a parallel runway, a new air traffic control tower, and new avionics facilities.

Aircraft currently stationed at NAS Fallon include the F/A-18, F-14, A-6, and F-5 jet aircraft, and the H-3 and HH-1 helicopters. The Naval Fighter Weapons School (TOPGUN), Carrier Airborne Early Warning Weapons School and a Construction Battalion Unit (CBU) have recently relocated here. Currently NAS Fallon is the only Naval Facility where advanced integrated Carrier Air Wing strike training can take place, combining realistic flight training in electronic warfare, air-to-ground, air-to-air weapons delivery, special weapons delivery, and enemy evasion tactics. Military aircraft from the Navy, Air Force, Marine Corps, and Nevada Air National Guard train at NAS Fallon.

NAS Fallon uses seven ranges that are from eight to thirty miles from the base and runways. Pilots flying to these training areas pass over the extensive wetlands surrounding the station and through air space that is also occupied by varying numbers of birds. Densities of these birds are largely associated with fluctuating water levels and feeding habitats, and will vary with time of day and weather conditions. The proximity of flight training and bird habitat presents an increased risk of bird-aircraft strikes. We demonstrate ways in which bird research techniques can provide information to reducing this risk.

Our demonstration species, the American white pelican, is white with black primaries, and has a large yellow bill and a wingspan of 2.5-208 m. They swim and scoop fish into their bills within three feet of the water's surface, rather than plunging from the air like the brown pelican (*Pelecanus occidentalis.*) Individuals often work cooperatively to herd fish into shallow water where fish are more easily captured. White pelican flocks fly in lines and often circle high in the sky. They breed in colonies in ground nests and favor islands where there are fewer ground predators. A major breeding colony is located at Anaho Island in Pyramid Lake, at the terminus of the Truckee River and approximately 80 air km west-northwest of NAS Fallon. At Pyramid Lake, pelicans forage mostly on the surface on spawning Lahontan tui chub (*Gila bicolor obesus*) and the spawning run of the endangered cui-ui (*Chasmistes cujus*) near shallow waters at the mouth of the Truckee. These opportunities are insufficient to satisfy the requirements of the thousands of pelicans breeding at Pyramid, so many are forced to forage (alongside subadults and non-breeding adults) at distant sites such as Stillwater WMA, Lahontan Reservoir, and Carson, Walker, Washoe, Frenchman, and Davis Lakes. Round trips of 320 km are not uncommon. After young fledge, both breeders and young relocate to shallower waters throughout the West. Foraging areas like those in the Lahontan Valley are frequented until fall migration. Band returns from the Pyramid Lake colony indicate winter ranges mostly in western coastal Mexico. Pelicans move among breeding and foraging areas at all hours during their time in west-central Nevada. Such behavior places this large, soaring species in the military airspace of NAS Fallon operations, resulting in hazards to aircraft, personnel, the mission, and the pelicans.

Specific objectives of the Legacy demonstration:

- Track the movements of white pelicans during the nesting period to relate foraging areas and flight paths to the area of NAS Fallon and its ranges, and to the Stillwater WMA.
- Track the movements of white pelicans during the post-nesting period to relate foraging areas and flight paths to NAS Fallon and its ranges, and Stillwater WMA, and areas beyond.
- Use GIS to: display temporal/spatial bird movements relative to nesting areas, foraging areas, and military flight areas; and relate bird movements to habitat.
- Track movements of white pelicans along migration route(s) to the wintering areas and use GIS to display the migratory route(s) and wintering area(s) on a continental scale.

PRODUCTS

- Map of white pelican movements during the nesting period to relate foraging areas and flight paths to the area of NAS Fallon and its ranges, and to the Stillwater WMA.
- Map of white pelican movements during the post-nesting period to relate foraging areas and flight paths to NAS Fallon and its ranges, and Stillwater WMA, and areas beyond.
- GIS display of temporal/spatial bird movements relative to nesting areas, foraging areas, and military flight areas; and relate bird movements to habitat.
- Map of white pelican movements along migration route(s) to the wintering areas.

METHODS

STUDY AREA

Lahontan Valley is broad and flat, with elevations ranging from 1,170-1,268 m above sea level. It is classified as a cold desert on the basis of its aridity, elevation, latitude, and severity of winters. Summers are often intensely hot, however, and the mean temperature at Fallon is about 10.5°C. The frost-free season is generally about 150 days and mean precipitation is less than five inches. Non-riparian areas are dominated by big sagebrush (*Artemisia tridentata tridentata*) and salt and alkali flats. Irrigated farm and pastureland is extensive, and historic wetlands are also present. There are few trees except along watercourses, with Fremont cottonwood (*Populus fremontii*) and willow being dominant. Wetlands are divided among the following habitats: 1) Wet Meadows, with stands of grass, rush and sedge, 2) Freshwater Marsh, with cattail, hardstem bulrush (*Scirpus acutus*) and Sago pondweed (*Potamogeton pectinatus*), 3) Brackish-Water Marsh, with alkali bulrush (*Scirpus maritimus var. paludosus*), widgeon grass (*Ruppia maritima*) and muskgrass (*Chara spp.*), 4) Mudflats, which in wet years become shallow lakes teeming with tiny plants and animals, and 5) Uplands, that include hundreds of small silt dunes dotted with greasewood bushes that form low islands and peninsulas in the marsh.

CAPTURE AND RADIOMARKING.

We captured pelicans in May and June 1996. Captures in May were at night during the dark of the moon at the breeding colony on Anaho Island. June captures were at Carson Lake and Stillwater by hand net from an air boat. Each pelican was fitted with a PTT having an 11g conventional transmitter (received at 216 Mhz) epoxied to it. PTT's were to be attached by a backpack harness constructed of .5" teflon ribbon. Individuals were marked with a solution of picric acid (yellow) applied to the head and/or neck feathers, and were banded with USFWS butt-end bands. We had conducted a successful test of attachment in April on a captive white pelican at the Texas State Aquarium in Corpus Christi. Dr. R. Meese, a cooperator in our Legacy program, had previous experience radio marking brown pelicans. He joined our field team for the first two applications of PTT's on 14 May and 18 June to ensure proper transmitter attachment.

PTTs were high power (0.5 watt), 95g units with four individual sensors: voltage, temperature, activity, and altitude (a pressure sensor). PTTs were calibrated to the 1,197 m above sea level benchmark on NAS Fallon's runway. Two PTT's (11982, 11983) were programmed as: season 1: 14 hours on, 12 hours off for 3 months; season 2: 8 hours on, 84 hours off for 4 months; season 3: off (mid-January 1997, mid-December 1996 respectively). The remaining 5 PTTs (11984, 5716, 5717, 5718, 5719) were programmed as: season 1: 14 hours on, 12 hours off for 3 months; season 2: 8 hours on, 72 hours off for 3 months; season 3: off (mid-December 1996).

The inclusion of altitude sensors on PTTs provided researchers with valuable insight into avian soaring flight. For example, such sensors can be used to measure the climb rates of soaring birds relative to thermal strength and to determine hourly and daily variations in the maximum and minimum altitudes of such flight. Given the potential value of these sensors in understanding avian flight performance and behavioral patterns, one objective of our demonstration was to ascertain the accuracy of PTT altitude sensors. Ultimately, our goal is to demonstrate the usefulness of radio telemetry for understanding the relationships of bird flight and local meteorology. Information from such an effort can be applied to reduce the risk of collisions of birds and aircraft.

MONITORING

We observed general pelican behavior and movement, and monitored conventional telemetry frequencies with a hand-held receiver from a vehicle using rooftop omnidirectional and yagi directional antennas to detect radio tagged individuals. When we detected individuals, we made a determination as to whether they were at ground level nearby or aloft at some distance. Based on the number of available signals and their orientation, we selected an individual to actively pursue, with the goal of obtaining visual contact while continuing to monitor other available signals. If a radio-marked individual was seen, we approached it as closely as possible without causing it to fly, then obtained our GPS position and estimated the distance and direction to the pelican from that position. Working from a schedule of satellite overpasses, we then attempted to keep the subject pelican in view during one or more overpasses and to record GPS information during each. In addition, during each overpass we recorded the GPS position of the observer and the following information on each pelican from which a signal was being received: (a) whether or not the individual was flying or at ground level, and (b) the compass direction and estimated distance, if applicable, from the GPS location we can triangulate on a signal and learn the approximate location of an individual at ground level even when it cannot be seen. Location estimates collected in this manner serve as independent corroboration of Argos positions. Also, for each GPS position collected, we recorded temperature, cloud cover, wind speed and direction, and sometimes barometric pressure to use in interpretation of altitude sensor data received from the PTTs via the Argos satellites.

Argos altitude data were available for four pelicans in the Fallon, NV area from 10 to 19 July 1996. During each satellite overpass in which data were retrieved, the altitude A in feet of each bird was calculated by converting Argos hexadecimal readings to decimal readings D, and then entering the decimal readings into the appropriate conversion formula:

- PTT 5716: $A = -158.18240 + 45.33059D + 0.06569D^2 + 1000(P - 29.92)$
- PTT 5717: $A = -229.75334 + 45.24002D + 0.06744D^2 + 1000(P - 29.92)$
- PTT 5718: $A = -184.59237 + 40.12735D + 0.10328D^2 + 1000(P - 29.92)$
- PTT 11984: $A = -207.97601 + 44.46975D + 0.07567D^2 + 1000(P - 29.92)$

where P is the barometric pressure at sea-level in inches of mercury. The hexadecimal data were only available as integer output, hence the mean vertical resolution of the four altitude sensors combined was approximately 19.3 m for D between 0 and 250 (approximately 0 and 4,572 m). Note that these sensors measure altitude as a function of the change in barometric pressure with height. Therefore, it is necessary to correct each altitude reading because of temporal variations in the barometric pressure. Hourly barometric pressure data (corrected to sea level) were obtained from nearby NAS Fallon to facilitate these adjustments. The proximity of the NAS to the Stillwater NWR (approximately 13 km) and the typically negligible variations in barometric pressure over these horizontal distances justified the use of these data. A methodology was then applied to identify those corrected altitude data that could be statistically verified for accuracy.

The accuracy of the PTT altitude sensors was examined by contrasting the corrected altitude measurements obtained from Argos data with the elevations of radio-marked pelicans on the earth's surface during these satellite overpasses. The latter data set was obtained using a car and a hand-held conventional radiotelemetry receiver to locate instrumented pelicans within the Stillwater NWR. When a signal was first received, the bird's general location was identified using a Yagi directional antenna, compass, and a portable GPS (Garmin GPS 45) receiver. The observer then attempted to close in on the bird if it was suspected to be on the ground.

Distinguishing between a flying bird and one on land or in the water was possible given the relatively rapid increase in signal strength over short distances (i.e., two or three km) when approaching a non-flying bird, and the relatively short distances (i.e., two or three km) over which such signals could be received. These fluctuations in signal strength were used to home-in on radio-marked individuals, and aided the observer in identifying which flock an instrumented pelican was in when multiple flocks were observed. Although it was often difficult to visually identify a radio-marked individual within a flock, a reasonable estimate of the bird's location was obtained by approaching the flock as closely as possible without disturbing it (i.e., typically within a few hundred meters), and then using the equipment described above to gather additional location data. When taken altogether, observations of radio-marked birds were used to determine the effective time an individual spent at any particular location.

The non-flying period for an individual as defined in this study is the time from which a radio-marked pelican was first identified as non-flying, to the time at which this same bird started flying or pelican monitoring efforts ceased for the day. An analysis of Argos altitude sensor accuracy was completed by comparing those Argos data available during these sit periods to the elevation of the earth's surface as obtained from a digital altimeter (Pretel Altiplus A2). All observations of non-flying radio-marked pelicans gathered between 10 and 19 July 1996 were obtained within the vicinity of Stillwater Point Reservoir and Upper Foxtail Lake. Although it would be desirable to know the exact elevation at the location of each pelican observation, a constant elevation was assumed for these comparisons given the proximity of the reservoir to the lake (i.e., less than one mile at closest points), uncertainty in the exact location of non-flying pelicans, and the relatively flat nature of the terrain. The elevation of the parking lot adjacent to the reservoir was used in these comparisons, and was estimated at 1,193 m.

RESULTS

CAPTURE AND RADIOTAGGING

On the first scheduled night, 14 May, high winds precluded access to Anaho Island. We unsuccessfully attempted capture at Carson Lake by hand net from an air boat. Continuing on to Stillwater WMA, we captured one pelican by hand net. PTT# 11983 was fitted and plans were made for the next round in June. This first individual was not color marked. On the night of 18 June we captured one pelican by net gun at Stillwater. We fitted PTT# 11982 on this subject at Carson Lake and picric acid solution was applied to the head feathers only. On the night of 19 June we captured 14 pelicans at Stillwater using a cannon net. We fitted the remaining five PTTs (11984, 5716, 5717, 5718, 5719) and individuals were marked with a stronger solution of picric acid (head and neck). All subject pelicans were of undetermined sex and breeding status

MONITORING

Between 18 May and 5 September, one or two biologists spent 29 days in the field tracking and observing instrumented pelicans. Detections of different individuals averaged 2.28 per day, or a total of 66 over the 29 days. Of these, only 15 were of subjects at ground level when we were within two miles during an overpass that resulted in an Argos location estimate of LC 0 or better. Of these 15, six were under direct observation during the overpass that resulted in the Argos location. Five of these location estimates were LC 0. The average distance between the Argos location and the known location of the subject for four of these five was 3.41 kilometers. The fifth LC 0 location estimate was obviously an unreliable one, showing a difference of 74 kilometers. The final Argos location estimate of a pelican under observation was an LC 1. The difference between Argos location and known location was 1.285 kilometers. We found conventional signals to be detectable at up to 1.75 miles on pelicans at ground level and estimated reception at up to 25 miles on pelicans aloft. It was often impossible to obtain visual contact with an individual, even when it was known to be at ground level. Roads in the area are limited, and marshes and watercourses often stood between the subject and us. GPS positions of observer and compass direction of flying pelicans taken during satellite overpasses did not prove useful in verifying Argos locations received during those overpasses. The error present in Argos location estimates and the unknown distance from observer to subject made those compass directions mostly meaningless. We observed that individual pelican movements were mostly in concert with others of the species, in groups of a few to several hundred. We also confirmed immediately that instrumented pelicans behaved normally and were well integrated in these groups. Therefore, we assume data collected on these sentinel individuals are applicable to the pelican population from which we sampled.

The seven PTTs operated a total of 704 days, resulting in 2,445 locations. Mean numbers of locations per day varied from a low of 3.24 (PTT 5717) to a high of 4.23 (PTT 11982.) LC 0 locations predominated, accounting for 53.54% of all locations. LC 1-3 locations were 11.29% of the total, and the remaining 35.17% was composed of the A-Z classes with unknown accuracy. Percent of locations by individual unit in LC 0-3 varied from 56.92% (PTT 5717) to 73.12% (PTT 11982.)

No GIS layers on habitat or topography for the demonstration area were available from NAS Fallon at the time of this report. Transportation layers were rejected as not germane to the objectives of the demonstration. In addition, an overlay of all locations of all PTTs within the demonstration area was rejected because it forced too much data onto too little map space. The resulting maps (Figs. II-1 through II-6) reflect the demonstration area during each of the months from May through October. GIS overlays are land ownership, major lakes, intermittent water, and all pelican locations in LC 0-3 received for a month. Figs. II-1 and II-6 each contain locations on only one pelican (PTTs 11983 and 5718, respectively). July (Fig. II-3) depicts more locations within the Lahontan Valley than any other month. Heavy use of Stillwater is evident, along with significant numbers of locations at Pyramid and Walker Lakes. The many locations not associated with water resources, however, stand out even more sharply. Most of these represent a pelican aloft in the airspace (as do many of the locations closer to water sources.) The juxtaposition of these with the layer representing NAS Fallon and its ranges brings the bird strike threat into clear focus. Figures II-7 through II-13 show LC 0-3 location estimates throughout the western U.S. for each pelican throughout the demonstration period. On these maps, movement capabilities and the variety of pelican survival strategies are apparent: 11982 (Fig. II-7) left the Lahontan Valley and returned often; 5716 (Fig. II-10) ranged far from the area once when its breeding cycle was completed; 5718 (Fig. II-12) never left the demonstration area during the period its PTT was operational.

The following is a summary of locations of each bird (identified by PTT number) for the duration of our demonstration:

Pelican 11982 (Fig. II-7) used the Stillwater/Pyramid Lake corridor for only 8 days before making the first of seven round trips to California's Central Valley. Absences from this corridor varied from two to eight days, and this is the only individual to return to the NASF area after leaving. On 21 August it left the area and relocated near the central Oregon/California border. A class 1 location on 23 September 1996 placed this individual near Tule Lake NWR, California. The PTT battery failed shortly thereafter.

Pelican 11983 (Fig. II-8) stayed in the Stillwater/Pyramid Lake corridor for 3.5 weeks, then moved south some 50 miles from Fallon to the Walker Lake area. This bird foraged in that general vicinity for about 5 weeks and made some illustrative nighttime flights (apparently soaring over nearby mountain ranges) before relocating to California's Central Valley. A class 0 location on 26 August 1996 placed this individual west of Merced, California. No locations were received after 30 August 1996, and we could not determine the cause.

Pelican 11984 (Fig. II-9) heavily used the Fallon area for five weeks after capture, then relocated to California's Central Valley. We last received a location estimate on 27 November 1996; this LC 0 estimate located the pelican to the east of Riverside, California.

Pelican 5716 (Fig. II-10) remained in the Stillwater/Pyramid Lake corridor for one month after capture, with heavy use of the Fallon area. It briefly used Malheur NWR, Oregon during its relocation to the Payette, Idaho area. It left that area in mid September, stopping briefly near the Great Salt Lake on its way to the Salton Sea in southern California. In mid October it departed that area and migrated down the west coast of mainland Mexico. On 2 December 1996 a class 0 location placed it on the coast of Colima state at about 19° north latitude.

Pelican 5717 (Fig. II-11) used the Stillwater/Pyramid corridor for almost seven weeks before an unusual weather pattern assisted it in a swift relocation to the area of Logan, Utah. In early September it left that area and traveled to the Salton Sea. On 11 October 1996 a final class 1 location still placed it there; we could not determine the cause of the loss of PTT contact.

Pelican 5718 (Fig. II-12) was the only individual to remain in the corridor for the entire demonstration period. An LC 1 location estimate placed it at Stillwater NWR on 23 October 1996; just prior to when the PTT battery was expired.

Pelican 5719's (Fig. II-13) move to California's Central Valley was timed closely with 11982's first trip, but this individual did not return. A class 0 location on 28 September 1996 placed it near Milpitas, California, at the extreme southern end of San Francisco Bay. PTT batteries exhausted shortly thereafter.

While we observed fairly consistent numbers of pelicans in the Lahontan Valley during the demonstration period, they were not always the same individuals on a day-to-day basis. There is apparently a previously unsuspected degree of interchange among pelicans of different geographic areas, at least in the intermountain west. Nonbreeding adults, which are not tied to the area by nesting demands, might appear in the area for only the briefest of periods. Results are giving us information on movement capabilities and inclinations of this highly mobile species, and the sometimes dramatic influences of weather on pelican behavior and movement. On 5 August 1996, Nevada experienced an unusual summertime upper-level trough, with winds aloft at 20 to 40 knots from the southwest and west-southwest. Number 5717 left the Fallon area (Fig. II-11) sometime after 0919, and was to the north of the Great Salt Lake by 1718. Over the last 2.5 hours of this journey it averaged about 108 kph, obviously aided by a significant tailwind. On 3 July #11982 averaged about 81 kph on one of its west-to-east crossings of the Sierra Nevada Mountains.

During the 10-day period from 10 to 19 July 1996, 24 non-flying periods were identified among the four radio-marked pelicans frequenting the Fallon, NV area (Table II-1). Argos data were available during 12 of these 24 periods, resulting in a total of 17 Argos altitude measurements where the accuracy of altitude sensors was verifiable. Non-flying periods were divided into groups based on PTT numbers because of calibration differences between individual sensors. A mean altitude was then calculated for each radio-marked pelican by dividing the sum of Argos altitude readings for each bird by the number of readings obtained during the 10-day period.

Table II-1: Sit periods identified for four PTT-marked pelicans in Fallon, NV area from 10 to 19 July 1996. Times of coinciding satellite overpasses and corresponding PTT altitude data are also shown. LT = Local Time

PTT	Date	Sitting Period (LT)	Argos Data Available?	Argos Time (LT)	Argos Altitude (m)
5716	10-Jul	1344-1648	N	NA	NA
	11-Jul	0905-0915	N	NA	NA
		1600-1615	N	NA	NA
	12-Jul	827-1600	Y	9:44:12	1198.397
				14:08:18	1207.894
	13-Jul	800-926	Y	9:21:21	1209.221
	14-Jul	1701-1716	N	NA	NA
	15-Jul	1056-1543	Y	13:36:35	1200.510
				15:14:19	1202.310
	16-Jul	1511-1802	Y	17:53:07	1207.199
	17-Jul	1234-1718	Y	14:53:57	1204.151
	18-Jul	1101-1130	N	NA	NA
11984	10-Jul	1515-1648	N	NA	NA
	11-Jul	828-845	N	NA	NA
		1600-1615	N	NA	NA
	12-Jul	1505-1600	N	NA	NA
	13-Jul	743-940	Y	9:18:38	1140.836
	16-Jul	1503-1802	Y	15:04:51	1134.173
				17:53:11	1139.157
	17-Jul	716-1718	Y	7:51:06	1137.221
				13:13:40	1142.205
				14:56:17	1136.109
5717	12-Jul	901-1010	N	NA	NA
	17-Jul	1601-1740	N	NA	NA
	18-Jul	1408-1643	Y	14:43:18	1213.428
5718	17-Jul	926-1045	Y	9:34:06	1129.768
		1707-1740	N	NA	NA
	18-Jul	840-1107	Y	9:11:22	1147.175
	19-Jul	713-1127	Y	8:47:31	1137.401
Birds *n* = 4	**Days** *n* = 10	**Non-Flying Periods** *n* = 24	**Non-flying Overpasses** *n* = 12	**# Argos Measurements** *n* = 17	

Table II-2 shows the means and standard deviations of PTT altitude data gathered during pelican non-flying periods.

Table II-2

PTT	5716	5717	5718	11984
	1198.397	1213.428	1129.769	1140.836
	1207.895		1147.176	1134.173
	1209.221		1137.401	1139.157
Altitudes	1200.510			1137.221
	1202.311			1142.205
	1207.200			1136.109
	1204.152			
Mean	1204.240	1213.428	1138.114	1138.283
Std. Dev.	4.0559	NA	8.726424	3.013

The magnitude of the error between the mean altitude and the assumed elevation of the earth's surface (1,193 m) for each pelican is 11.25, 20.44, 54.87, and 54.70 m for PTT numbers 5716, 5717, 5718, and 11984 respectively. In contrast, the standard deviation for each PTT altitude group is on the order of 3 to 10 m. Inspection of these statistics indicates that although individual altitude sensors exhibit a bias that is in some cases nearly three times larger than the vertical resolution of the sensors (for PTT numbers 5718 and 11984 specifically), the bias exhibited by any one sensor is relatively consistent among all altitude readings obtained by that particular sensor (as inferred by the small magnitudes of the standard deviations). Therefore, these figures suggest that a constant correction factor may be applied to PTT altitude measurements to obtain more accurate estimates of pelican altitudes. Such factors can easily be incorporated into preexisting calibration formulas for individual sensors. Interpretation of these results requires caution, however, given the small sample size of PTT altitude measurements coinciding with observations of sitting pelicans. This small sample size precludes a more rigorous statistical analysis of these data. In addition, sensor performance was examined at only one altitude, rather than over the 4,572 m range the sensor is designed to encompass. Therefore, it is possible that the correction factor varies with altitude, and hence is not constant.

DISCUSSION

Although ground tracking and observations provided less input than expected in verifying Argos positions, the indication is that most LC 0 or better Argos locations reliably reflect the area of use; the better location classes, as expected, have an even higher degree of accuracy. Location estimates from the Argos system allowed us to document the movements of pelicans among lakes, wetlands, and other habitats in the Lahontan Valley, and in relation to NAS Fallon, its ranges, and the lands managed for wildlife nearby (Figs. II-1 through II-6.).

Results of the analysis of accuracy of the data from the altitude sensors suggest that PTT altitude sensors can be used to obtain accurate information on the elevations of birds. Further testing is necessary, however, to validate these claims. Future altitude sensors will be checked for accuracy before they are attached to birds. Such testing will be performed in a more controlled environment (e.g., using a plane or a car to vary sensor altitudes), and will result in more accurate and more abundant information regarding sensor performance. Furthermore, such testing will also focus on determining how sensor performance varies over a wide-range of altitudes (as opposed to the single altitude examined herein). Although initial testing of sensor accuracy should be conducted using a controlled approach, ground-based observations of satellite telemetry equipped pelicans are still useful in determining how sensor performance varies over the lifetime of PTT units. Ground-based observations of satellite telemetry equipped pelicans should be used in the future to augment results obtained during the initial round of sensor testing to obtain this latter objective.

Of the two individuals whose PTT batteries lasted long enough to determine wintering areas, one traveled to western coastal Mexico as expected. The other (Fig. II-9) apparently had settled into southern California for the winter. Most of the others were on the air long enough to obtain significant information on their patterns of movement after the breeding season. The American white pelican is not a solitary species and we nearly always observed our radiomarked pelicans in the company of other pelicans. Therefore, all the above information is generally applicable to the local population. One example of the technology's effectiveness was the sighting by a USFWS biologist on 24 June of a color-marked pelican feeding its young on Anaho Island, Pyramid Lake from 1355-1358 hours. Of the five pelicans so marked, all but one were elsewhere during a fortuitous corresponding satellite overpass. At 14:28 that one, #5716, was located by Argos at a position that plots to southeast Anaho Island.

Our objectives were focused on the use of lands and airspace around NAS Fallon. One of these, relating bird movements to habitat within the demonstration area, was not realized because no GIS layers on habitat were available. Both NAS Fallon and Stillwater NWR-WMA presently have contractors assembling these data. Once these layers are in place, they can map pelican locations over habitat using our location data, data management program, and Arcview extension, and ArcView. The salient disappointment of the demonstration in terms of meeting objectives was the revelation, provided by Argos positions, of the great interchange of pelican populations in the area during the demonstration period. The relatively swift departure of several instrumented pelicans from the Lahontan Valley deprived us of significant data for which we had expended precious resources. Shorter battery life than predicted on PTTs also resulted in the collection of less migration and wintering data than expected. However, the use of the Argos system was uniquely effective for documenting these unexpected movements. The information emphasizes the Fallon area's importance for pelicans, whether breeding birds or transients, and it reveals that the risk of collisions with aircraft derives from pelicans with diverse behaviors.

MANAGEMENT IMPLICATIONS

There are several management issues to which our results are relevant. First, our radiotracking, observations of pelican flight behavior, and collection of weather data gave us confidence that we can model the general relationships between pelican soaring flight and the boundary layer of the atmosphere and its thermals. This model, in turn, can be used to predict when pelicans will soar, and to what altitudes. The information from the model can be used to plan aircraft flights to minimize the risk of collision with these large birds.

Of interest to military flight planners, as well as wildlife managers, was our finding that individual American white pelicans range widely in the Lahontan Valley region, and venture well beyond the area, sometimes returning to it. Thus, pilots should be aware that the pelicans might be encountered throughout the intermountain west and California, albeit widely dispersed, as well as in concentrations around breeding colonies and feeding areas (lakes, streams, irrigation canals, wetlands). Wildlife managers now know that even during the breeding season, the Stillwater area likely is used by "visitors" from throughout the west.

Finally, our tracking and observations reveal information about the extent to which "resident" birds move within the region. American white pelicans regularly fly from several to 100 or more km a day to move among feeding, roosting, and breeding sites. The extensive area from Pyramid Lake, through the Lahontan Valley and south, apparently is necessary to sustain the local pelican population from which we studied individuals.

RECOMMENDATIONS

In 1996 all PTTs were fitted to foraging pelicans of unknown breeding status, and six of the seven were activated on 18 and 19 June. Because the first young pelicans began to fledge from the colony at Anaho Island during the last week in June, our chances of selecting pelicans that would frequent the area for an extended data collection period were severely reduced. In 1997 we should begin the demonstration earlier and assure that half the PTTs are fitted to breeding adults at Anaho Island. The acceptable risk we take is that the individuals we instrument may choose to forage outside the Lahontan Valley. In addition, the acquisition and use of a message monitor by field personnel to intercept and record PTT sensor data would significantly increase the available database Aerial tracking and location of subjects would help to fine-tune interpretation of altitude sensor data when used in conjunction with message monitor receptions. PTTs should be programmed more conservatively to assure that they remain active until the subjects reach their wintering grounds. And finally, we should utilize the newly available 20g PTTs to expand this demonstration to the white-faced ibis, another species of serious concern to NAS Fallon.

ACKNOWLEDGEMENTS

Bill Henry of Stillwater NWR and Floyd Rathbun of NAS Fallon led the efforts for pelican capture and other logistical support. The Stillwater NWR provided additional assistance. Also, Anita Delong of Stillwater NWR made a timely observation of our PTT and color-marked bird feeding young at Anaho Island. Michele Setter and the Texas State Aquarium are acknowledged for their cooperation in testing a harness design. Dr. Robert Meese, University of California-Davis, has provided invaluable advice and assistance with radio marking and radio tracking.

White Pelican Location Estimates

Naval Air Station Fallon - May, 1996

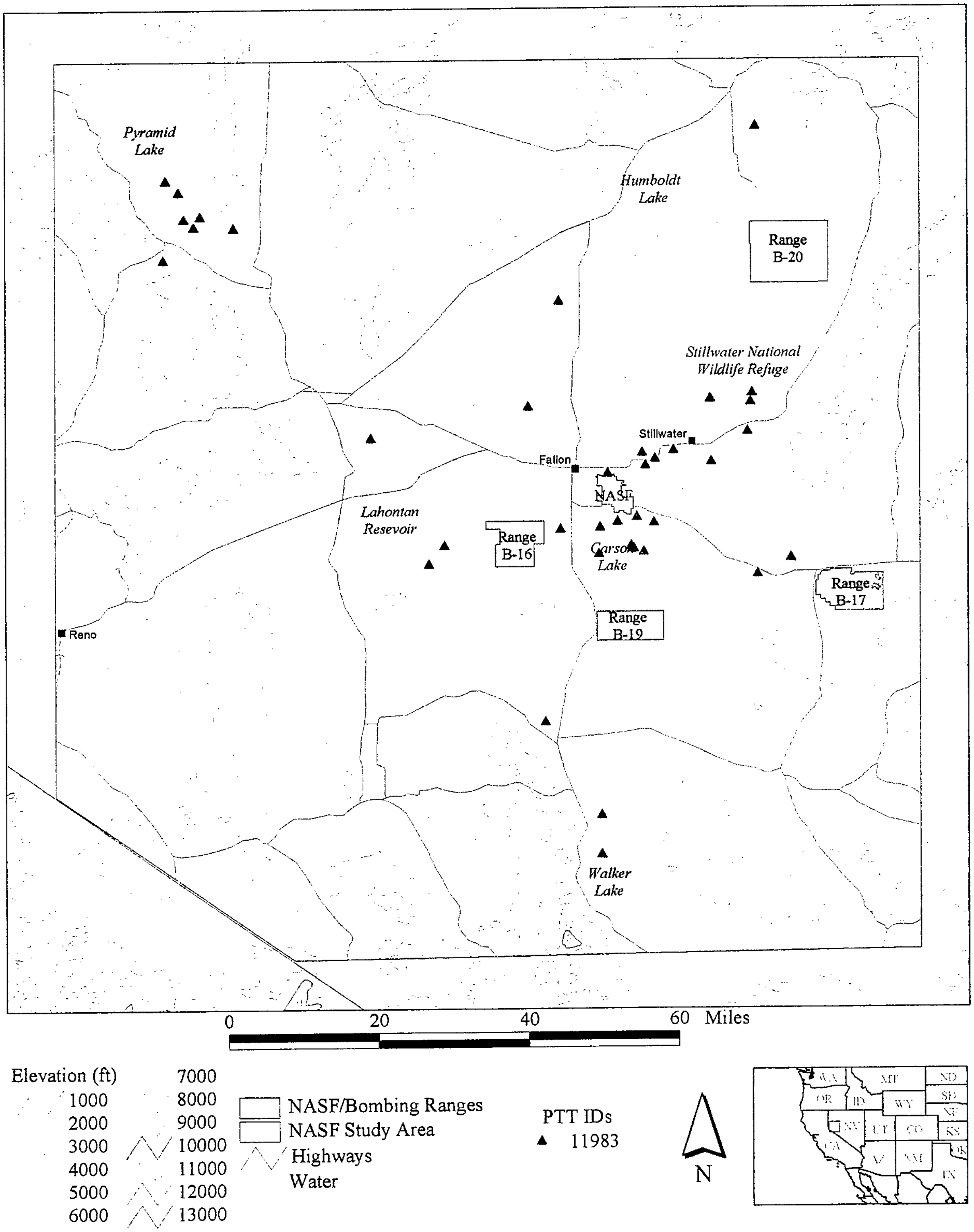


Figure II-1. Location Estimates of White Pelican #11983 in the NASF study area; May, 1996.

White Pelican Location Estimates

Naval Air Station Fallon - June, 1996

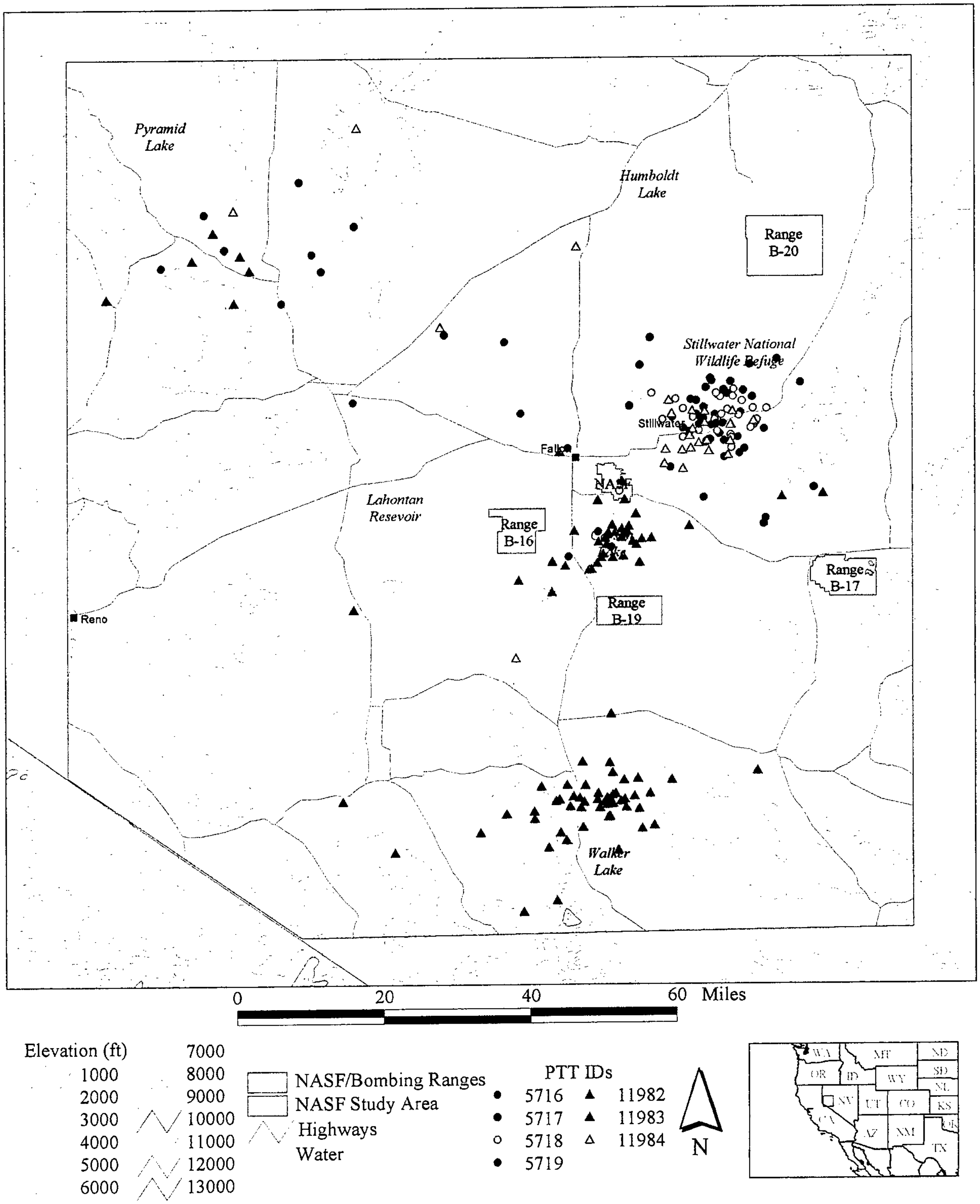


Figure II-2. Location Estimates of all PTT-marked White Pelicans in the NASF study area; June, 1996.

White Pelican Location Estimates

Naval Air Station Fallon - July, 1996

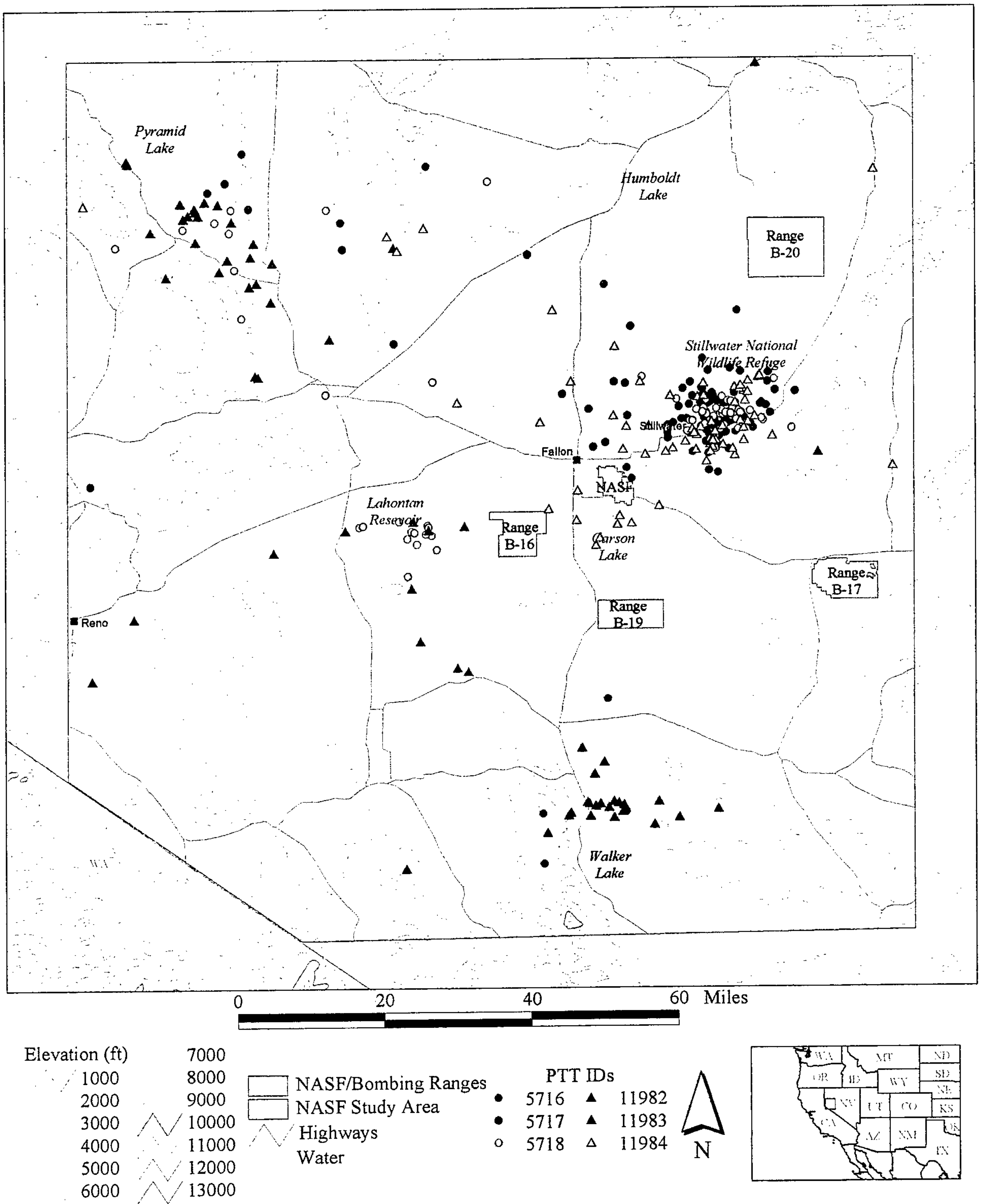


Figure II-3. Location Estimates of all PTT-marked White Pelicans in the NASF study area; July, 1996.

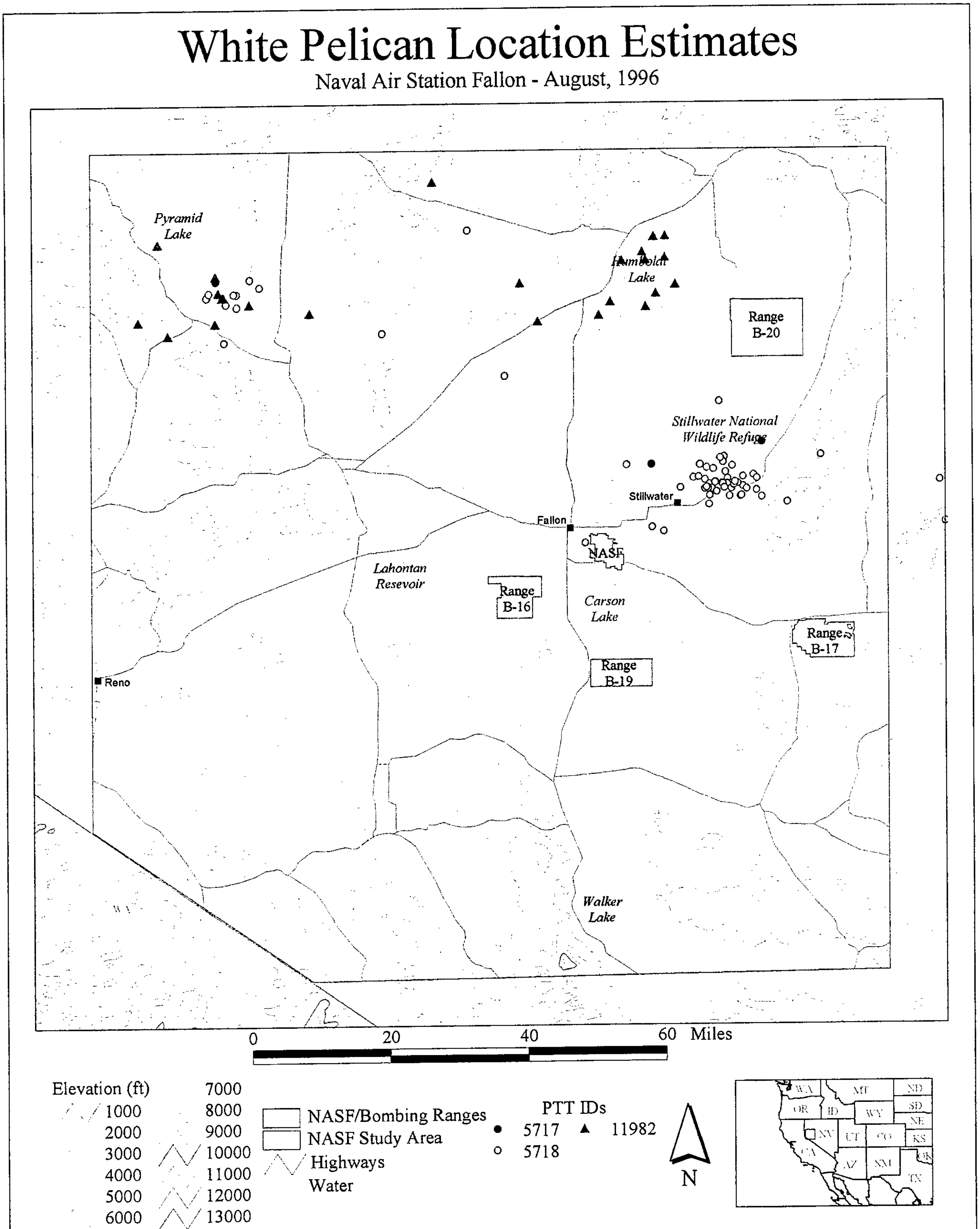


Figure II-4. Location Estimates of all PTT-marked White Pelicans in the NASF study area; August, 1996.

White Pelican Location Estimates

Naval Air Station Fallon - September, 1996

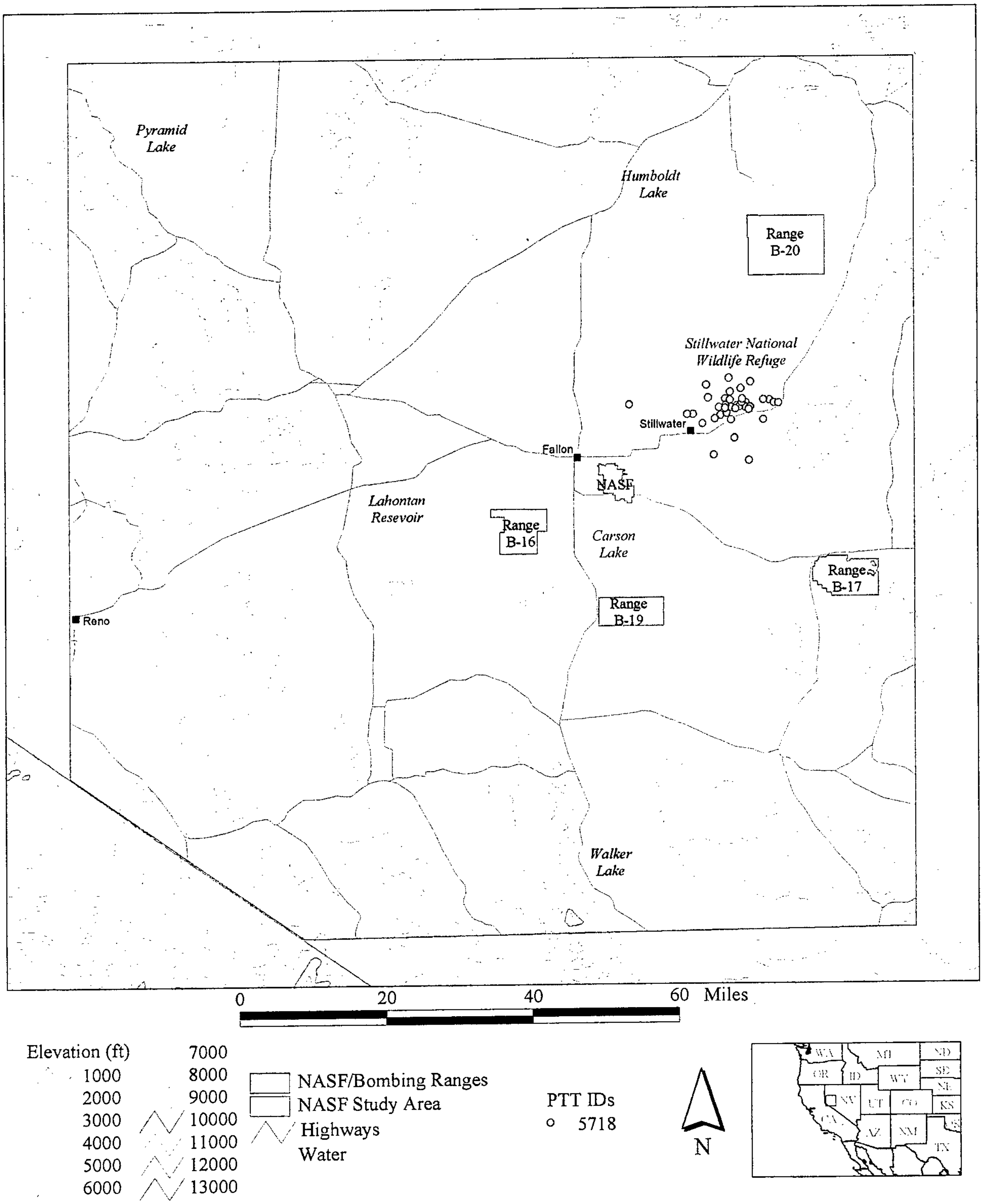


Figure II-5. Location Estimates of White Pelican #5718 in the NASF study area; September, 1996.

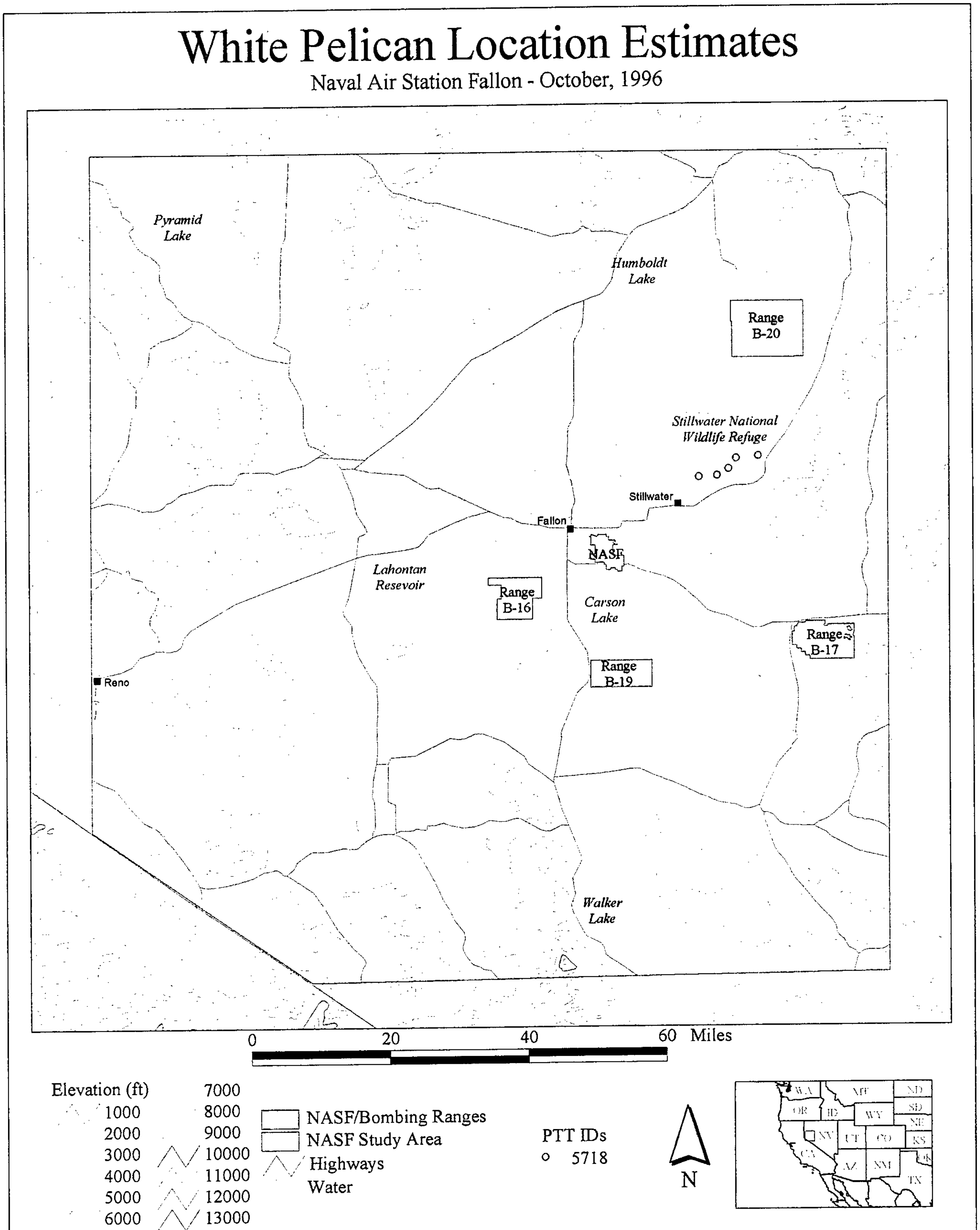


Figure II-6. Location Estimates of White Pelican #5718 in the NASF study area; October, 1996.

White Pelican Migration

PTT # 11982 - Instrumented at Naval Air Station Fallon

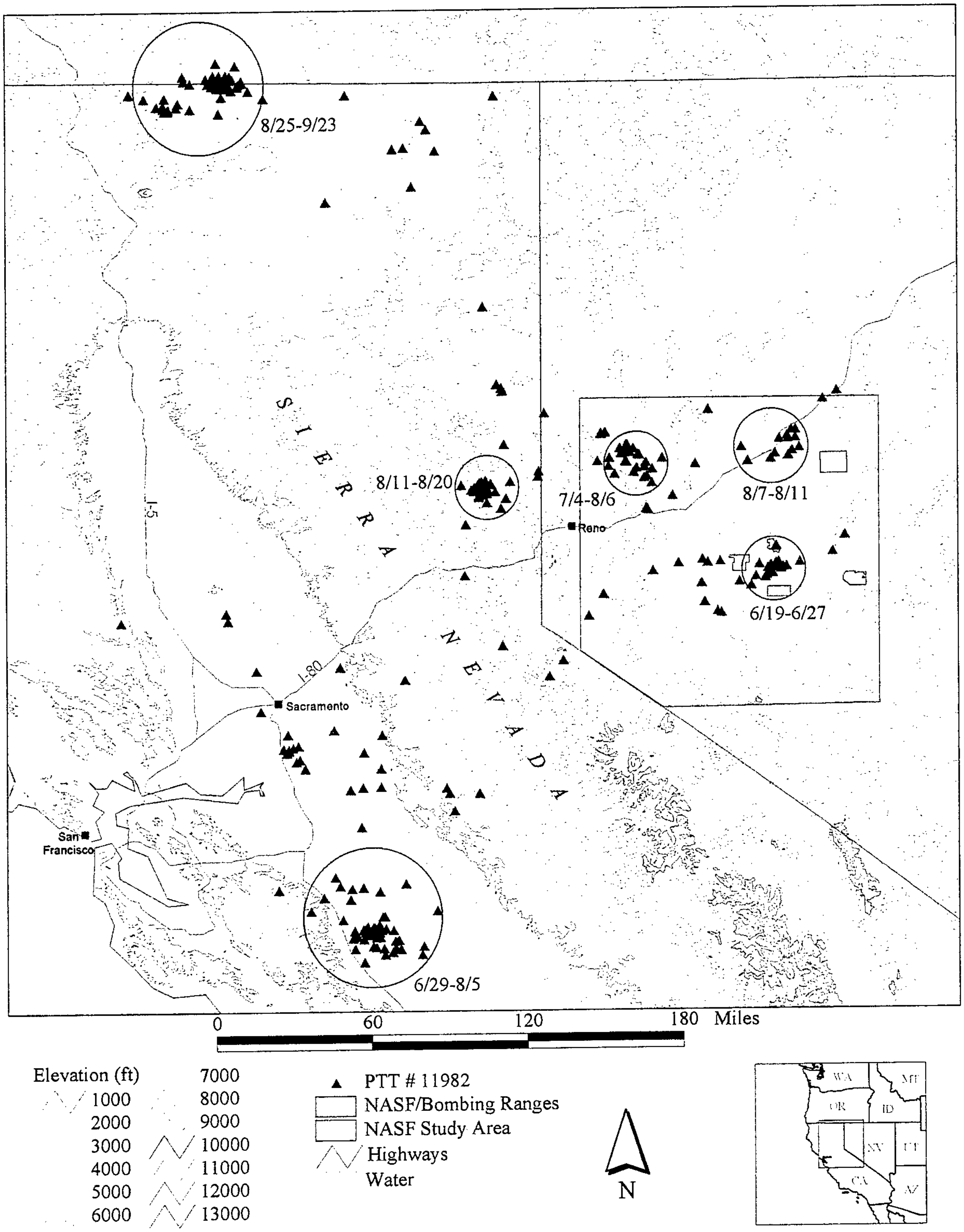


Figure II-7. Location Estimates showing White Pelican migration; PTT 11982.

White Pelican Migration

PTT # 11983 - Instrumented at Naval Air Station Fallon

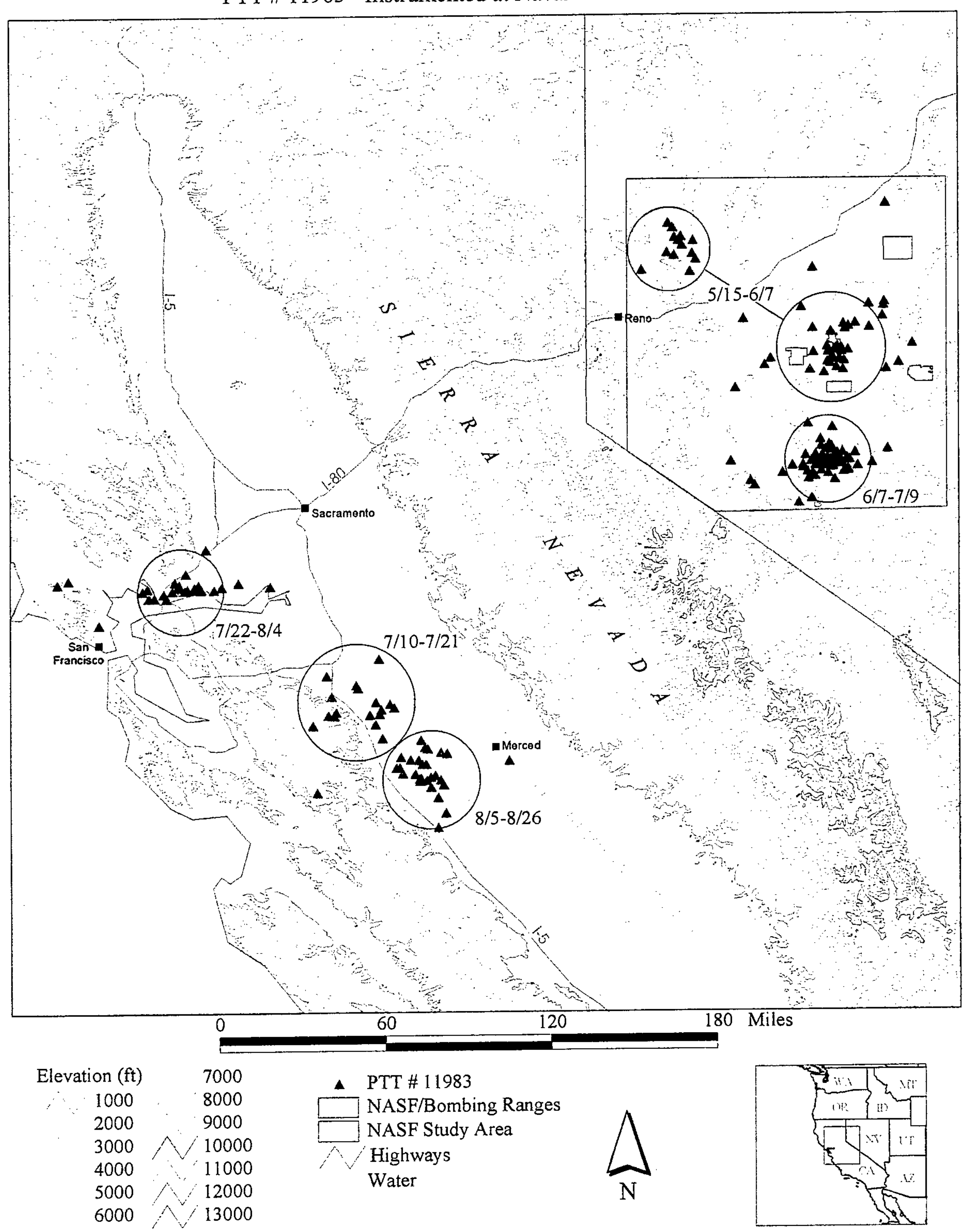


Figure II-8. Location Estimates showing White Pelican migration; PTT 11983.

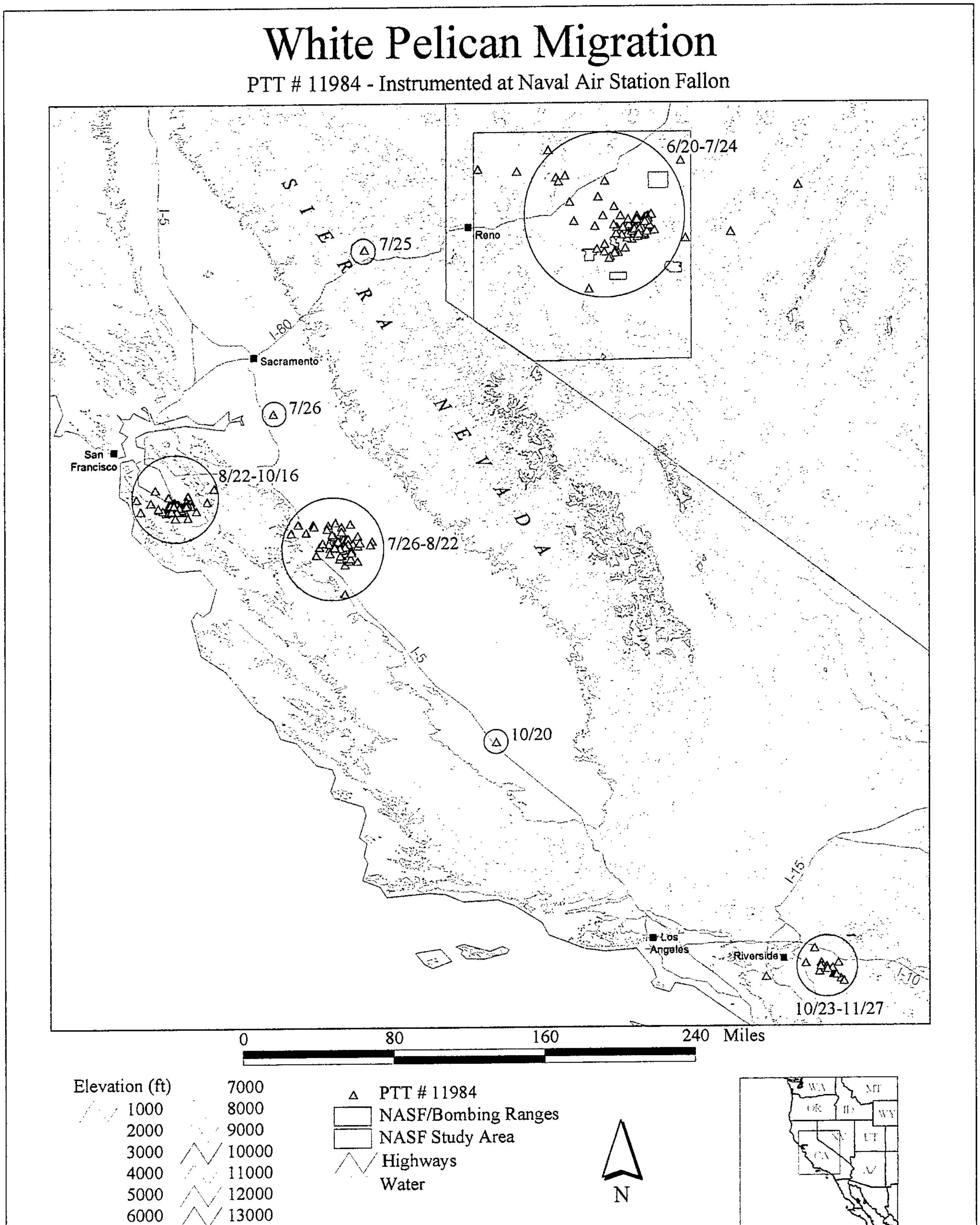


Figure II-9. Location Estimates showing White Pelican migration; PTT 11984.

White Pelican Migration

PTT # 5716 - Instrumented at Naval Air Station Fallon

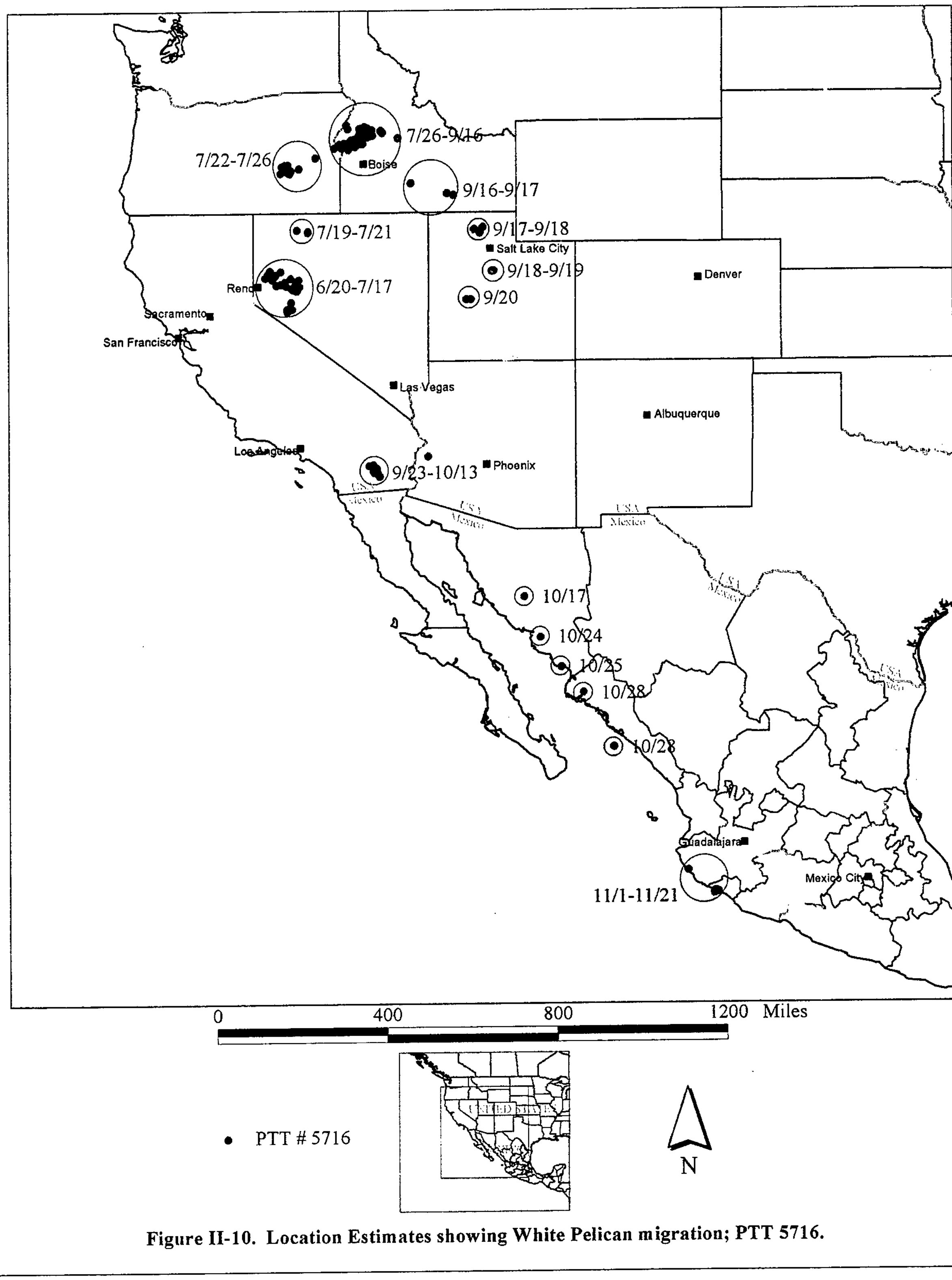


Figure II-10. Location Estimates showing White Pelican migration; PTT 5716.

White Pelican Migration

PTT # 5717 - Instrumented at Naval Air Station Fallon

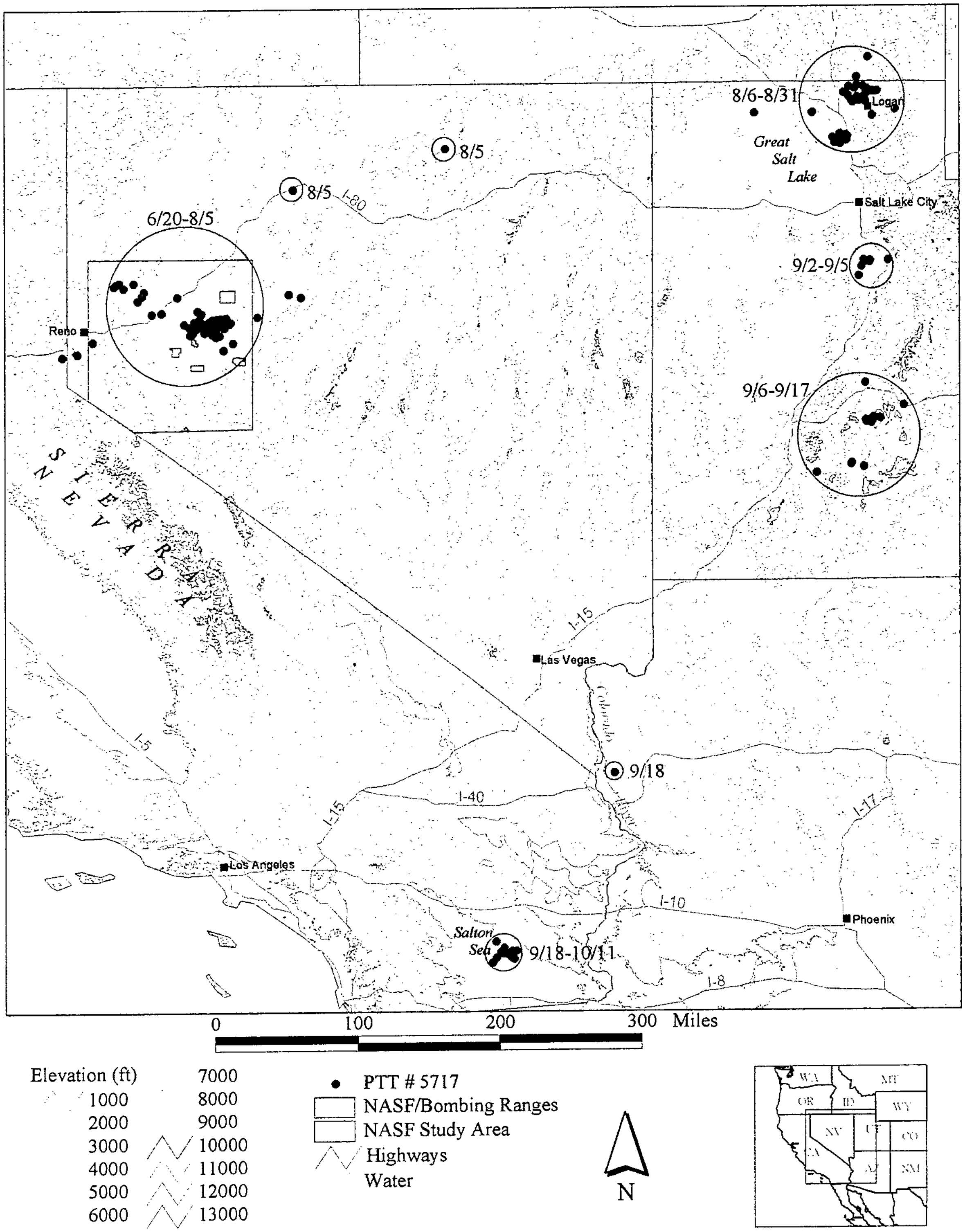


Figure II-11. Location Estimates showing White Pelican migration; PTT 5717.

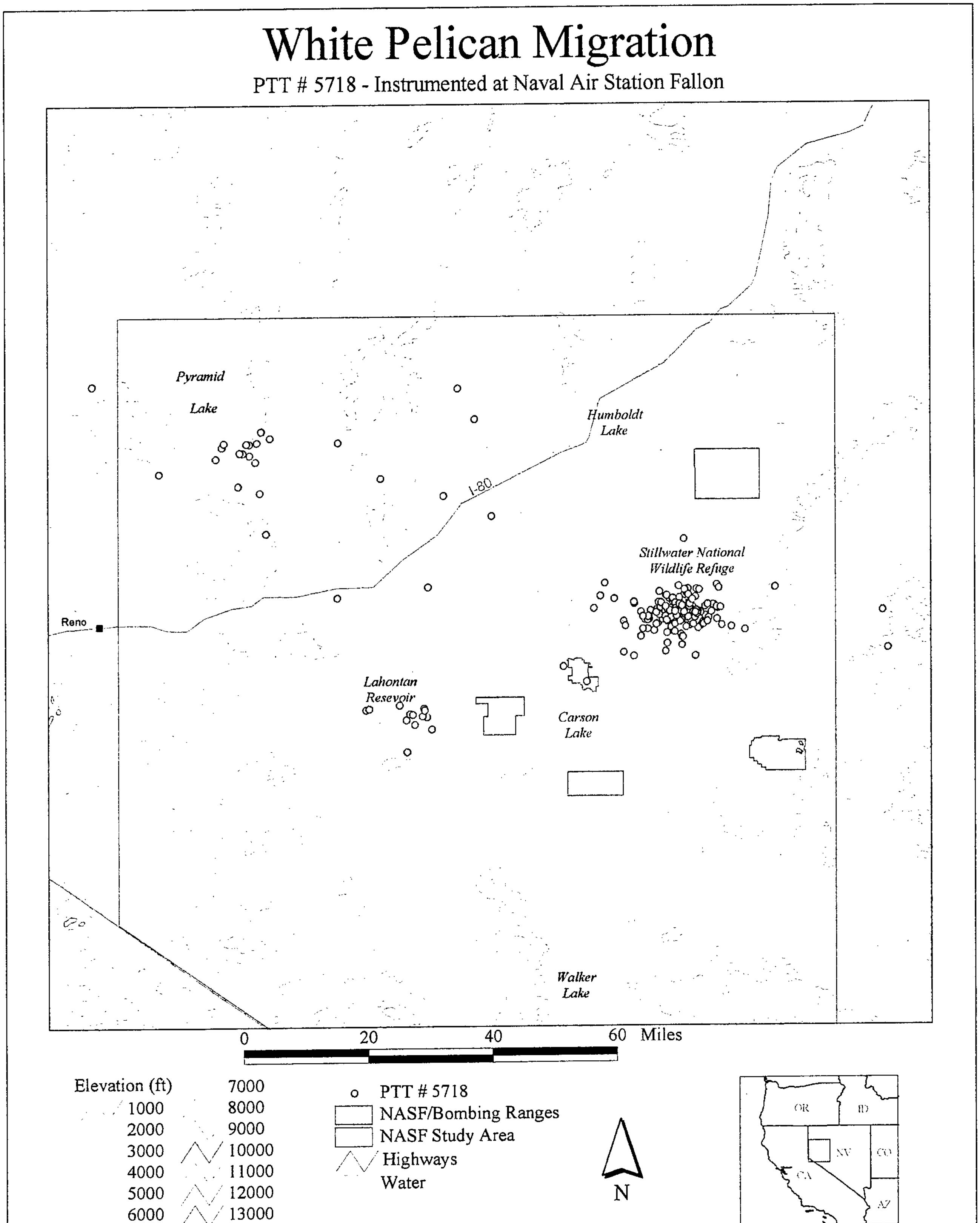


Figure II-12. Location Estimates showing White Pelican migration; PTT 5718.

White Pelican Migration

PTT # 5719 - Instrumented at Naval Air Station Fallon

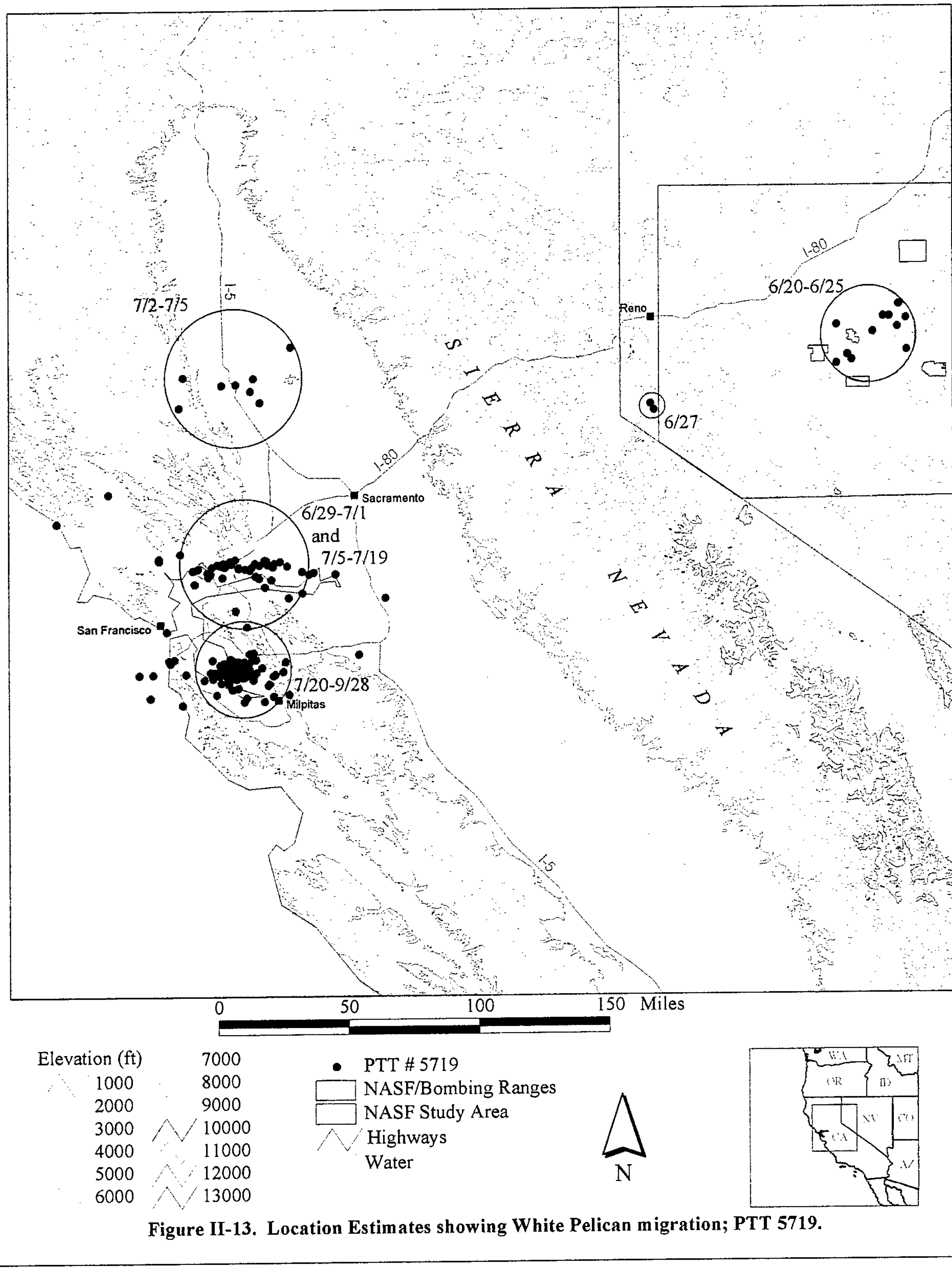


Figure II-13. Location Estimates showing White Pelican migration; PTT 5719.

ORCHARD TRAINING AREA, IDAHO

INTRODUCTION

PURPOSE

This Legacy demonstration highlighted new methods to enable managers to track movements of animals in relation to military training. Any conflicts between military training on the Orchard Training Area (OTA) and the raptors that use the Snake River Birds of Prey National Conservation Area (SRBOPNCA) for nesting and foraging need to be identified so measures can be implemented to minimize them.

Safety and security considerations limit accessibility to portions of the OTA during times of training and also when there is no training. We demonstrated new methods that enable managers to remotely "track" movements of animals in relation to military activity, and therefore with much less interference with training than is necessary with more conventional methods. Using these methods and technologies, conflicts between military training on the OTA and the raptors that use the SRBOPNCA for nesting and foraging can be identified, and measures implemented for wildlife management.

BACKGROUND

Military training began in the vicinity of the OTA in 1941, during World War II, when three 1,036-ha practice bombing ranges were established. In 1943, a 5,666-ha air-to-ground gunnery range was added. These ranges were mostly west of the current OTA, and were closed in 1948. The Idaho Army National Guard (IDARNG) obtained permission to establish the training area in 1953, following negotiation involving the Idaho Congressional delegation, the Department of the Army, and the Department of the Interior (USDOI). In the ensuing years, the U.S. Army Corps of Engineers and the U.S. Marine Corps also were given permission to train within the boundaries of the OTA. Substantial improvements in the form of roads, mechanized targets, and tank training lanes have been made by the IDARNG. Training is authorized until the year 2015 under the existing Memorandum of Understanding with the USDOI Bureau of Land Management (BLM).

The Snake River Birds of Prey Natural Area was established in 1971 by Public Land Order 5133 to protect one of the largest known nesting concentrations of raptors in the world. This order withdrew 10,811 ha of public land in and adjoining the Snake River Canyon. The boundaries of the OTA were adjusted to eliminate training near the more delicate and higher-use raptor habitats closest to the canyon. When the

Secretary of the Interior established the Snake River Birds of Prey Area by withdrawal of 195,463 ha of public land (Public Land Order 5777) in 1980, the withdrawal included all of the OTA. Military training activities were specifically authorized to continue by that order. Likewise, when the Snake River Birds of Prey National Conservation Area (SRBOPNCA) was established in 1993 (Public Law 103-64) to permanently protect the land withdrawn under the above PLOs, military training in the OTA was permitted to continue unless it is determined to be inconsistent or incompatible with the protection of raptor populations or the conservation of habitats, and where such inconsistencies or incompatibilities cannot be mitigated, modified, or reduced to meet the goals of Public Law 103-64.

The IDARNG is actively reducing the effects of military training on the environment. In 1987, it implemented a natural resource conservation program that resulted in more restrictive regulations for training activities. These restrictions limited ground-disturbing activities to previously disturbed areas. It also implemented the Integrated Training and Management Program (ITAM). Under ITAM, Land Condition and Trend Analysis plots were established and are being monitored; lands are being rehabilitated, suppression of fires has become a priority; and environmental briefings are given to troops training in the OTA. In 1988, the IDARNG and the BLM initiated an 8-year study to assess habitat alteration and associated wildlife in the SRBOPNCA. Part of this study focused on the potential effects of military training on raptors that use the area. Prior to this study, the effects of military training on raptors in the SRBOPNCA were largely unknown. As results have become available, the BLM and Idaho National Guard began management and mitigation as necessary. Additionally, new research to isolate effects likely will be undertaken.

Fourteen species of raptors breed in the SRBOPNCA and ten other species winter there. For our demonstration, we chose three species: wintering golden eagles (*Aquila chrysaetos*), breeding ferruginous hawks (*Buteo regalis*), and the Swainson's hawk (*Buteo swainsoni*), which is a Neotropical migrant. We chose these species because: 1) they are large raptors that can carry the radio transmitters; and 2) previous studies have documented that these species use the military training areas.

Golden eagles are 76 - 102 cm long, with a wingspan from 203 - 224 cm. They show slight sexual dimorphism, with males usually being smaller than females. Resident eagles in the NCA typically nest in the Snake River canyon, although they occasionally nest on power poles. These resident eagles make hunting forays into the OTA during the breeding season, but do not typically spend time in the OTA during the non-breeding season (winter months). Instead, some adult eagles that winter in the OTA are migrants that nest in Alaska and northern Canada, and only use the OTA from autumn through spring (November - March/April). Principal prey for golden eagles are black-tailed jackrabbits (*Lepus californicus*). Other prey species found in or near the OTA are Nuttall's cottontail (*Sylvilagus nuttallii*), ring-necked pheasants (*Phasianus colchicus*), yellow-bellied marmots (*Marmota flaviventrus*) and Townsend's ground squirrels (*Spermophilus townsendii*). Wintering golden eagles also exploit the carcasses of cattle and sheep that die in the OTA.

Ferruginous hawks are 58 cm long, with a wingspan of 135 cm. They were a Federal Candidate 2 species (listing as threatened or endangered might be appropriate, but the United States Fish and Wildlife Service lacks sufficient data to support listing) under the previous categories of the Endangered Species Act. They nest in the Snake River canyon and on rocky outcrops or power lines on the plains above the canyon, and migrate out of the area in the fall. Primary prey of ferruginous hawks in the NCA are black-tailed jackrabbits and Townsend's ground squirrels. Populations fluctuate with jackrabbit abundance.

Swainson's hawks' average 53 cm in length, with a wingspan of 132 cm. Weights range from an average of 725 grams for males to 1050 grams for females. Localized declines have made the Swainson's hawk a species of concern throughout its range. Extensive southward migration to the Pampas region of Argentina, and colonial roosting have made it vulnerable to agricultural pesticides, particularly organophosphates. The Swainson's hawk nests in trees throughout the western United States. While Swainson's hawks do not nest on the OTA (due to a lack of available nesting trees) they frequently forage within the OTA, preying on Townsend's ground squirrels, other microtines, small birds, and insects.

Specific objectives of the Legacy demonstration:

- Demonstrate remote tracking capability in conjunction with triangulation and homing.
- Use conventional telemetry to ground track birds, and to validate satellite telemetry methods.
- Monitor movements of military vehicles (e.g., tanks) during training exercises via a GPS receiver on board the tank, including integration of military technology (e.g., DFIRST [Deployable Force-on-Force Instrumented Range System]) when possible.
- Use GIS to display temporal spatial relationships among military vehicles and golden eagles; and as applicable, to relate raptor locations to military training areas, status of military training, nest sites, and habitat; display migration routes and determine breeding areas of golden eagles that winter in the OTA; display migration routes and determine wintering areas of ferruginous hawks and Swainson's hawks that breed and/or forage in and around the OTA.

PRODUCTS

- Maps of golden eagle movements and wintering grounds.
- Maps of ferruginous hawk movements and wintering grounds.
- Maps of Swainson's hawk movements and wintering grounds.
- Correlations between military training and raptor movements within the OTA.

METHODS

STUDY AREA

The OTA occupies 56,022 ha of the 196,225 ha SRBOPNCA in southwestern Idaho. The National Guard uses the OTA primarily for armored vehicle training including firing of live ammunition, firing of lasers, tank maneuvering, bivouacking, helicopter maneuvering and firing, and small arms firing. Most firing of live ammunition occurs from firing ranges (cinder rock pads from which tanks are fired) permanently located just inside the Range Road that encompasses the impact area; all training rounds are fired from the ranges into the impact area. Artillery is fired from areas outside of Range Road, but is aimed towards the Artillery Impact Area (Fig. III-1) within Range Road. Maneuvering and bivouacking occur primarily outside or immediately inside Range Road. Assembly areas (where tents and/or fueling occur) are temporarily located outside the impact area as needed. During the summer months, the OTA serves as the Annual Training Site for the Idaho, Montana, and Oregon Army National Guard units that constitute the 116th CAV

BDE, as well as other units from around the country. During the winter, most activity is concentrated in the northern portions of the OTA, where year-round schools are conducted by the Combat Vehicle Transition Training Team for National Guard Units from all over the country.

The topography of the study area is generally flat or slightly rolling, and is punctuated with a few prominent buttes and outcrops. Habitat is shrubsteppe vegetation dominated by big sagebrush (*Artemisia tridentata*), green rabbitbrush (*Chrysothamnus viscidiflorus*), salt-desert shrubs, notably shadscale (*Atriplex confertifolia*), and grassland (native and exotic grasses, and forbs).

CAPTURE AND RADIOMARKING

Schedules of military training used for this study were distributed only to individuals with a need to know. The Range Control Officer was notified each time a researcher entered or exited the OTA. Access to the impact area of the OTA was controlled; researchers entered only under physical escort by trained IDARNG personnel. Each field biologist obtained a safety briefing prior to January 2, 1996.

The demonstration was sub-permitted under the following permits issued to Michael N. Kochert, National Biological Service Raptor Research and Technical Assistance Center, 3948 Development Ave. Boise, ID 83705: Master-station Federal Bird Marking and Salvage Permit number 20537; Federal Fish and Wildlife Permit number PRT-690558 for scientific collecting; State of Idaho scientific collecting/banding permit number SC2204826.

Golden Eagles

We surveyed the OTA 1-2 times per week starting on 28 November 1995 to determine perches regularly used by adult golden eagles and nearby areas suitable for placing traps. We emphasized the northeast portion of Range Road from Christmas Mountain to Range 14 (Fig. III-1) for trapping golden eagles because most of the military training activity during the winter months occurs on Ranges 1 and 10. Previous studies determined that adult golden eagles exhibited strong fidelity to winter use areas, and we assumed that they likely would remain near the area where they were captured. We attempted to trap 4 adult golden eagles beginning 9 January 1996, using leg-hold traps surrounding a mule deer carcass. We placed capture sets in view of habitual perch locations or along regularly used flight paths. We observed traps from trucks parked approximately 2 km away.

We instrumented each captured adult eagle with a 105 g backpack package including an 85g Platform Terminal Transmitter (PTT; 401 MHz) and a 20 g harness, as well as a 15 g conventional tail-mounted transmitter (164 MHz). We radio-tagged each individual captured unless: 1) the eagle weighed < 4000 g (at which point the transmitter and PTT would weigh > 3% of the eagle's body mass); 2) the eagle had an injury that might be exacerbated by carrying the transmitters; or 3) the eagle appeared to have come from a non-target area. We took the following morphological measurements: mass (g), wing chord (mm), wing span (mm), a wing tracing (mm), footpad (mm), bill depth (mm), hallux length (mm), and culmen length (mm). We drew approximately 3 ml of blood from captured eagles for analysis of lead content for collaborators in a USGS study. Each captured eagle was banded with a USFWS band on the right leg, and given a unique identifying paint spot on one wing for aid in identifying individuals visually.

Ferruginous hawks

We obtained nest site information from the National Biological Service Raptor Research and Technical Assistance Center staff, who were conducting surveys of ferruginous hawks throughout the Snake River Birds of Prey National Conservation Area. We selected individuals for capture based on proximity of the nest to the OTA (we wanted local birds that nested in or close to the OTA), and on status of the nesting attempt (birds with successful nesting attempts were more likely to remain in the area). We trapped 7 adult ferruginous hawks in May and June 1996. We placed traps near habitual perches, along regularly used flight paths, and within view of the nest. We targeted capture during mid brood-rearing (young 2 - 5 weeks old), when adults were likely to be tenacious and not abandon their young.

We instrumented all captured ferruginous hawks with 33g backpack packages (approximately 30 g PTT and 3 g harness), except at one site where we captured both adult birds and instrumented only the male. We took the following morphological measurements of each individual (if possible): mass (g), wing chord (mm), wing span (mm), footpad (mm), bill depth (mm), hallux length (mm), and culmen length (mm). Each captured hawk was banded with a USFWS band on the right leg (unless previously banded).

Swainson's Hawks

Swainson's hawk nest sites near the OTA were surveyed for breeding activity in early May. Breeding adults were captured using dho-gazas with great-horned owls as lures, and/or bal-chatri traps with gerbils as bait. Each captured individual was radio-tagged with a 33g PTT in a backpack configuration. Measurements taken included: mass (g), wing chord (mm), and footpad (mm). Each captured hawk was banded with a USFWS band on the left tarsus, and a red anodized band on the right tarsus. Additionally, the bottom half of the rectrices were painted with a non-toxic, quick dry paint to facilitate observations of individuals. We took the following morphological measurements of each individual (if possible): mass (g), wing chord (mm), wing span (mm), footpad (mm), bill depth (mm), hallux length (mm), and culmen length (mm). Each captured hawk was banded with a USFWS band on the right leg (unless previously banded).

MONITORING

Golden Eagles

Observations of eagles were scheduled to correspond with scheduled military training and the duty cycle of the PTTs. We attempted to obtain visual observations of radio-tagged eagles during days that we were trapping other eagles and when we were monitoring military activity. Locations were verified using a GPS unit (Garmin 45). If the eagle was not observed, but the general location could be estimated by triangulation, we used that estimate of eagle location. The objective in obtaining all possible visual and triangulated locations was to demonstrate the ability to ground track eagles as well as to obtain data via satellite, and to compare these locations to the location estimates obtained via satellite.

PTTs were configured to transmit approximately 8 hr every 24 hours during cycles of military training and 8 hr every 56 hr between cycles (see Table III-1).

Table III-1. Platform terminal transmitter (PTT) duty cycles for golden eagles radio tracked in the Orchard Training Area in southwestern Idaho in 1996. PTT duty cycles were set to take advantage of military training cycles as they were anticipated in December 1995.

Transmission season	Approximate date range	Schedule of transmissions
1	28 Dec 1995 - 12 Jan 1996	8 hr on / 36 hr off
2	13 Jan 1996 - 26 Jan 1996	4.8 hr on / 4.8 hr off
3	27 Jan 1996 - 23 Feb 1996	8 hr on / 48 hr off
4	23 Feb 1996 - 30 Mar 1996	4.8 hr on / 4.8 hr off
5	31 Mar 1996 – battery life	8 hr on / 40 hr off

At the end of March 1996, the PTT was scheduled to change to transmit 8 hr every 52 hr to record the migration out of the study area. Satellite derived location data were obtained via the Service Argos every 4 days. Additionally, data were accessed on line as needed to locate an individual and all data obtained via satellite were provided at the end of each month by Argos. Service Argos codes each satellite-derived location estimate for quality, based on characteristics of the signals that are used to calculate each location. This scale increases from an undetermined precision to a precision of 150 m. Visual locations were verified with a GPS (Garmin 45 GPS).

Ferruginous hawks

PTT duty cycles were set to transmit 8 hr every 64 hr for approximately 3 months. After 3 months, the PTTs were scheduled to transmit 8 hr every 92 hr until the battery expired. This transmission cycle allowed us to follow the individuals through the breeding season, and to track them to where they spent the winter months. Satellite-derived locations were obtained from Service Argos.

Swainson's Hawks

We observed radio-tagged individuals to determine if the transmitter packages were influencing behavior after capture and before the onset of migration. Individuals were observed at the nest site until, by using satellite-derived location estimates, we determined that the individual had left the study area.

Swainson's hawk PTTs were programmed to provide maximum information during the autumn migration period (Table III-2). After migration, transmissions would be less frequent, thereby extending the duration of time the PTTs transmitted to include the overwintering period and northward migration back to breeding areas. Satellite-derived locations were obtained from Service Argos. We compared known locations (obtained through resighting and obtaining locations of individuals (using a Garmin 45 GPS unit) with those obtained via satellite. Linear error was determined for paired sightings that occurred within 1 hr of each other.

Table III-2. Platform terminal transmitter (PTT) duty cycles for SWHA radio tracked in the vicinity of the Orchard Training Area in southwestern Idaho in 1996.

PTT ID	Transmission season	Approximate date range	Schedule of transmissions
19215 deployment mid-July	1	mid-Jul – mid-Sep	7 hr on - 168 hr off (175 hr cycle for 8 cycles)
	2	mid-Sep – mid-Nov	8 hr on - 28 hr off (36 hr cycle for 40 cycles)
	3	mid-Nov - end	8 hr on - 137 hr off (155 hr cycle until battery drained)
19222-i19224,19232-19233 deployment mid-August	1	mid-Aug - mid-Sep	7 hr on - 168 hr off (175 hr cycle for 4 cycles)
	2	mid-Sep – mid-Nov	8 hr on - 28 hr off (36 hr cycle for 40 cycles)
	3	mid-Nov - end	8 hr on - 137 hr off (155 hr cycle until battery drained)

MILITARY ACTIVITY

During the winter golden eagle studies, we used Meridian Magellan GPS units to track the movements of tanks during training. Locations were logged automatically at 10 min intervals during a training day. We gathered data on days chosen to coincide with the most favorable days for obtaining eagle location estimates from the satellites. GPS data were downloaded to a computer at the end of each day.

During June 1996, Stanford Research International (SRI) collected data on military training via the DFIRST system. This system monitored individual military elements (tanks and other military vehicles) using GPS units. The system provided information on date of location, time of location, position of element (latitude, longitude, altitude), position of weapon on element, rate of travel of element, and status of firing activity of element. To reduce the quantity of data transferred from SRI to Boise State University in Jan 1997, the database was sub-sampled to eliminate all but the first occurrence of a location when the element remained stationary for an extended period, without firing activity.

Instances of contemporaneous animal locations and military training were identified as those where the location estimates were within 15 min of each other. During periods of military activity monitoring, locations of elements were obtained on a minute-by-minute basis. As a result, the number of contemporaneous location estimates was limited by the number of animal location estimates provided by the Argos satellite system. We calculated the distance between birds and military elements.

RESULTS

The IDARNG has a fully functional GIS capability in the Environmental Section at Gowen Field. The Environmental Services Office of the Army National Guard uses GIS (ArcInfo, and ArcView) to manage vegetation layers, as well as to create maps.

CAPTURE AND RADIOMARKING AND MONITORING

Golden eagles

We captured 8 golden eagles wintering in the OTA from 9 January - 30 January 1996 (Table III-3), with an additional trapping effort on 5 March 1996 to replace a radio-tagged eagle that had been found dead (causes unrelated to our study). One additional eagle was captured opportunistically in December 1995 to remove an old PTT). Seven of the individuals captured were adults and 2 were sub-adults. We initially instrumented 4 adults with a PTT and conventional, tail-mounted transmitter. One of the PTT-marked eagles was found dead, so we placed that PTT on another individual.

Table III-3. Golden eagles captured in the Orchard Training Area in southwestern Idaho during the winter of 1995-96

Date	Band Number	Sex	Mass	Wing chord	Wing span	PTT Number
5 Jan 96	629-18118	M	4080	568	1964	
10 Jan 96	629-18119	M	4230	590	1996	
12 Jan 96	629-18120	M	4180	582	1938	
13 Jan 96	629-18121[a]	F	4680	605	2038	5728(A)
18 Jan 96	629-18122	M	3380	580	2020	
20 Jan 96	629-18123	M	4680	625	1998	5729
23 Jan 96	629-18124	M	1380	630	1960	5730
30 Jan 96	629-18125	M	4305	590	1980	5731
05 Mar 96	629-18126	F	5280	625	1980	5728(B)

[a] Found dead from poison. The PTT was recovered and placed on a different individual.

We attempted to obtain simultaneous observation of tank movement, satellite-determined eagle location estimates (satellite locations), and visually obtained eagle location estimates (visual locations) on 14 days. On another 8 days, we attempted to obtain simultaneous satellite locations and visual locations. We simulated military training activity on an additional 2 days by driving in the area during days when the military was not training. We were unable to obtain enough simultaneous visual observations and satellite-derived location estimates to make comparisons using linear error among Location Classes (LC). These eagles were difficult to find this year because eagle movement patterns deviated from those of previous years on which we based our study design. This year, eagles ranged extensively outside the OTA

We obtained data from golden eagle PTTs on an average of 106 days during the study period (2 Jan - 5 Sep 1996). The mean number of location estimates we obtained per day was 3.66; the mean number of location estimates with an estimated error <=1,000m was 0.72.

Of 1,564 total location estimates we obtained on eagle PTTs, 301 (19.57%) had estimated error <1000 m. This result is slightly elevated because one PTT was stationary for a period; without this individual PTT, we obtained 224 estimates with estimated error <1000 m of 1,272 total location estimates (17.61%). (Table III-7, at the end of Section III).

Compared to previous findings of studies in the Orchard Training Area, the wintering adult eagles exhibited less fidelity to the area in which they were captured. Only two eagles were consistently located within the OTA; additionally, we rarely obtained visual locations on these individuals because they were inside the Range Road (Fig. III-1), and not accessible to observers. One eagle (5729) left the study area soon after capture and remained in southeastern Oregon for the remainder of the winter and the breeding season (Fig. III-2). Two eagles (5728A and 5730) were occasionally located in the OTA, but we rarely obtained visual contact (Fig. III-2). Two eagles (5728B and 5731) used the area consistently during the winter, but we were seldom able to visually locate them (Fig. III-2). These circumstances demonstrate the value of radio tracking via satellite.

Two golden eagles studied during 1996 migrated to distant breeding locations in northern British Columbia (Fig III-2). Duration of these migration movements averaged 20.5 days. One individual departed from the OTA on 3 March, arriving at its destination on 25 March (24 days later); the other departed on 13 March, arriving at its breeding season location on 28 March (17 days later). The other 2 eagles did not migrate, remaining in the vicinity of their wintering areas (5729 in Oregon, and 5728B in the OTA) into the breeding season (Fig. III-2).

Military movements and eagle locations

We obtained the training schedules from the IDARNG Range Control for information concerning what days training was planned. We obtained 8 tracks of tanks over the course of the study. These primarily represent typical military activity for this period on Ranges 1 (MPRC), 5, 6, and 10 (see Fig. III-3).

Winter use of the OTA by the Idaho National Guard is sparse. We concentrated our efforts to obtain information on movements of military elements in early March, when most military activity was taking place. GPS units placed on tanks or on other military vehicles enabled us to obtain tracks of military vehicle movement where each point in the track was identified by date, time, and location (latitude/longitude).

Eagle locations obtained via satellite are identified by date, time, and an accuracy classification. Because we are able to obtain movements of tank tracks with GPS, points within the track could be matched by date and time to eagle locations obtained either visually or via satellite (Table III-3, at the end of Section III). Our analyses revealed poor coincidence of PTT data and tank tracks. Golden eagles had largely departed the training area prior to the intensive military training period, so location estimates that were contemporaneous were not usually viable matches because the eagles had departed the OTA (for migration) and therefore were out of the area of military influence. Likewise, we were unable to visually locate those that remained at times that coincided with training.

Ferruginous hawks

We captured 7 ferruginous hawks during May and June, 1996 (Table III-4). There were only 2 occupied nesting areas in the interior of the OTA that were optimal for the demonstration. At one of these sites, the pair had apparently made no attempt to nest, and we were not able to find them. At the second site, we trapped the female of the pair; although the pair had recently failed, the nest's proximity to upcoming training made the pair good candidates for this demonstration. We then selected individuals that were nesting on the power line that marks the northern boundary of the OTA. We trapped 4 individuals from 3 nests with older nestlings (near-fledging age). In each case, we marked the male of the pair. We then trapped at sites that were close to the OTA, but south of the southern boundary. At these last 2 sites, we captured and marked the female of the pairs.

Table III-4. Ferruginous hawks captured in the vicintiy of the Orchard Training Area in southwestern Idaho during the breeding season of 1996.

				Wing		PTT
Date	Band Number	Sex	Mass	chord	span	Number
30 May	1207-23430	F	2055	440	1440	5737
5 Jun	877-47637	M	1455	419	1429	11979
12 Jun	877-47638	M	1305	446	1422	11980
12 Jun	1207-23460[a]	F	1955	435	1460	
20 Jun	877-47639	M	1155	425	1410	11981
28 Jun	1207-23431	U	1555	430	1470	19195
28 Jun	1207-23432	F	1795	456	1500	11986

[a] Previously banded.

We obtained data from ferruginous hawk PTTs on an average of 92 days during the study period (1 Jun 1996 - 30 Apr 1997). The mean number of location estimates we obtained per day was 2.01; the mean number of location estimates with an estimated error <=1000m was 0.40. Of 1,142 total location estimates we obtained on ferruginous hawk PTTs, 236 (20.31%) had estimated error <1,000 m (Table III-7, at the end of Section III)

Ferruginous hawk movements at the end of the breeding season differed among individuals. One female (5737, from a failed nesting attempt) left the OTA immediately; she traveled widely in northern Nevada until mid-August, when she briefly visited west central Nevada before moving into Colorado (Fig. III-4). Another female (19195) left the area about 7 July, traveling to southern Saskatchewan. Signals from the third (11986) never left the SRBOPNCA, and the activity sensor indicated that the PTT was not moved after 22 July. We were unable to relocate this individual, and do not know whether the PTT was shed by the hawk, or whether the individual died. Male ferruginous hawks remained in the area slightly longer than females. The earliest male to depart the OTA (11979) left on 23 July, moving briefly to Central Montana before moving to south-central Nevada. The second (11980) departed about 8 August and moved east, following the Snake River to south central Idaho. The third (11981) also moved east along the Snake River to south central Idaho, departing around 27 Aug.

Wintering areas varied widely among individuals (Fig. III-4), although all wintering locations were south of Idaho. One female (5737) spent the winter months in southern Nevada. The remaining female (19195) spent the winter in southwestern Kansas. One male (11981) spent the winter in southern California; and another male (11980) apparently wintered in northern Baja, Mexico, although data are sparse. The activity sensor on the remaining male (11979) indicated that the PTT stopped moving in southern NV, where it had been since 26 August. We do not know if the hawk shed the transmitter at this location, or whether it died.

We were able to track 3 of the ferruginous hawks back to the SRBOPNCA in the spring of 1997. Two males were detected in the vicinity of the SRBOPNCA first: the earlier was 3 March (11980), the other (11981) returned 11 March. One female returned on 19 March (19195). Another female (5737) did not return to the NCA, but arrived on the Idaho/Oregon border (to the southeast of the 1996 capture site) on 16 March, and remained until transmissions stopped on 6 June.

Military movements and ferruginous hawks

Spring and summer is the primary period of training on the OTA. The most intensive training period in 1996 took place in June. During this period, a demonstration of the Deployable Force-on-Force Instrumented Range System (DFIRST) was implemented by SRI International and the 116th Cav Bde. DFIRST is a system capable of tracking military element movements and reporting engagement simulation events and results using GPS and line-of-site radio communications. We obtained data (date, time, location) from these exercises to relate to ferruginous hawk movements.

Date, time, and an accuracy classification identify ferruginous hawk locations obtained via satellite. With the locations of tanks obtained using the DFIRST system, points within the tank tracks were matched by date and time to ferruginous hawk locations obtained via satellite. However, most of the DFIRST tracking did not coincide with the duty cycles of the ferruginous hawks. We obtained only 3 location estimates of FEHA that were within 8 hr of a tank location. Each of these was within 1 hour of the military activity. Distance between military vehicles and ferruginous hawks during a single training day could be calculated to look at relative movements, but the paucity of data prohibited analysis. Contemporaneous military activity and ferruginous hawk location estimates are exhibited in Table III-5.

Table III-5. Contemporaneous location estimates of military training elements and ferruginous hawks (FEHA) in the Orchard Training Area, June 1996.

Tank Data Obtained from Military Training					FEHA Data Obtained from Service Argos					
Date	Time	Lat	Lon	Elevation	PTT #	Date	Time	LC	Lat	Lon
6/17/96	15:23:16	43.10919	-116.092	900	11981	6/17/96	15:45:16	A	43.717	-116.51
6/17/96	15:23:16	43.10919	-116.092	900	11979	6/17/96	15:47:31	0	43.364	-116.198
6/6/96	14:26:59	43.24965	-116.166	1027	11979	6/6/96	14:48:57	1	43.337	-116.166

Swainson's Hawks

During 8 Aug - 4 Sep 1996, we captured 6 adult Swainson's hawks and equipped each with a PTT (Table III-6). Of these, 1 was identified as male, and 5 were identified as female. Three were captured using bal-chatri; the remainder was captured using dho-ghazas. Four were from known breeding pairs; 2 were of unknown breeding status.

Table III-6. Swainson's Hawks captured in the vicinity of the Orchard Training Area in southwestern Idaho during the summer of 1996. Color bands were red and each was placed on the right tarsus. Tails were mearked using non-toxic paint on the lower half of all feathers.

Date	Band Number	Color Band	Sex	Mass (g)	Wing chord (mm)	Footpad (mm)	Tail marker	PTT number
15 Aug 96	1807-47867	H/M	F	1010	426	85.0	red	19215
29 Aug 96	1807-47874	D/1	F	950	400	77.0	orange	19222
29 Aug 96	1807-47876	H/N	F	1220	430	82.0	red	19223
31 Aug 96	1807-47877	H/P	F	1060	400	75.5	red	19224
04 Sep 96	1807-47878	H/R	F	1120	420	79.0	red	19232
04 Sep 96	1807-47879	E/1	M	920	403	76.0	blue	19233

We observed radiomarked SWHAs on 11 days during August and September 1996. All observations were made in the nesting area (<1.6km from the nest site). Two individuals were only observed on the day of capture; the remaining 4 were observed from 2 – 4 days (excluding the day of capture). We observed no complications from capture and marking.

Nest sites were revisited in spring 1997, after satellite-derived location estimates revealed that the individuals had returned to the study area. All 6 individuals returned to the study area and were identified by color bands on the right tarsus. Five individuals were wearing PTTs; 1 (19232) had lost its PTT during the wintering period. Two of the SWHAs marked in 1996 formed a pair in 1997 (19232,19233), laid eggs and bred successfully. Two others (19223,19224) mated with non-instrumented SWHAs and bred successfully. The remaining 2 individuals were of unknown breeding status, although 1 (19215) was suspected to be non-egg laying.

We obtained data from Swainson's hawk PTTs on an average of 73.67 days during the study period (4 Aug 1996 - 28 Apr 1997). The mean number of location estimates we obtained per day was 1.95; the mean number of location estimates with an estimated error <=1000m was 0.35. Of 862 total location estimates we obtained on Swainson's hawk PTTs, 156 (17.81%) had estimated error <1,000m (Table III-7, at the end of Section III).

Swainson's hawks were captured late in the breeding season; therefore data collected prior to migration were sparse. Swainson's hawks departed from the vicinity of the OTA during late September 1996. Two individuals (19215, 19223) traveled through Colorado and the panhandle of Texas before arriving along the Gulf Cost of Mexico at the US/Mexico border (Fig. III-5). One (19233) traveled a western route that took it through Southwestern Arizona, and western Mexico, before crossing Mexico and arriving on the Gulf Coast north of Veracruz, Mexico. The remaining 3 hawks (19222, 19224, 19232) traveled along the east side of the Rocky Mountains, through New Mexico, into central Mexico to the Gulf Coast, north of Veracruz Mexico. From the Veracruz area, they followed the west coast of Central America, until they reached the Andes Mountains in Columbia. They traveled the east side of the Andes into the plains of Argentina during mid - late November (15-28 Nov).

We tracked 5 of the Swainson's hawks on their northward migration. The route through South and Central America was similar to the route they had taken south. However, once in Mexico, they diverted onto different paths. Three (19215, 19222, 19224) apparently took paths similar to those on which they traveled south. One (19233) appeared to take a more easterly route, whereas the last (19223) took a more westerly route (Fig. III-5). The dates that individuals were detected in the vicinity of the OTA varied from 27 Feb 97 - 28 Apr 97, although 3 of the 5 returned within 1 week (27 Feb - 5 Mar) during the spring.

DISCUSSION

In the early 1990's, BLM and the IDARNG conducted an in-depth study of the birds of prey in the SRBOPNCA (Dept. of the Int. 1996). In part, this study evaluated the effects of military training in the Orchard Training Area on the natural resources; this included the immediate and secondary behavioral effects of training activity on raptors and on the habitats that are a critical to the populations in the area. These data are available to assist in addressing other environmental issues that might inhibit the ability of National Guard units to maintain military readiness. Questions about the effects of military training on raptors have presented issues that could significantly affect the readiness of reserve components in many states. Like the OTA, training areas used by reserve components are often public lands managed by Department of the Interior, and often include sensitive habitat and breeding areas for sensitive species. As in the OTA, public interest in effects of military training on these natural resources could have the end result of impeding training while baseline studies are conducted.

We were able to demonstrate the ability to obtain simultaneous location estimates of birds and military elements in the OTA, using 2 mechanisms: (1) our own GPS units on tanks, and (2) integration of an existing military technology (DFIRST) into our GIS. Using GIS we were able to display these location estimates, relating them spatially to each other, and to physiographic features, biological features, and habitat. We obtained location data remotely on the military elements and the raptors, thereby proving that pertinent data can be collected with little affect to military training activity. Moreover, we proved in principle that data collected in existing military tracking programs can be transitioned for use in natural resource management.

We were also able to track all study species on their movements away from the study site: golden eagles to likely breeding areas in Canada (Fig. III-2), SWHAs to wintering areas in Argentina (Fig. III-5), and ferrugious hawks on their varied movements around the Western US and Mexico (Fig. III-4). Long-range movements of these species illustrate the benefits of tracking via satellite over more traditional ground or aerial-tracking. The logistics of following individuals over long distances can be difficult as well as expensive. These extensive excursions also bring into focus the need to consider the year-round movements of birds when investigating local changes in populations. Unfortunately, timing of military training and available satellite data was not optimal. Our goal to demonstrate the variety of benefits of tracking birds via satellite (e.g., across seasons) precluded gathering sufficient data to make statistical inferences, for which more intensive data during shorter periods would have been required, at least in 1996. The tracking capabilities demonstrated here for long periods (e.g., migration cycles) could be concentrated in shorter periods to provide remotely obtained location estimates at a greater data rate.

MANAGEMENT IMPLICATIONS

We can apply the technology of tracking animals via satellite with existing military technologies (i.e., those used to track military elements) to reduce personnel time in the field and to benefit military readiness. For example, it takes personnel that are monitoring natural resources out of the hazardous environment of active military training. Also, it enhances military readiness by (1) disencumbering military assets that would otherwise have to escort natural resources personnel into secure areas for data collection; and (2) enhancing the amount of time a military unit can train by reducing the amount of direct natural resource monitoring or management tasks.

RECOMMENDATIONS

Intensive collection of bird location data that corresponds temporally to military training can be achieved by coordination of military training schedules and PTT duty cycles. Such data would enable us to evaluate local bird movements and military training activity. By doing so, we could design studies to provide sufficient data for statistical analyses. A cooperative effort with military software designers that would enable integration of wildlife tracking data into the DFIRST system would allow more timely intervention of conflicts. Alternatively, creating a program for wildlife monitoring that would incorporate data from military training programs directly (for display and analysis) would allow post-hoc analysis without copious data manipulation. These types of integration will provide 2 capabilities: 1) real time monitoring of proximity of mobile military elements and sensitive wildlife; and 2) a database for analyses of potential cause and effect relationships among training and wildlife.

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Table III-7. Percentage of each location class (LC) grouping obtained for PTTs deployed in the Orchard Training Area in 1996.

	Golden Eagles					Ferruginous Hawks							Swainson's Hawks						
LC	5728	5729	5730	5731	ALL	5737	11979	11980	11981	11986	19195	ALL	19215	19222	19223	19224	19232	19233	ALL
0	51.712	57.975	59.919	55.973	56.39	49.618	32.5	48.227	52.511	31.034	35.115	41.50	39.706	39.394	31.126	38.922	32.432	32.576	35.693
1 – 3	26.37	14.724	18.826	18.363	19.57	13.359	33.5	9.2199	13.242	22.414	30.153	20.31	13.971	23.03	21.854	14.97	12.613	20.455	19.423
A -Z	21.918	27.301	21.255	25.664	24.03	37.023	34	42.553	34.247	46.552	34.733	38.185	46.324	37.576	47.02	46.108	54.955	46.97	33.296

Table III-3. Contemporaneous location estimates of military training elements and Golden eagles (GOEA) in the Orchard Training Area, March 1996.

Military Element Data from GPS unit				GOEA Data obtained from Service Argos					
Date	Time	Latitude	Longitude	ID	Date	Time	LC	Latitude	Longitude
3/6/96	19:11:34	43.24654	-116.018	5731	3/6/96	19:11:35	0	42.488	-114.852
3/6/96	20:49:24	43.24707	-116.021	5731	3/6/96	20:49:48	0	42.517	-115.354
3/7/96	20:41:50	43.24675	-116.021	5731	3/7/96	20:41:41	0	42.759	-115.694
3/8/96	18:49:14	43.24267	-116.152	5731	3/8/96	18:49:39	0	42.908	-115.236
3/16/96	20:48:32	43.27339	-116.076	5728	3/16/96	20:48:22	0	43.018	-116.543
3/15/96	19:15:39	43.34571	-116.235	5728	3/15/96	19:15:05	0	43.18	-116.154
3/13/96	17:17:14	43.52736	-116.321	5728	3/13/96	17:17:23	A	43.23	-116.023
3/17/96	15:49:46	43.27981	-116.1	5728	3/17/96	15:49:13	Z	43.24	-116.139
3/13/96	19:38:32	43.31498	-116.154	5728	3/13/96	19:38:40	0	43.244	-116.224
3/16/96	22:22:39	43.27259	-116.076	5728	3/16/96	22:22:17	0	43.258	-116.215
3/17/96	17:30:59	43.29556	-116.063	5728	3/17/96	17:30:15	0	43.266	-116.298

3/12/96	20:26:44	43.52713	-116.32	5728	3/12/96	21:26:31	0	43.268	-116.208
3/15/96	16:35:27	43.2812	-116.189	5728	3/15/96	16:35:06	0	43.275	-116.019
3/12/96	19:50:28	43.43514	-116.234	5728	3/12/96	19:50:24	0	43.278	-115.99
3/12/96	17:40:50	43.2765	-116.185	5731	3/12/96	17:40:32	0	43.331	-115.981
3/17/96	18:54:18	43.24757	-116.018	5728	3/17/96	18:54:26	0	43.376	-116.467
3/12/96	16:00:30	43.28127	-116.189	5731	3/12/96	16:00:11	0	43.379	-116.06
3/6/96	20:50:25	43.24683	-116.024	5728	3/6/96	20:50:51	0	43.41	-115.799
3/13/96	19:33:22	43.31576	-116.154	5731	3/13/96	19:33:26	0	43.536	-115.761
3/6/96	22:33:16	43.24808	-116.018	5728	3/6/96	22:32:57	0	43.542	-116.009
3/7/96	16:08:13	43.24016	-116.038	5728	3/7/96	16:07:50	0	43.623	-115.929
3/16/96	22:27:19	43.27165	-116.076	5729	3/16/96	22:27:27	0	43.77	-117.792
3/6/96	19:13:35	43.24676	-116.018	5730	3/6/96	19:13:45	0	43.806	-116.652
3/13/96	21:18:56	43.25711	-116.073	5731	3/13/96	21:18:41	0	43.84	-115.692
3/17/96	20:37:34	43.24998	-116.025	5729	3/17/96	20:37:35	0	43.944	-117.504
3/8/96	18:50:15	43.24527	-116.149	5729	3/8/96	18:50:24	B	43.957	-117.792
3/7/96	20:38:48	43.24667	-116.018	5729	3/7/96	20:38:44	0	44.064	-117.589
3/12/96	15:59:28	43.28111	-116.189	5729	3/12/96	15:59:22	0	44.09	-117.661
3/6/96	19:09:29	43.24682	-116.018	5729	3/6/96	19:09:15	0	44.1	-117.756
3/13/96	19:38:00	43.31492	-116.154	5729	3/13/96	19:37:57	0	44.104	-117.455
3/13/96	21:16:15	43.26069	-116.071	5729	3/13/96	21:16:05	0	44.185	-117.142
3/15/96	19:11:33	43.32292	-116.217	5729	3/15/96	19:11:42	0	44.19	-117.861

3/16/96	16:13:01	43.27212	-116.076	5729	3/16/96	16:12:59	0	44.215	-117.629
3/12/96	17:41:50	43.27635	-116.185	5729	3/12/96	17:41:51	0	44.338	-117.61
3/7/96	16:10:18	43.23967	-116.037	5730	3/7/96	16:10:00	1	44.634	-117.713
3/8/96	18:51:15	43.24543	-116.147	5730	3/8/96	18:51:03	0	45.228	-118.614
3/15/96	19:16:39	43.35291	-116.235	5731	3/15/96	19:16:37	2	45.909	-114.162
3/16/96	17:26:32	43.27227	-116.075	5731	3/16/96	17:26:23	B	46.044	-114.731
3/12/96	17:39:50	43.27661	-116.185	5730	3/12/96	17:40:31	A	46.18	-119.587
3/12/96	16:00:30	43.28127	-116.189	5730	3/12/96	16:00:23	0	46.225	-119.451
3/12/96	18:08:37	43.27661	-116.185	5730	3/12/96	18:08:31	0	46.293	-119.637
3/16/96	16:12:00	43.27216	-116.076	5731	3/16/96	16:11:54	B	46.636	-113.686
3/13/96	19:36:58	43.31496	-116.155	5730	3/13/96	19:37:01	0	46.67	-119.572
3/13/96	21:17:22	43.25992	-116.071	5730	3/13/96	21:17:09	0	46.803	-119.816
3/16/96	17:51:11	43.2721	-116.076	5731	3/16/96	17:51:13	0	47.311	-113.647
3/16/96	16:09:55	43.27293	-116.075	5730	3/16/96	16:09:01	0	48.265	-120.035
3/15/96	19:19:45	43.37198	-116.234	5730	3/15/96	19:19:19	0	48.305	-120.252
3/16/96	17:50:10	43.2721	-116.076	5730	3/16/96	17:50:14	0	48.4	-120.592
3/17/96	18:51:41	43.24746	-116.018	5731	3/17/96	18:51:49	B	48.414	-113.953
3/17/96	20:34:59	43.24821	-116.017	5731	3/17/96	20:34:54	0	48.935	-113.37
3/17/96	18:55:23	43.2475	-116.018	5730	3/17/96	18:55:38	0	49.227	-120.212
3/17/96	20:37:34	43.24998	-116.025	5730	3/17/96	20:37:25	0	49.855	-120.229

Orchard Training Area (OTA)

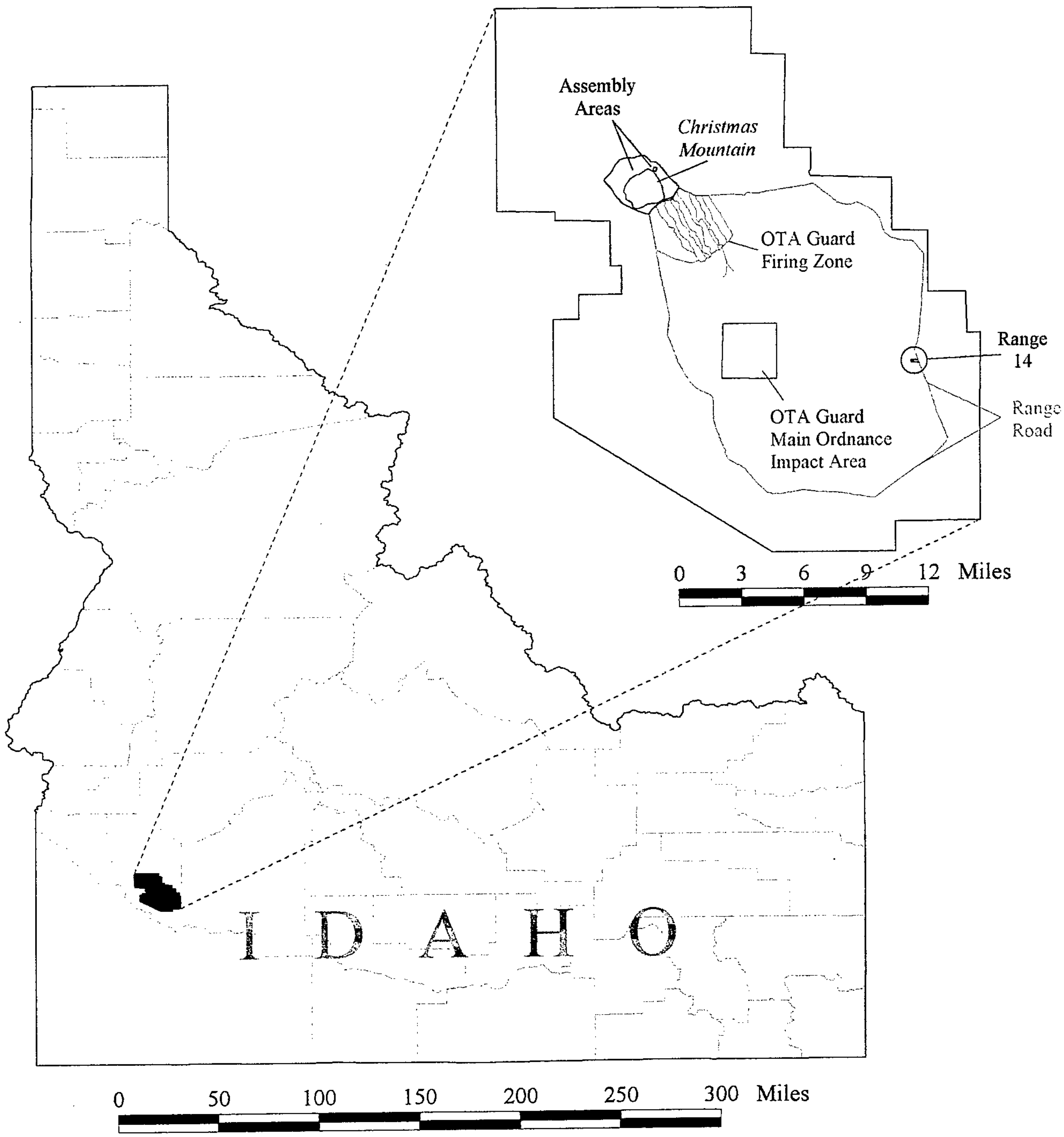
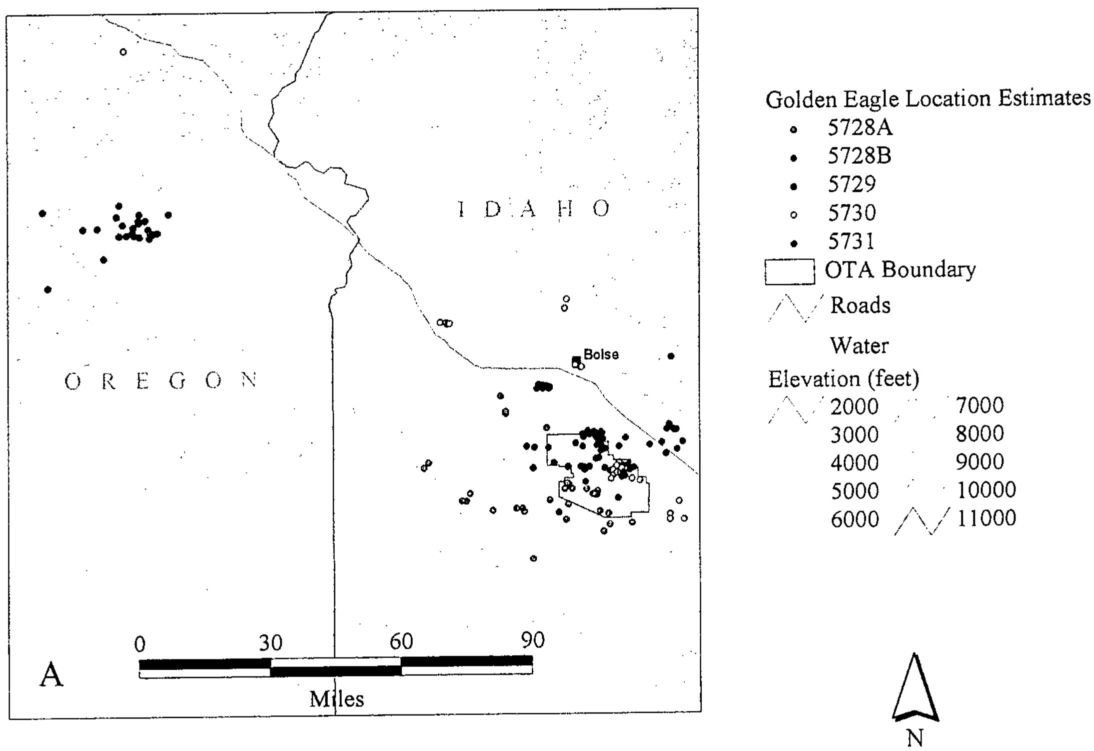


Figure III-1. Orchard Training Area (OTA), in reference to the state of Idaho, and a view of selected military features.

Golden Eagle Migration and Wintering Grounds

Orchard Training Area (OTA) Study - January 2 to November 14, 1996



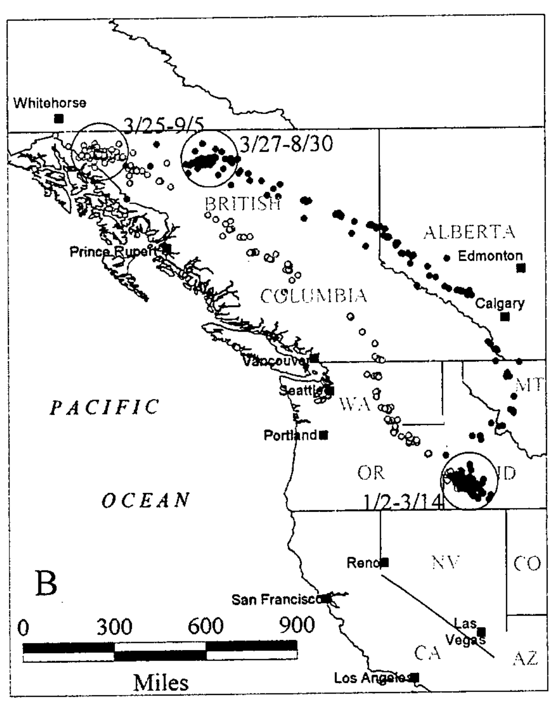


Figure III-2. Golden Eagle Migration and Wintering Ground Information.

A. Golden Eagle location estimates on and around the Orchard Training Area; January 2 to August 5, 1996.

B. Golden Eagle location estimates showing migration to northern British Columbia; January 2 to September 5, 1996.

Orchard Training Area
Military Activities

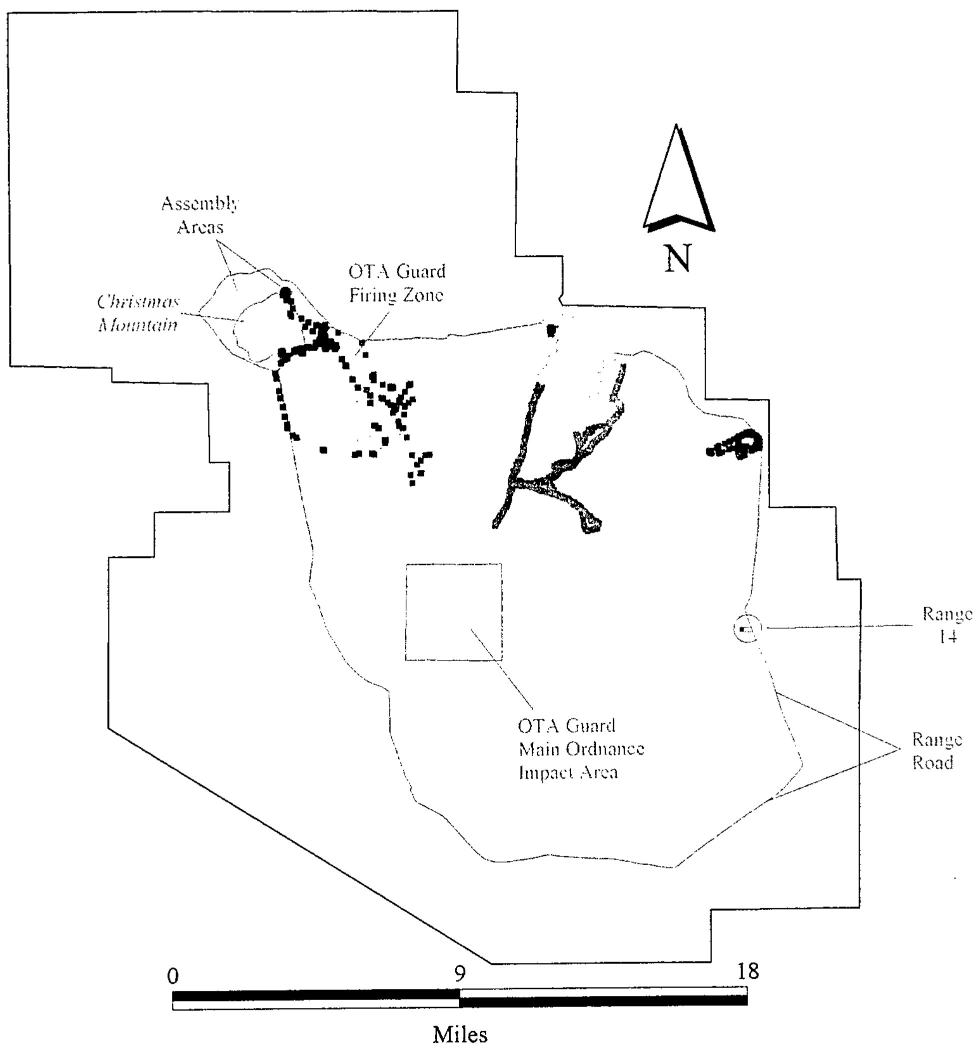


Figure III-3. GPS Estimates of Tank Locations

- Range 1 - March 8, 1996
- Range 1 - March 14, 1996
- Range 1 - March 12, 1996
- Range 1 - March 16, 1996
- Range 5 - February 16, 1996
- Range 5 - March 16, 1996
- Range 6 - March 1, 1996
- Range 10 - March 17, 1996

Ferruginous Hawk Migration and Wintering Grounds

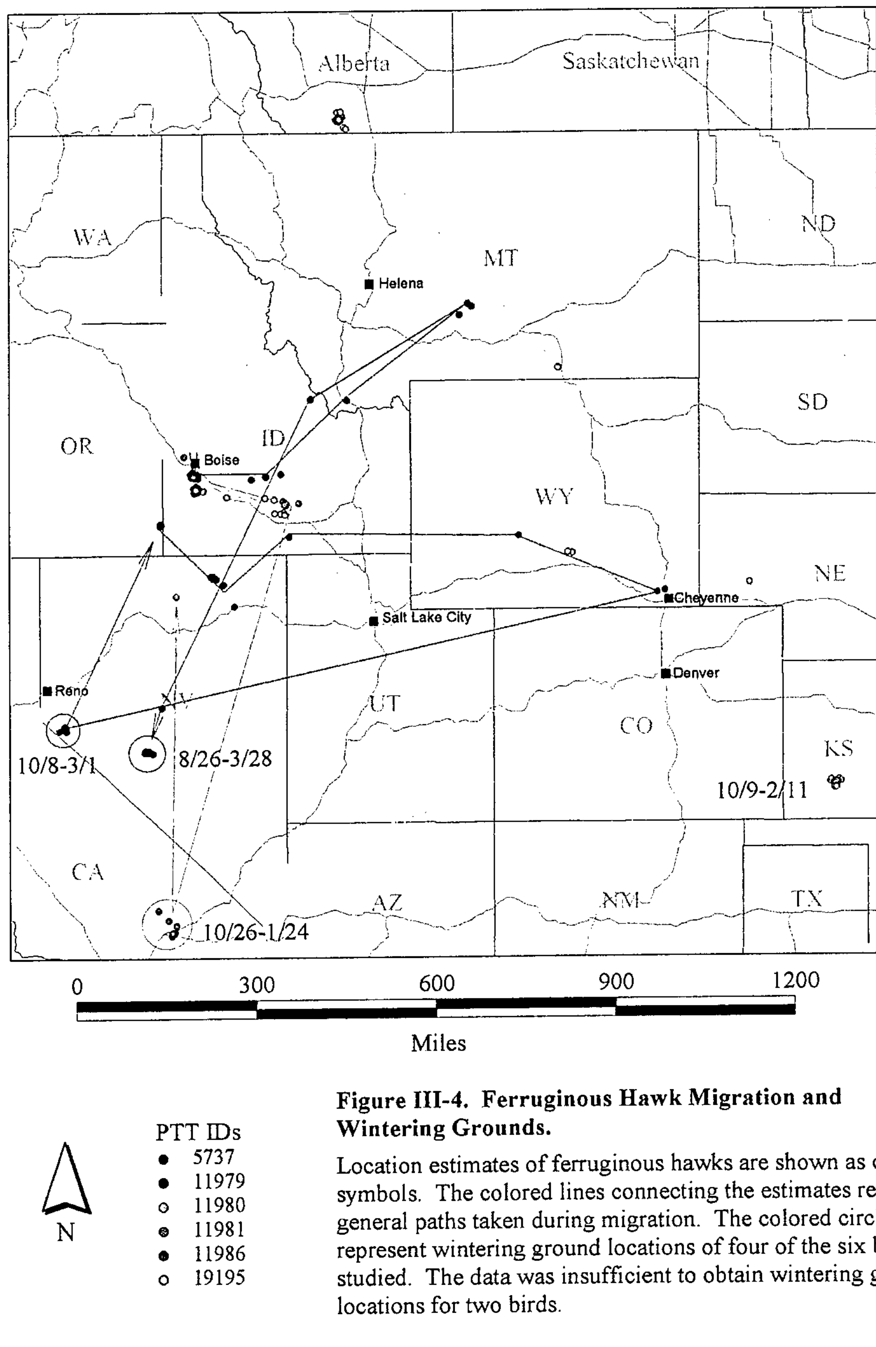
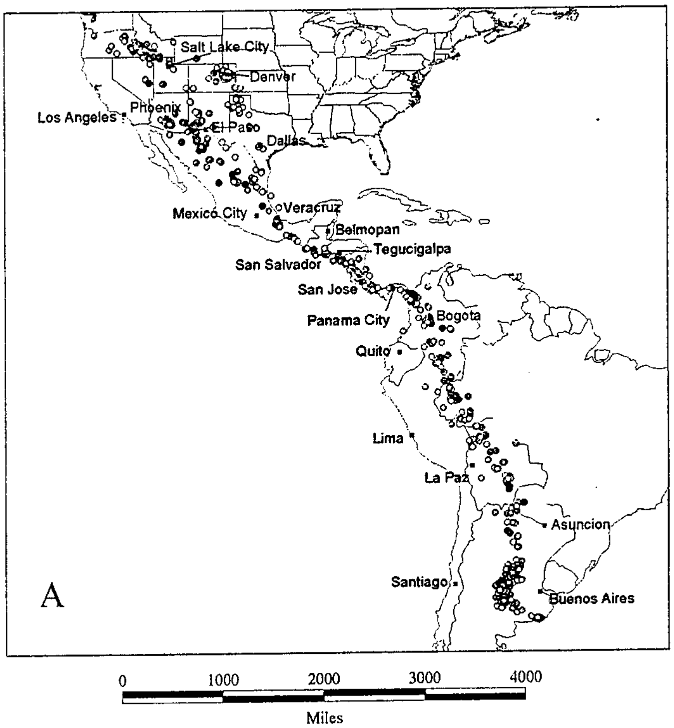


Figure III-4. Ferruginous Hawk Migration and Wintering Grounds.

Location estimates of ferruginous hawks are shown as colored symbols. The colored lines connecting the estimates represent general paths taken during migration. The colored circles represent wintering ground locations of four of the six birds studied. The data was insufficient to obtain wintering ground locations for two birds.

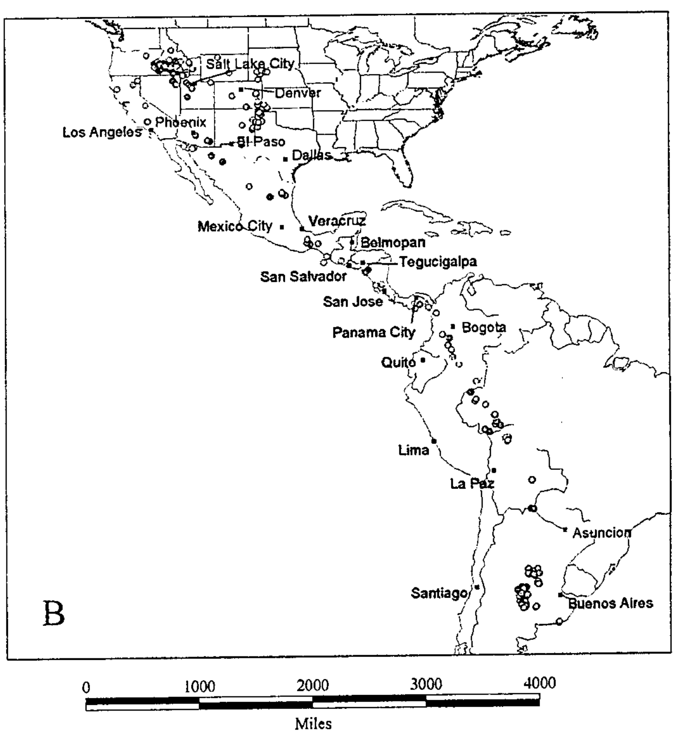
Swainson's Hawk Migration and Wintering Grounds



PTT IDs and Dates of Locations

- 19215 Aug. 14, 1996 to Feb. 27, 1997
- 19222 Aug. 30, 1996 to Feb. 25, 1997
- 19223 Aug. 27, 1996 to Feb. 27, 1997
- 19224 Aug. 29, 1996 to Feb. 28, 1997
- 19232 Aug. 30, 1996 to Dec. 31, 1996
- 19233 Aug. 30, 1996 to Feb. 23, 1997

N



PTT IDs and Dates of Locations

- 19215 Nov. 28, 1996 to Sept. 11, 1997
- 19222 Nov. 18, 1996 to Sept. 18, 1997
- 19223 Nov. 27, 1996 to June 24, 1997
- 19224 Dec. 11, 1996 to Sept. 6, 1997
- 19233 Dec. 16, 1996 to Sept. 19, 1997

Figure III-5. Swainson's Hawk Migration and Wintering Grounds

A. All location estimates showing southward migration.

B. All location estimates showing northward return migration.

WHITE SANDS MISSILE RANGE, NEW MEXICO

INTRODUCTION

PURPOSE

Wildlife biologists at White Sands Missile Range (WSMR) are charged with the management of native species of wildlife and of oryx, an introduced species of African antelope. In fact, the primary natural resources issue among WSMR, White Sands National Monument, and the San Andres National Wildlife Refuge concerns oryx use of their lands. This Legacy demonstration provided remote technology for tracking and monitoring oryx throughout the 2.2 million acre WSMR installation. Information collected about land use and respective jurisdictional boundaries crossed by this species can be applied to make decisions regarding range carrying capacity, and allowable take via hunting. Other management decisions regarding military training in areas used heavily by this species are made easier once animal land use and habitat requirements are more fully understood. This Legacy project demonstrated the utility of tracking animals via space-based systems, which enable the monitoring of target wildlife species without disturbance by "on the ground" conventional observation and telemetry techniques. Additionally, the monitoring of wildlife species using satellite-based technology was not impeded due to training schedules, material testing procedures, or areas closed to human traffic due to the presence of unexploded ordinance or sensitive military operations.

BACKGROUND

White Sands Missile Range (WSMR) is a Test and Evaluation Command Installation operated primarily for the support of research, development, test, and evaluation of weapon and space systems, subsystems, and components. WSMR, established in 1945, is the largest all-overland test range in the Western Hemisphere, and is the Department of the Army's (DA) largest installation, covering approximately 2.2 million acres. With the addition of several extension areas, the range can be expanded to nearly four million acres for certain types of testing. WSMR is bordered by Fort Bliss (DA) to the south and by Holloman Air Force Base to the west. At the end of fiscal year 1992, the installation employed 2,717 military personnel and contractors. Between 1945 and 1989, a total of 38,029 missile firings were completed at WSMR, including the world's first atomic explosion at the Trinity site on July 16, 1945.

Facilities located entirely within WSMR boundaries include: the San Andres National Wildlife Refuge (U.S. Fish and Wildlife Service; USFWS), the White Sands National Monument (WSNM; National Park Service), and the National Aeronautics and Space Administration (NASA) White Sands Test Facility. The Joranda Experimental Range (USDA Forest Service; USFS) also overlaps over a portion of WSMR.

WSMR has cooperative agreements with the New Mexico Department of Game and Fish (NMDGF), USFWS, Bureau of Land Management (BLM), the USFS, and The Nature Conservancy. The New Mexico State University Cooperative Fisheries and Wildlife Research Unit (NMSUCRU) of the National Biological Service conducts research with WSMR.

Lands within WSMR were used by prehistoric peoples, but permanent White and Hispanic settlements were uncommon until the late 1800's, following the defeat of the Apache Indians. The primarily native grass range lands were used for livestock grazing and small scale mining operations until 1950, when all nonfederal co-use contracts were rescinded. With the exception of feral horses, most of these lands have not been grazed by livestock for over 40 years.

Vegetation surveys in the area have a long history, beginning during an 1846 Mexican War expedition and most recently by The Nature Conservancy. The flora is largely representative of the Chihuahuan Desert, with influences from the southern Rocky Mountains, the Great Plains, and the Mogollon Rim. The rich plant diversity of WSMR, greatest in the mountainous regions, reflects both the variety of habitat types and past land use practices. Only one federally listed endangered plant species is found on WSMR, Todsen's pennyroal (*Hedeoma todsenii*). There are about 159,000 acres of Piñon-Juniper mountains on WSMR but no commercially viable forests, with only a very small stand of ponderosa pine growing near the summit of Salinis Peak.

The WSMR area has been digitized from U.S. Geological Survey, 7.5 minute topographic maps on the DA-developed Geographic Resources Analysis Support System (GRASS) software. The Nature Conservancy is surveying vegetation on WSMR in cooperation with the Department of Defense under contract with the USFWS. Wildlife management on WSMR, for non-game and threatened and endangered species, is largely for protection only because information required for management of these species is not available. Species listed as threatened or endangered species (TES) have been documented on WSMR; however, a complete survey of TES, game birds, and mammals has never been performed. Acquiring more knowledge of these species is imperative for WSMR wildlife management. Management of game species is much more developed.

Numerous species of New Mexico game birds occur on WSMR. The diversity of wetland game birds is primarily a function of WSMR's proximity to the Rio Grande River and to the Bosque del Apache National Wildlife Refuge to the west of the range. Over fifteen species of New Mexico game mammals also are known to occur, and seasonal hunts are conducted under strict control of WSMR and NMDGF managers. Major game animals hunted on WSMR are mule deer, pronghorn, and oryx. All three species exhibit stable to increasing populations and offer the potential for increased hunting opportunities. The primary game management problem is the scheduling of hunts around military testing, and having the personnel required to maintain proper hunter safety and military security.

Of the game animals on WSMR, the least is known of the oryx. Introduced to WSMR from Africa in 1969, the oryx has steadily increased its population and expanded its range within and outside the boundaries of the missile range. Surveys in 1995 showed an estimated oryx population between 1,700-2,000. Sightings off range and in mountainous regions are becoming more frequent. Oryx range throughout the WSMR. They require no direct water source and make good use of vegetation in the salt-flat regions. WSMR and the NMDGF cooperate on several seasonal hunts, including a depredation hunt. Oryx became the object of organized recreational trophy hunts in 1974 and population reduction hunts in the late 1980's. In 1996, about 450 oryx were harvested through these two methods. Although current survey methods are not sufficient to provide an accurate estimate, 1997 survey data and local observations put the oryx population at about 2,000-2,500, an increase of 20% since 1990.

The primary natural resources issue among WSMR, WSNM, and the San Andres NWR concerns oryx use of their lands. The National Park Service manages for native species and considers exotic species undesirable and has mandated the removal of oryx. To that end, a fence has been constructed to exclude oryx from WSNM lands. This fence was completed in the spring of 1996, at which time removal of oryx began.

The above population numbers indicate that oryx have propagated beyond expectations and that they have the potential to cause conflicts with the military missions at WSMR. Some documented conflicts are: (1) oryx penetrate fences and threaten technical missions with ground sensor equipment in the War Impact Target (WIT); (2) oryx wander onto the runways at Holloman AFB and must be removed; (3) oryx have expanded their range south of Highway 70, interfering with mission activities and creating safety concerns; (4) oryx must be removed from WSNM, which has a policy excluding exotics; and (5) oryx congregate around roads and have caused vehicle collisions in the past.

As oryx numbers increase and/or they expand their range, they exacerbate the following actual and potential conflicts/management concerns which require study: (1) the incident rates of the above conflicts would increase; (2) oryx dispersal off WSMR increases conflicts with adjacent federal and private landowners; (3) oryx movements and activities may conflict with wildlife on the San Andres' National Wildlife Refuge (where oryx may compete for forage with other, native wildlife); (4) oryx populations may expand beyond the harvest targets and require more hunting days, thereby conflicting with military mission requirements. The above conflicts, actual and potential, provide compelling reasons to study the movements and population dynamics of this animal and to develop a meaningful management plan based on data acquired using appropriate methods. No comprehensive studies of the population dynamics of the oryx at WSMR exist. The Legacy project at WSMR has successfully demonstrated to WSMR wildlife managers that they have at their disposal an important new tool.

Specific objectives of the Legacy demonstration:

- Demonstrate the capability of Service Argos telemetry to obtain, via satellite, location estimates of seven free-roaming African oryx on the two million plus acre White Sands Missile Range during the spring, summer, and autumn seasons.
- Use GIS to display the movements of oryx, and relate these movements to habitat, topography, military testing, and jurisdictional boundaries (e.g., WSNM fence).
- Describe the accuracy of locations relative to these boundaries.

PRODUCTS

- Maps relating oryx locations to jurisdiction boundaries and available habitat and land use databases.
- Provision of data and results in paper and electronic formats to local wildlife managers.
- Provision of any customized software associated with data management, analyses, maps, etc. to local wildlife managers.
- An ArcView 3.0a project file, associated scripts, PTT point coverages, and Arc/Info overlay coverages, will be made for the White Sands GIS staff.

METHODS

ΓUDY AREA

Most of WSMR lies within the Tularosa Basin, a closed drainage basin varying in elevation between ›ur and five thousand feet. The remainder lies within the Joranda del Muerto Basin. The Tularosa Basin is ɔund on the west by the San Andres, Organ and Oscura Mountains, and to the east by the Sacramento ⁽ountains. Elevation on the WSMR rises from about 4,000 feet near Lake Lucero to 8,959 feet at Salinis ɜak. The world's largest gypsum deposits, known as White Sands, are located within WSNM and wholly ithin WSMR. Climate at WSMR is characterized as moderately severe, semi-arid high desert, continental, ith summers having hot, dry days and moderate nights and generally cool winters. Annual rainfall averages st over 10 inches in the basin and 17 inches at elevations around 8,000 feet.

APTURE AND RADIOMARKING

Oryx capture and marking was coordinated with the removal of oryx from WSNM after the ɔmpletion of the exclusion fence. New Mexico Game & Fish and WSMR staff and colleagues conducted ıe capture and marking, with manpower, vehicles, sedatives, and veterinary assistance donated by NMGF. wo capture methods were used. The first, used in March, employed a helicopter to locate candidate ıimals, and then to deploy net guns to stop the animals. Tranquilizer darts were used to render the animals ıfe to handle. The chosen animal was immobilized by firing a net gun from a Bell Jet Ranger helicopter hile directly above. After the net had entangled the animal, a second person would exit the helicopter and lminister 3 ml of a 200 mg/ml dose of etamine/xylazine sedative using either a dart gun or a jab stick. he helicopter then returned to the staging area to pick up and deliver two more team members to the ıpture site to assist in handling, processing, and fitting of the oryx with the PTT collar. Four persons often :e needed to control and hobble the animal. Measurements taken included: horn length, basal horn rcumference, tail length, body length, face length, neck circumference, hock to toe length, heart rate, and :mperature. Water was applied to the animal to keep it from overheating during processing. Before :lease, a prophylactic 9 ml dose of antibiotic (penicillin) was administered to the animal. The capture team ıen departed for the next animal while two team members remained with the original animal until it had :covered sufficiently for the collar to be checked for proper orientation.

The second capture method (used in May) consisted of selecting animals from herds (sighted from ınge roadways) and employing tranquilizer darts and a lasso. The capture team was transported in six ·ucks, some of which dispersed to locate candidate animals while the remainder convoyed to reported ghtings. This capture method was designed to locate oryx within 50 yards of a road, then sedate the nimal by firing a tranquilizer dart from the bed of a pick-up truck. The sedative used was Carfentanil :itrate, 1 ml per dart. This is a powerful, reversible drug that is tightly regulated, requiring special licensing.)r. Mike Forsyth was so licensed, and he administered all sedatives. Processing included taking blood ımples and pertinent measurements, and fitting the collars while monitoring vital signs.

NMGF and WSMR staff and colleagues conducted the capture and marking with capture protocol, ersonnel, equipment, drugs, and veterinary services contributed by the NMGF. Boise State University .RC staff collected and managed data. Analyses were led by RRC staff in cooperation with WSMR staff

On 18 May the remaining five PTTs were fitted on animals spaced throughout WSMR, using tranquilizer darts from ground vehicles. Each oryx was downed within 12 minutes of darting and recovered within 15 minutes of processing. All participants felt that this was the preferred method of capture. The first oryx was collared at 0905 hrs. along the exclusion fence at WSNM, and the last was collared at 2020, over one hundred road miles to the northwest on the west side of the San Andres mountains.

MONITORING

Throughout the summer and fall of 1996, Susan Jojola Elverum was able to locate and observe the oryx, note behavior, and plot their location on a map. During this period she also recovered three PTT collars that were torn off by oryx. The animals were able to tear the collar material at the dorsal area of the neck. Two of these were recovered using the conventional transmitter signal, while the third was found using Argos location estimates. An excerpt from Ms. Elverum's report reads:

> I approached the "fallen collar" at the angle from which I had received the strongest signal using radio telemetry in the weeks prior; I assumed where the two [angles] (my angle and the satellite locations area) intersected would be my greatest chance of locating the collar. This proved to be true, although the satellite locations were so many and of such high quality that the locations alone, without prior knowledge of radio signals, would have been enough to locate the collar. The actual search method consisted of walking a zigzag pattern back and forth in the area described.

PTT #5732 ceased transmission after only five days, and was recovered from the ground, off the oryx, on 18 December, 1996. PTT #5733 transmitted for 6 months and was recovered from the ground on 21 December, 1996. PTT #19193 was recovered from the ground on 13 January, 1997.

The Legacy demonstration has provided WSMR biologists with their first mapping of oryx movement patterns. Performance of PTTs varied among individuals. The seven PTTs transmitted a total of 813 days, resulting in 1384 locations. Mean locations per day ranged from 1.285 to 2.028 and break out as follows:

#05732: 5 total locations over 5 days;
#05733: 77 locations over 180 days;
#19190: 357 locations over 347 days;
#19191: 197 locations over 344 days;
#19192: 346 locations over 346 days;
#19193: 240 locations over 345 days;
#19194: 162 locations over 346 days.

Location estimates of location class (LC) 0 predominated, accounting for 32.7% of all locations. LC 1,2,3 location estimates combined accounted for 18.6% of location estimates. The remainder (LC A,B,Z) accounted for 48.4%. The PTT with the highest percentage of more accurate location estimate classes (#19193) had 30.3% of all locations ranked in LC 1,2, or 3.

DISCUSSION

We met our objectives of attaining Argos location estimates of adequate quality and sufficient quantity to enable us to identify the general area of use for the selected oryx. We tracked these oryx through all four seasons and were able to describe and analyze these movements in GIS layers displaying vegetation, topography, and jurisdictional boundaries. Some of the results are described below.

Based on our one-year project, and considering current climatic conditions, oryx seem to stay within a defined area or territory throughout the year and do not move over a large area (Fig. IV-1). Home range areas (90% convex polygon home range, Fig. IV-2) of selected oryx were distinct but highly variable, ranging from 1,166 - 16,778 ha (#5733 = 4,105 ha; #19190 = 14,127 ha; #19191 = 2,406 ha; #19192 = 16,778 ha; #19193 = 1,166 ha; and #19194 = 9,328 ha). Selected oryx that were relocated outside the WSNM did not disperse, but remained close to the new exclusion fence (Fig. IV-3).

PTTs provided location estimates in a variety of geographic areas: 3 PTTs (#19190, #19191, and #19192) were on animals located in the white sands basin; 2 PTTs (#5732 and #5733) were on animals located on the east side of the San Andres Mountains, with access to deep canyons; and 1 PTT (#19194) was on an animal tagged in the Poison Hills area, also characterized by steep canyons. PTT #19193 was on an animal located in an open area of the Joranda at approximately 5,000' elevation (Fig. 4-4).

When overlaid on vegetation layers, Argos location estimates can be used to analyze seasonal use areas (Fig. IV-5). As a follow-on to this Legacy sponsored demonstration effort of Service Argos PTTs, we are currently demonstrating Global Positioning System (GPS) PTTs that have been developed through support from the DoD's Strategic Environmental Research and Development Program (SERDP). Three GPS PTTs are being deployed on oryx at WSMR to demonstrate their utility for wildlife management on military lands. The GPS PTTs will provide higher quantities of location fixes, as well as enhanced accuracy of locations, typically to within 100 meters or less. The results of the current demonstration will be compared to those of the original WSMR demonstration reported herein.

MANAGEMENT IMPLICATIONS

Location data obtained via satellite demonstrated that WSMR biologists can use satellite telemetry technology to answer a variety of wildlife management questions. For example, telemetry via satellite could be used to answer the following management questions:

- What is the annual home range of oryx at WSMR?
- What is the seasonal habitat use of oryx at WSMR?
- How do oryx movements relate to the War Impact Target?
- Do oryx and pronghorn use the same foraging habitat at WSMR?

RECOMMENDATIONS

Although the PTT collar material has proven adequate for other ungulates, oryx were able to remove three of the seven collars. Therefore any future oryx collars should be more heavily reinforced

ACKNOWLEDGEMENTS

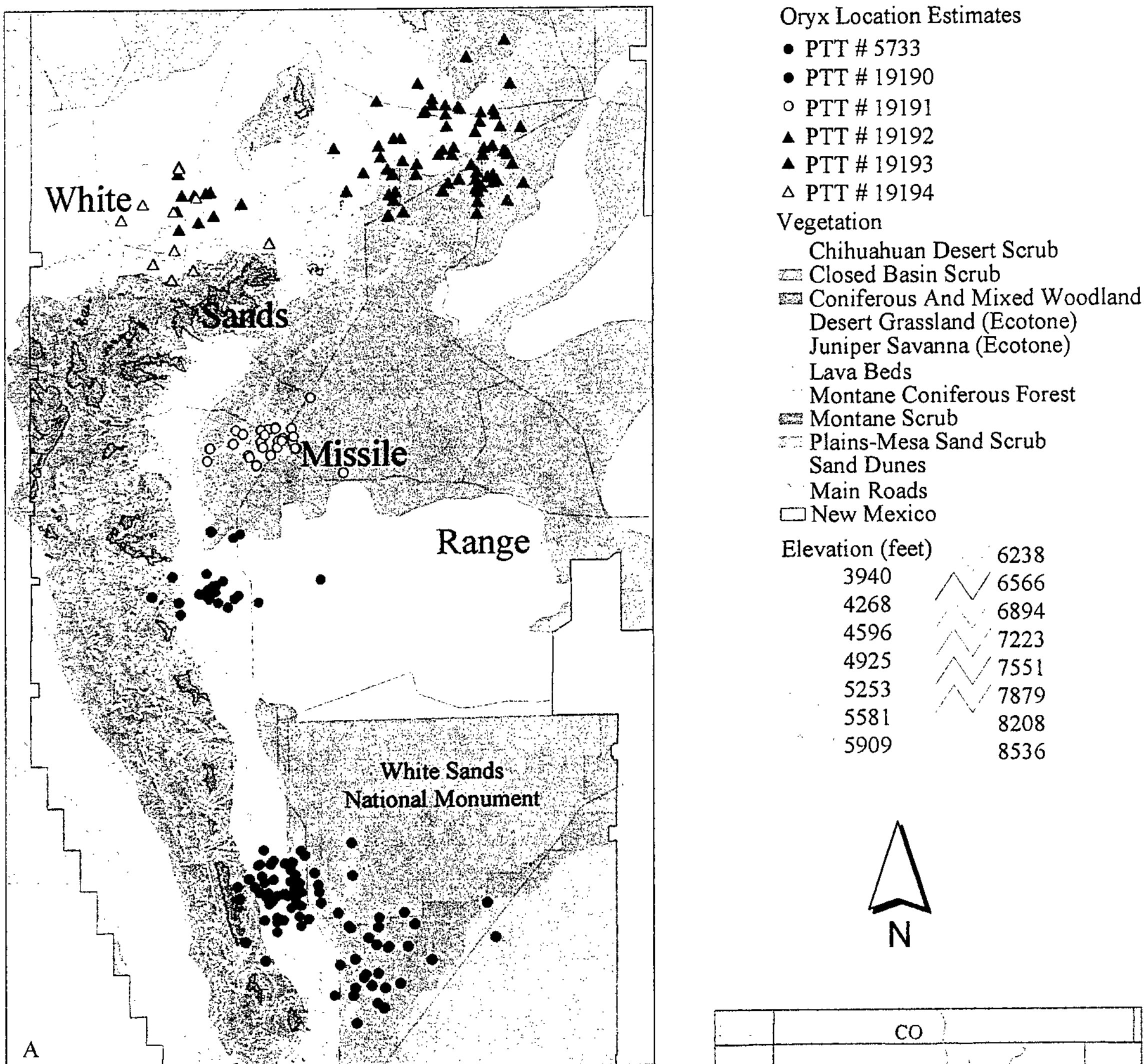
We thank Patrick Morrow, and Janet Greenlee of WSMR for their ongoing interest and support of the project; Lee Duff, Patrick Snyder, Darryl Wyebright, and the New Mexico Game and Fish Department for their excellent support of the tagging effort; Philip Zwank of New Mexico State University and the NBS; and Susan Jojola Elverum, also of NMSU, for her work in conventional radio tracking.

Table IV-1 Oryx Capture Data

PTT ID/CHANNEL #	5732(27)	5733(30)	19190(34)	19191(37)
EAR TAGS L/R	42	41	none	none
SEX	Male	Female	Female	Male
CONV. TX MHz	150.267	150.3	150.34	150.372
DATE	3/27/96	3/27/96	5/18/96	5/18/96
TRAP TECHNIQUE	OH1	OH1	veh./dart gun	veh./dart gun
LOC. DESCRIPTION	San Andres Canyon	Hembrillo Canyon	Baird Ranch gate	Rhodes Canyon
GPS LOCATION	32.714N 106.514W		32.657N 106.414W	33.156N 106.499W
		MEASUREMENTS (INCHES)		
EAR LENGTH L/R			8.0/8.0	/8
SHOULDER HEIGHT			51	52
FACE LENGTH	16		15	15
GIRTH			58	65
HIND FOOT L/R	/21		20/19	/17
TAIL LENGTH	31 with hair		18	17
BODY LENGTH			56	63
NECK CIRCUMFERENCE	32		25	35.5
HORN LENGTH L/R	36.5/37			32.5/24(broken)
HORN BASAL L/R	6.75/6.75		7.0/6.0	7/6.5

PTT ID/CHANNEL #	19192(43)	19193(47)	19194(40)
EAR TAGS L/R	None	none	none
SEX	Female	Male	Female
CONV. TX MHz	150.431	150.469	150.399
DATE	5/18/96	5/18/96	5/18/96
TECHNIQUE	veh./dart gun	veh./dart gun	veh./dart gun
LOC. DESCRIPTION	1m W of 9&8 junct.	Burris Well Rd./Martin Tank	Poison Hills
GPS LOCATION	33.442N 106.295W	33.427N 106.568W	33.156N 106.605W
		MEASUREMENTS (INCHES)	
EAR LENGTH L/R	8.5/10	9.75/10	/9
SHOULDER HEIGHT			52
FACE LENGTH	17	16	15
GIRTH	51	54	64
HIND FOOT L/R	/18	/14	19.5/19
TAIL LENGTH	27	31	17
BODY LENGTH	52.25	48	63
NECK CIRCUMFERENCE	24	25	26
HORN LENGTH L/R	38/37.875	33.5/31.25	35/35
HORN BASAL L/R	6.75	7.5	/6

Oryx Location Estimates
White Sands Missile Range
April 3,1996 to May 9, 1997



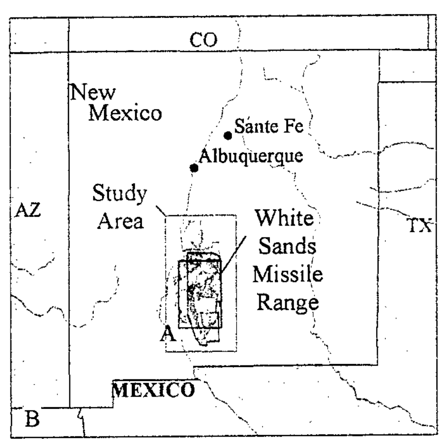
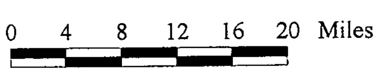


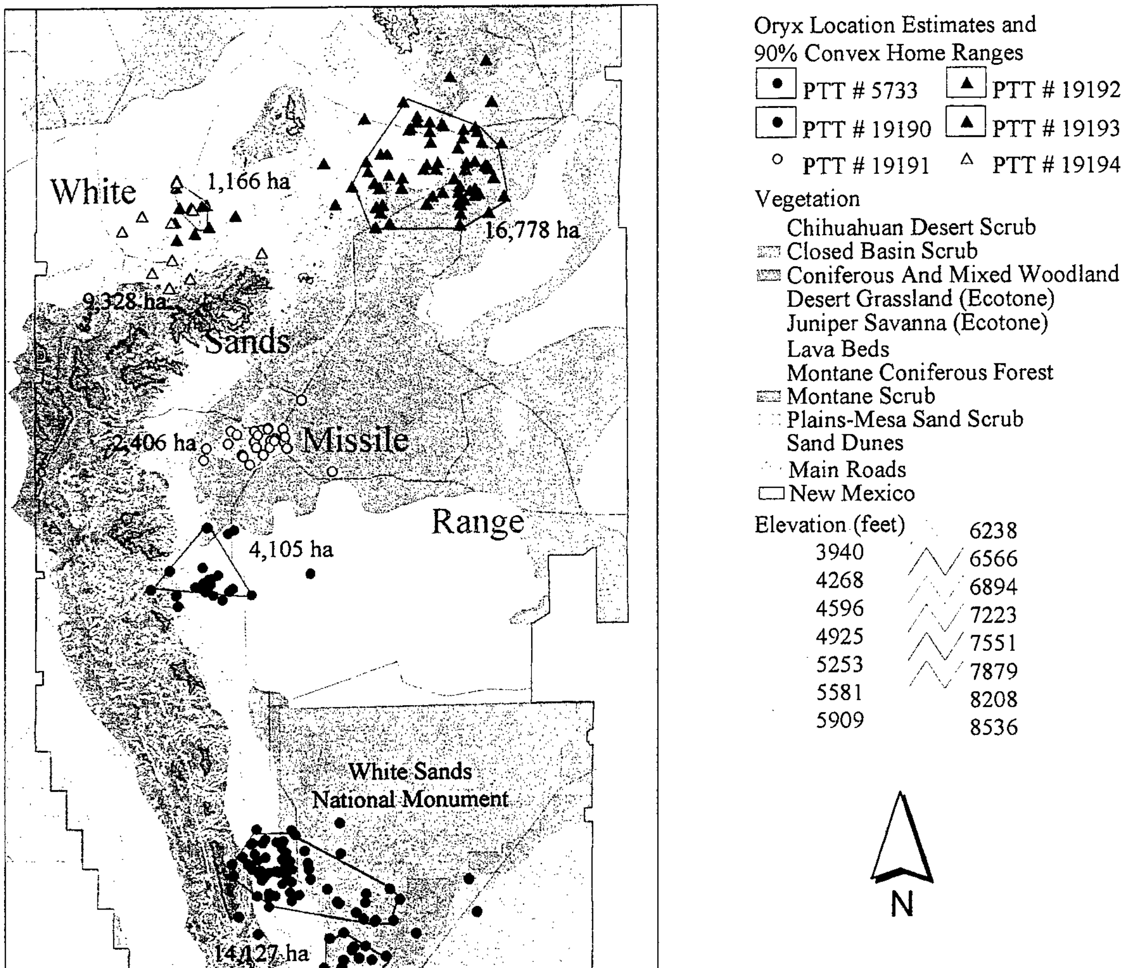
Figure IV-1. Oryx Location Estimates and Reference Information

A. Vegetation and all Oryx location estimates.

B. Reference.



Oryx Location Estimates
White Sands Missile Range
April 3, 1996 - May 9, 1997



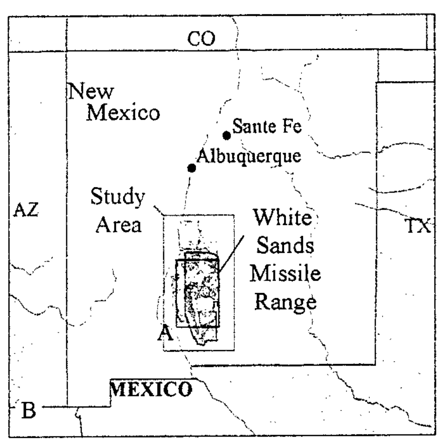


Figure IV-2. Oryx Location Estimates, Convex Home Ranges, and Reference Information

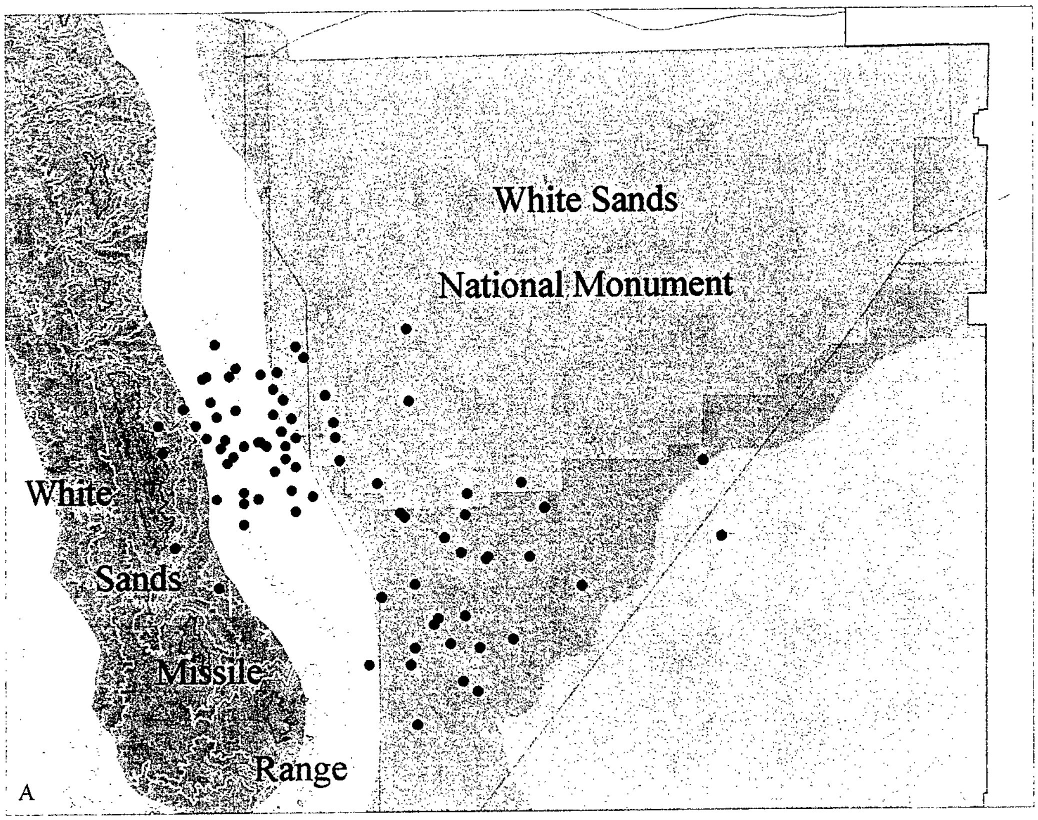
A. Vegetation and all Oryx location estimates plus convex home range polygons based on 90% of Argos location estimates.

B. Reference.

Oryx PTT# 19190 Location Estimates

White Sands Missile Range

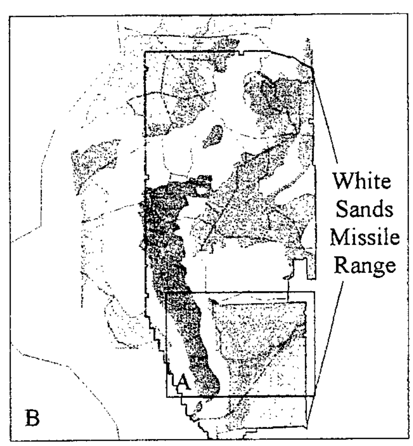
May 18, 1996 - May 9, 1997



Vegetation
- Chihuahuan Desert Scrub
- Closed Basin Scrub
- Coniferous And Mixed Woodland
- Desert Grassland (Ecotone)
- Juniper Savanna (Ecotone)
- Lava Beds
- Montane Coniferous Forest
- Montane Scrub
- Plains-Mesa Sand Scrub
- Sand Dunes
- Main Roads
- New Mexico

• PTT # 19190

Elevation (feet)	
	5909
3940	6238
4268	6566
4596	6894
4925	7223
5253	7551
5581	7879



N

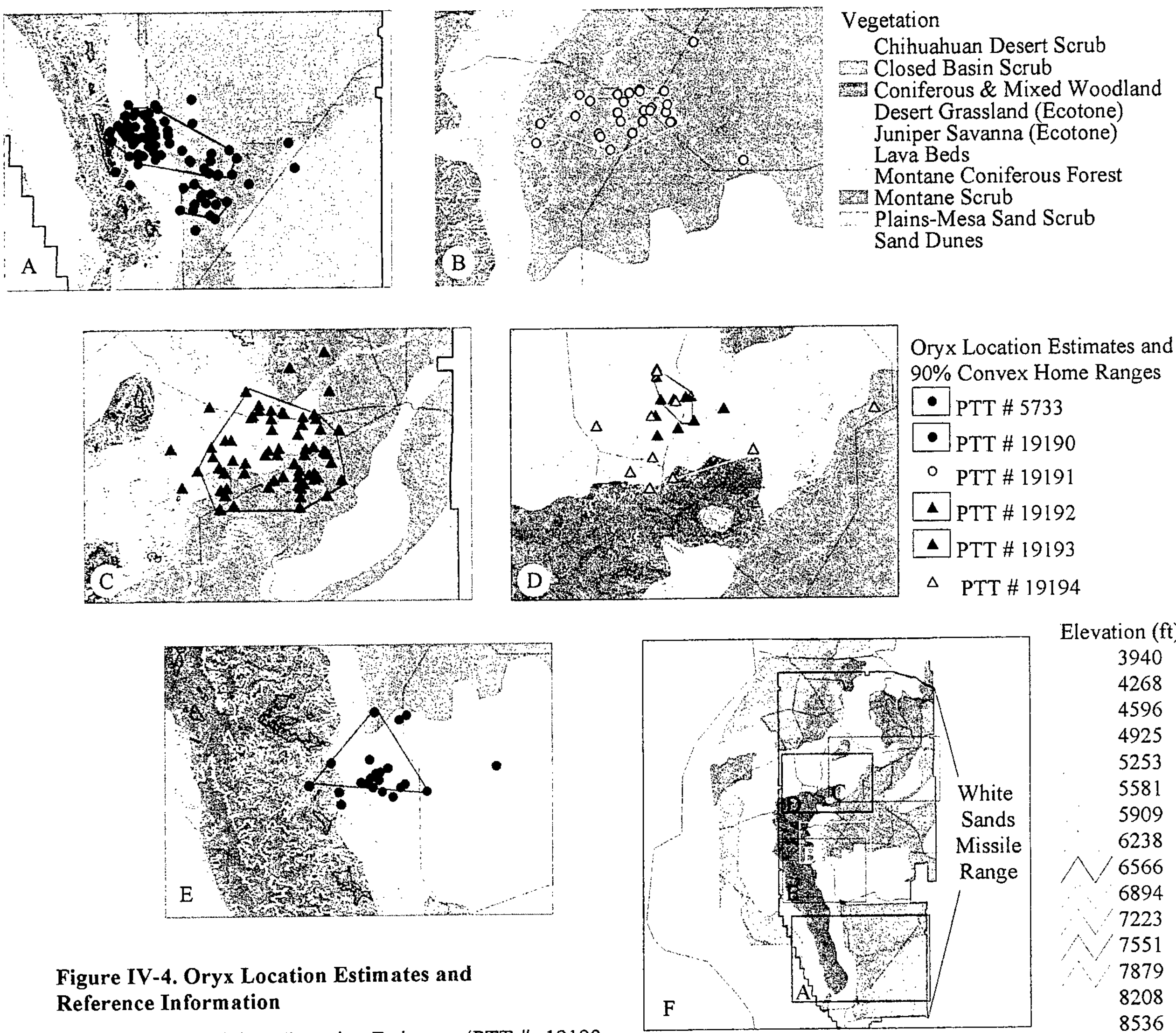
0 4 8 12 16 Miles

Figure IV-3. Oryx PTT# 19190 Location Estimates and Reference Information

A. Vegetation and Oryx PTT# 19190; shows location vincinity of White Sands National Monument.

B. Reference.

Oryx Location Estimates
White Sands Missile Range
April 3, 1996 - May 9, 1997



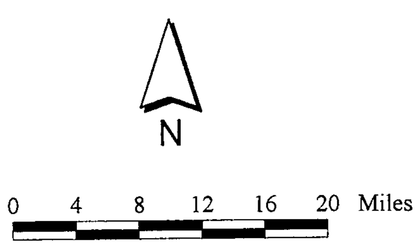


Figure IV-4. Oryx Location Estimates and Reference Information

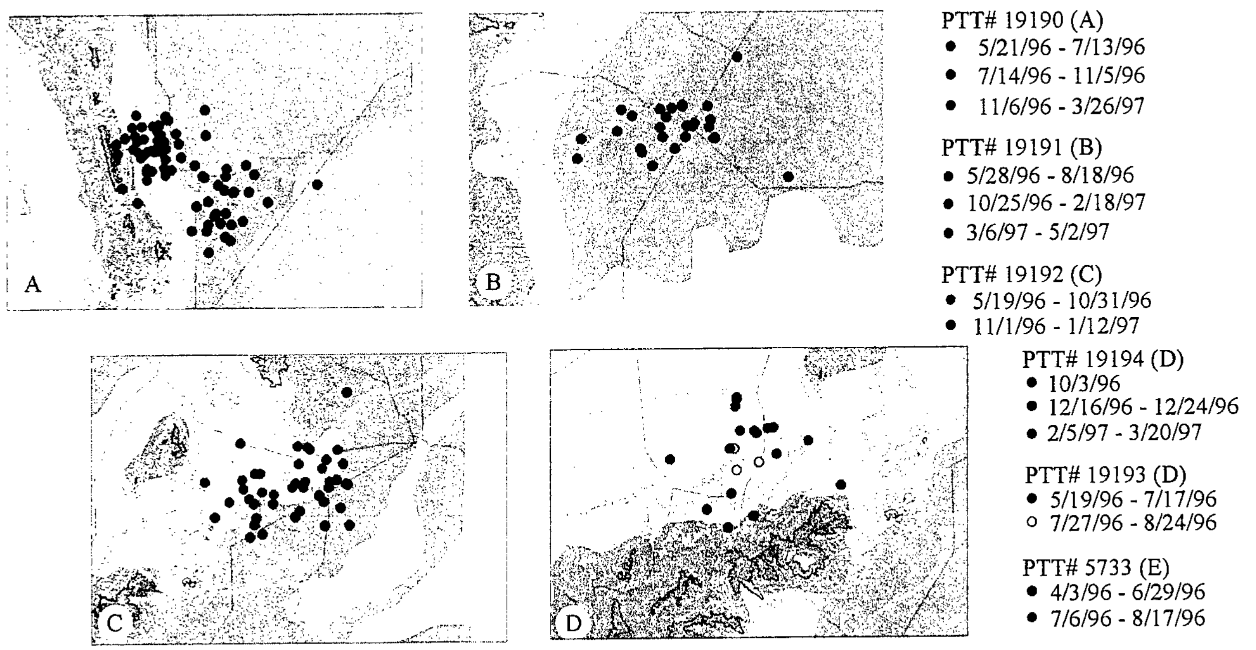
A, B, C. Individual Oryx Location Estimates (PTT #s 19190, 19191, and 19192, respectively). All animals located in the White Sands Basin.

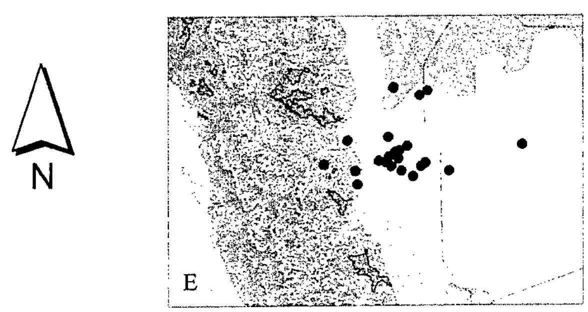
D. PTT #19194 was on an animal tagged in the Poison Hills area, also characterized by steep hills. PTT #19193 was on an animal located in an open area of the Joranda at approximately 5000' elevation.

E. PTT #5733 was on an animal located on the east side of the San Andres Mountains, with access to deep canyons.

F. Reference.

Oryx Location Estimates
White Sands Missile Range
April 3, 1996 - May 9, 1997





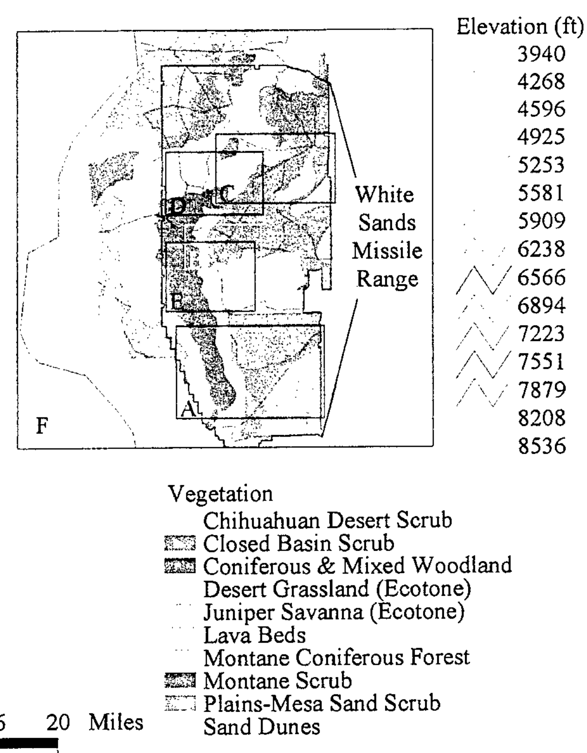


Figure IV-5. Oryx Location Estimates separated by date ranges. Most PTT location estimate datasets can be analyzed by date to display distinct seasonal use areas.

A. Individual Oryx Location Estimates PTT #19190.

B. Individual Oryx Location Estimates PTT #19191.

C. Individual Oryx Location Estimates PTT #19192.

D. Individual Oryx Location Estimates PTTs #19193 and #19194.

E. Individual Oryx Location Estimates PTT #5733.

F. Reference.

PARTNERS IN FLIGHT

Travel Routes and Distances of Migrating Peregrine Falcons (*Falco peregrinus*) and Swainson's Hawks (*Buteo swainsonii*) in the Western Hemisphere

Abstract: We describe and contrast the migration routes, length of migration, and duration of migration of peregrine falcons (*Falco peregrinus*) and Swainson's hawks (*Buteo swainsoni*) in the Western Hemisphere. We radio tracked migrants using the Argos satellite system as part of our Partners in Flight studies to conserve Neotropical migrants. Our initial samples were 34 Swainson's hawks from representative areas of their breeding range, and 61 peregrine falcons captured at nest sites across the North America boreal forest and low Arctic or on the migration routes along the mid-Atlantic and Gulf of Mexico coasts. Peregrine falcons used at least 3 broad, general routes south from the breeding areas, and individuals have stopped migrating as far north as the U.S.A. mid-Atlantic coast and as far south as central Argentina. The radiomarked peregrine falcons have used coastal routes, mid-continental routes, and water-crossing routes: the Davis Strait and Caribbean Sea. During northward migration, peregrines radio marked at Padre Island Texas, U.S.A. diverge for destinations from central Alaska, U.S.A. across the continent to west-central Greenland. In contrast, Swainson's hawks converged in eastern Mexico on the Gulf of Mexico coast. Southward, these hawks followed a narrow, well-defined path through Central America, across the Andes Mountains in Columbia, and east of the Andes to central Argentina where they all spent the austral summer. Swainson's hawks' northward migration largely retraced their southward route.

INTRODUCTION

In this section, we describe the difference in migration patterns of two species of raptors with different flight behavior; predominately soaring flight by Swainson's hawks and predominately flapping flight by peregrine falcons. We also relate our results to the larger conservation vision of Partners in Flight, especially as it relates to Neotropical migratory raptors.

The process of natural resource management and planning begins with a thorough inventory and description of a natural system's flora and fauna. A central component of effective planning and management is the acquisition of comprehensive scientific information on: (1) highly mobile species (such as migratory birds or other widely ranging animals); (2) rare, elusive, sensitive, threatened, or endangered species (as well as candidate species); (3) species of concern or otherwise special management species, such as exotics or big game species; and (4) animals that frequent inaccessible habitats or extremely rugged terrain. Species inventory and monitoring is a difficult and time consuming effort in itself. Gathering substantial management information—such as habitat delineations, range analyses, key species interactions, and impact assessments—often requires intensive study over many years at a level of effort that may not be feasible with conventional, low technology approaches.

This is especially true for migratory birds that cross geo-political boundaries seasonally and must be managed (by law in the U.S. under the Migratory Bird Treaty Act of 1918) at both ends of their migrations and all important points along migration routes. Each year millions of birds representing hundreds of species cross dozens of geo-political boundaries during their migration from their North American breeding grounds to milder climates in Central and South America and the Caribbean. During migration, these birds stop to rest and feed in areas that provide resources to shelter them and to fuel their flight. These "stopover" areas constitute critical habitat for many species. Without continual management of these habitats, substantial loss of avifauna could result. In fact, many of these species are declining in numbers annually. Threats to migratory species can occur anywhere along migration routes. Pinpointing problems or reasons for a species' decline is often extremely difficult as a result.

Radio tracking via satellites offers a capability to track individual animals very closely to provide the kinds of data that are necessary for effective resource management planning and conservation. Satellite-based tracking and monitoring techniques provide unique advantages over other techniques and methods in a variety of applications. For example, information on migratory species could not be cost effectively gathered from their entire ranges in any other way.

METHODS

Individuals were captured and radio marked from autumn 1993 through the summer 1997. Method of capture varied by location and species. Satellite-received transmitters (Microwave PTT 100) weighing 20g or 30g were attached with backpack attachment methods. PTT transmission cycles generally were 8 hrs on, and the "sleep," or off, periods ranged from 1 – 6 days.

We used the Argos satellite system to radio track the birds. Argos is a polar orbiting system that collects and processes environmental data, including location estimates, from autonomous platform transmitter terminals (PTTs) and distributes the data to users. Argos sends processed data from the satellites to distribution centers for additional computing of the PTT location estimate, using principles of the Doppler Shift. Computed locations and sensor data (e.g., battery voltage, activity) are then distributed to users. Each location estimate is associated with a measure of accuracy; location accuracy (designated by location class, LC) is assigned by Argos and is determined using parameters of the satellite overpass and PTT position relative to the overpass. Standard locations are: LC 3, with an estimated accuracy <= 150 m; LC 2, with an estimated accuracy of 150 – 350 m; LC 1, with an estimated accuracy of 350 – 1000 m; and LC 0, with an estimated accuracy > 1000 m. LC 0, LC A, LC B, and LC Z location estimates have failed certain quality control checks; consequently, there is no upper limit on their accuracy. However, these latter locations are available upon request and we used them because data with estimated accuracy <1000 m can be sparse, and the scale at which we were working (the Western Hemisphere) is compatible with the additional possible error.

We categorized each location estimate as having been obtained during a northward migration, a southward migration, or on a breeding area or a "winter" area (austral summer south of the equator). We defined the start of a migration as the first location after which all subsequent locations occurred away from the breeding, wintering, or migration capture site (a uni-directional movement). Likewise, we defined the end of migration as the point after which all subsequent points were localized (non-directional movement). Typically there was a lapse of at least 48 hours between the 8 hour transmitting cycles, therefore the first or last location estimate during migration usually was easily discernable because of the relatively long distance moved during migration compared to proximity of locations in the breeding or wintering area. If we ceased to obtain location estimates before we received multiple days of localized location estimates from a PTT, we categorized that migration data set as incomplete. Likewise, if a migration ended with a PTT activity sensor indicating that the PTT had ceased all motion, we presumed that the PTT had fallen off or that the bird had died, and thus categorized the migration as incomplete.

Our analyses of rates of migration are based on one location estimate selected from each transmission cycle for each bird (during some cycles, no location estimates were obtained). Within each transmission cycle for each bird, we selected the representative location estimate based on the LC (in order of preference: 3, 2, 1, A, B, Z). If there was more than 1 location estimate with the preferred LC within the cycle, the first one acquired was selected as the representative location. Visual inspection of the estimates was the basis for removing obvious outliers from the data.

We calculated the distance traveled (km) from a representative location estimate to the subsequent representative location estimate by converting the geographic data (decimal degree) to Robinson projection of the world and calculating the distance, thereby obtaining a distance traveled between successive pairs of representative location estimates for each bird. Rates of travel between pairs of representative location estimates (km/d) were calculated by determining the time between each representative location estimate and its predecessor (in days) and dividing the distance traveled by the number of days it took to travel that distance.

The total number of days from the last day that a bird's location was recorded at the departure point (breeding, wintering, migration survey location) to the day it was first recorded at the destination at the other end of the migration was divided by 3 for full migration data sets (breeding to wintering or vice versa) and 2 for partial migrations (migration capture location to wintering or breeding area) to delimit "segments" of migration as 1st third or 'early', 2nd third or 'mid', and last third or 'late'.

We compared the cumulative distance traveled (the sum of all the segments) for each individual with the shortest distance between the beginning and the end of the migration (the straight line distance between the first and last representative migration location estimates) for all complete migrations using paired T-tests. We analyzed the following 7 subsets of the data: each species northward and southward migration separately (4 tests), each species combined northward and southward migrations (2 tests), and the entire data set (species combined).

We used the rate of travel data that are associated with the segments of the migrations to describe the pattern of the rate of travel, as well as to compare rates of travel *per se*. By pattern, we mean the general tendency for the rate of travel through all the segments. We tested for similarities of patterns between species or between northward and southward migration. Rates of travel for complete migrations were compared among species (peregrine falcon, Swainson's hawk) and direction of travel (north, south) using 2-factor repeated measures ANOVA with the segment of the migration as the repeated measure.

We then compared rates between direction of travel for the 2 species separately and rates between the species for the 2 directions of travel separately using 1-factor repeated measures ANOVAs; the segment of the migration was the repeated measure for both analyses. We used orthogonal contrasts to test for differences among the three segments of migration for each of the 4 species and direction combinations. Rates of travel for partial migrations were compared for peregrine falcons only (no Swainson's hawks were captured on migration).

RESULTS

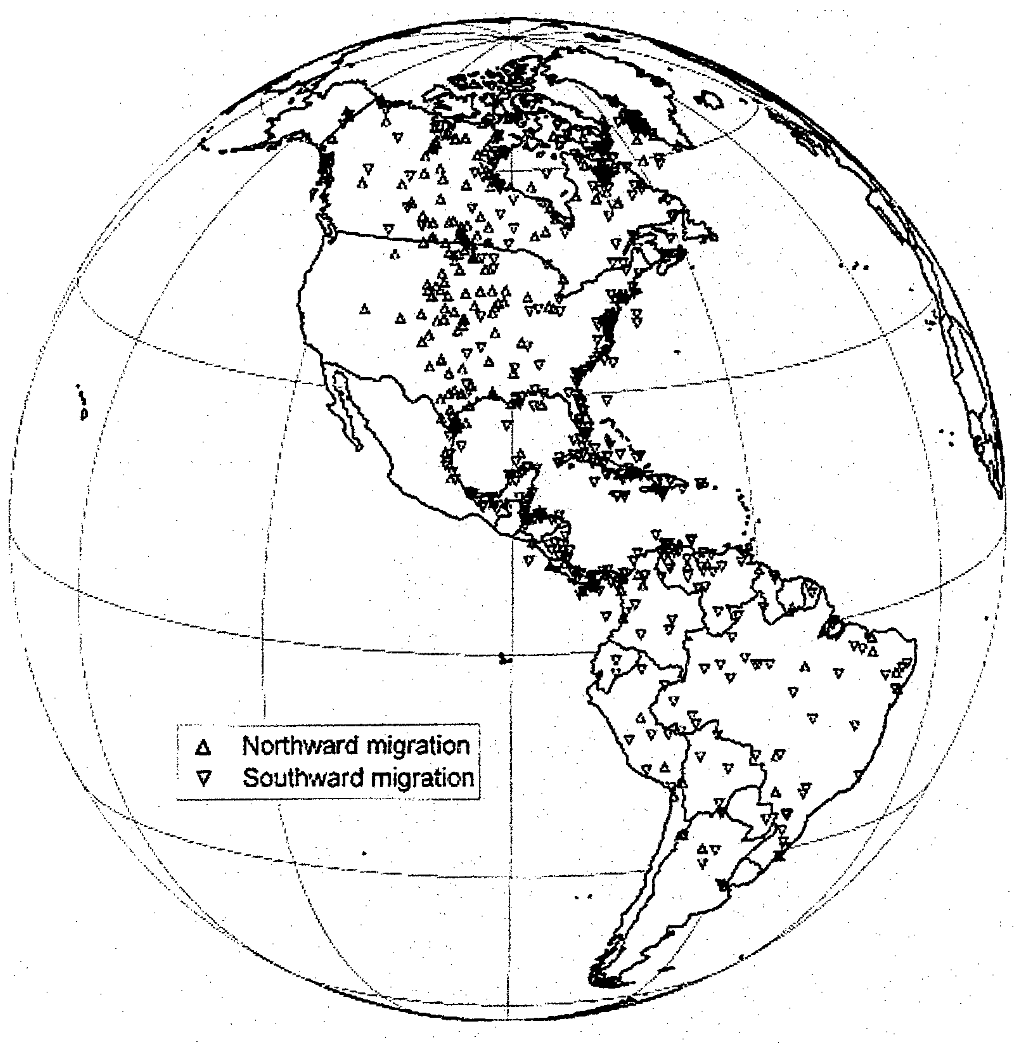
We captured 57 peregrine falcons and 34 Swainson's hawks. Of the peregrine falcons, 3 individuals were radiomarked with 20 g PTTs and 54 were radio marked with 30 g PTTs; 2 were after hatch year (AHY) males, 55 were AHY females; 31 were marked on migration at Padre Island or Assateague Island; 26 were marked on breeding grounds in Greenland, Quebec, or the Northwest Territories (Table V-1). We marked all of the Swainson's hawks with 30 g PTTs, in breeding range in 8 states and provinces; all were AHY and the sex distribution was unknown (Table V-1). We omitted 17 peregrine falcons and 7 Swainson's hawks from analyses because we did not obtain a migration track from an origin (breeding area, migration capture site) to a destination (breeding area, winter area).

Table V-1. Locations and year of capture and radio marking of peregrine falcons (PEFA) and Swainson's hawks (SWHA).

		YEAR				
SPECIES	LOCATION	1993	1994	1995	1996	1997
PEFA						
	KANGERLUSSUAQ, GREENLAND		8		2	6
	ASSATEAGUE ISLAND, MD/VA	2	5	2	3	
	PADRE ISLAND, TX		12	2	3	2
	RANKIN INLET, NT		4			
	LEAF PASS, PQ		4			
	KOKSOAK, PQ		2			
SWHA	IDAHO			4	6	
	UTAH				3	
	CANADA				7	
	ARIZONA				2	
	OREGON				6	
	CALIFORNIA				1	
	COLORADO				3	
	MINNESOTA				2	

Peregrine falcons -- We obtained 21 complete and 14 partial southward migration tracks and 7 complete and 11 partial northward migration tracks of peregrine falcons (Table V-2). Overall, southward tracks are over a broad front, including coastal and inland routes over large landmasses, with frequent use of water crossings over the Gulf of Mexico and Caribbean Sea (Fig. V-1). Winter destinations ranged from 40° N to 40° S latitude and 36° to 98° W longitude. Conversely, northward routes tended to be inland until the Texas Gulf Coast, where they fanned out to various northern destinations; north routes rarely included water crossings.

Figure V-1: Peregrine falcon migration.



Swainson's hawks – We obtained 27 complete southward and 19 complete northward migration tracks of Swainson's hawks (Table V-2). Southward and northward routes followed a similar track, almost entirely inland except through Central America. There were no crossings of large bodies of water (Fig. V-2). Relative to the falcons, Swainson's hawks used the same region during the winter (30° - 40° S latitude; 61° to 64° W longitude).

Fig. V-2: Swainson's Hawk migration

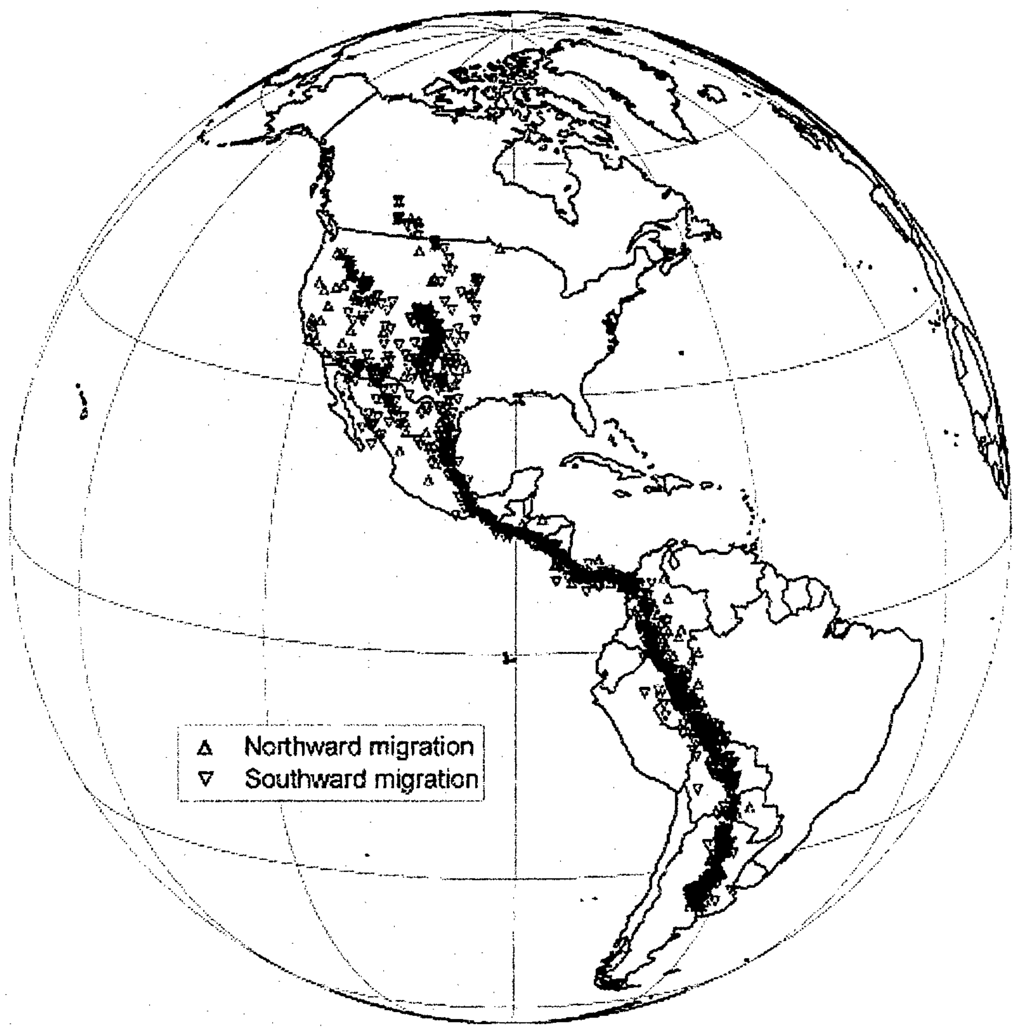


Table V-2. Sample sizes and mean rates of travel for peregrine falcons (PEFA) and Swainson's hawks (SWHA).

DATA TYPE	PEFA	SWHA
N INDIVIDUALS TAGGED	57	34
N INDIVIDUALS USED IN ANALYSES	40	27
N ONE-WAY ORIGIN TO DESTINATION (N or S)	28	46
N PARTIAL S	14	
N PARTIAL N	11	
N DISTANCE TOTAL MIG S	21	27
N DISTANCE TOTAL MIG N	7	19
MEAN TOTAL PARTIAL DISTANCE S	6,978.29	
MEAN TOTAL PARTIAL DISTANCE N	6,732.56	
MEAN TOTAL COMPLETE DISTANCE S	8,843.32	12,000.24
MEAN TOTAL COMPLETE DISTANCE N	9,610.21	12,047.82
MEAN SEGMENT DISTANCE S	850.21	586.89
MEAN SEGMENT DISTANCE N	1,181.59	946.01
MEAN RATE S	179.55	167.43
MEAN RATE N	229.65	150.49
FULL MIGRATION		
RATE 1st SEGMENT S	153.02	124.33
RATE 2nd SEGMENT S	182.28	191.19
RATE 3rd SEGMENT S	195.53	186.78
RATE 1st SEGMENT N	234.22	117.44
RATE 2nd SEGMENT N	261.1	186.87
RATE 3rd SEGMENT N	193.63	147.16
PARTIAL MIGRATION		
RATE 1st SEGMENT S	180.72	
RATE 2ndSEGMENT S	170.07	
RATE 1st SEGMENT N	166.74	
RATE 2ndSEGMENT N	192.91	

Analyses of full migration – Regardless of direction, routes taken by migrating peregrine falcons and Swainson's hawks did not reflect the shortest distance between breeding and wintering areas (Table V-3). Overall, the pattern in rates of travel across the 3 segments of full migration (early, mid, late) on northward migration compared to southward migration did not differ depending on the species. Given this result (i.e., no "species effect"), we can examine species separately to isolate differences in patterns of rate of travel among segments of migration. There is no significant difference in the pattern of rates of travel between north and south migrations of peregrine falcons and Swainson's hawks. Additionally, Swainson's do not travel at different rates on southward than on northward migration. Peregrine falcons, however, travel faster on northward than on southward migration.

Table V-3. Results of T tests comparing the cumulative distance traveled (the sum of all segment of travel) with the direct (or shortest possible) distance traveled (the straight-line distance between origin and destination).

Test		N	Mean Cumulative Distance	Mean Direct Distance	Mean difference (SD)	95% Confidence Interval	t	d.f.	P
All		74	10877.01	9486.39	1390.62 (869.87)	1189.09 – 1592.16	13.75	73	<0.000
SWHA	All	46	11998.21	10648.80	1349.41 (641.75)	1158.85 – 1539.99	14.26	45	<0.000
	North	19	11995.34	10686.99	1308.34 (676.68)	982.20 – 1634.50	8.43	18	<0.000
	South	27	12000.28	10621.92	1378.32 (627.46)	1130.10 – 1626.53	11.41	26	<0.000
PEFA	All	28	9035.04	7576.72	1458.33 (1162.65)	1007.50 – 1909.15	6.64	27	<0.000
	North	7	9610.21	7737.38	1872.83 (1010.43)	938.34 – 2807.32	1.90	6	=0.003
	South	21	8843.38	7523.16	1320.16 (1199.33)	774.23 – 1866.09	5.04	20	<0.000

Examining northward migration separately from southward migration, we can compare patterns of rate of travel between species. There is no difference between species in patterns of their rates of travel among segments of the migration in either direction. The 2 species traveled at the same rates on southward migration, but on northward migration, peregrine falcons traveled at a greater rate than did Swainson's hawks.

Considering each direction of travel for each species, comparisons among segments of travel reveal that there were no differences in rates of travel among segments for either north or south migration of peregrine falcons. However, over all segments the rate of travel increased as peregrines approached the winter areas (Fig. V-4). There is no such trend in peregrines' northward migrations (Table V-4). Swainson's hawks travel more slowly in the beginning of their southward migrations, whereas the rates of travel in the middle and end segments of migration are similar (Table V-4). On northward migrations, they travel slower at the beginning of the migration than in the middle segment, but then reduce their rate of travel as they near their breeding grounds to a rate similar to those in the first segment.

Table V-4. Results of contrasts among segments of complete migration. Analyses were done separately for each direction of travel for each species.

SPECIES	DIRECTION	EARLY - MID	MID - LATE	EARLY – LATE
Peregrine	South	$F_{2,19} = 1.04$, $P = 0.37$	$F_{2,19} = 0.69$, $P = 0.51$	$F_{2,19} = 2.13$, $P = 0.15$
falcon		160.843 km/d	182.281 km/d	195.525 km/d
	North	$F_{2,5} = 0.27$, $P = 0.77$	$F_{2,5} = 0.56$, $P = 0.60$	$F_{2,5} = 1.10$, $P = 0.40$
		234.221 km/d	261.101 km/d	193.626 km/d
Swainson's	South	$F_{2,25} = 12.67$, $P < 0.001$	$F_{2,25} = 0.08$, $P = 0.92$	$F_{2,25} = 8.08$, $P < 0.01$
Hawk		124.331 km/d	191.185 km/d	186.783 km/d
	North	$F_{2,17} = 5.03$, $P = 0.02$	$F_{2,17} = 2.42$, $P = 0.12$	$F_{2,17} = 1.04$, $P = 0.37$
		117.442 km/d	186.876 km/d	147.160 km/d

Table V-4a. A different way of visualizing the contrasts (same letter = similar speeds).

SPECIES	DIRECTION	EARLY	MID	LATE
Peregrine falcon	South	A	A	A
	North	A	A	A
Swainson's Hawk	South	A		
			B	B
				C
	North	A		A
			B	B

Analyses of partial migration of peregrine falcons – The pattern in rates of travel for peregrine falcons from capture locations at migratory study sites on Padre Island and Assateague Island to breeding or wintering areas did not differ depending on whether the birds were traveling northward towards a breeding area or southward to a wintering area. Likewise, the overall rate of travel on northward migrations did not differ from rates on southward migrations. Within migrations of a given direction, there also was no difference in rates of travel.

DISCUSSION

The migration data described above is just a small fraction of the data CCRT has been collecting regarding Neotropical migrants. CCRT successfully developed a methodology and study protocol for application of satellite-based tracking to tundra peregrine falcons (*Falco peregrinus tundrius*, a formerly threatened Neotropical migrant) and Swainson's hawks (*Buteo swainsoni*, declining population) using the smallest available transmitters (20 gm) that interface with the Argos system. Peregrines frequent military bases across North America, while Swainson's hawks inhabit military lands throughout the western U.S. and Canada.

CCRT pioneered the application of space-based technology for the study of Neotropical migratory birds. Work on the tundra peregrine falcon is presently being conducted under the Legacy program to assist in the identification of key migratory and Neotropical habitat to support a wide variety of avian species common to both North and South America. This information will enable conservationists to identify key migratory and wintering habitats and to monitor these areas for the conservation of avian biodiversity.

SUCCESS STORY: UNDERSTANDING TUNDRA PEREGRINE FALCON MIGRATION PATTERNS

As part of the DoD's "Partners in Flight" activities, CCRT has applied dozens of commercially available 27gm and 20gm platform transmitter terminals (PTTs) since the autumn of 1993 to migrating tundra peregrine falcons (classified as "threatened" in the lower 48 states until 1997) along the coasts of Maryland and Virginia and the gulf coast of Texas. PTTs were also applied in peregrine breeding areas of Greenland and Eastern Canada. In only a few years, these transmitters, tracked via the Argos System, have provided more data of peregrine falcon migratory patterns than the past 25 years of conventional field studies and leg band returns. Scientists are now learning exactly where these birds travel, where they stop along their trek, and what threats may exist to their survival along the way. This research continues a tradition of DoD contributions to the recovery of endangered species, and in the case of peregrines, a wide-ranging species that occurs on military lands and training areas across the continent.

Results of this work have appeared in scientific publications and have been featured in radio and television news programs. This coverage and interest reveals the power of these advanced technology applications to collect valuable information on a globally distributed, transcontinental migrant.

Synopsis of CCRT's peregrine falcon research

CCRT's contribution to the development of satellite telemetry for use on Neotropical migrants stems from our endangered species program now in its twenty-eighth year. During the past three decades, we have conducted a comprehensive study of the tundra peregrine falcon *(Falco peregrinus tundrius)* throughout its breeding, migratory, and wintering range. Field research requirements to track and monitor this transcontinental Neotropical migrant shaped the development and application of low power, small Argos platform transmitter terminals (PTTs) now being used by scientists throughout the world.

We have conducted migration studies of the tundra peregrine and other sub-species on Assateague Island, VA, since 1970 and on Padre Island, TX, from 1978 to the present day. We have also conducted breeding ground research on the tundra peregrine falcon in West Central Greenland since 1972 near the town of Kangerlussauq, previously known as Sondrestrom U.S. Air Force Base. We have also conducted migration research on breeding tundra peregrines in Eastern Canada in Ungava Bay and along the Western shore of Hudson Bay at Rankin Inlet. We have conducted extensive research on the wintering biology of peregrine sub-species in Peru, Argentina, Chile, and Mexico. The application of satellite tracking for investigation of Neotropical avifauna migration patterns and wintering areas will constitute a major conservation tool into the next century.

Systematic collection of breeding ground biology and migratory information on these peregrines in Greenland, Assateague Island, and Padre Island has resulted in the marking of over 10,000 individuals. Our field research has documented the migratory population trends for this species over the past three decades, which can be related to a contiguous data base started in 1938 by North American falconer and naturalist, Alva Nye. This project constitutes the longest running continuous survey of peregrine falcons in North America.

Our studies of the breeding biology of the tundra peregrine in Greenland represents the most comprehensive, continuous breeding survey of the species outside the United States in this hemisphere. In Greenland we have studied the population dynamics of the peregrine, as well as many aspects of the breeding ground biology. Greenland has also been the site of our most thorough study of adult survival and their recruitment into the population. During the 1980's we were successful in demonstrating (through scientific means) an actual increase in the density of nesting pairs of Peregrines in our 3,000 square mile study area. Information from this program contributed significantly to understanding the recovery of the peregrine in North America after DDT induced declines. Today these valuable research and monitoring programs continue with exciting, ever changing research agendas. With new technologies and evolving field methods, we are now better able to understand and fully describe the intricate relationships which exist among key organisms — such as the peregrine falcon — their critical habitats, and their broad but declining avian prey base in the Americas.

SUCCESS: SCIENTIFIC RESEARCH RESCUES SWAINSON'S HAWK BEFORE THREATENED OR ENDANGERED STATUS LISTING IS NEEDED

CCRT's Legacy project contributed significantly to radio tracking of Swainson's hawks (SWHA) with satellite-based technology during 1995 and 1996. We monitored their distribution on and off military installations in the western U.S., where their numbers had been diminishing at an alarming rate for unknown reasons. The Swainson's hawk is listed as a species of concern by five states and the Bureau of Land Management, and as a special emphasis species by the U.S. Forest Service. Nesting population declines had been reported over much of the hawks' range, including Dugway Proving Grounds. With no obvious reason for this decline, scientists postulated that problems along migration routes or on wintering areas were responsible.

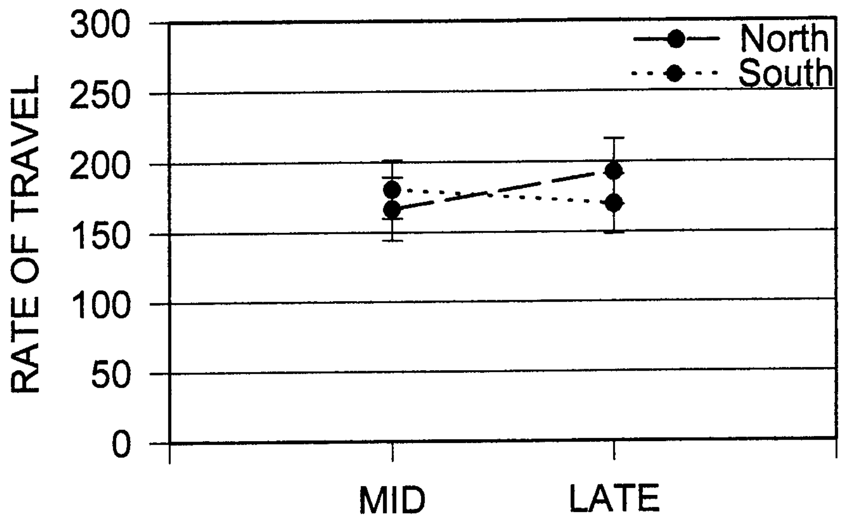
Four SWHA were marked with PTTs near the Idaho Army National Guard Orchard Training Area. SWHAs were also marked near Dugway Proving Ground, UT, Navy land holdings in Oregon, and the Rocky Mountain Arsenal (now a Fish and Wildlife Service refuge) in Colorado. The locations of these hawks were monitored on their North American breeding grounds, Argentinean wintering grounds, and along migration routes. Results of the satellite telemetry study revealed that large numbers of this species, in fact thousands at a time, were being killed on their South American wintering grounds.

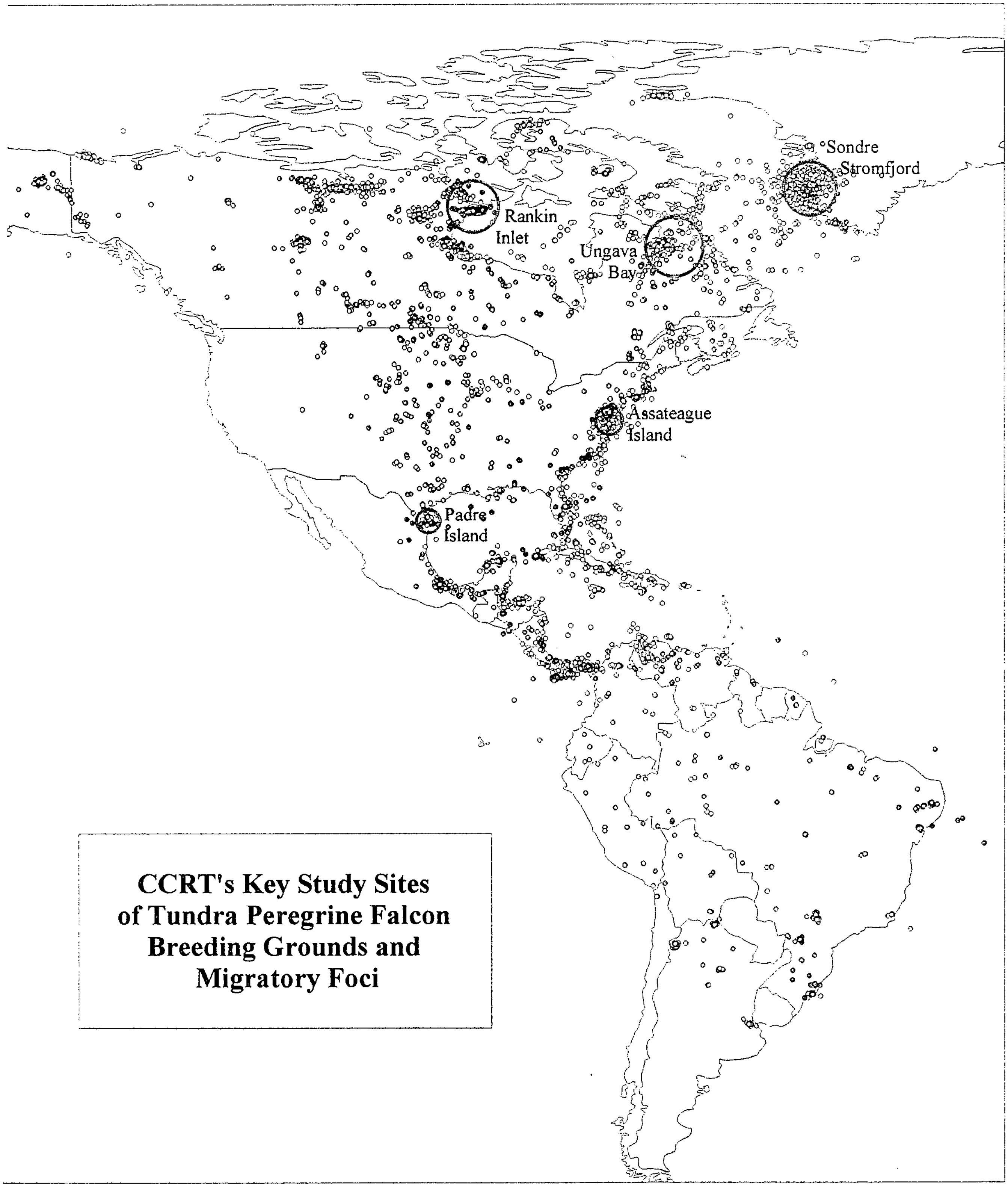
In January of 1996, scientists visited different areas indicated by the satellite derived location data. They counted over 4,000 dead SWHA, killed as an apparent side effect of pesticide applications to croplands, and these scientists believed the actual mortality numbers may have exceeded 20,000. Since adults represented nearly 90% of the dead birds and the entire Canadian SWHA population is estimated between 20–40,000 pairs, this loss represented a serious threat to the survival of the species.

It turned out that this catastrophic population decline resulted from the use of a toxic organophosphate pesticide, recently brought into use on the pampas of Argentina where these hawks winter in communal roosts. Through the use of remote tracking and monitoring technology, this environmental problem was identified and, within 18 months, remedied through collaborative government and private sector management and education. Keeping this raptor off the endangered species list saved millions of federal dollars by avoiding costly large-scale research and recovery programs and related habitat management activities in North America. This application of wildlife tracking via satellite is a perfect demonstration of the unique advantage this technology can provide in the study of a wide-ranging species.

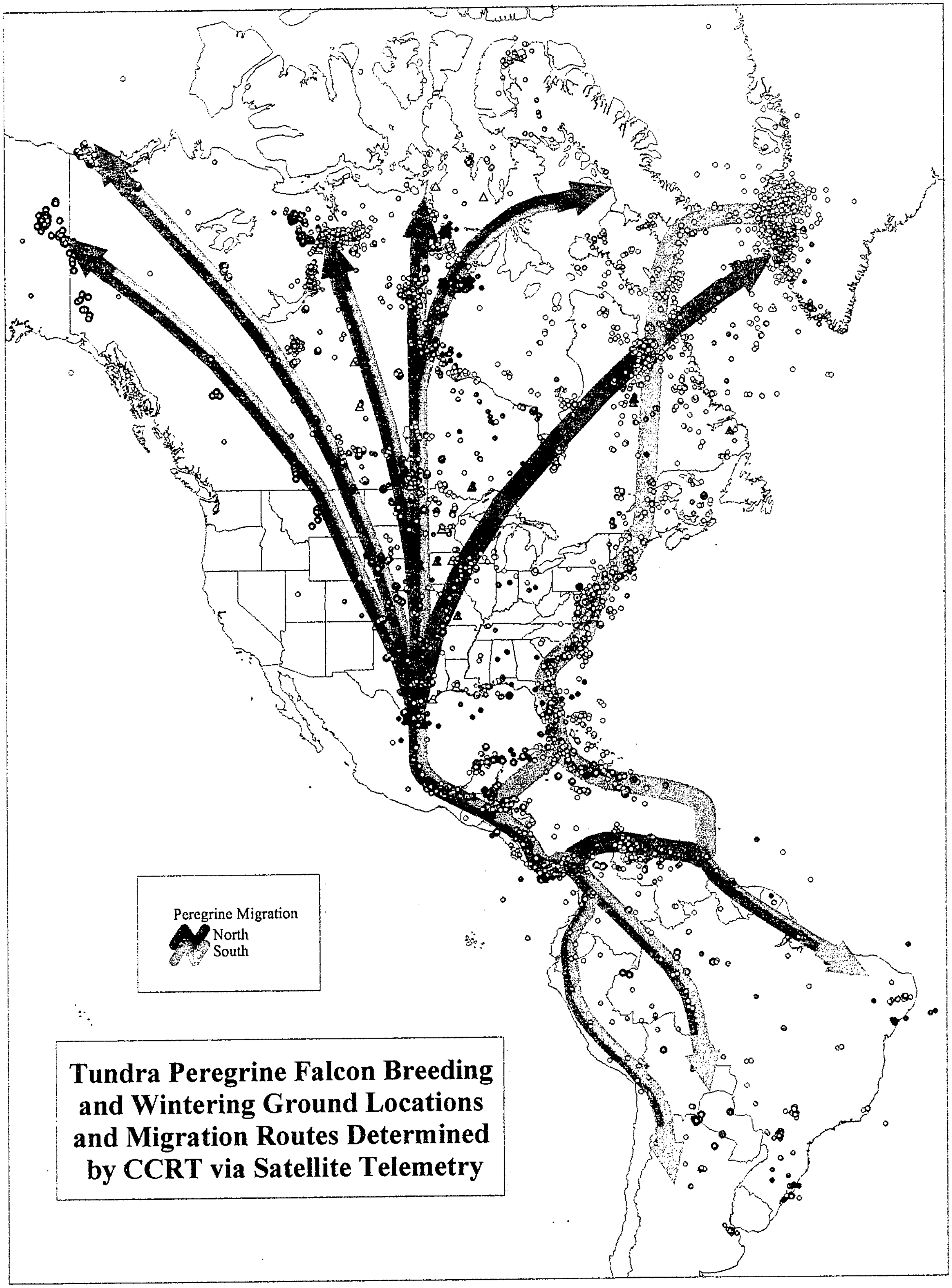
Acknowledgments -- The capture and marking of peregrine falcons was accomplished largely by T. Maechtle and M. Yates. Others who helped capture peregrines were J. Dayton. Invaluable field support was provided by W. G. Mattox, D. Bird, and R. Johnstone. The governments of Greenland and Denmark assisted with permits. The National Park Service and the U.S. Fish and Wildlife Service also provided assistance.

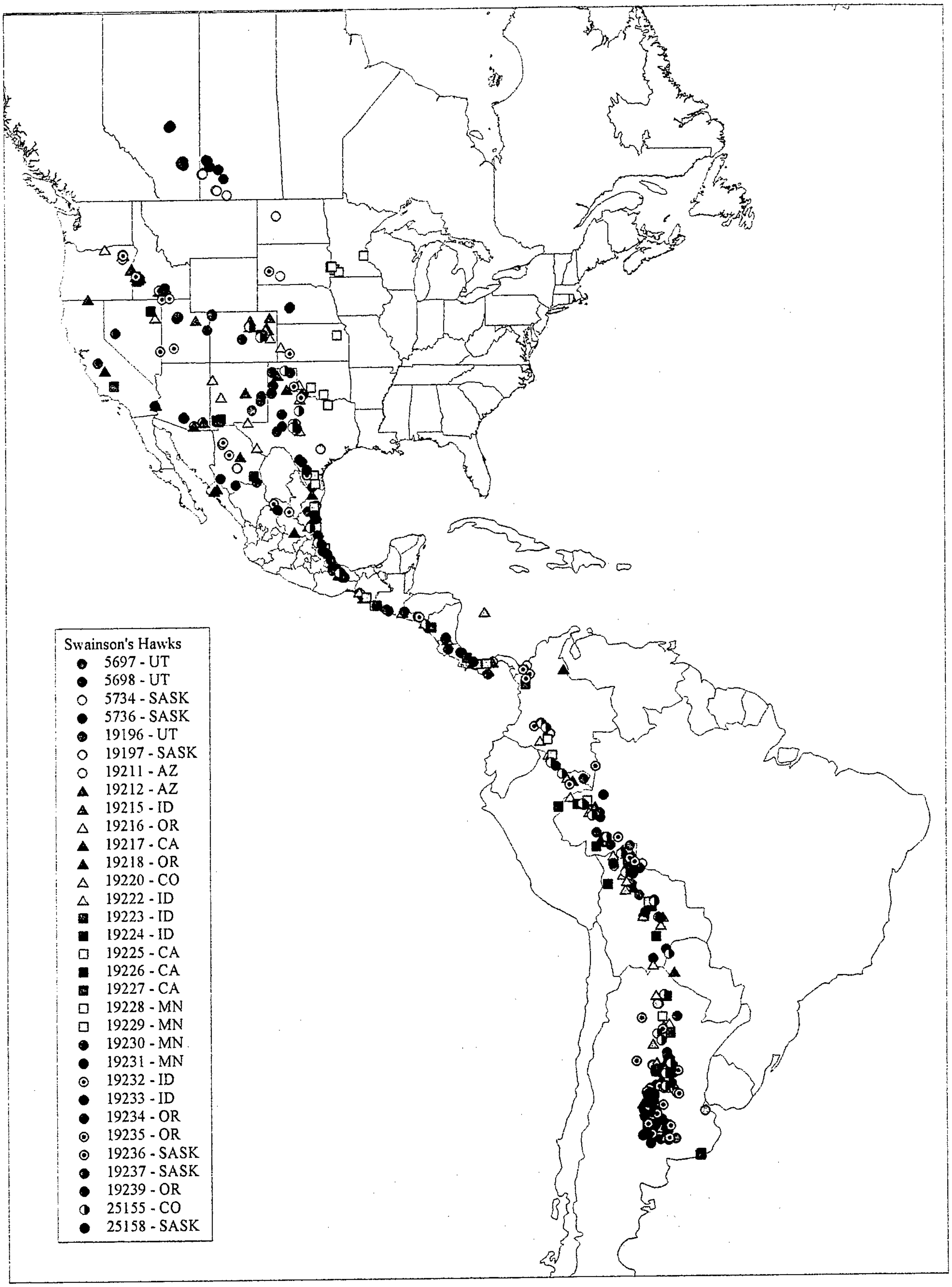
Figure V-4. Rates of migration for the 2 segments of partial migration for peregrine falcons on north (solid line) and south (dotted line) migrations.





CCRT's Key Study Sites of Tundra Peregrine Falcon Breeding Grounds and Migratory Foci


Peregrine Migration
North
South
Tundra Peregrine Falcon Breeding
and Wintering Ground Locations
and Migration Routes Determined
by CCRT via Satellite Telemetry


Swainson's Hawks
5697 - UT
5698 - UT
5734 - SASK
5736 - SASK
19196 - UT
19197 - SASK
19211 - AZ
19212 - AZ
19215 - ID
19216 - OR
19217 - CA
19218 - OR
19220 - CO
19222 - ID
19223 - ID
19224 - ID
19225 - CA
19226 - CA
19227 - CA
19228 - MN
19229 - MN
19230 - MN
19231 - MN
19232 - ID
19233 - ID
19234 - OR
19235 - OR
19236 - SASK
19237 - SASK
19239 - OR
25155 - CO
25158 - SASK

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APPENDIX

PRODUCT MAPS

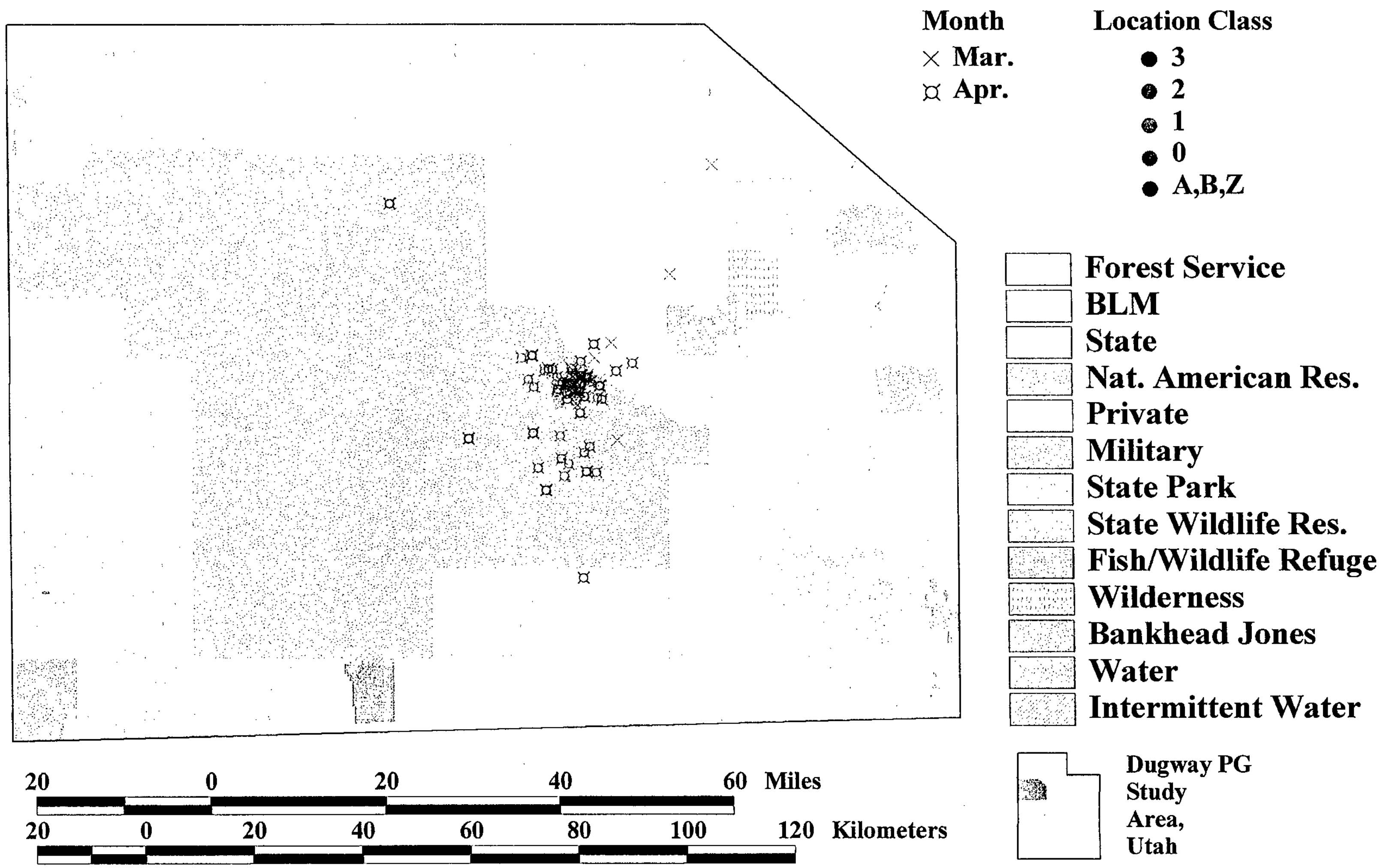

Figure DPG-1. Argos location estimates by month and location class for PTT #5725, attached to a pronghorn. Shown are location estimates from 3/1/96 to 4/30/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

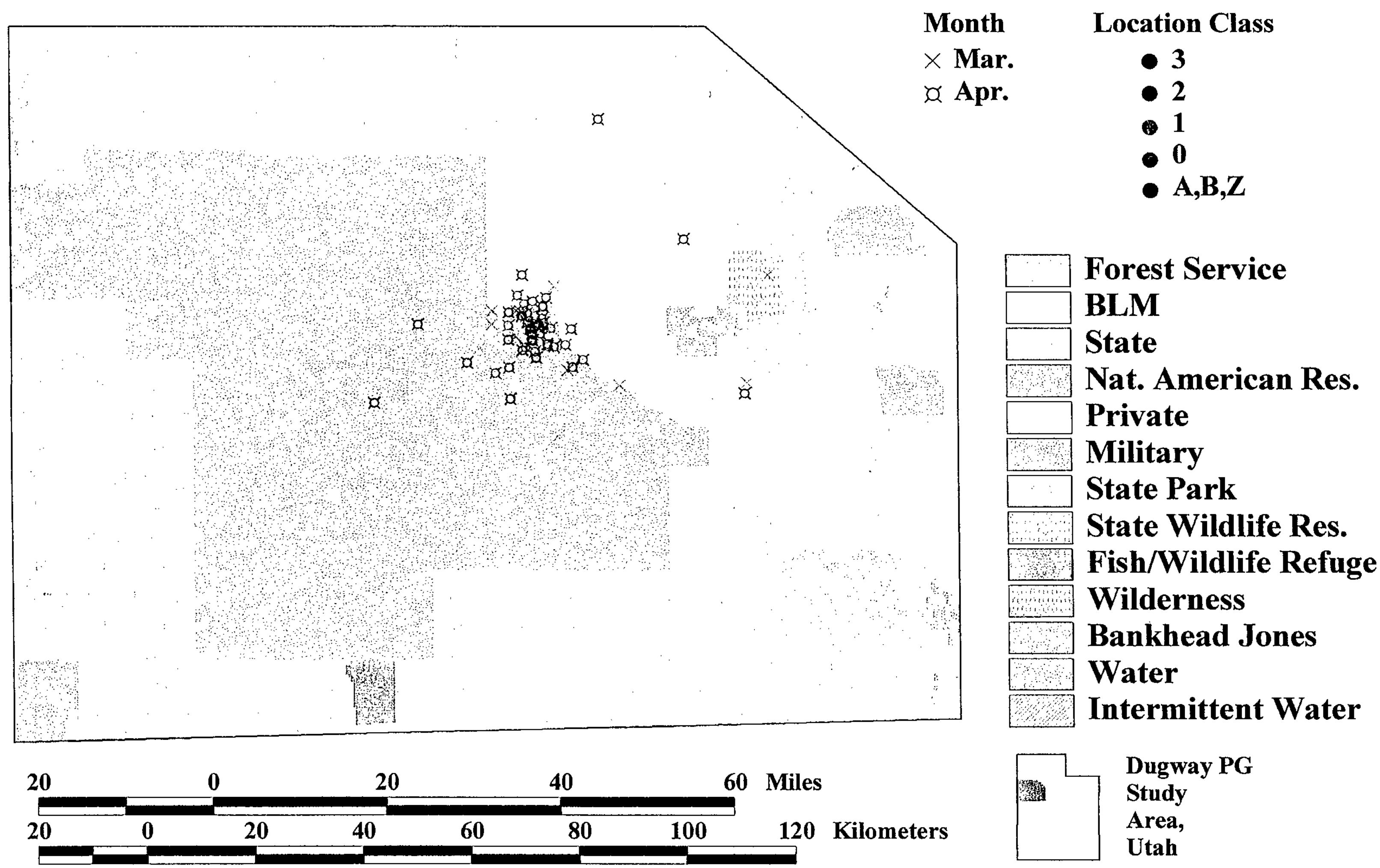

Figure DPG-2. Argos location estimates by month and location class for PTT #5723, attached to a pronghorn. Shown are location estimates from 3/1/96 to 4/30/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

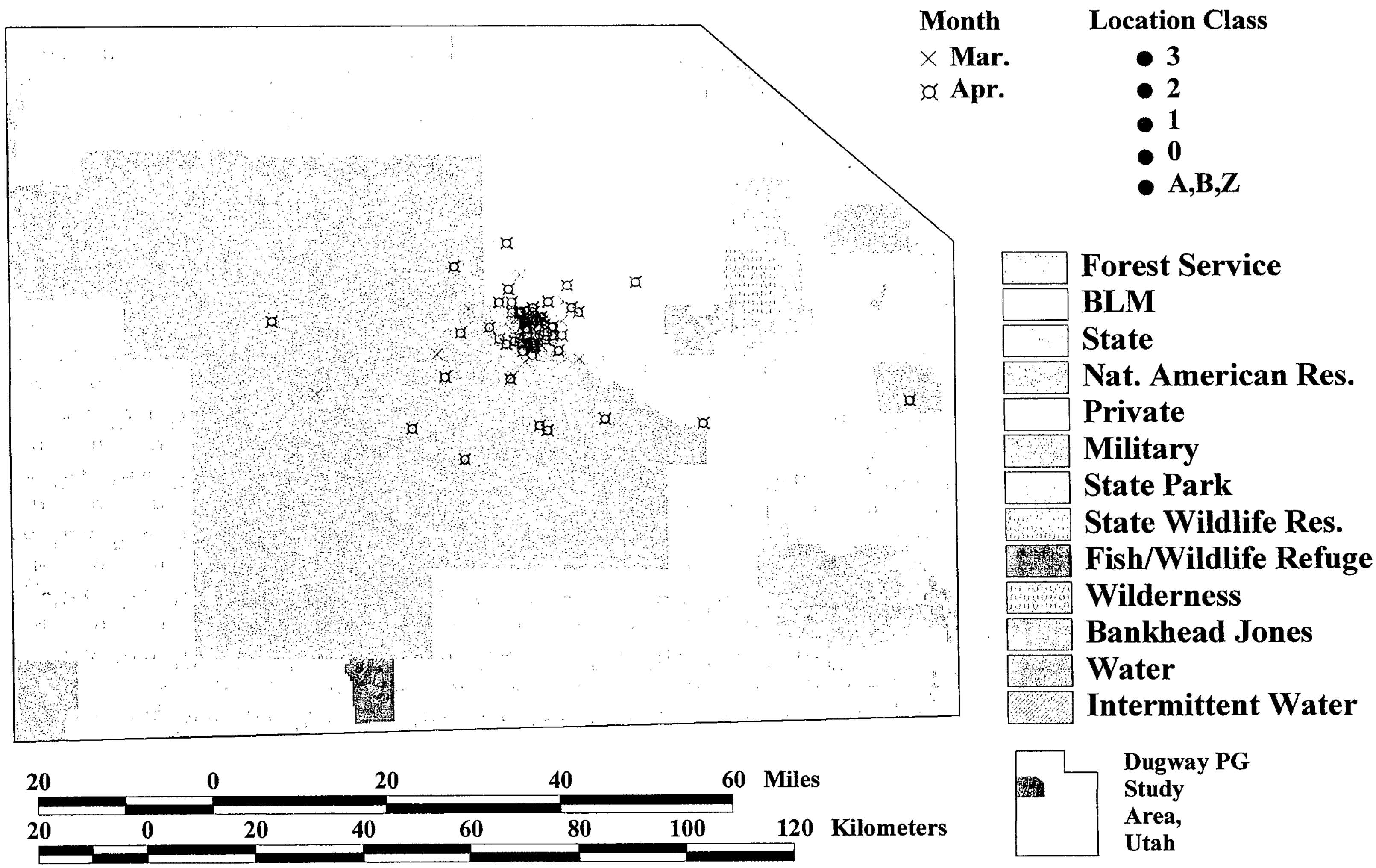

Figure DPG-3. Argos location estimates by month and location class for PTT #5720, attached to a pronghorn. Shown are location estimates from 3/1/96 to 4/30/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

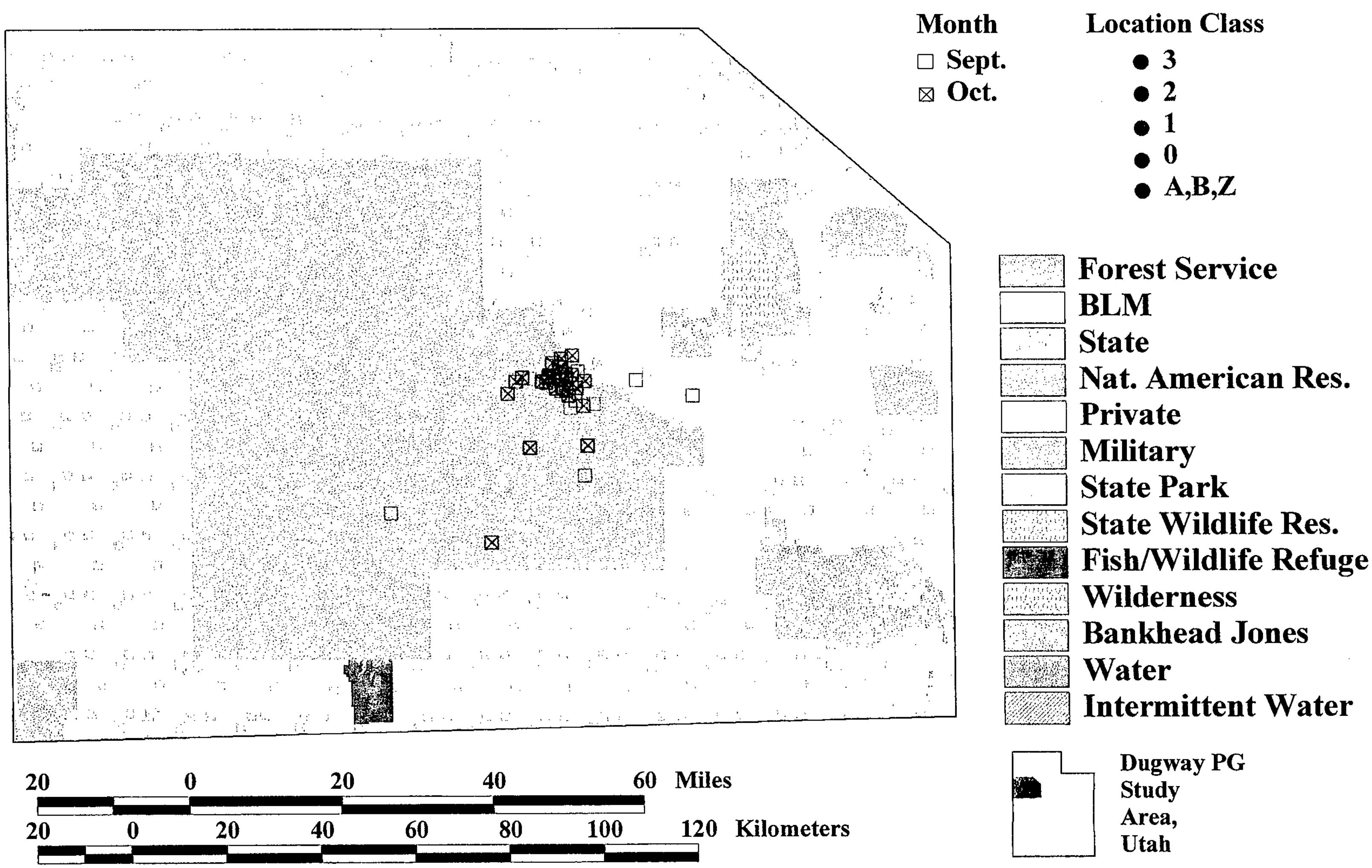

Figure DPG-4. Argos location estimates by month and location class for PTT #5725, attached to a pronghorn. Shown are location estimates from 9/1/96 to 10/31/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

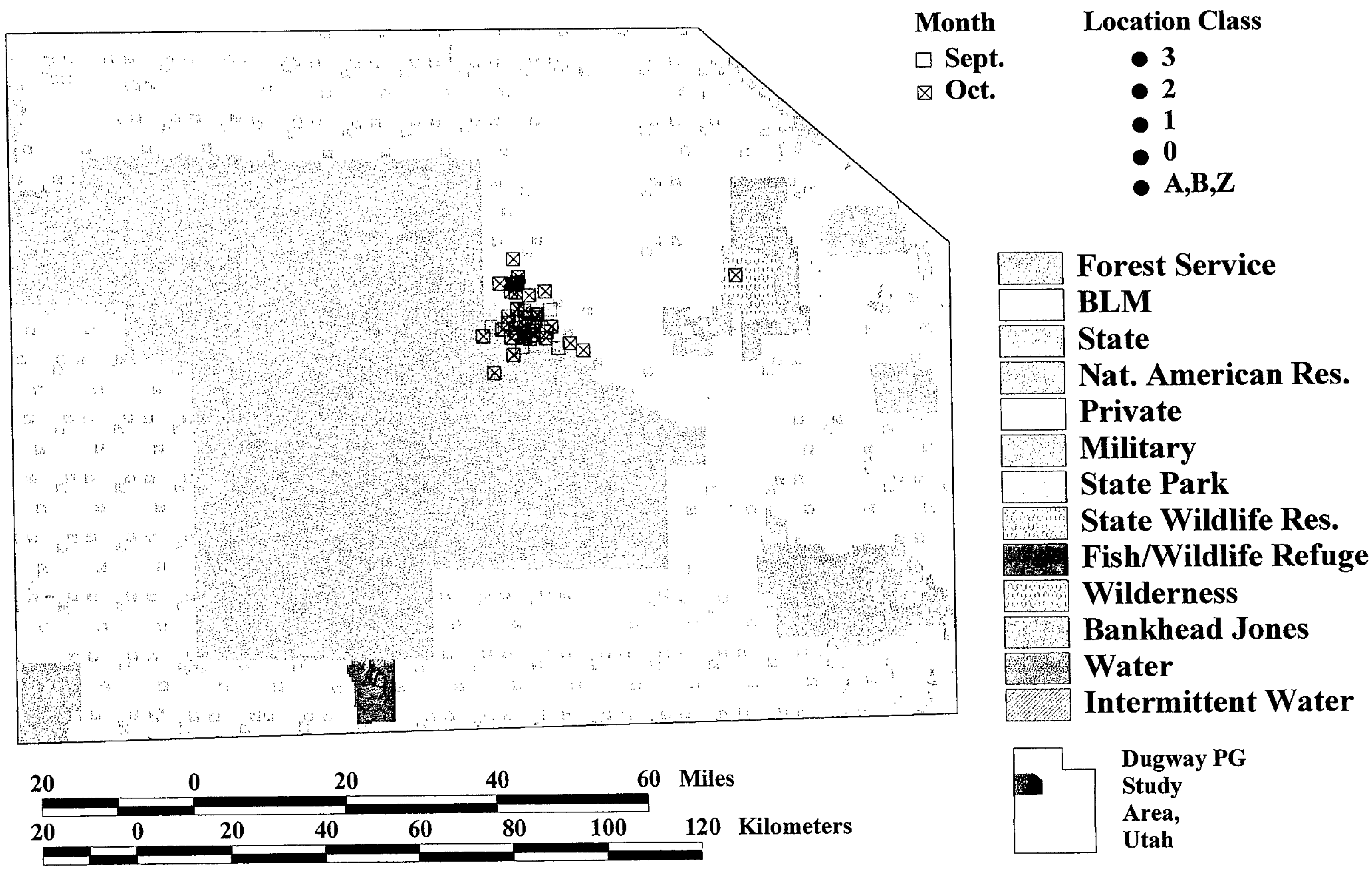

Figure DPG-5. Argos location estimates by month and location class for PTT #5723, attached to a pronghorn. Shown are location estimates from 9/1/96 to 10/31/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

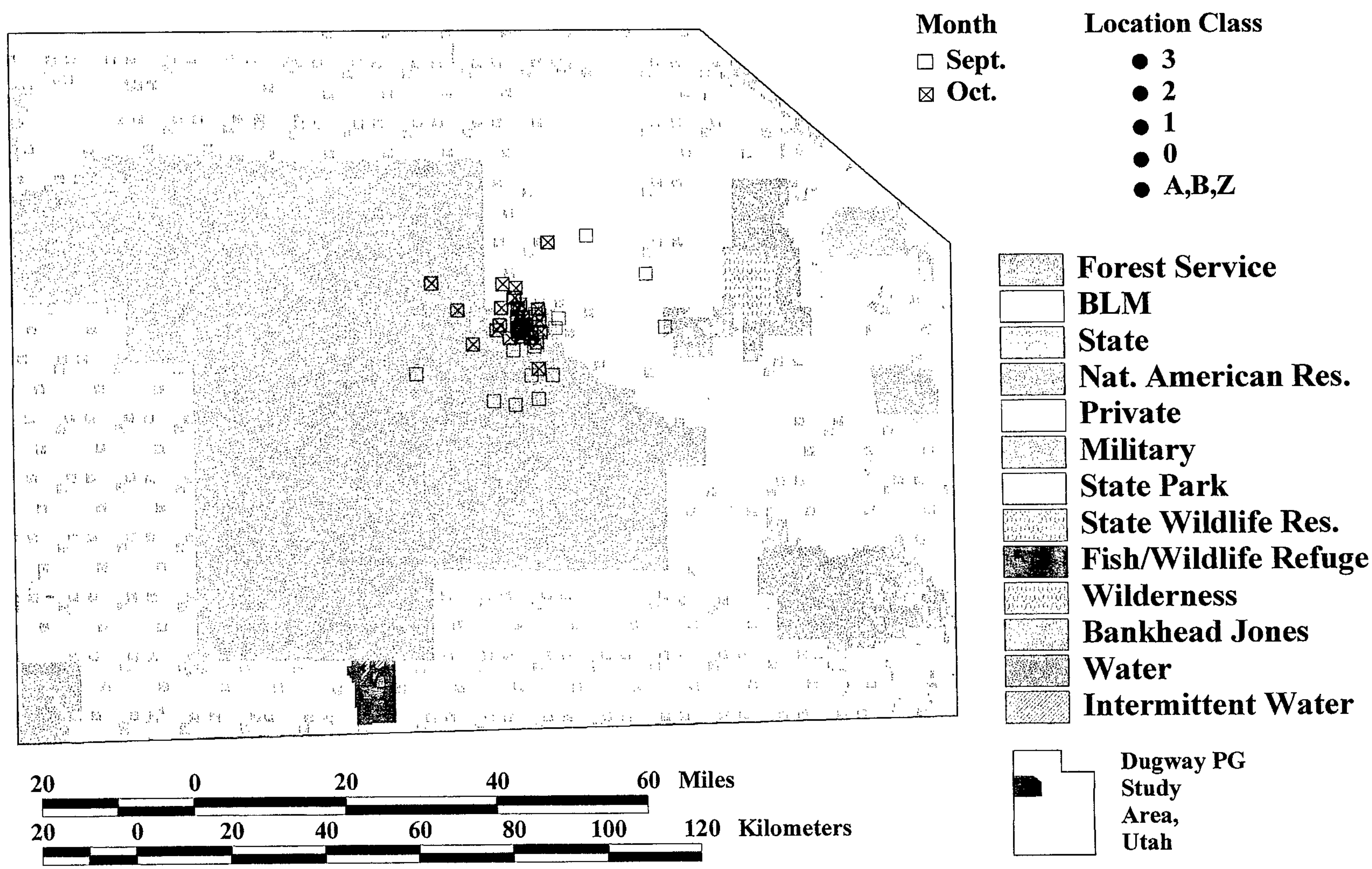

Figure DPG-6. Argos location estimates by month and location class for PTT #5720, attached to a pronghorn. Shown are location estimates from 9/1/96 to 10/31/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

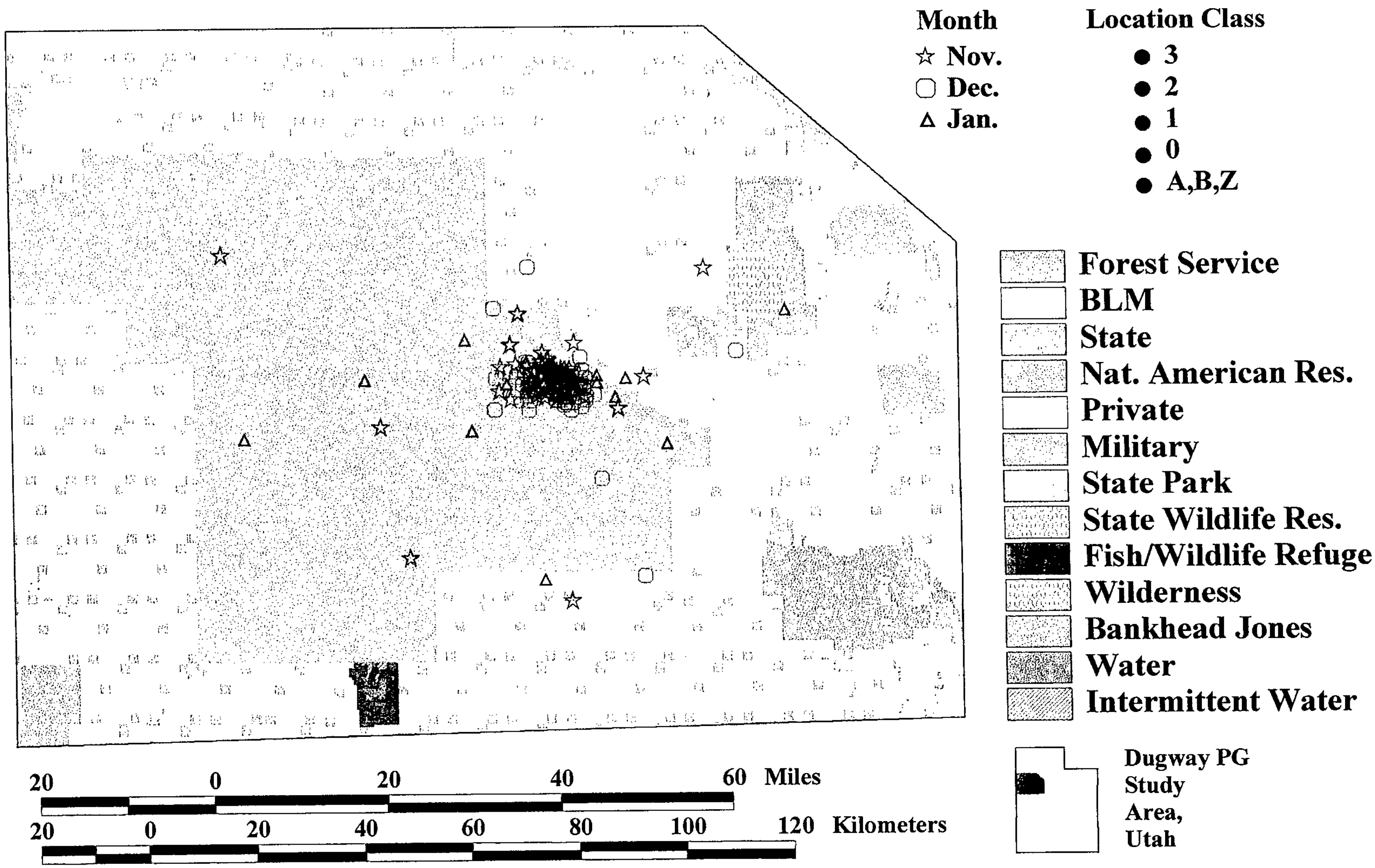

Figure DPG-7. Argos location estimates by month and location class for PTT #5725, attached to a pronghorn. Shown are location estimates from 11/1/96 to 1/31/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

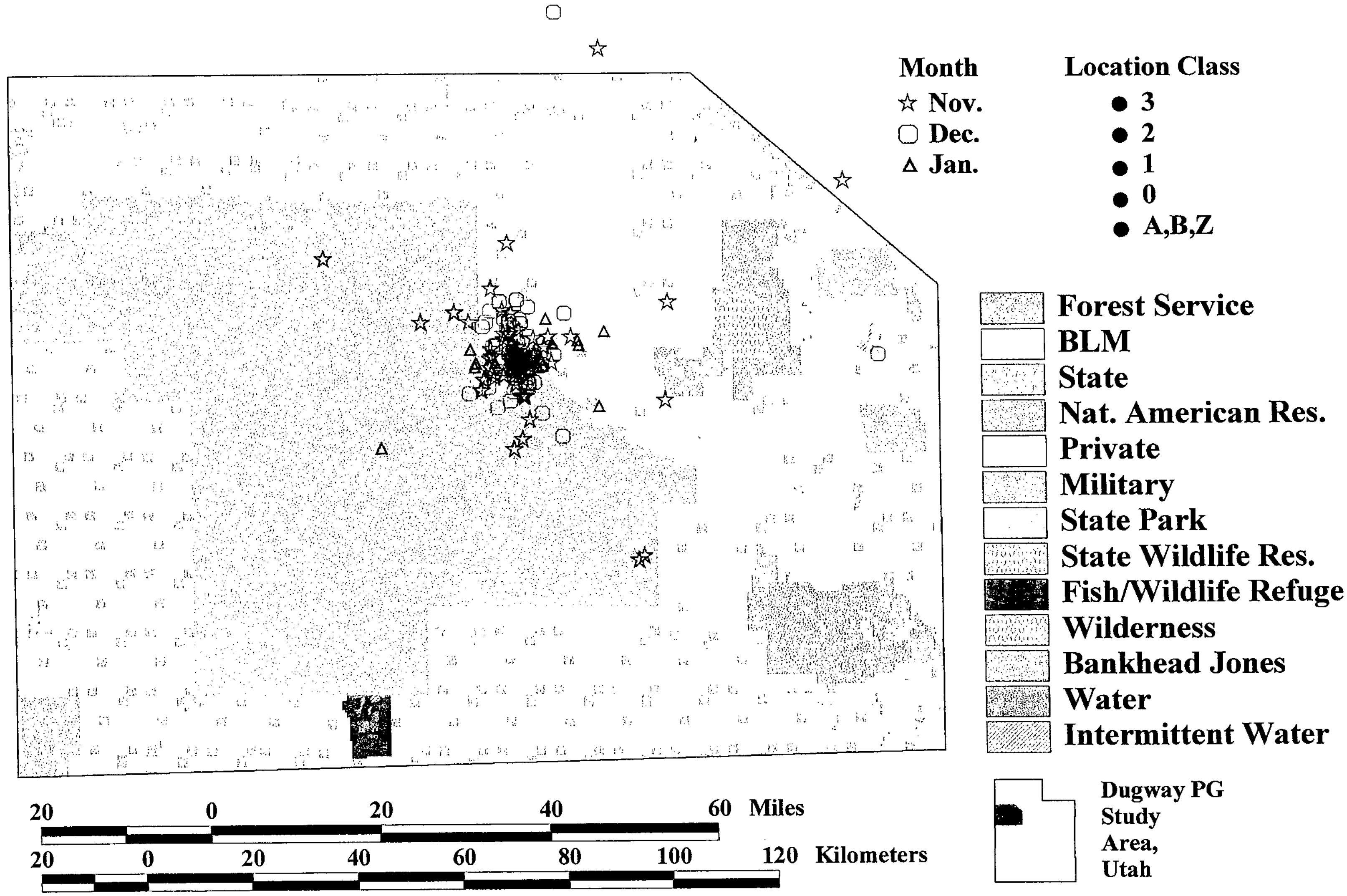

Figure DPG-8. Argos location estimates by month and location class for PTT #5720, attached to a pronghorn. Shown are location estimates from 11/1/96 to 1/31/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

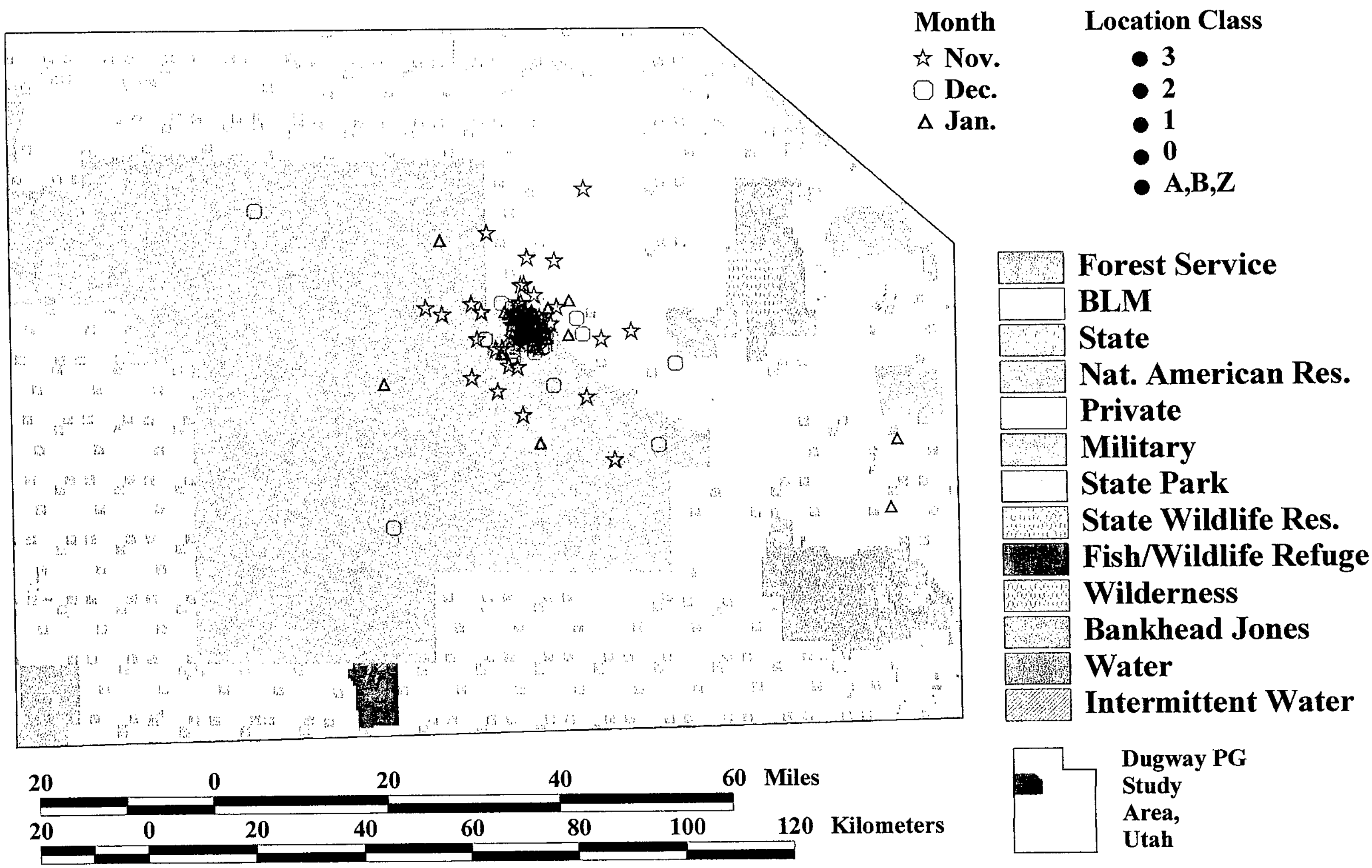

Figure DPG-9. Argos location estimates by month and location class for PTT #5723, attached to a pronghorn. Shown are location estimates from 11/1/96 to 1/31/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

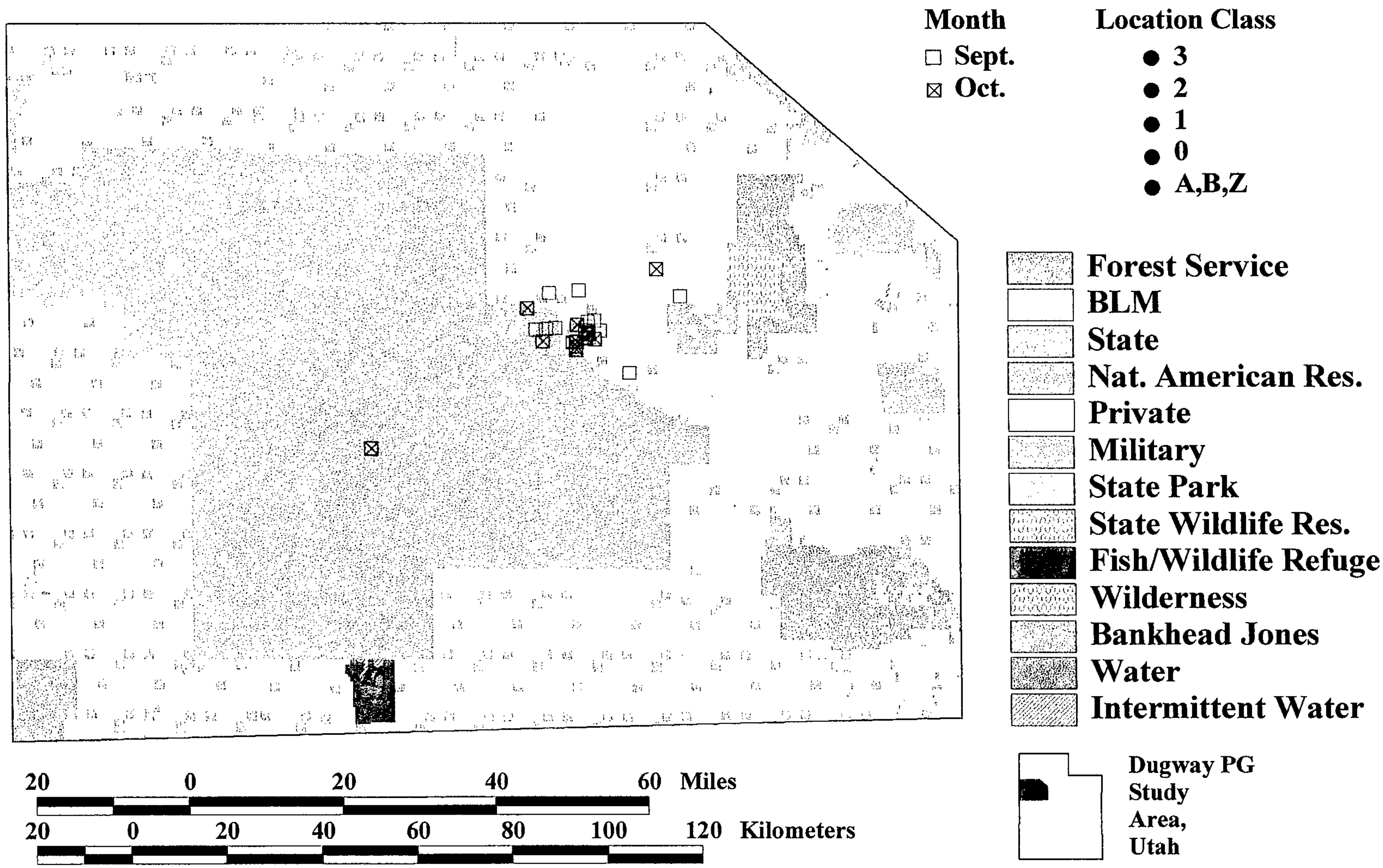

Figure DPG-10. Argos location estimates by month and location class for PTT #5700, attached to a feral horse. Shown are location estimates from 9/1/96 to 10/31/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

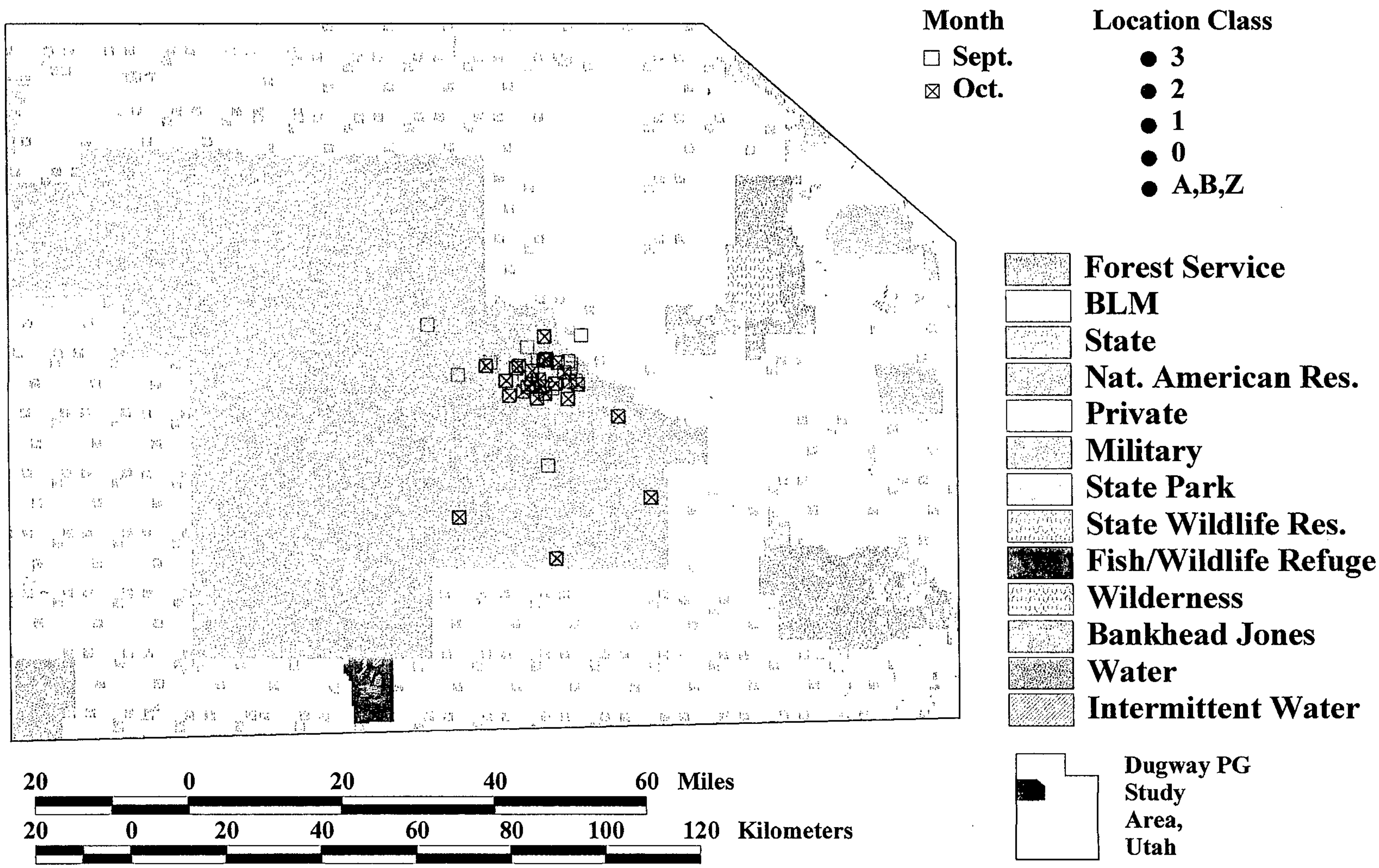

Figure DPG-11. Argos location estimates by month and location class for PTT #5710, attached to a feral horse. Shown are location estimates from 9/1/96 to 10/31/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

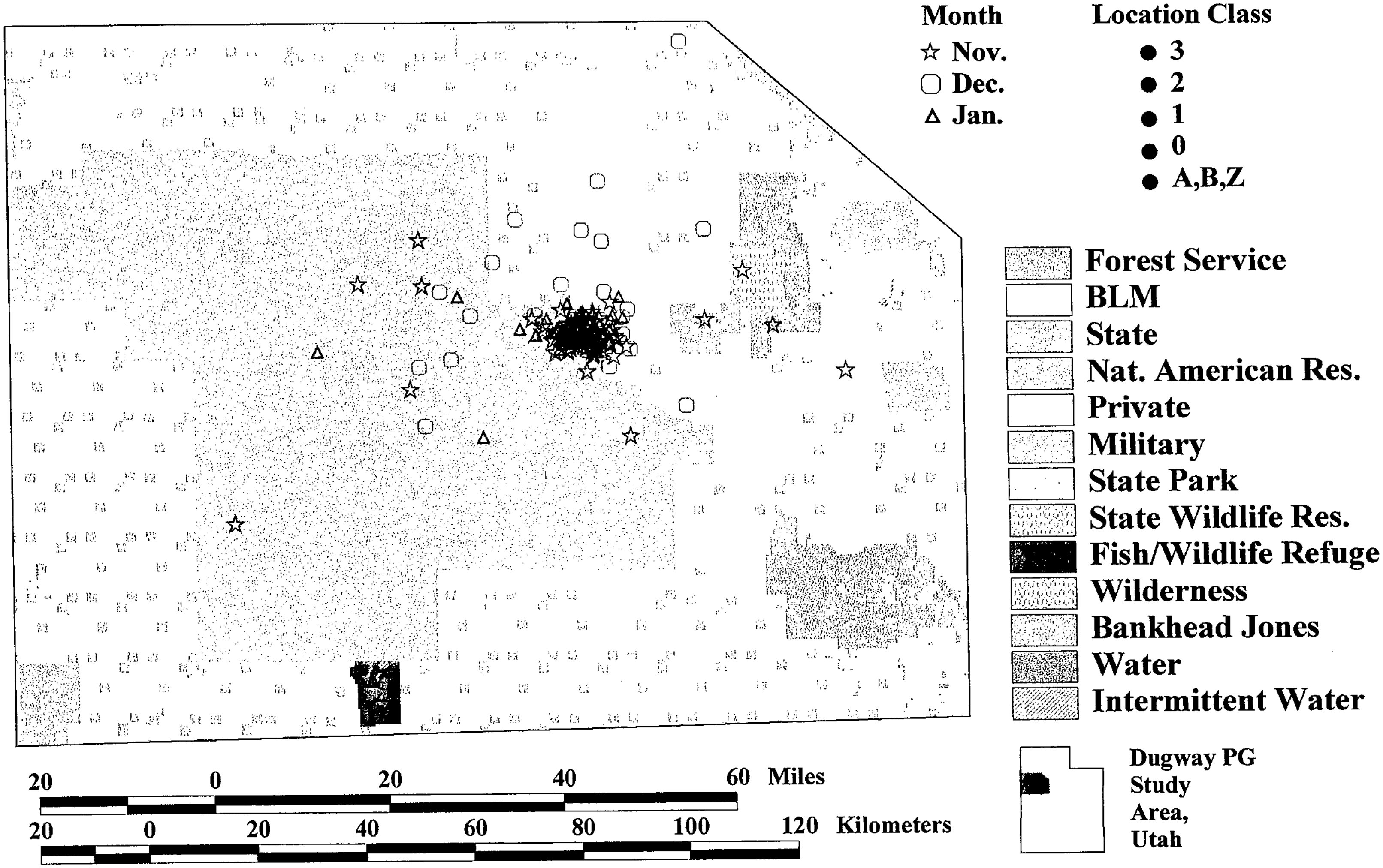

Figure DPG-12. Argos location estimates by month and location class for PTT #5700, attached to a feral horse. Shown are location estimates from 11/1/96 to 1/31/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

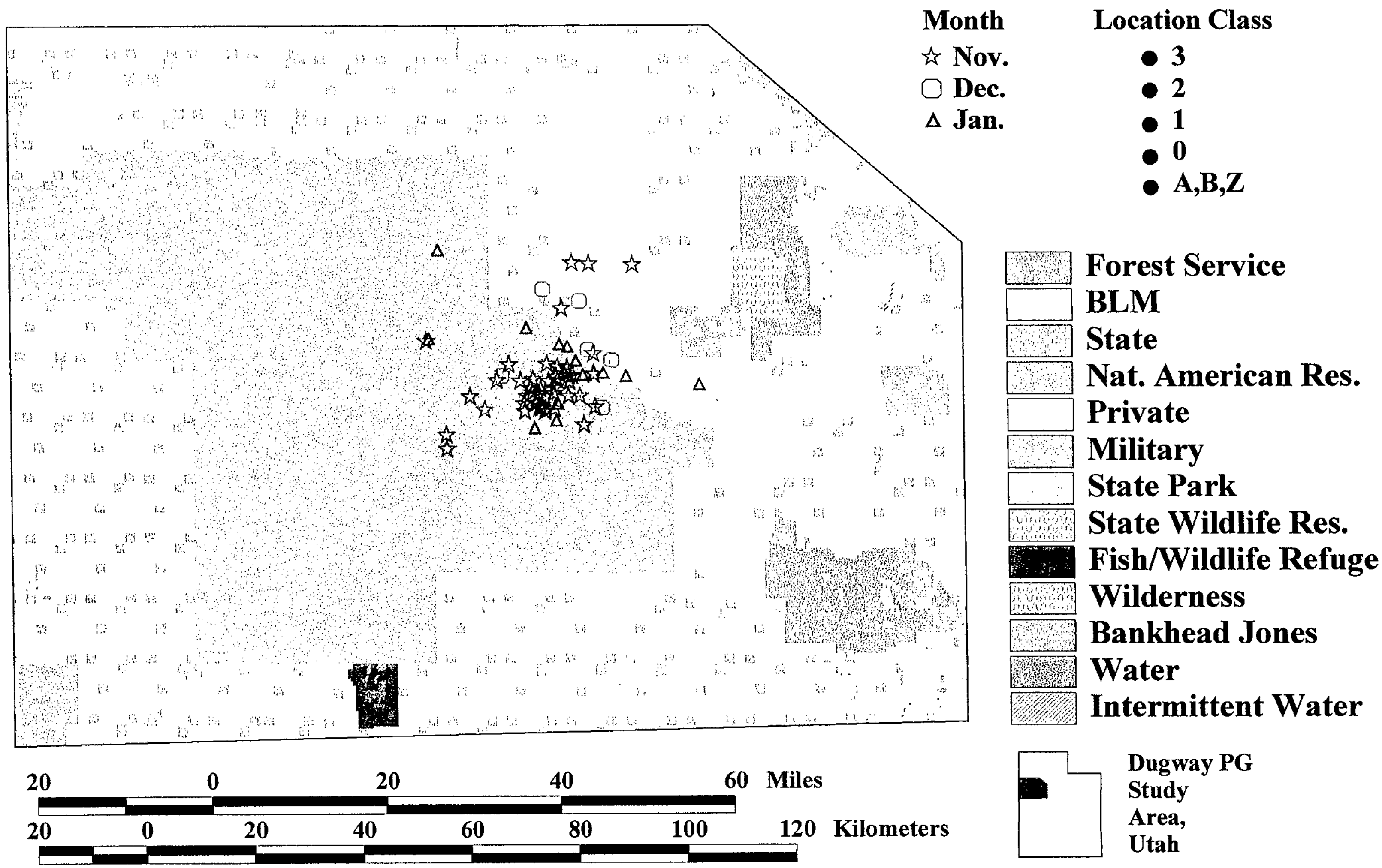

Figure DPG-13. Argos location estimates by month and location class for PTT #5710, attached to a feral horse. Shown are location estimates from 11/1/96 to 1/31/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

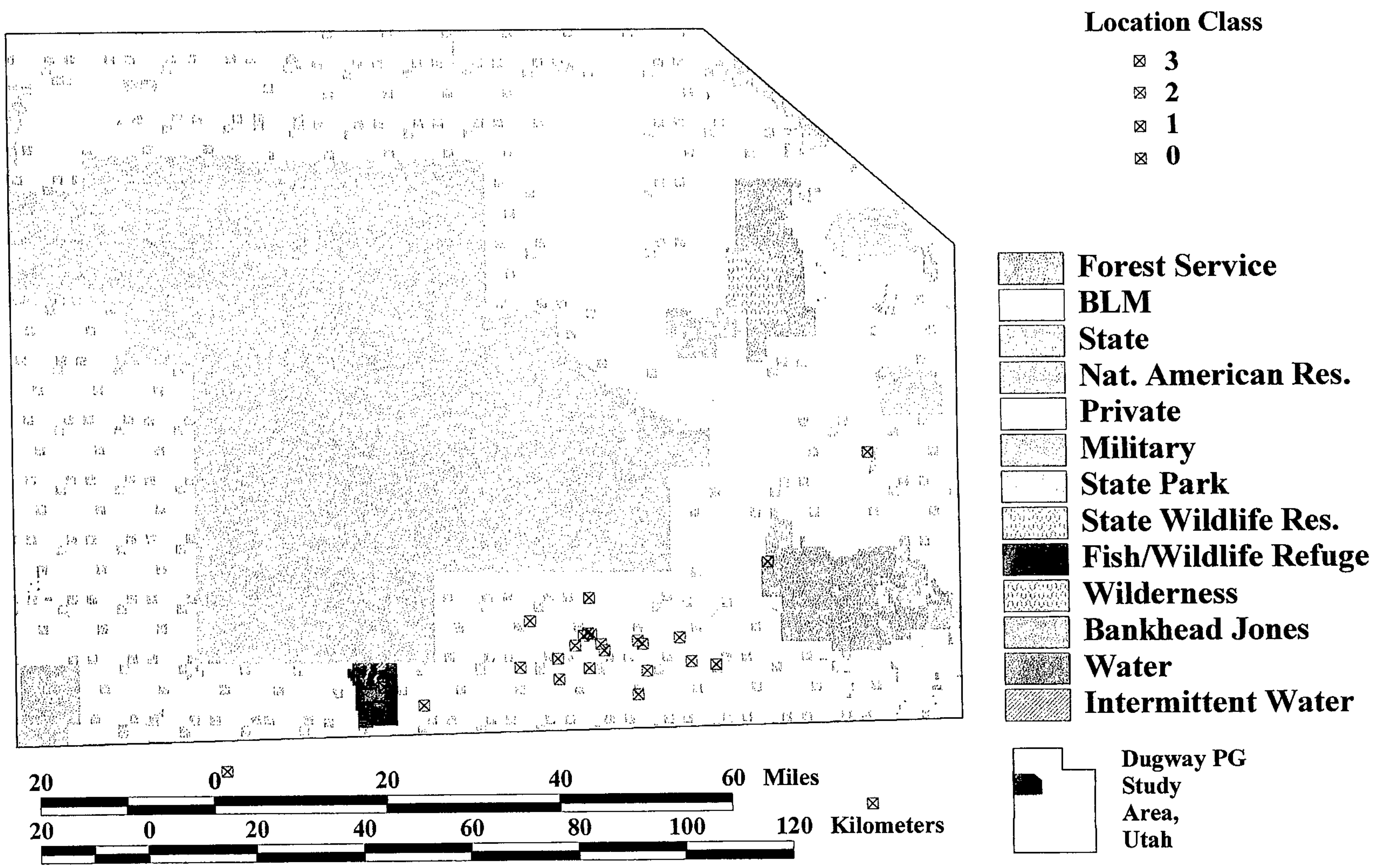

Figure DPG-14. Argos location estimates for PTT #11985, attached to a ferruginous hawk. Shown are location estimates from 6/16/96 to 6/27/96 and 1/27/97 - 3/3/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: Utah State Division of Information Technology Services.

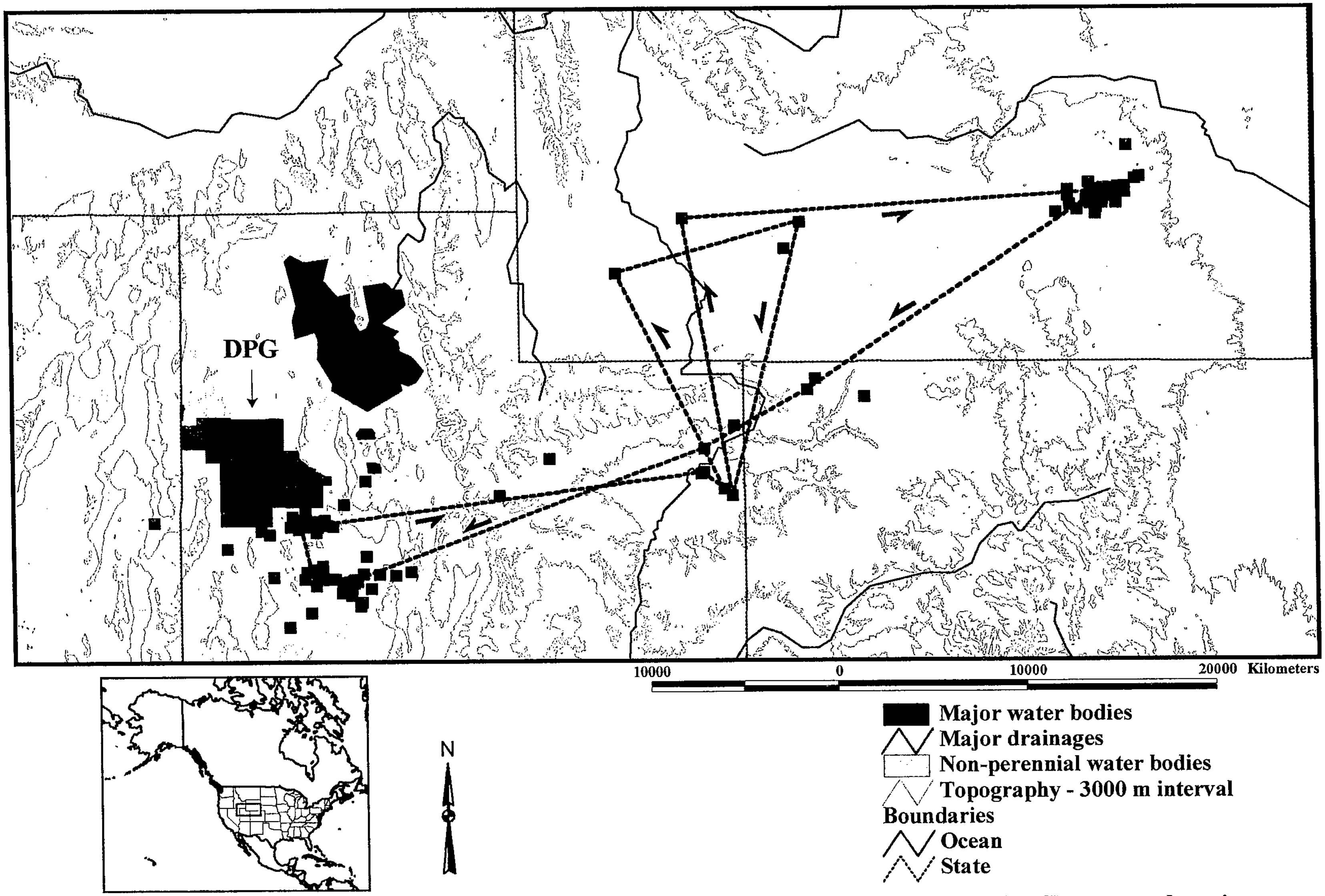

Figure DPG-15. Argos location estimates for PTT #11985, attached to a ferruginous hawk. Shown are location estimates of LC 0 - 3 from 6/16/96 - 3/3/97. Arrows denote direction of travel. Background Data Source: Digital Chart of the World.

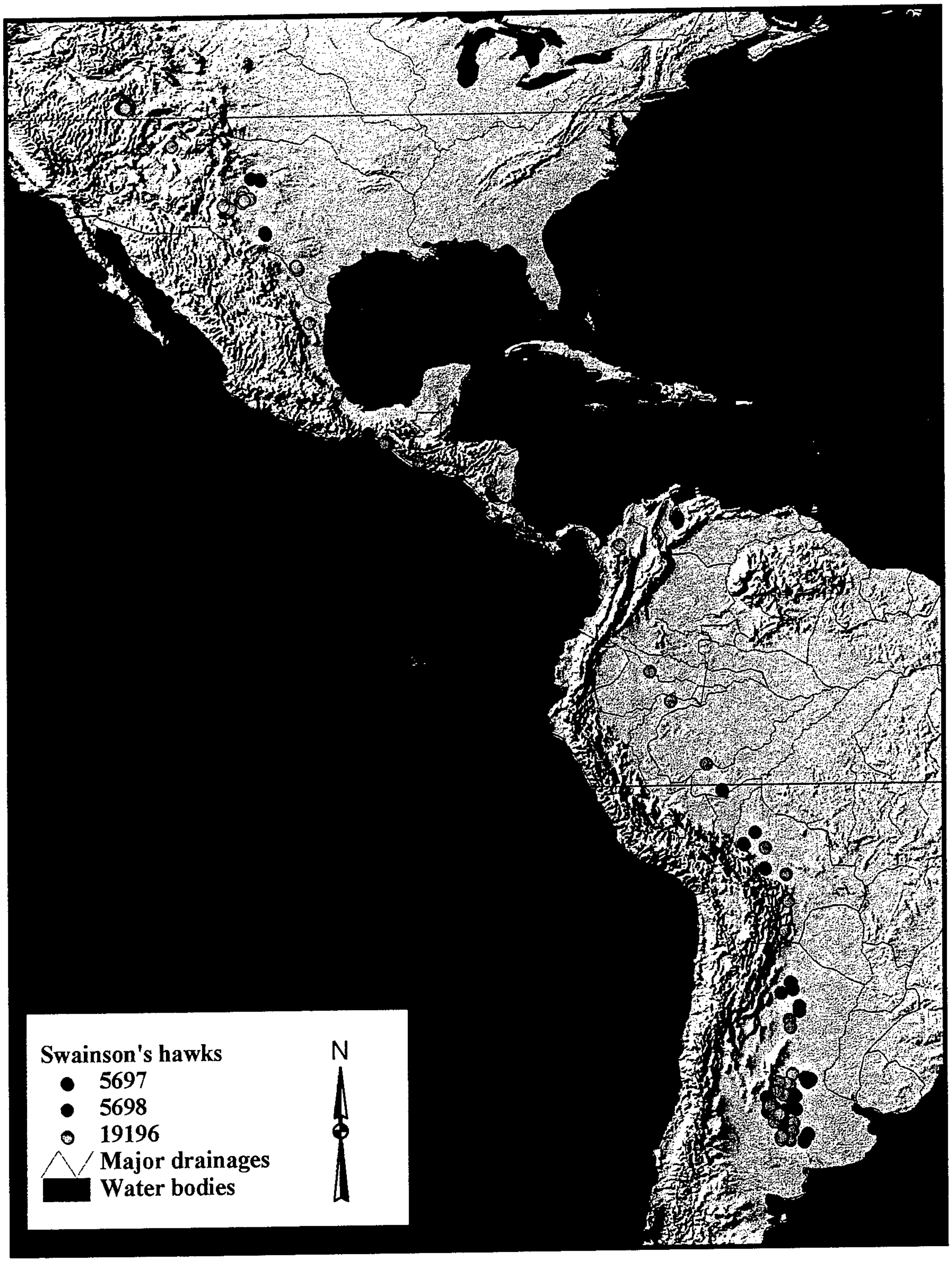

Figure DPG-16. Argos location estimates for 3 Swainson's hawks during southward migration. Shown are location estimates of LC 0 - 3 from 9/1/96 - 12/31/96. Background is a shaded relief map from a global digital elevation model (GTOPO30). Background Data Source: USGS.

Figure DPG-17. Argos location estimates for 2 Swainson's hawks during northward migration. Shown are location estimates of LC 0 - 3 from 1/1/97 - 5/31/97. Background is a shaded relief map from a global digital elevation model (GTOPO30). Background Data Source: USGS.

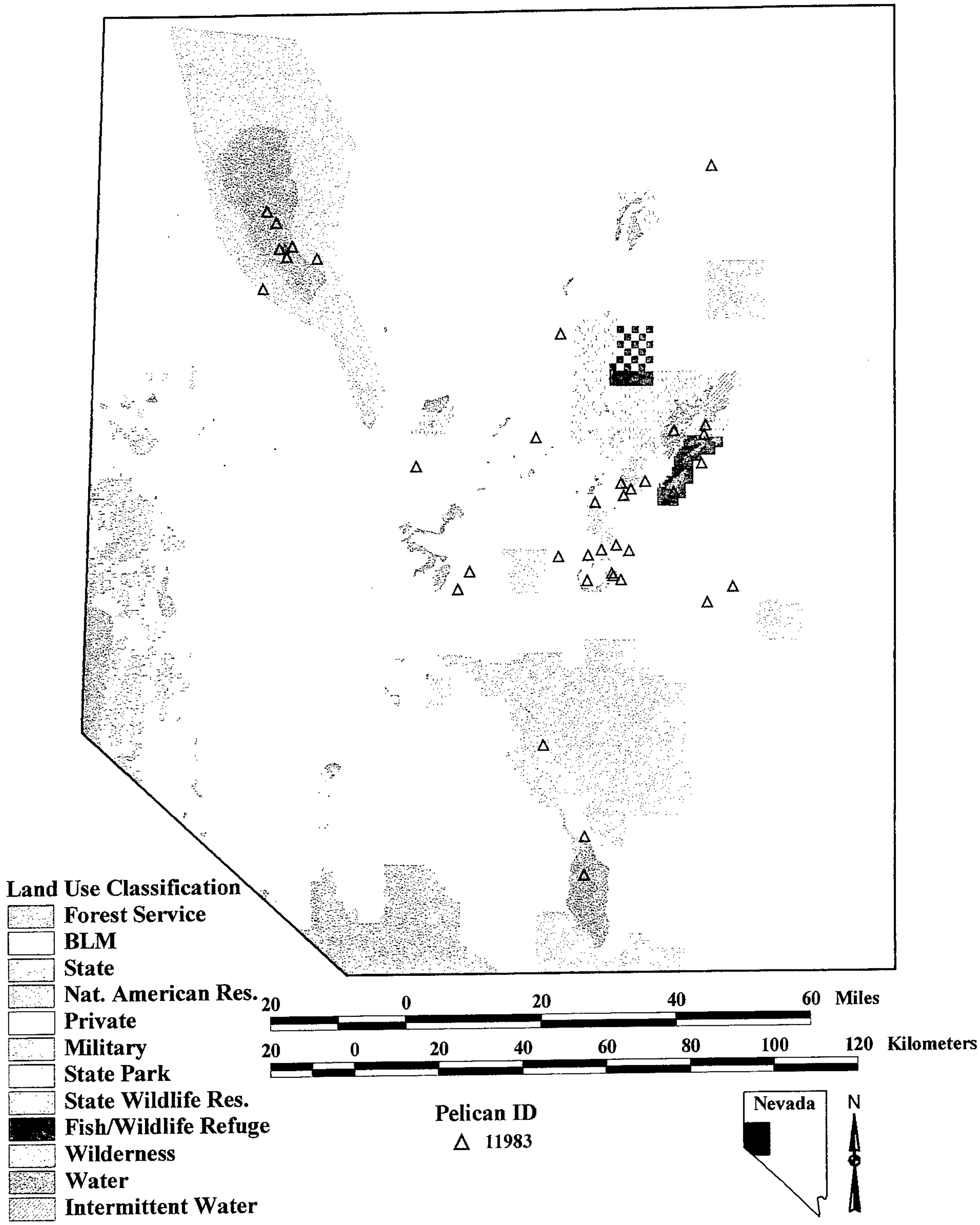

Figure NASF-1. Argos location estimates obtained in May 1996 for an American white pelican in the NAS Fallon study area. Shown are location estimates of LC 0 - 3. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: BLM, Reno.

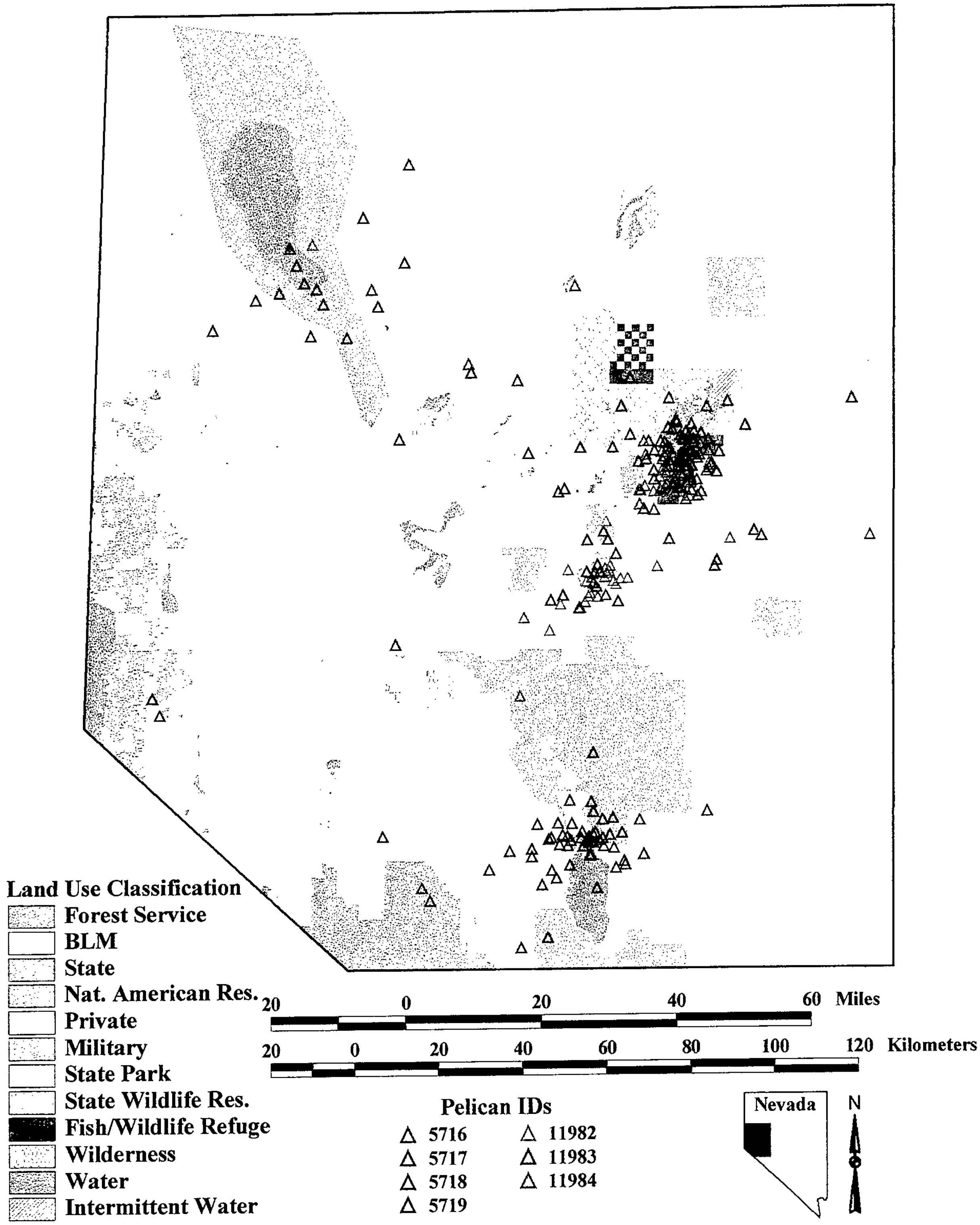

Figure NASF-2. Argos location estimates obtained in June 1996 for American white pelicans in the NAS Fallon study area. Shown are location estimates of LC 0 - 3. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: BLM, Reno.

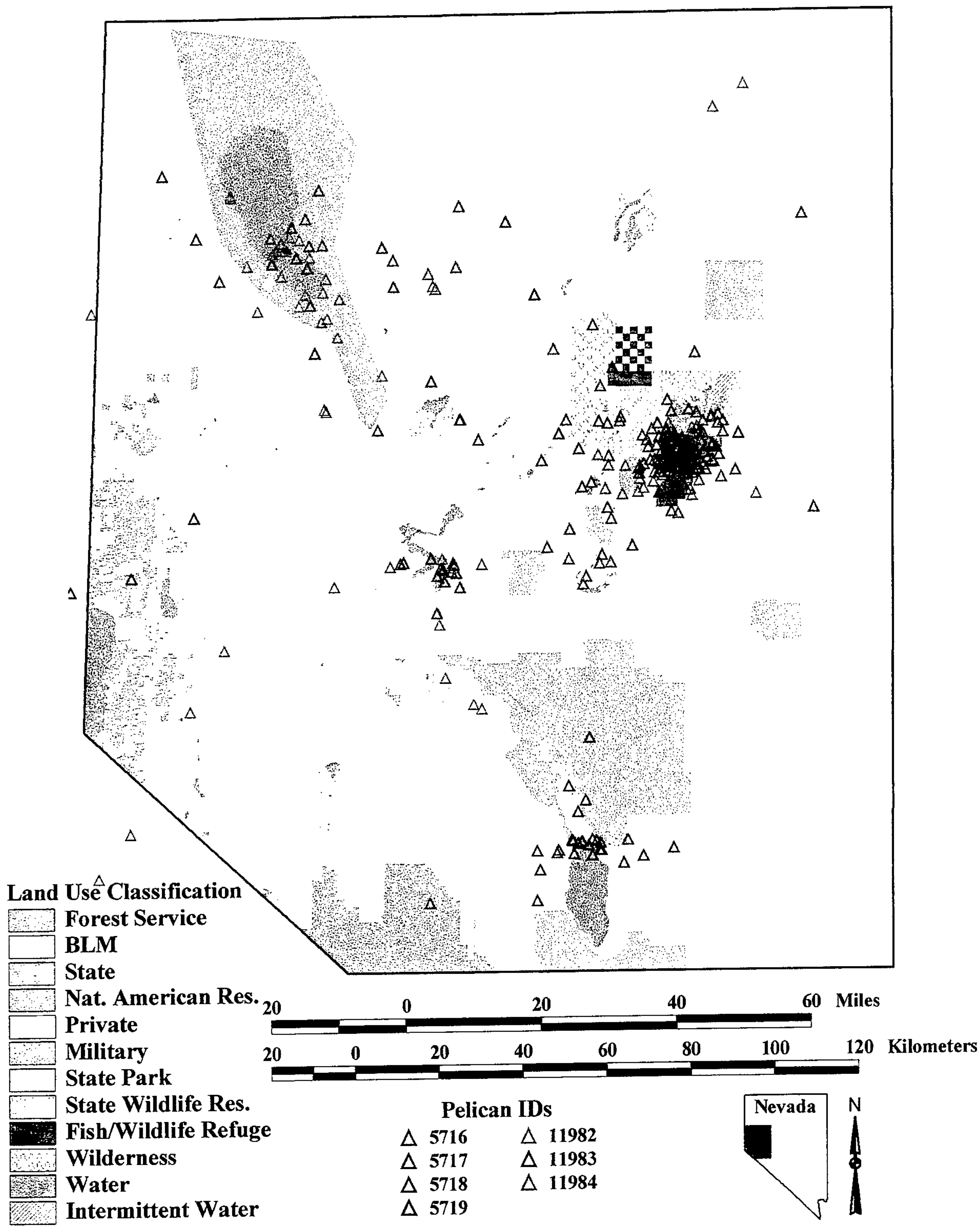

Figure NASF-3. Argos location estimates obtained in July 1996 for American white pelicans in the NAS Fallon study area. Shown are location estimates of LC 0 - 3. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: BLM, Reno.

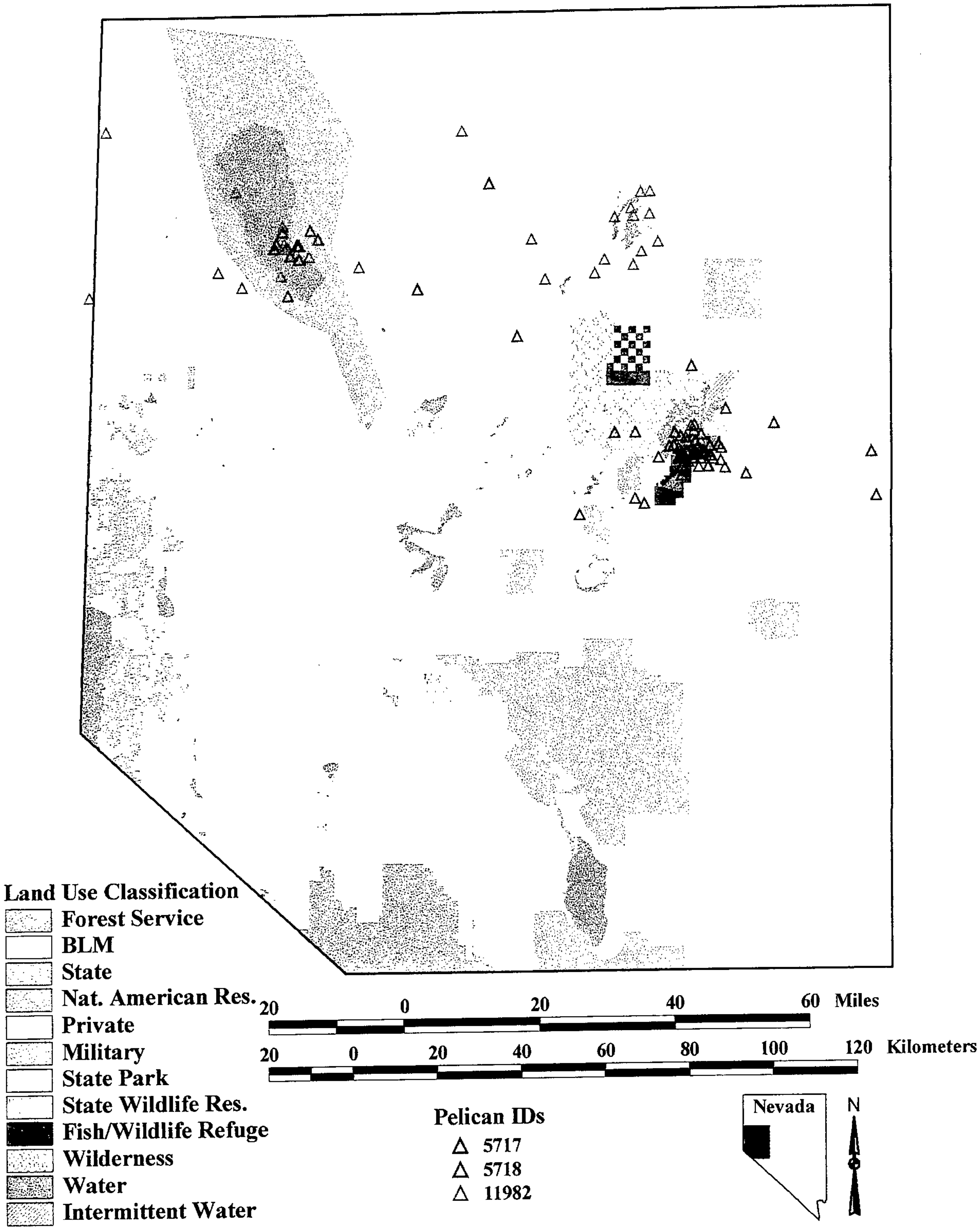

Figure NASF-4. Argos location estimates obtained in August 1996 for American white pelicans in the NAS Fallon study area. Shown are location estimates of LC 0 - 3. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: BLM, Reno.

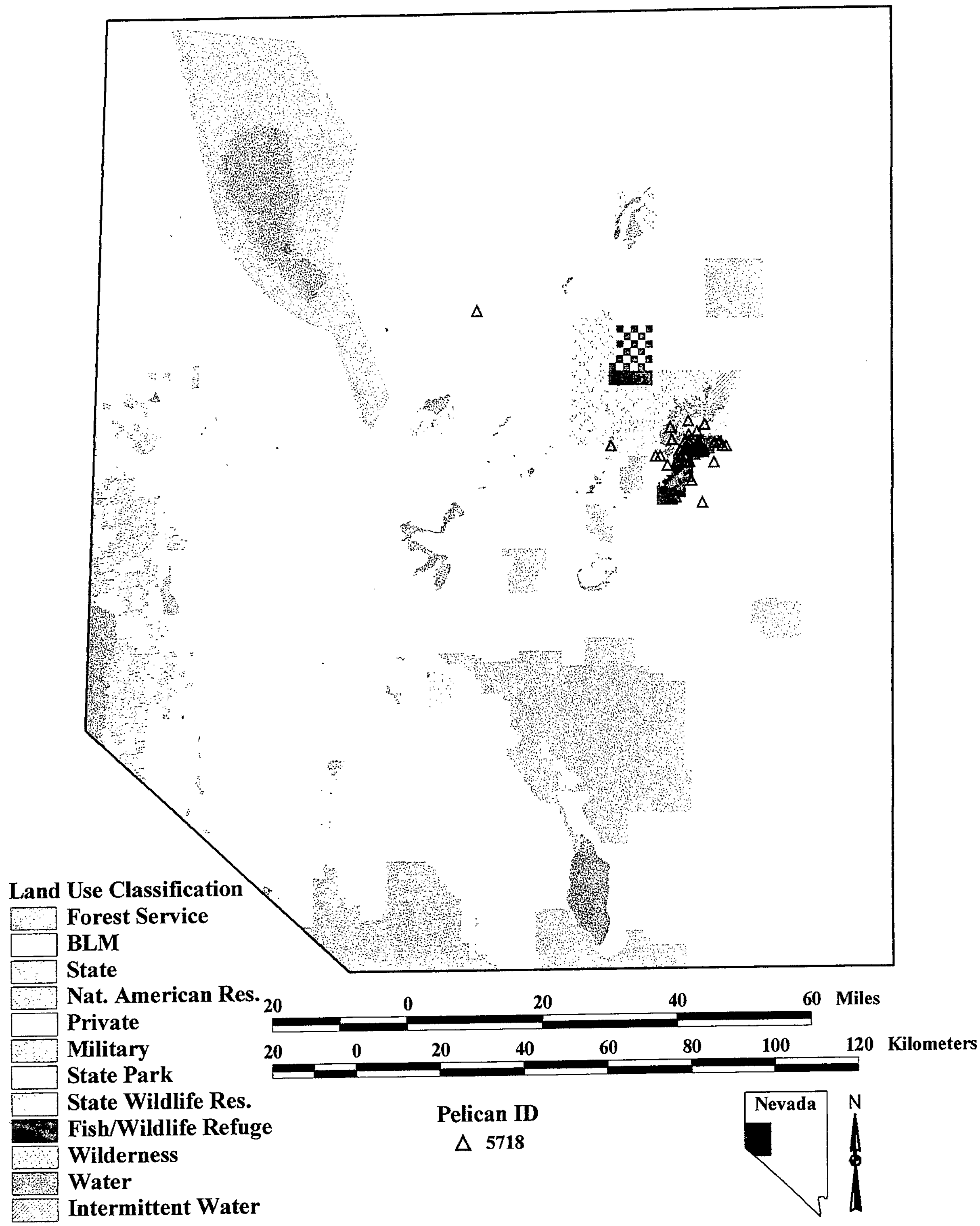

Figure NASF-5. Argos location estimates obtained in September 1996 for an American white pelican in the NAS Fallon study area. Shown are location estimates of LC 0 - 3. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: BLM, Reno.

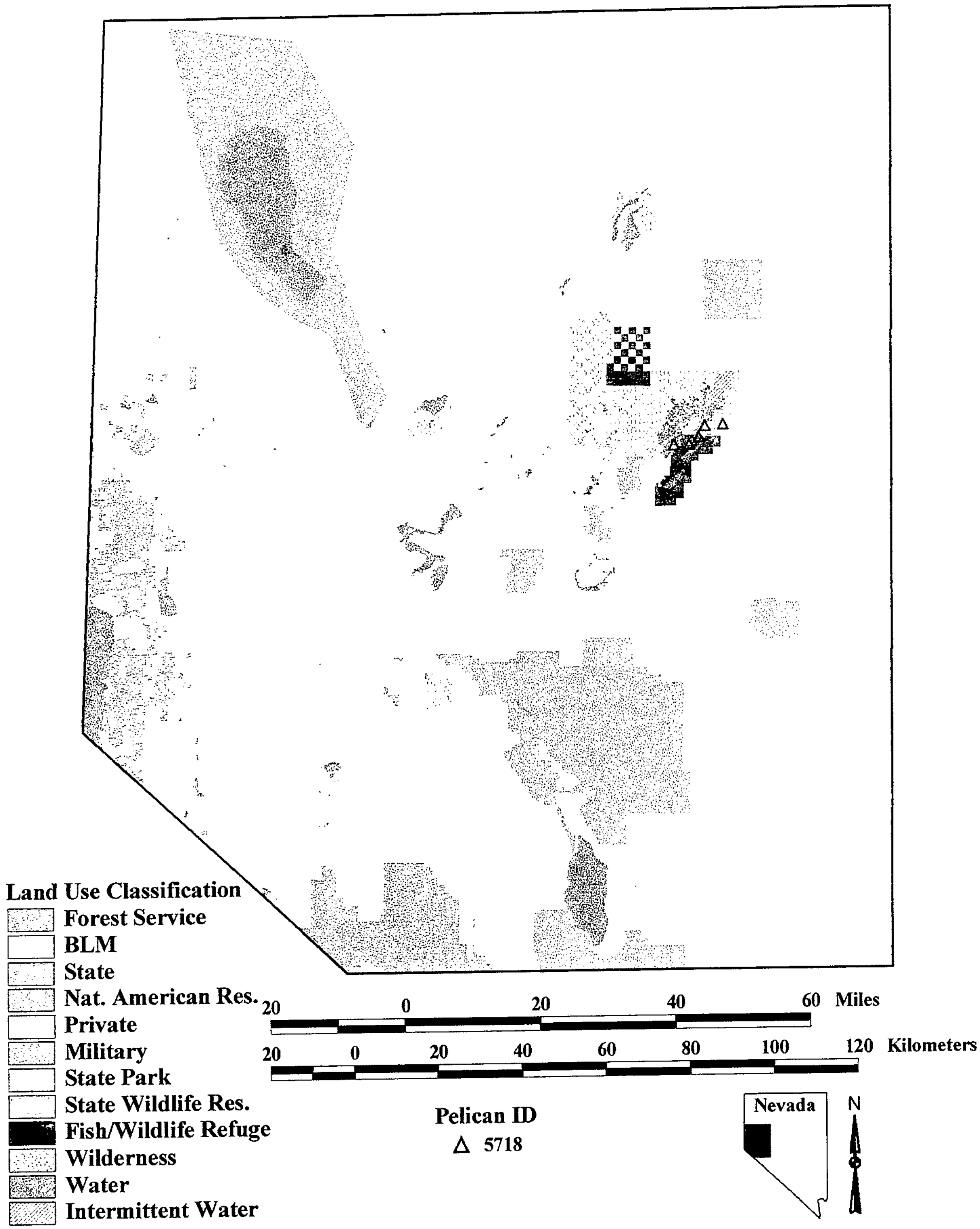

Figure NASF-6. Argos location estimates obtained in October 1996 for an American white pelican in the NAS Fallon study area. Shown are location estimates of LC 0 - 3. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: BLM, Reno.

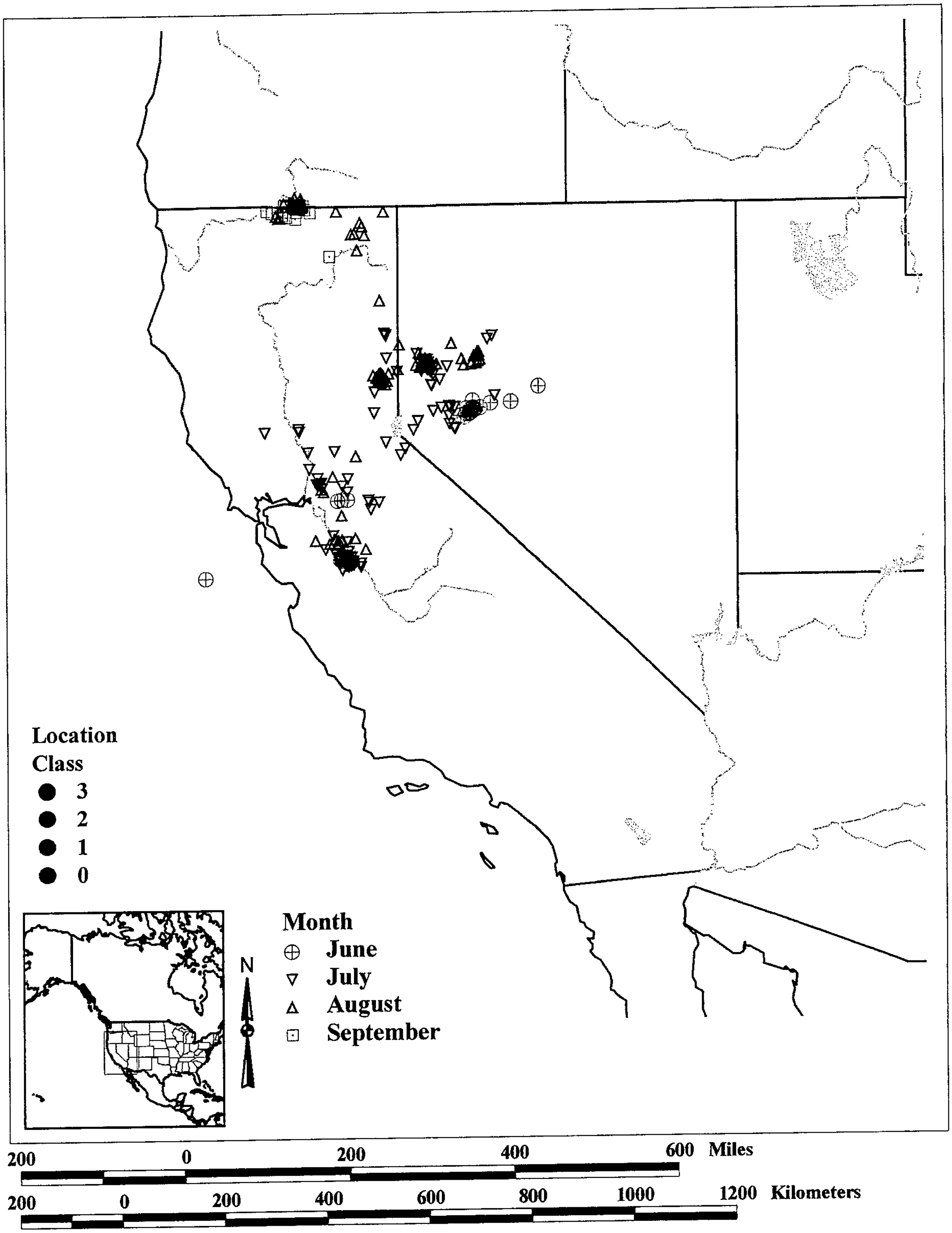

Figure NASF-7. Argos location estimates by month and location class for PTT# 11982 attached to an American white pelican. Shown are location estimates from 6/19/96 - 9/27/96.

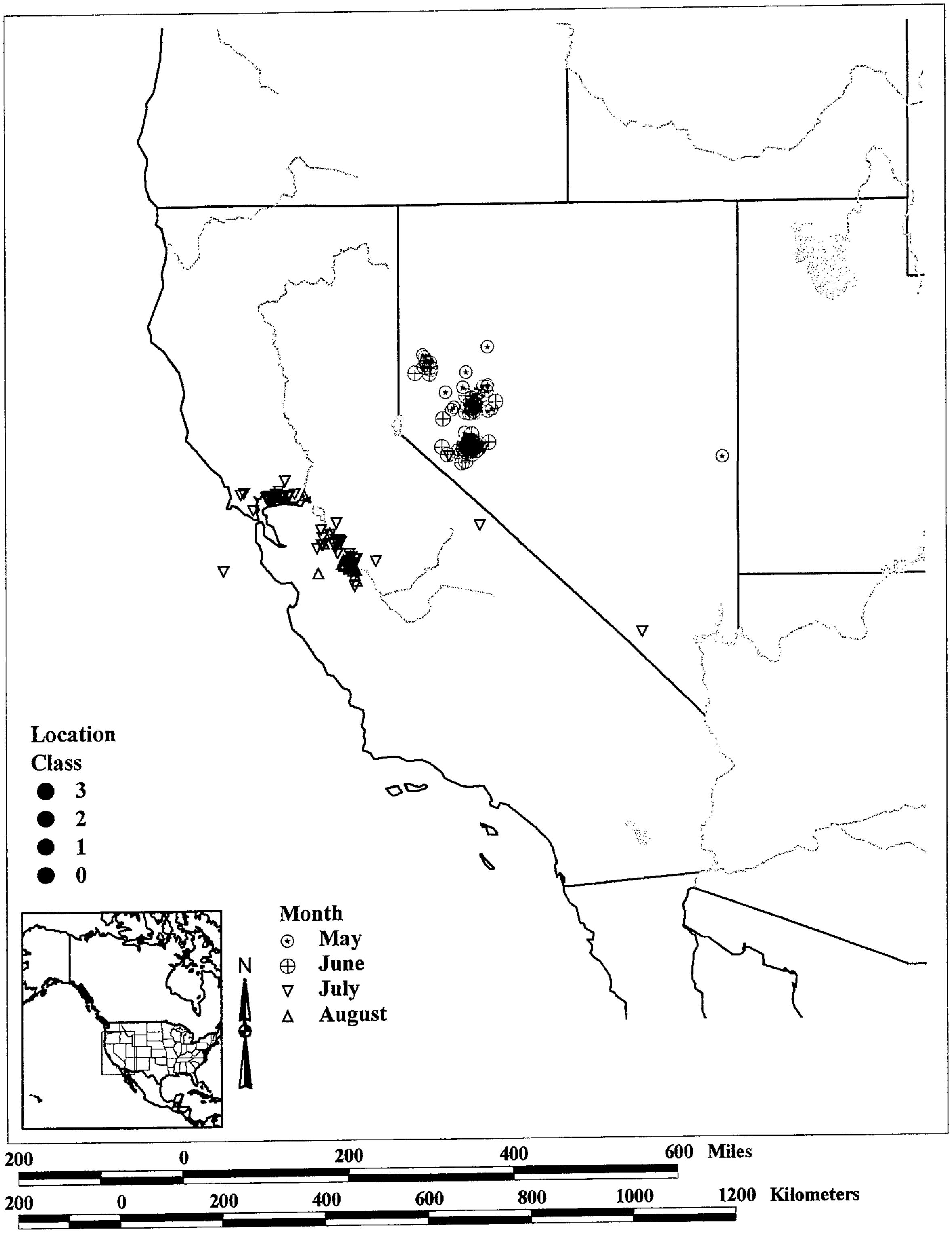

Figure NASF-8. Argos location estimates by month and location class for PTT# 11983 attached to an American white pelican. Shown are location estimates from 5/14/96 - 8/30/96.

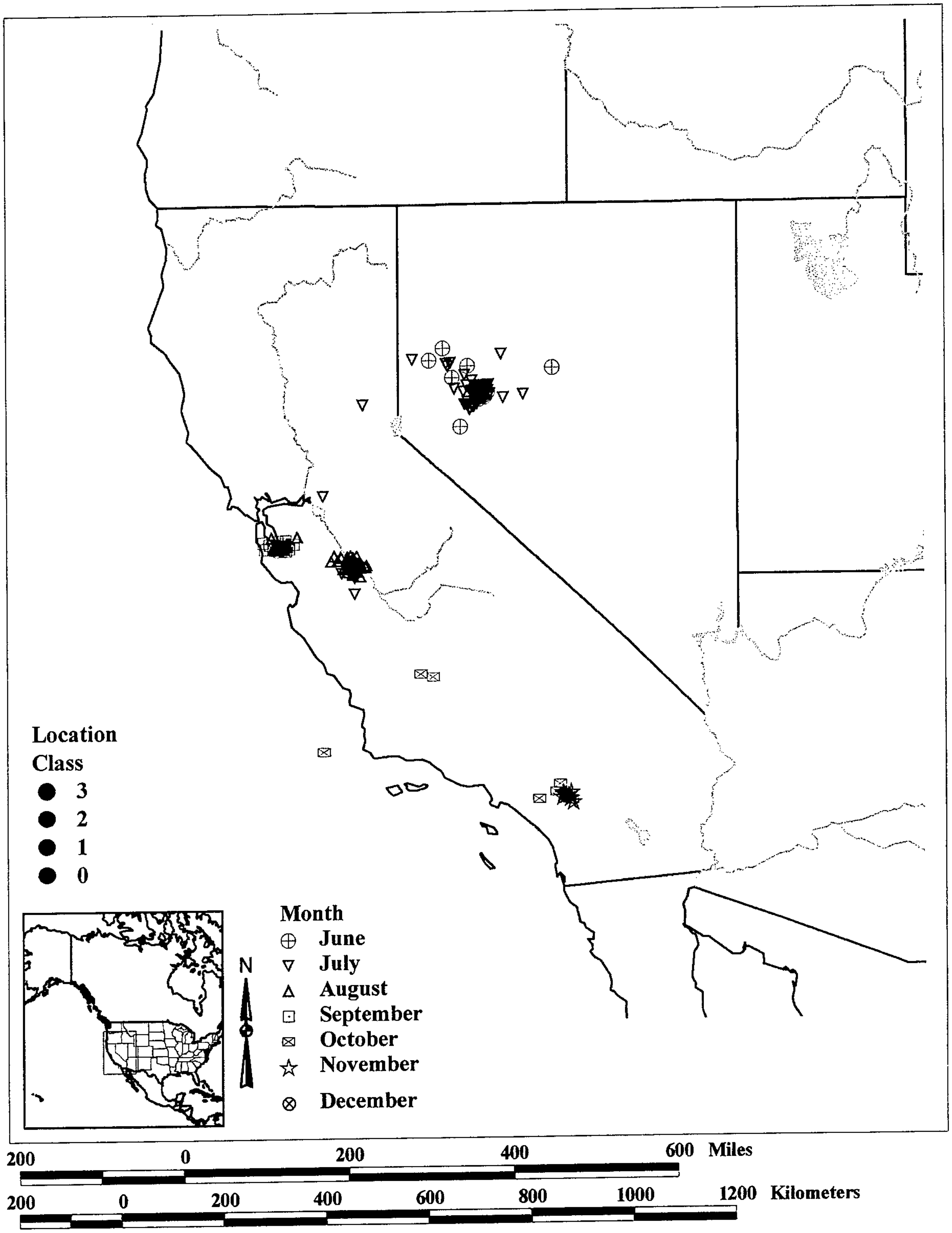

Figure NASF-9. Argos location estimates by month and location class for PTT# 11984 attached to an American white pelican. Shown are location estimates from 6/19/96 - 12/20/96.

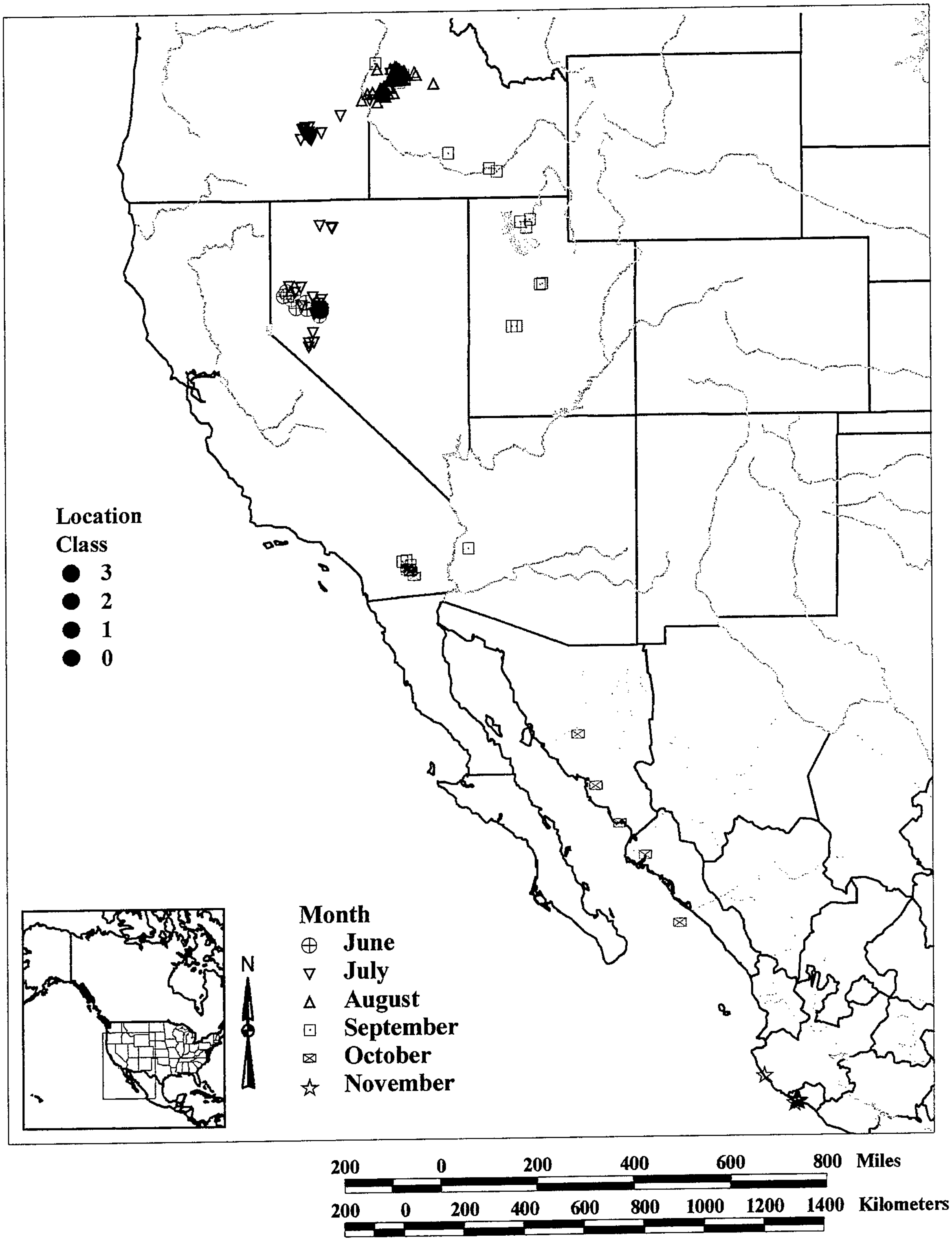

Figure NASF-10. Argos location estimates by month and location class for PTT# 5716 attached to an American white pelican. Shown are location estimates from 6/19/96 - 11/21/96.

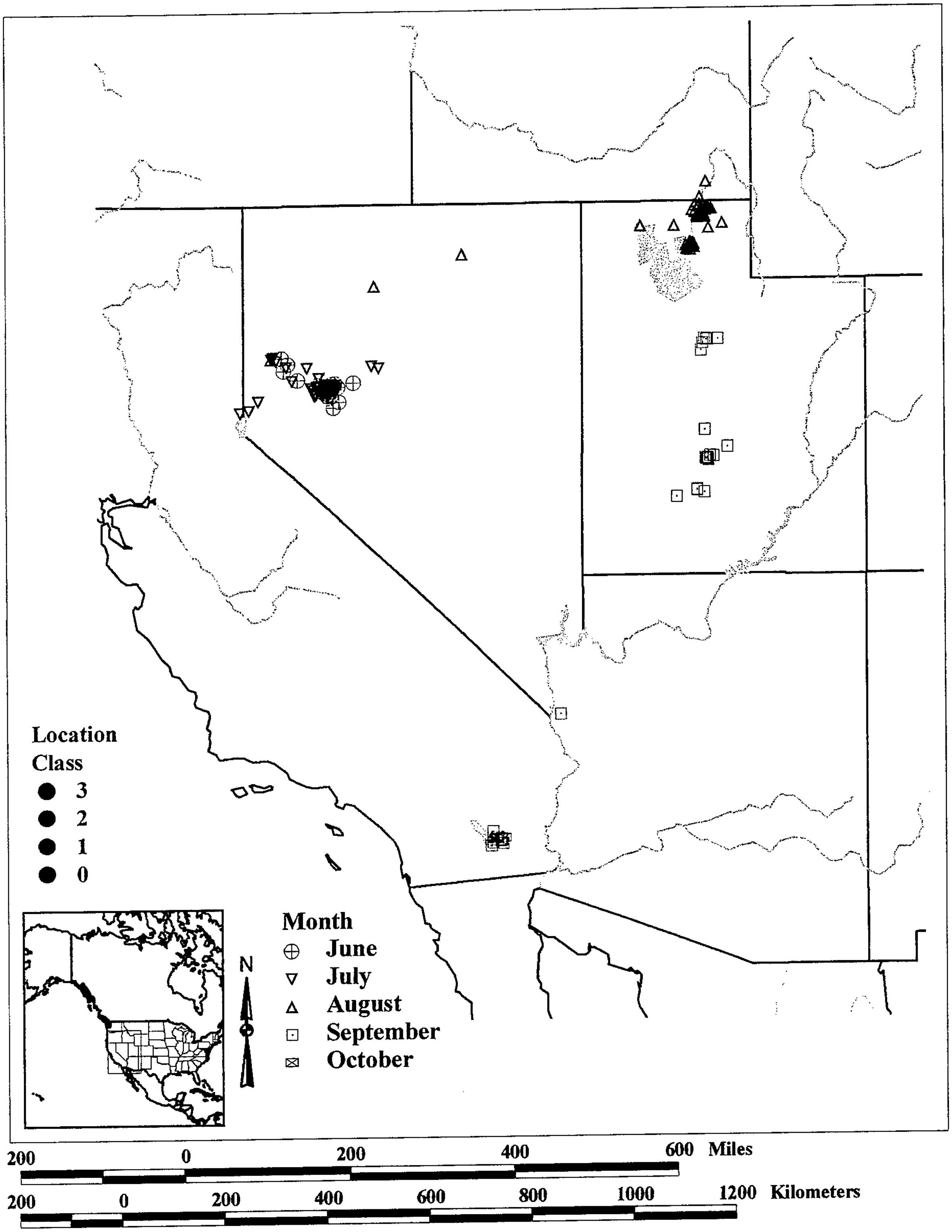

Figure NASF-11. Argos location estimates by month and location class for PTT# 5717 attached to an American white pelican. Shown are location estimates from 6/19/96 - 10/11/96.

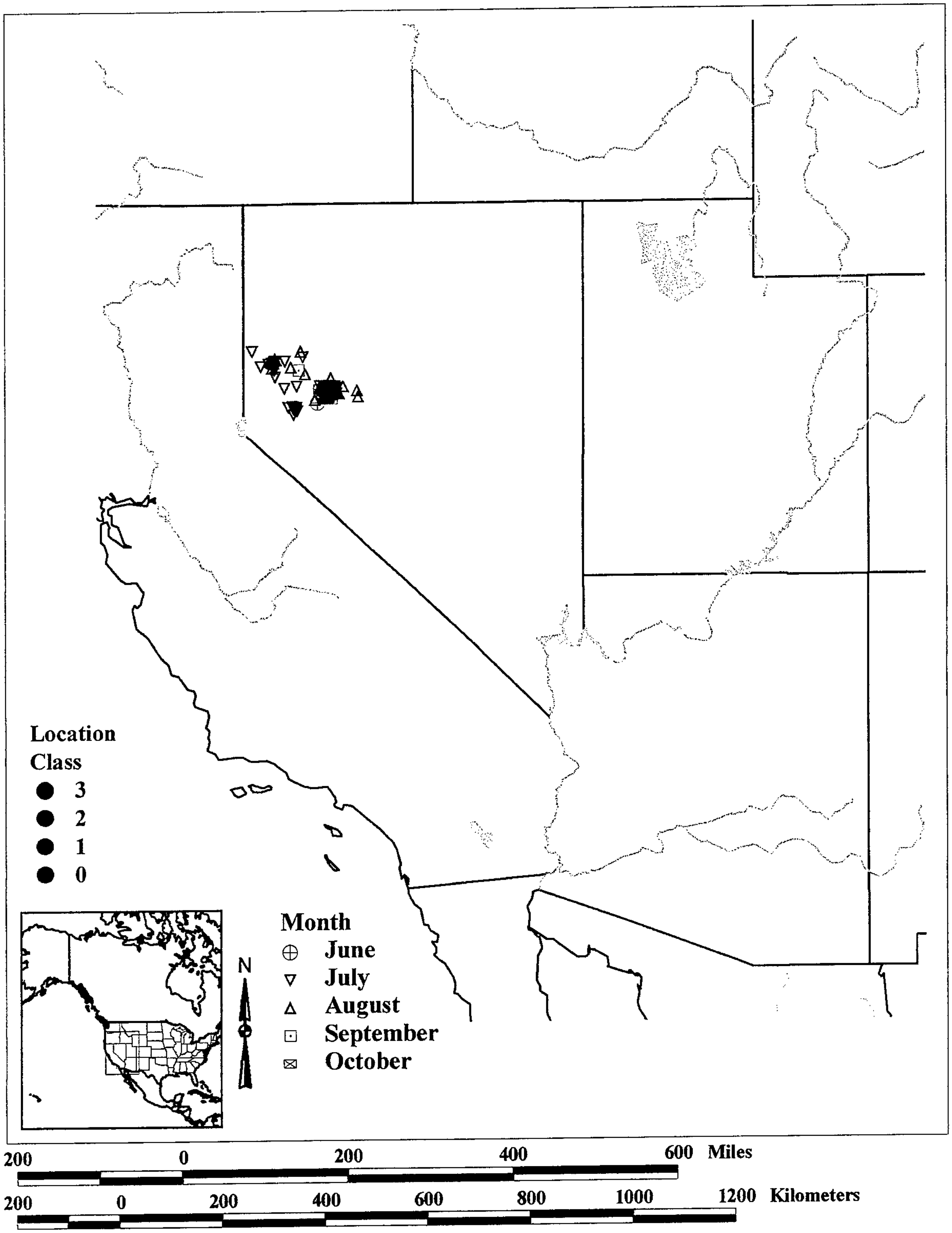

Figure NASF-12. Argos location estimates by month and location class for PTT# 5718 attached to an American white pelican. Shown are location estimates from 6/19/96 - 10/24/96.

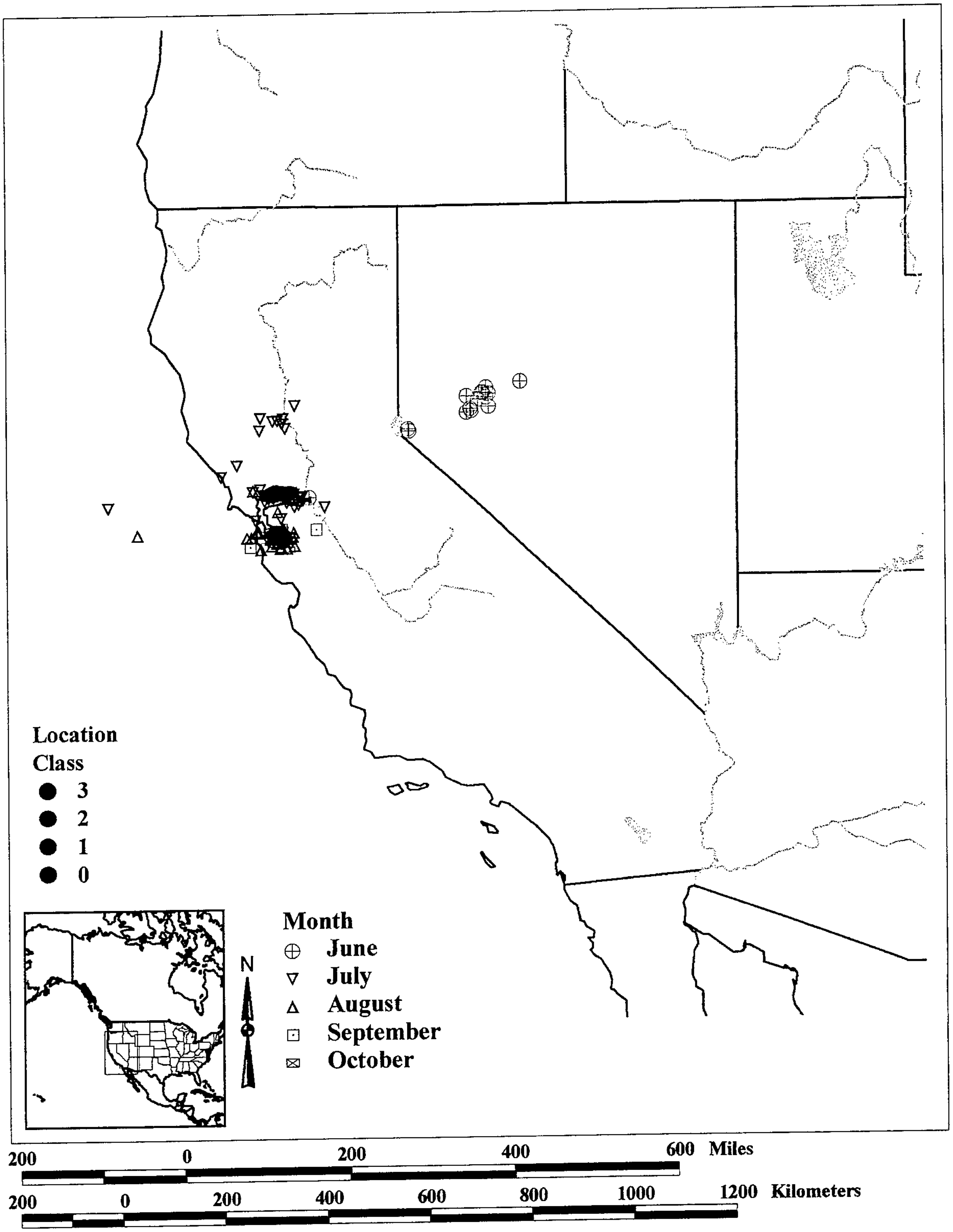

Figure NASF-13. Argos location estimates by month and location class for PTT# 5719 attached to an American white pelican. Shown are location estimates from 6/19/96 - 10/2/96.

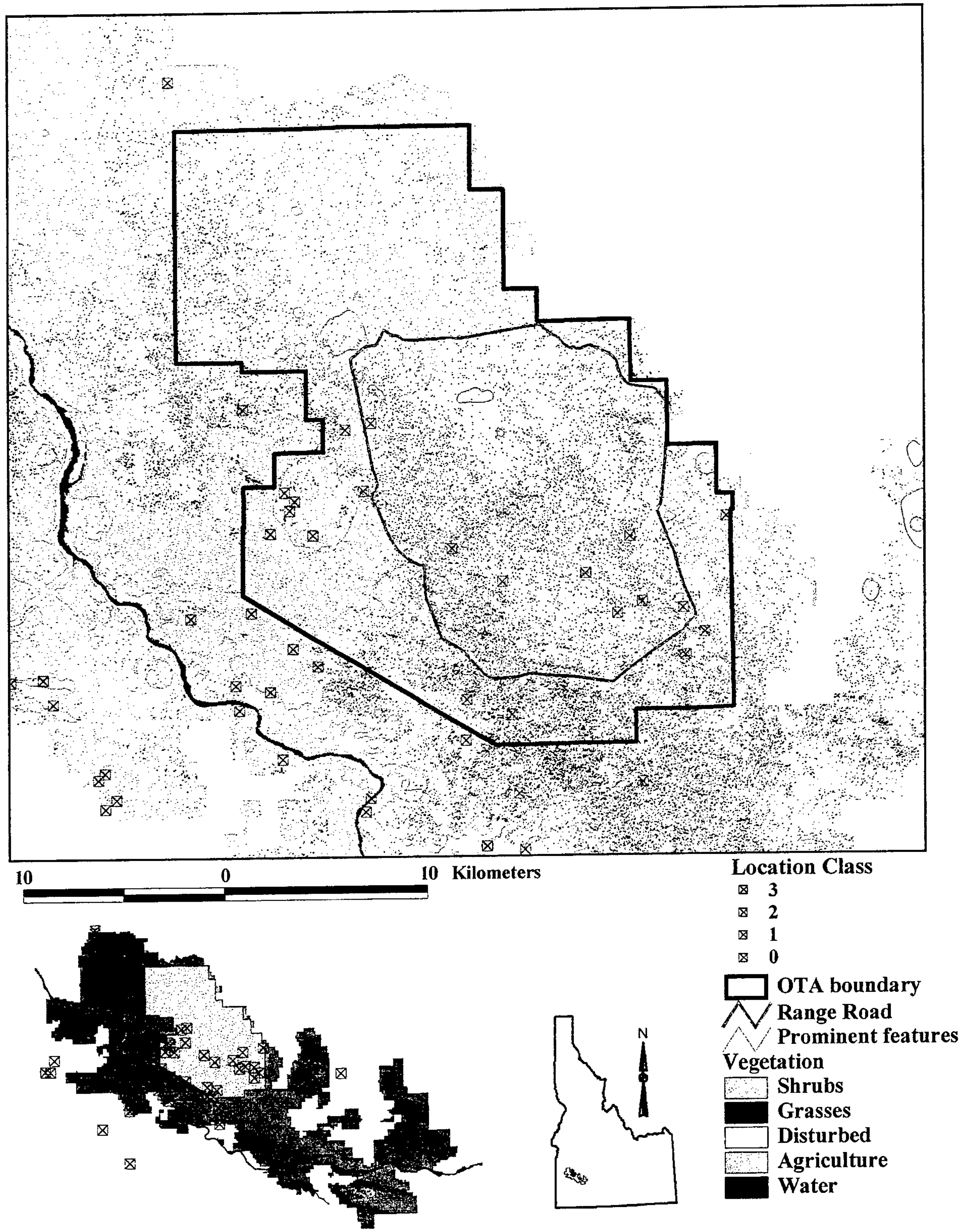

Figure OTA-1. Argos location estimates for PTT #5728A, attached to a golden eagle during the winter of 1996. Shown are location estimates from 1/13/96 - 2/12/96. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

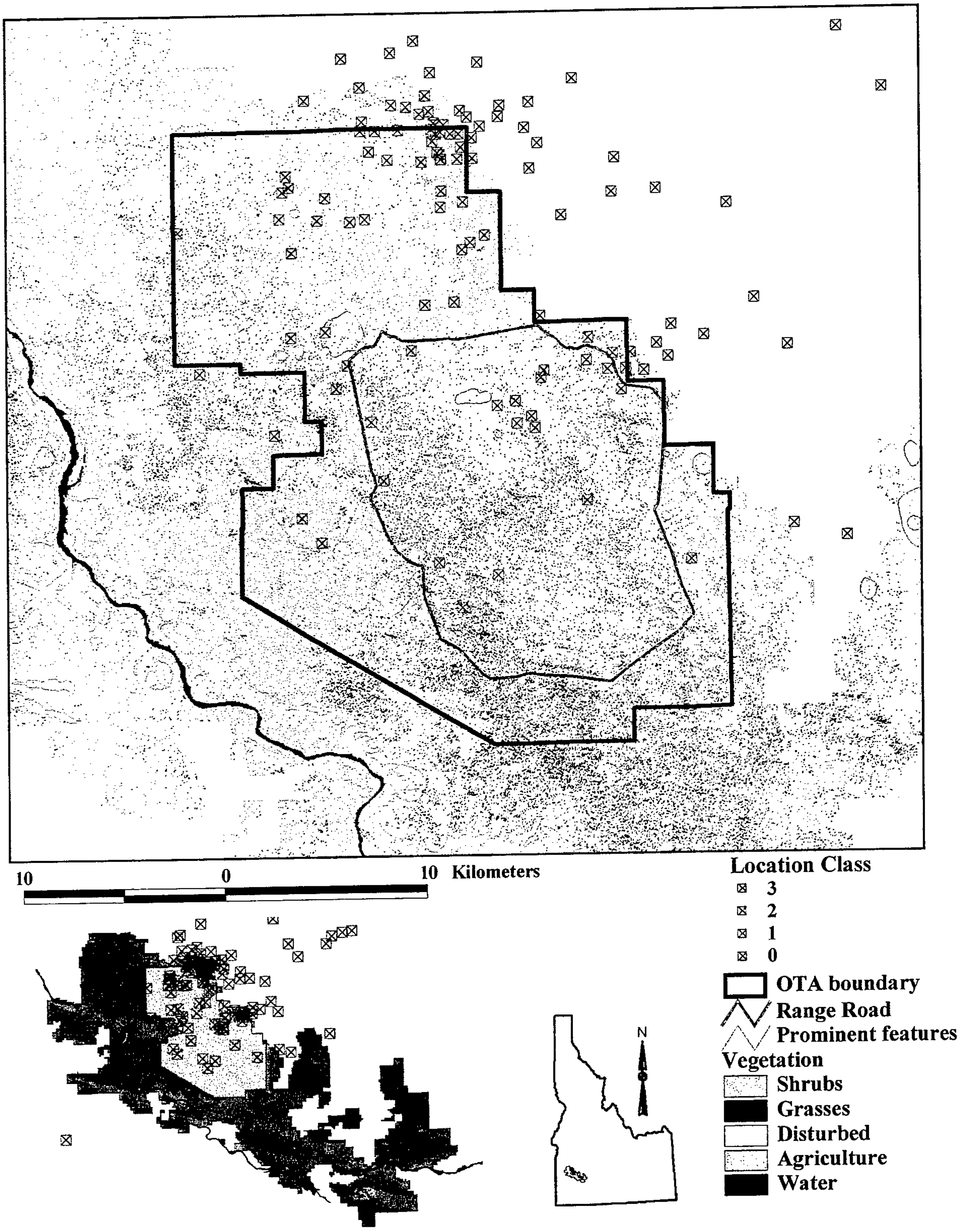

Figure OTA-2. Argos location estimates for PTT #5728B, attached to a golden eagle during the winter of 1996. Shown are location estimates from 3/5/96 - 5/8/96. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

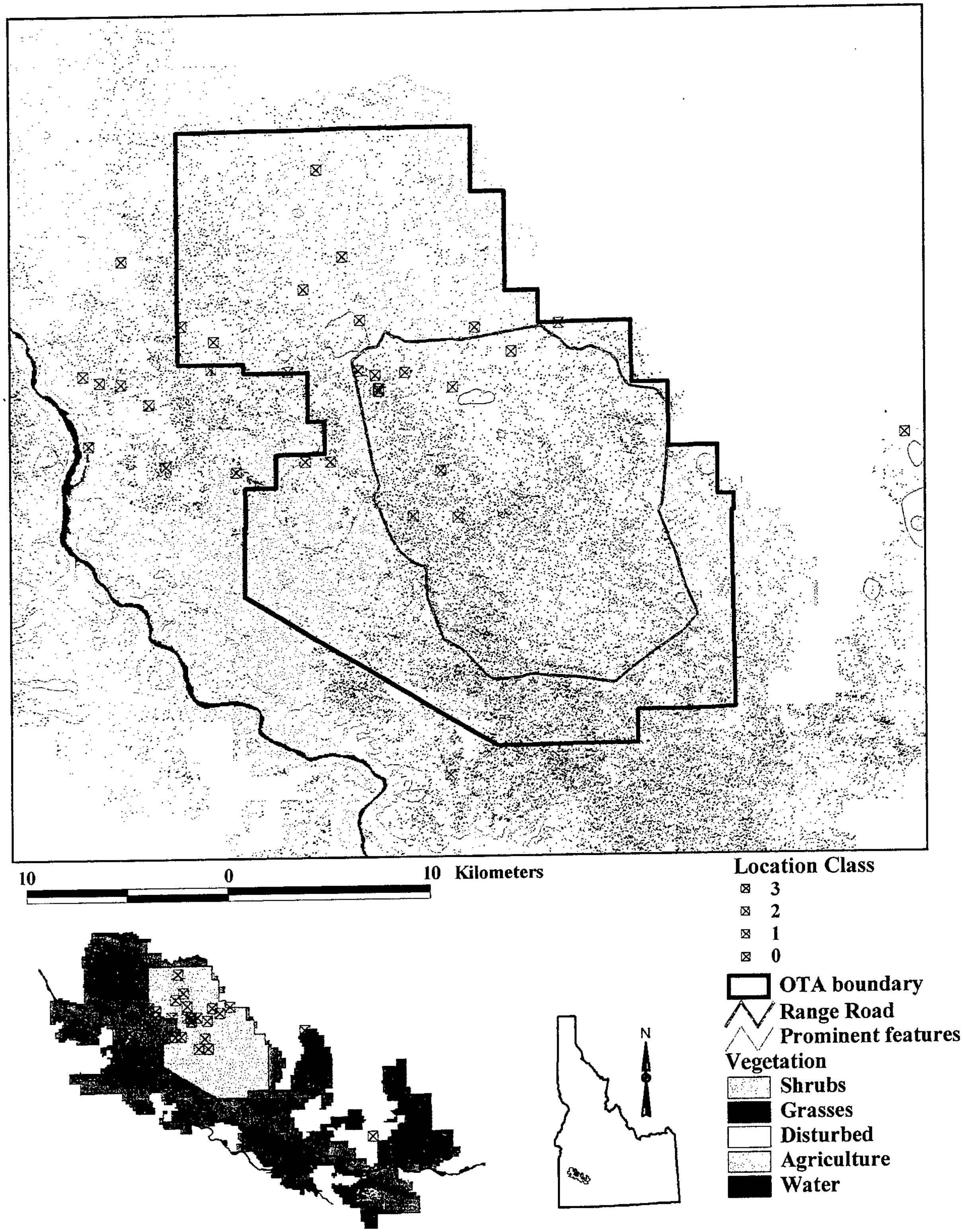

Figure OTA-3. Argos location estimates for PTT #5729, attached to a golden eagle during the winter of 1996. Shown are location estimates from 1/20/96 - 1/27/96. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

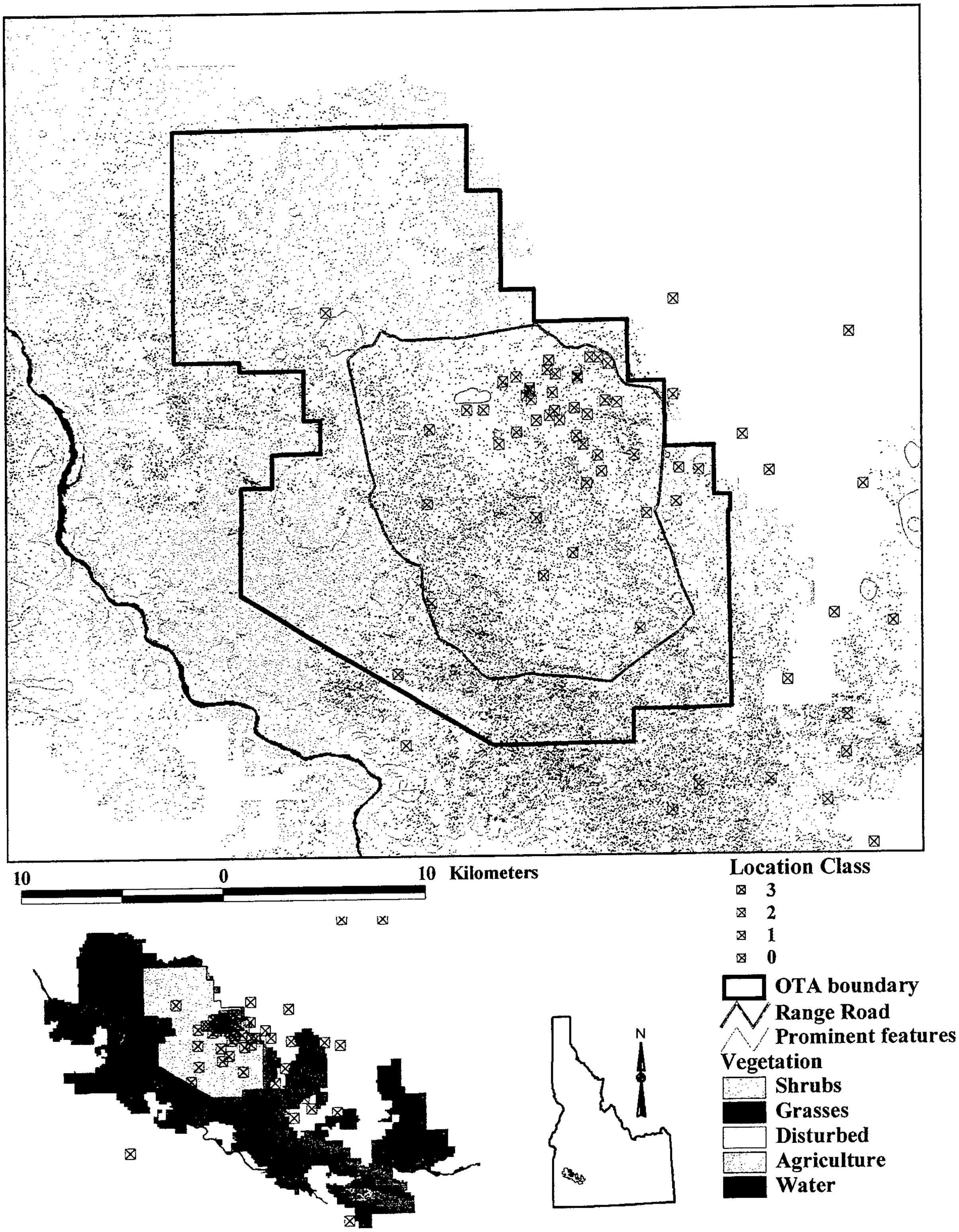

Figure OTA-4. Argos location estimates for PTT #5730, attached to a golden eagle during the winter of 1996. Shown are location estimates from 1/23/96 - 3/3/96. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

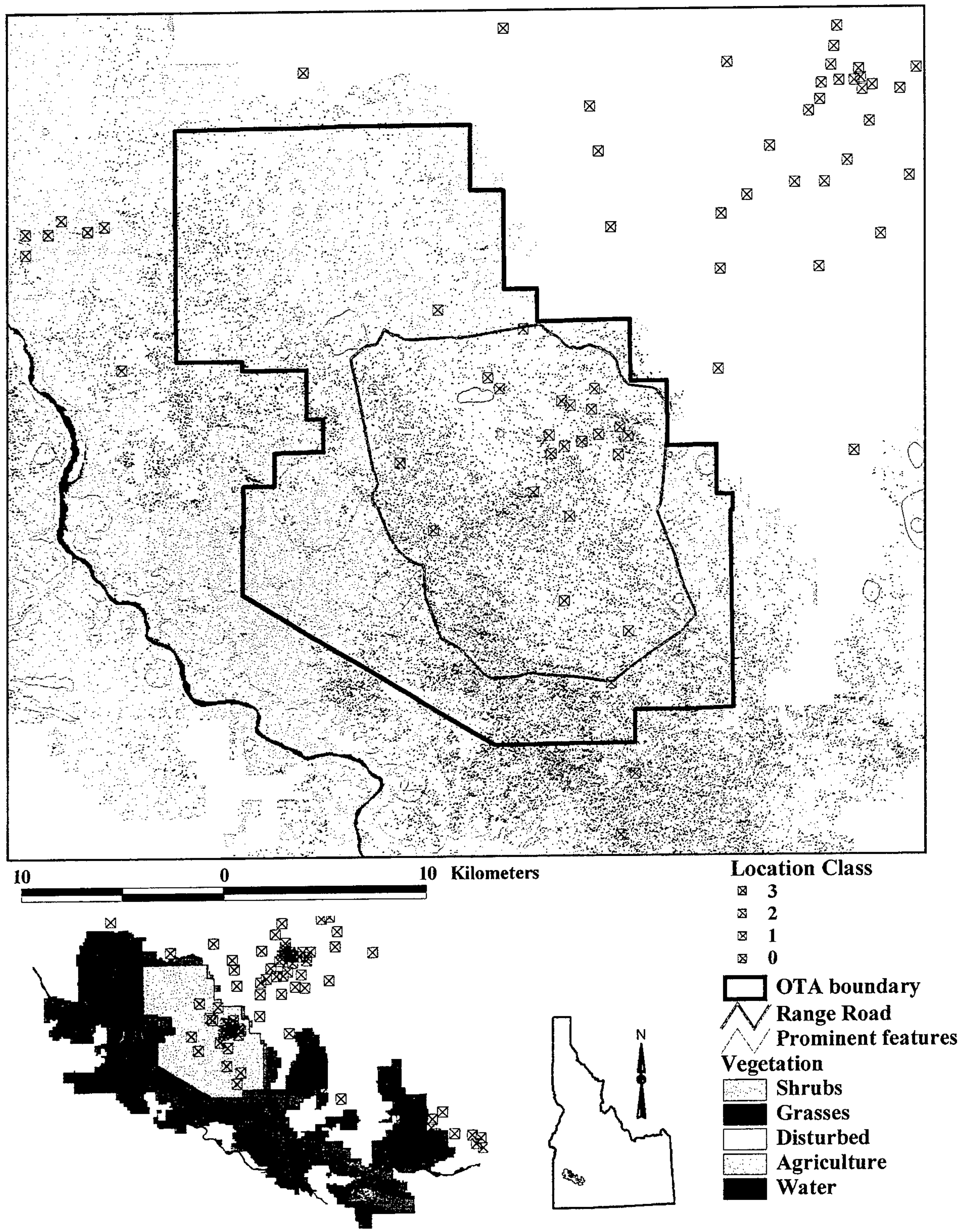

Figure OTA-5 Argos location estimates for PTT #5731, attached to a golden eagle during the winter of 1996. Shown are location estimates from 1/30/96 - 3/12/96. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

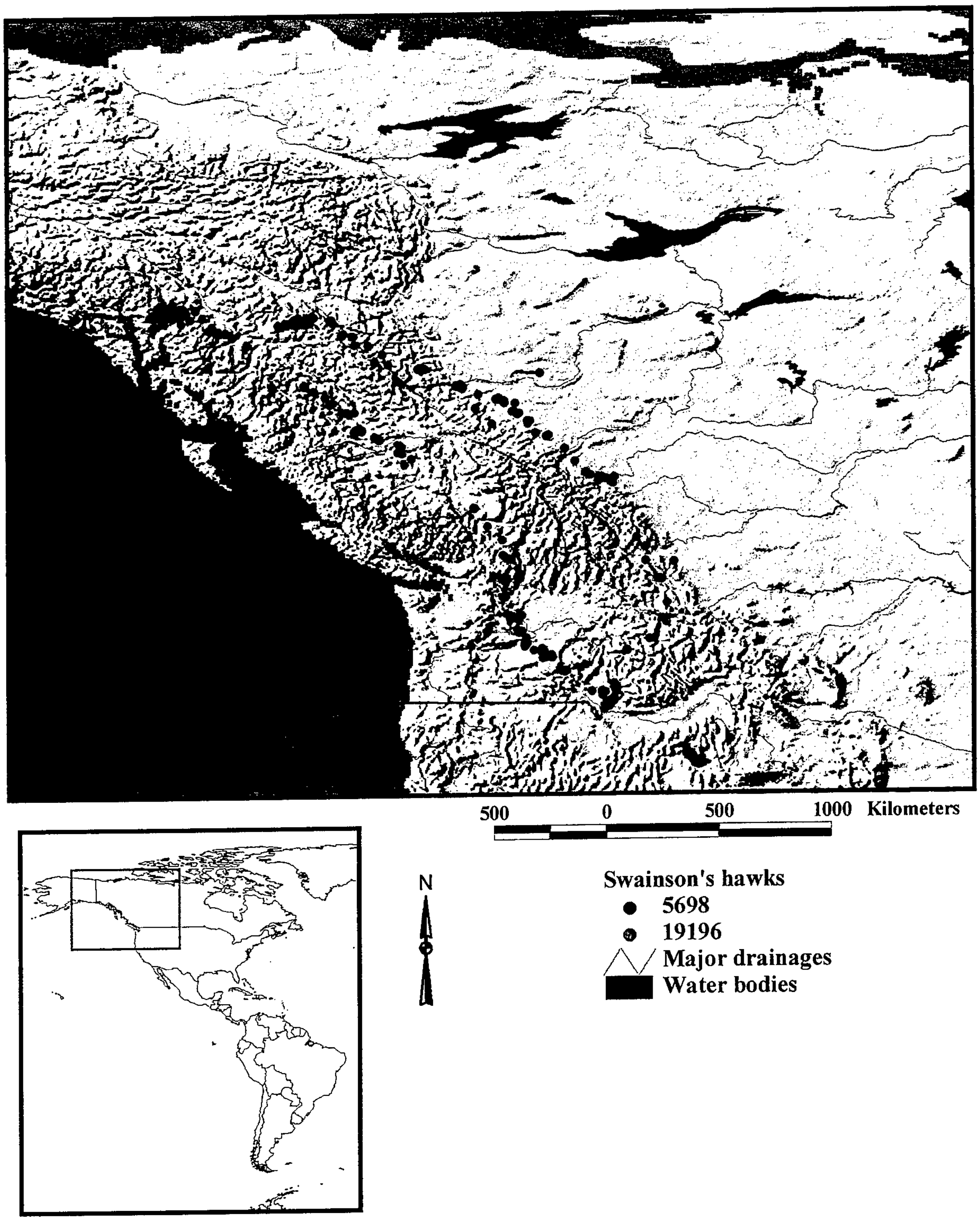

Figure OTA-6. Argos location estimates for 2 golden eagles during northward migration. Shown are location estimates of LC 0 - 3. Background is a shaded relief map from a global digital elevation model (GTOPO30). Background Data Source: USGS.

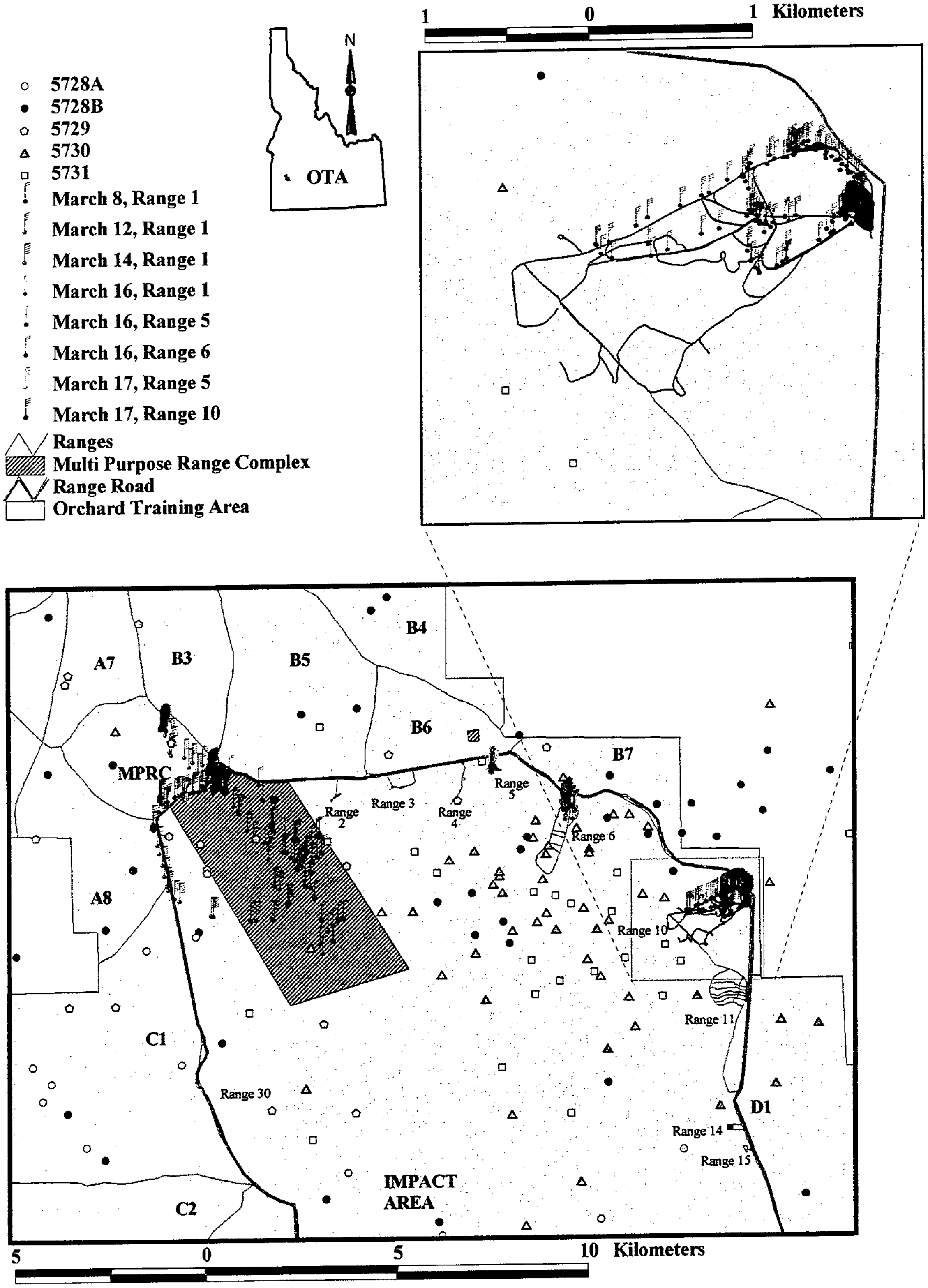

Figure OTA-7. Typical movements of tanks (identified by date) displayed with all l ocation estimates of LC 0 - 3 obtained from golden eagles in the vicinity of the ranges. Tank movements and eagle locations are not temporally matched.

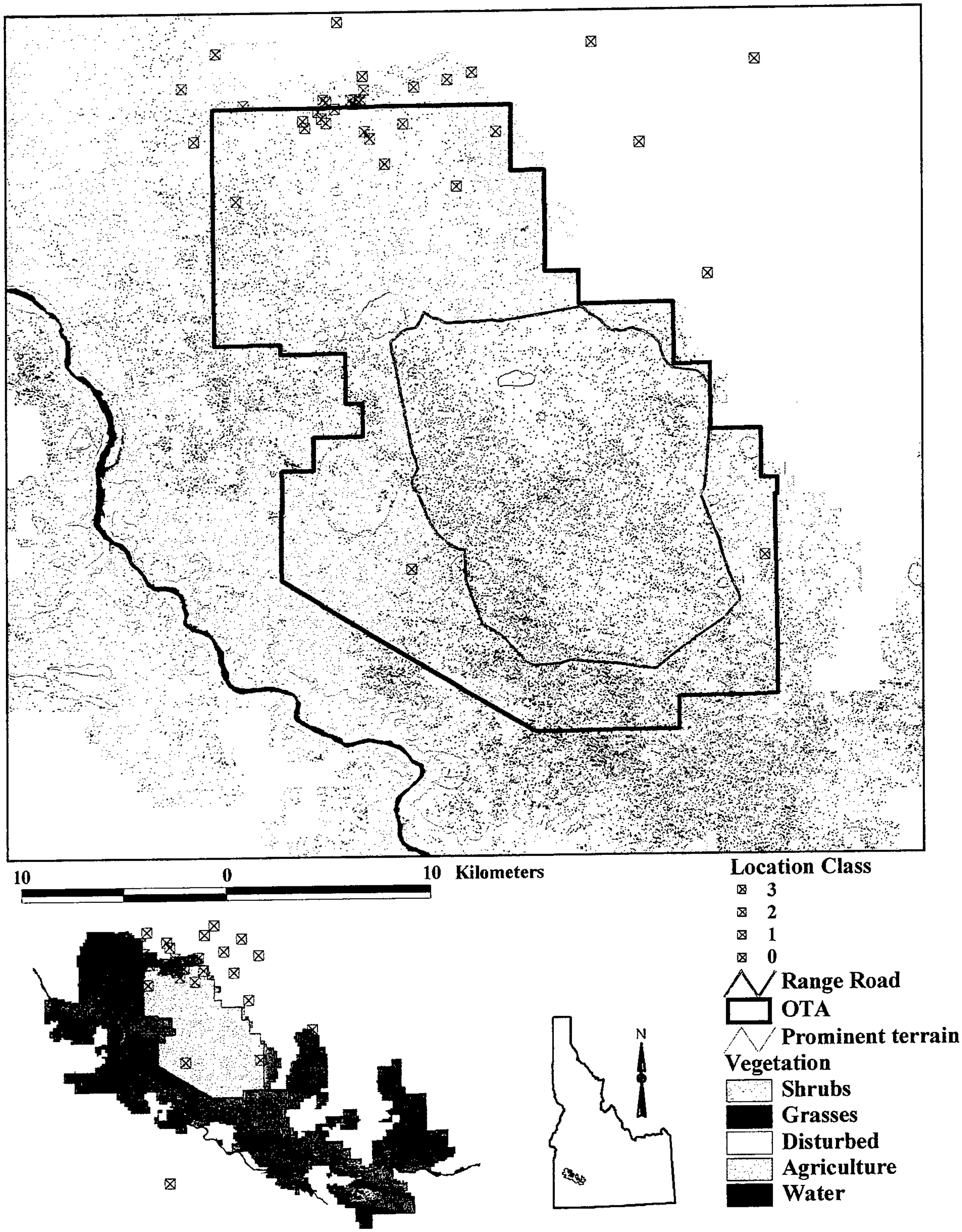

Figure OTA-8. Argos location estimates for PTT #11979, attached to a ferruginous hawk during the breeding season of 1996. Data shown are from 6/5/96 - 7/21/96. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

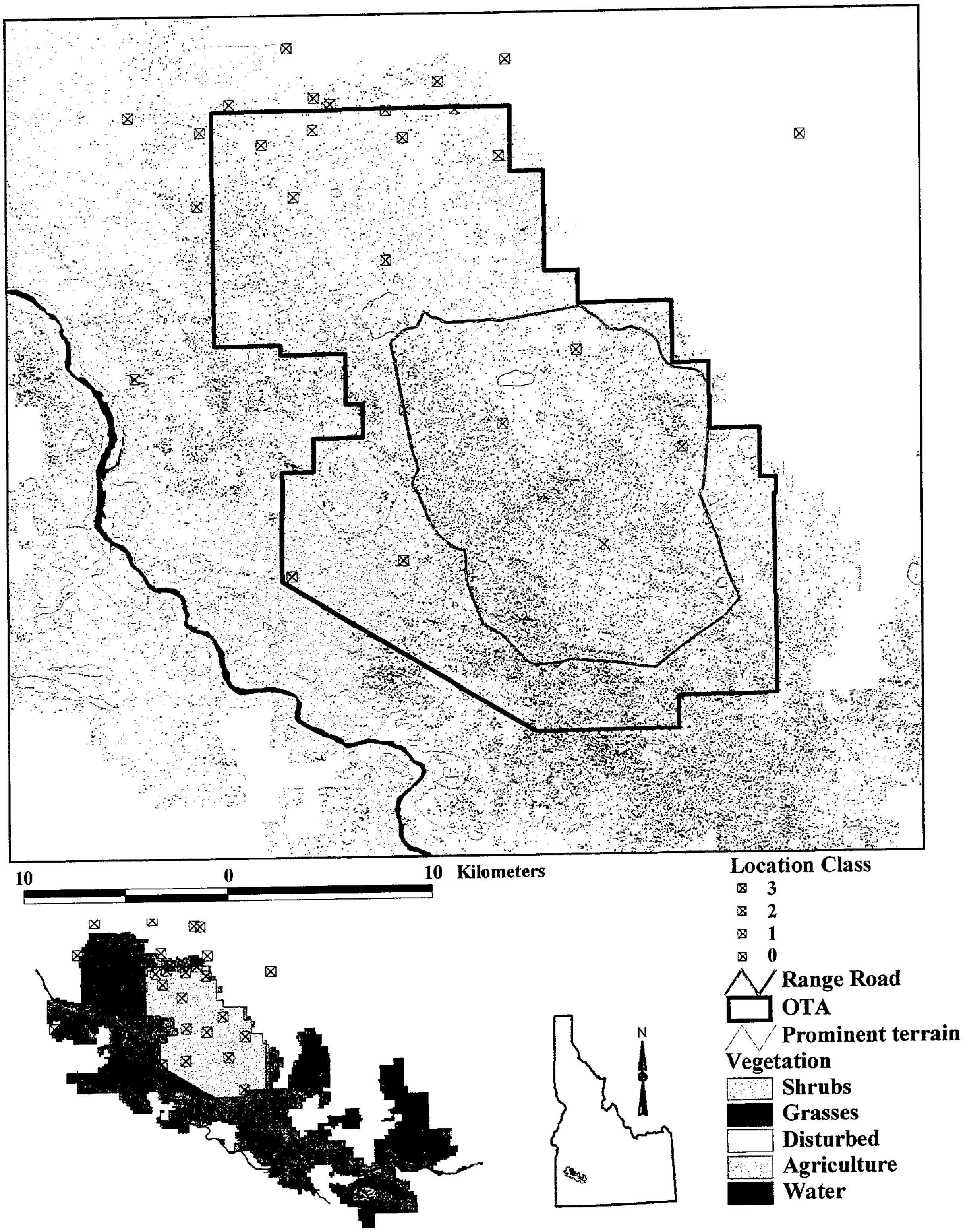

Figure OTA-9. Argos location estimates for PTT #11980, attached to a ferruginous hawk during the breeding season of 1996. Data shown are from 6/12/96 - 8/4/96 and 3/4/97 - 5/4/97. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

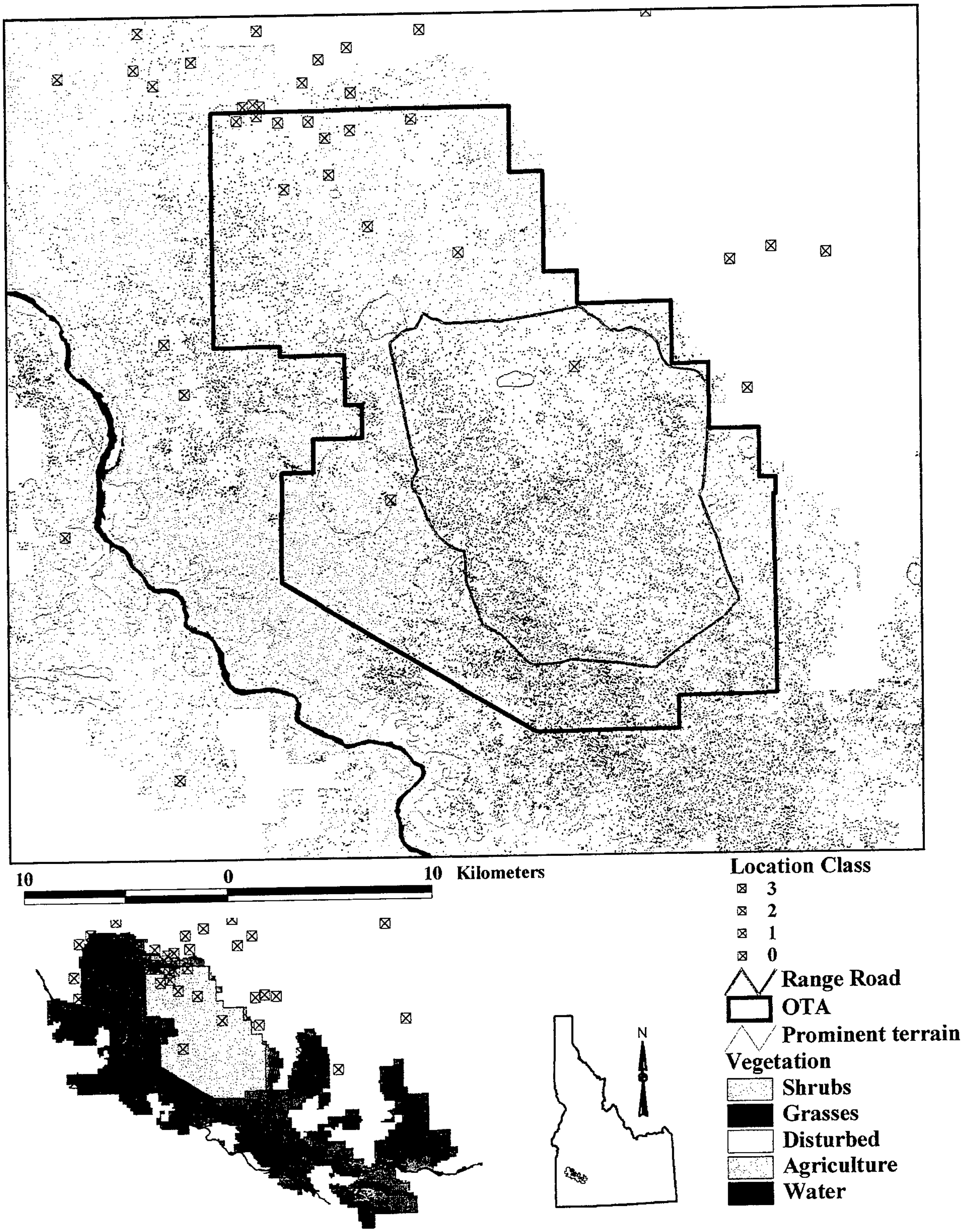

Figure OTA-10. Argos location estimates for PTT #11981, attached to a ferruginous hawk during the breeding season of 1996. Data shown are from 6/20/96 - 8/25/96 and 3/11/97 - 3/22/97. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

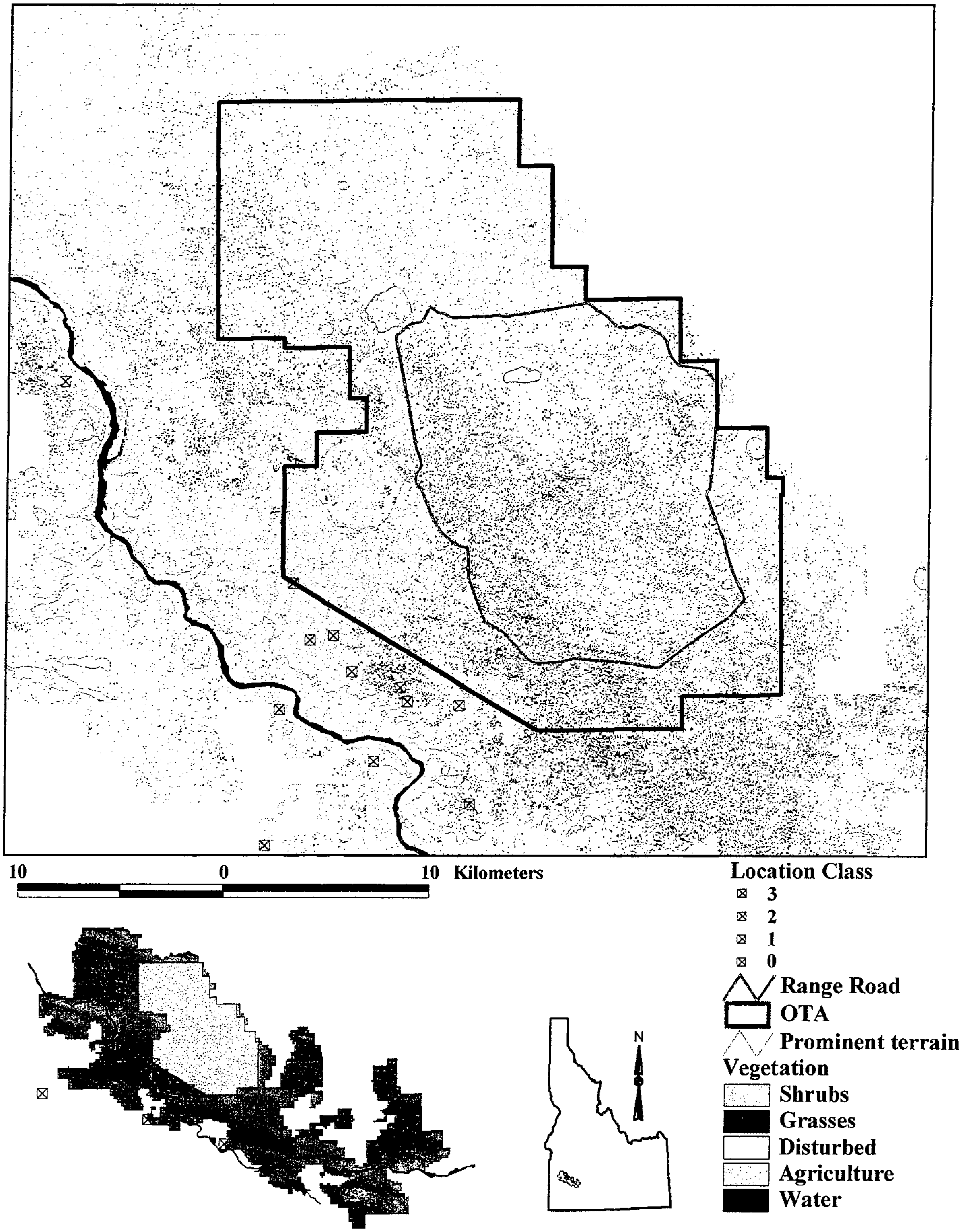

Figure OTA-11. Argos location estimates for PTT #11986, attached to a ferruginous hawk during the breeding season of 1996. Data shown are from 6/28/96 - 7/22/96. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

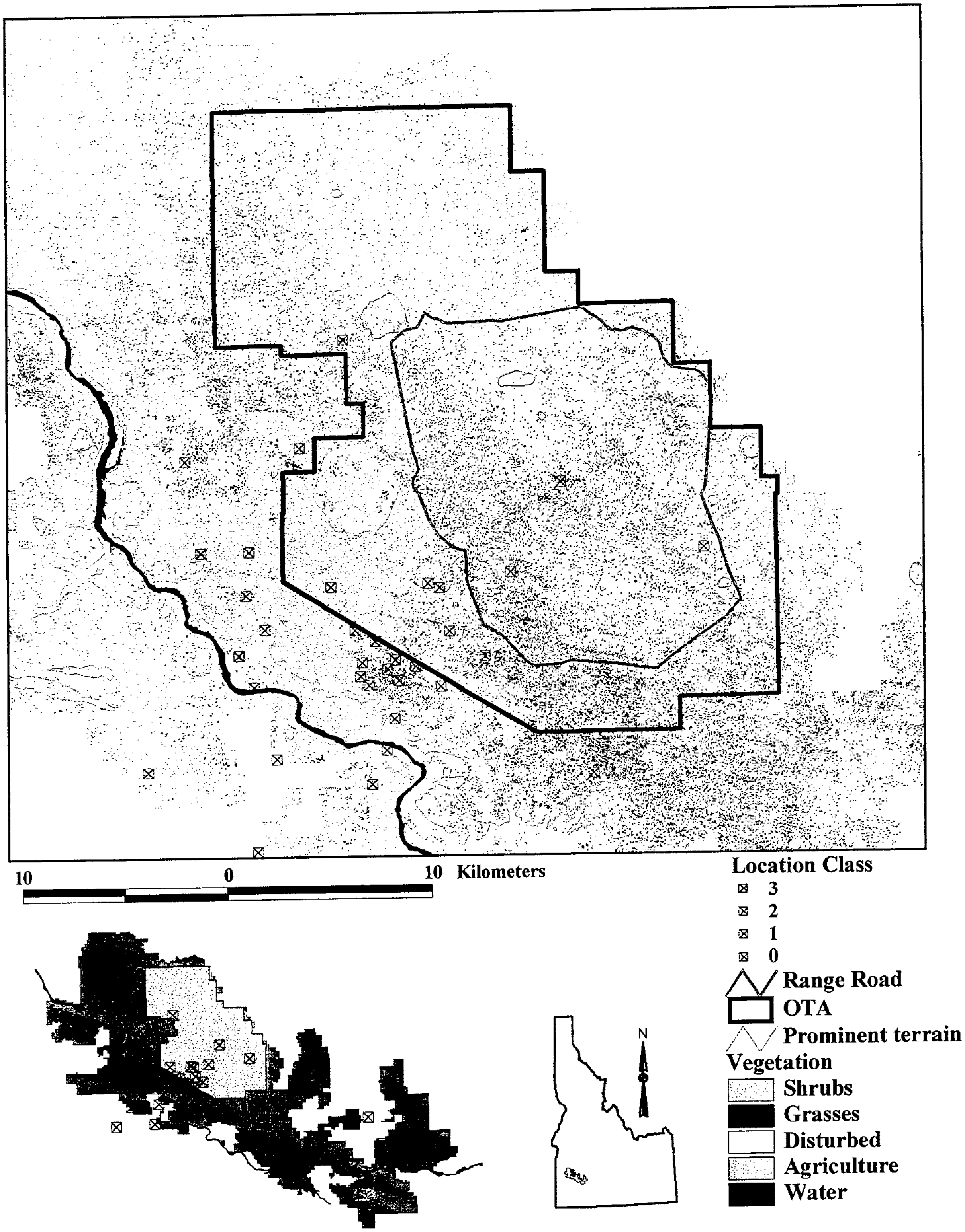

Figure OTA-12. Argos location estimates for PTT #19195, attached to a ferruginous hawk during the breeding season of 1996. Data shown are from 6/28/96 - 7/9/96 and 4/3/97 - 5/31/97. Background Data Source: USGS Forest and Rangeland Ecosystem Science Center, Snake River Field Station.

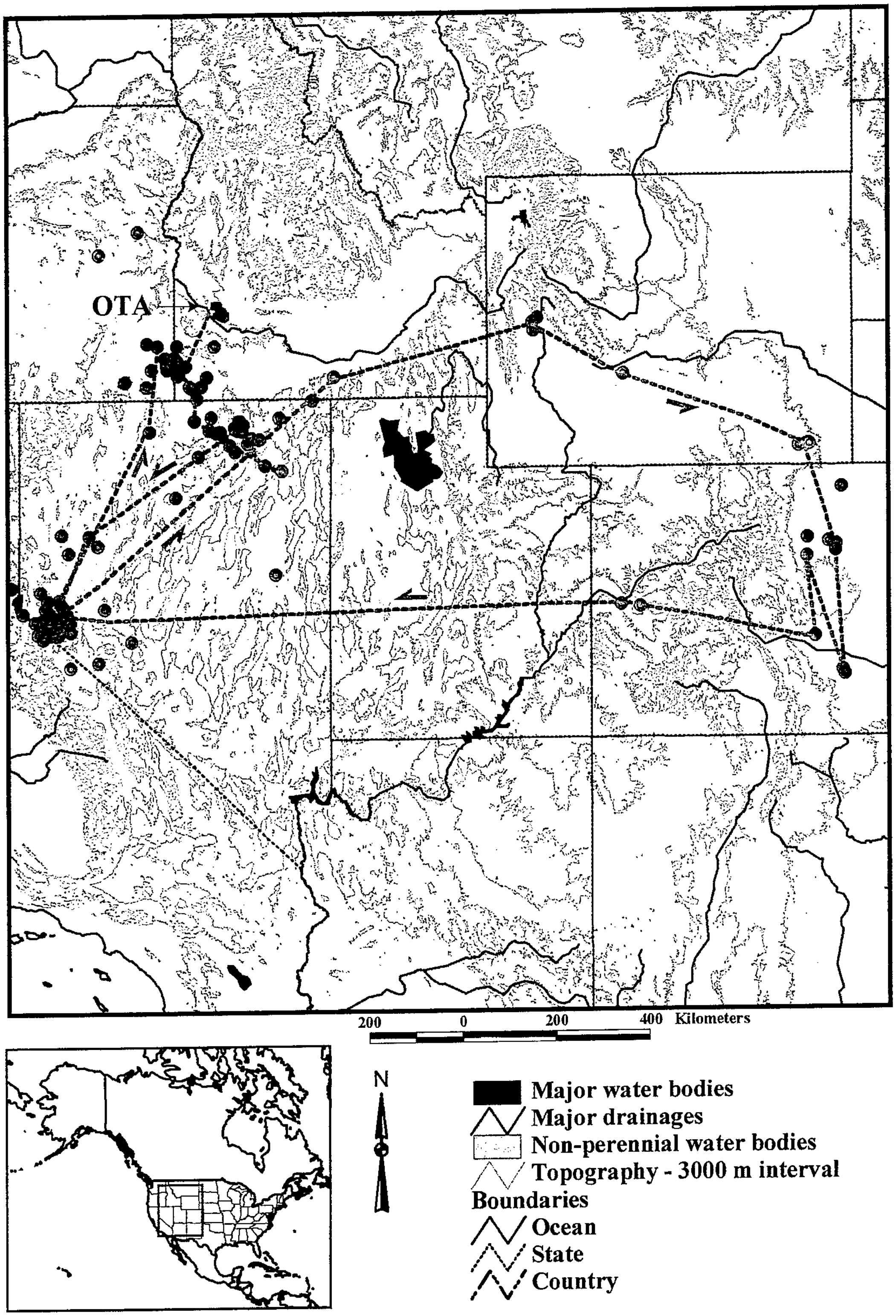

Figure OTA-13. Argos location estimates for PTT #5737, attached to a ferruginous hawk. Shown are location estimates of LC 0 - 3 from 5/30/96 - 5/26/97. Background Data Source: Digital Chart of the World.

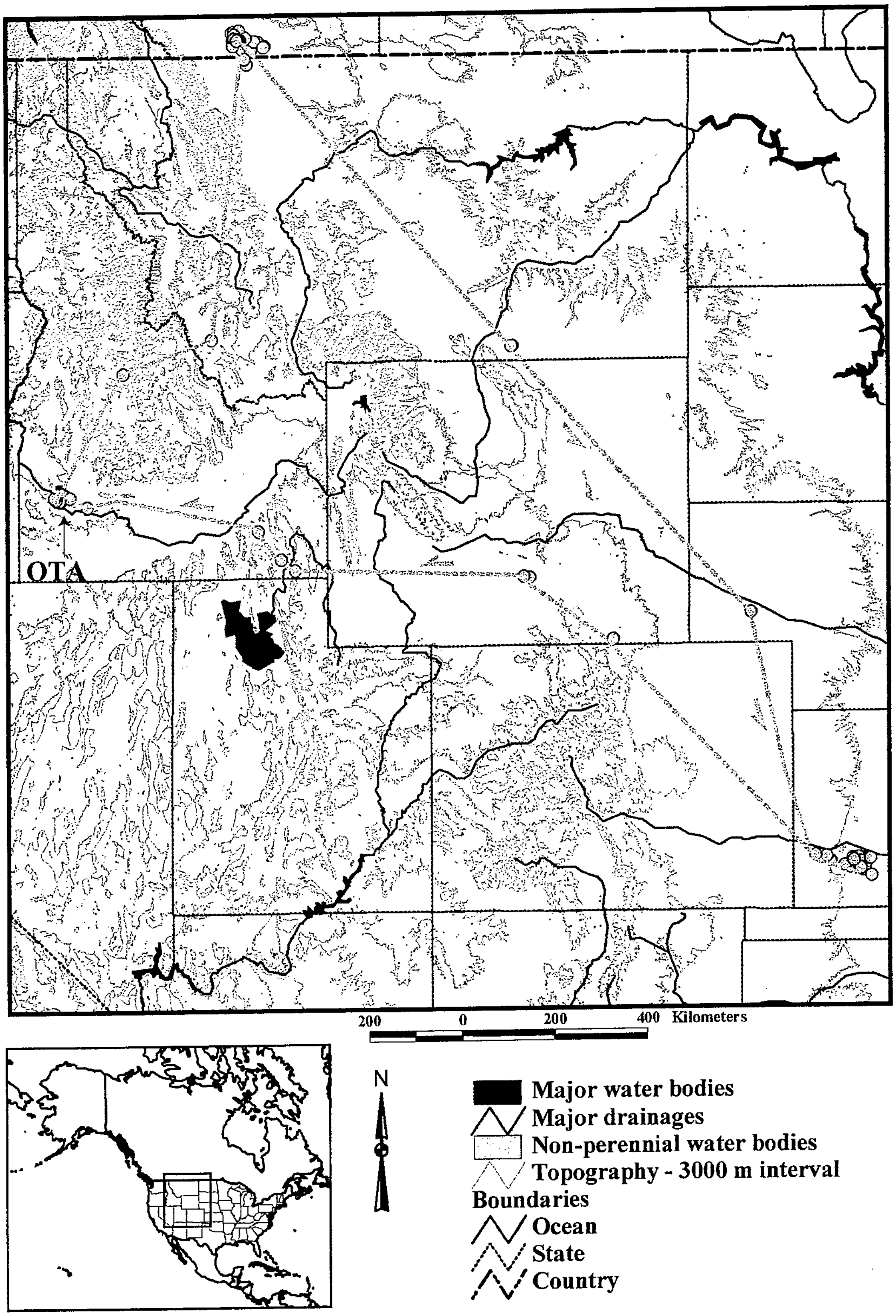

Figure OTA-14. Argos location estimates for PTT #19195, attached to a ferruginous hawk. Shown are location estimates of LC 0 - 3 from 7/9/96 - 4/3/97. Background Data Source: Digital Chart of the World.

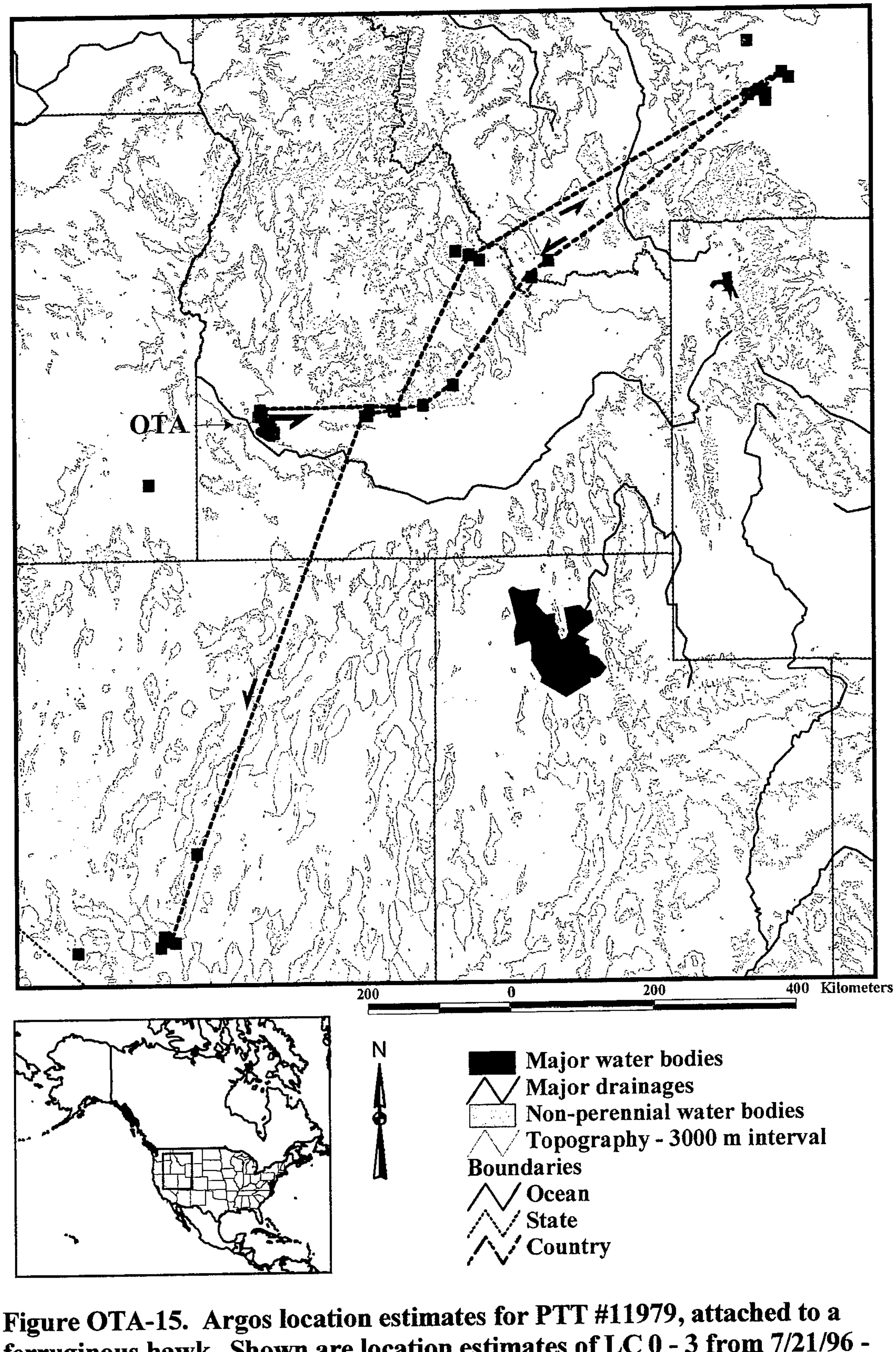

Figure OTA-15. Argos location estimates for PTT #11979, attached to a ferruginous hawk. Shown are location estimates of LC 0 - 3 from 7/21/96 - 11/24/97. Background Data Source: Digital Chart of the World.

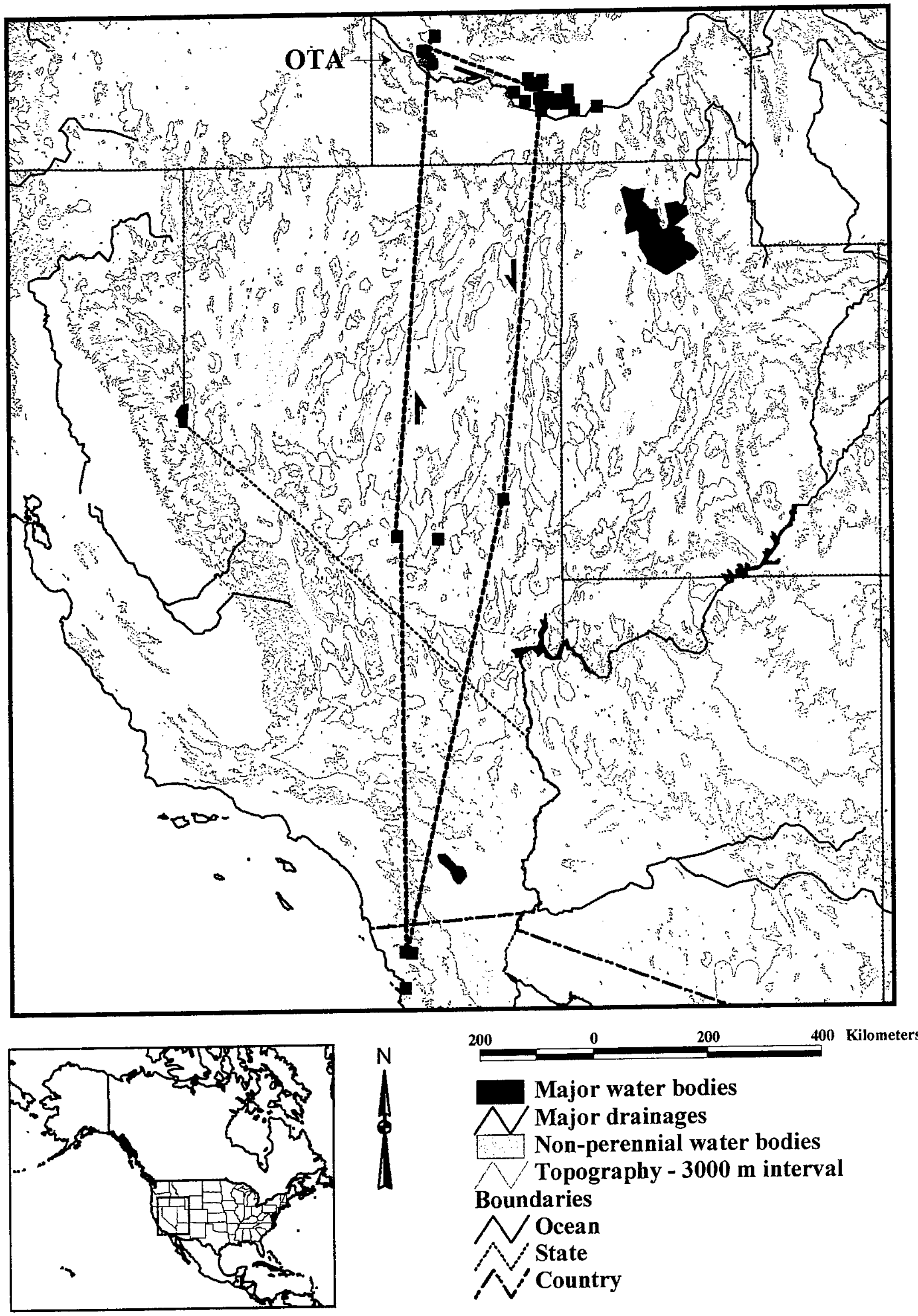

Figure OTA-16. Argos location estimates for PTT #11980, attached to a ferruginous hawk. Shown are location estimates of LC 0 - 3 from 8/4/96 - 5/4/97. Background Data Source: Digital Chart of the World.

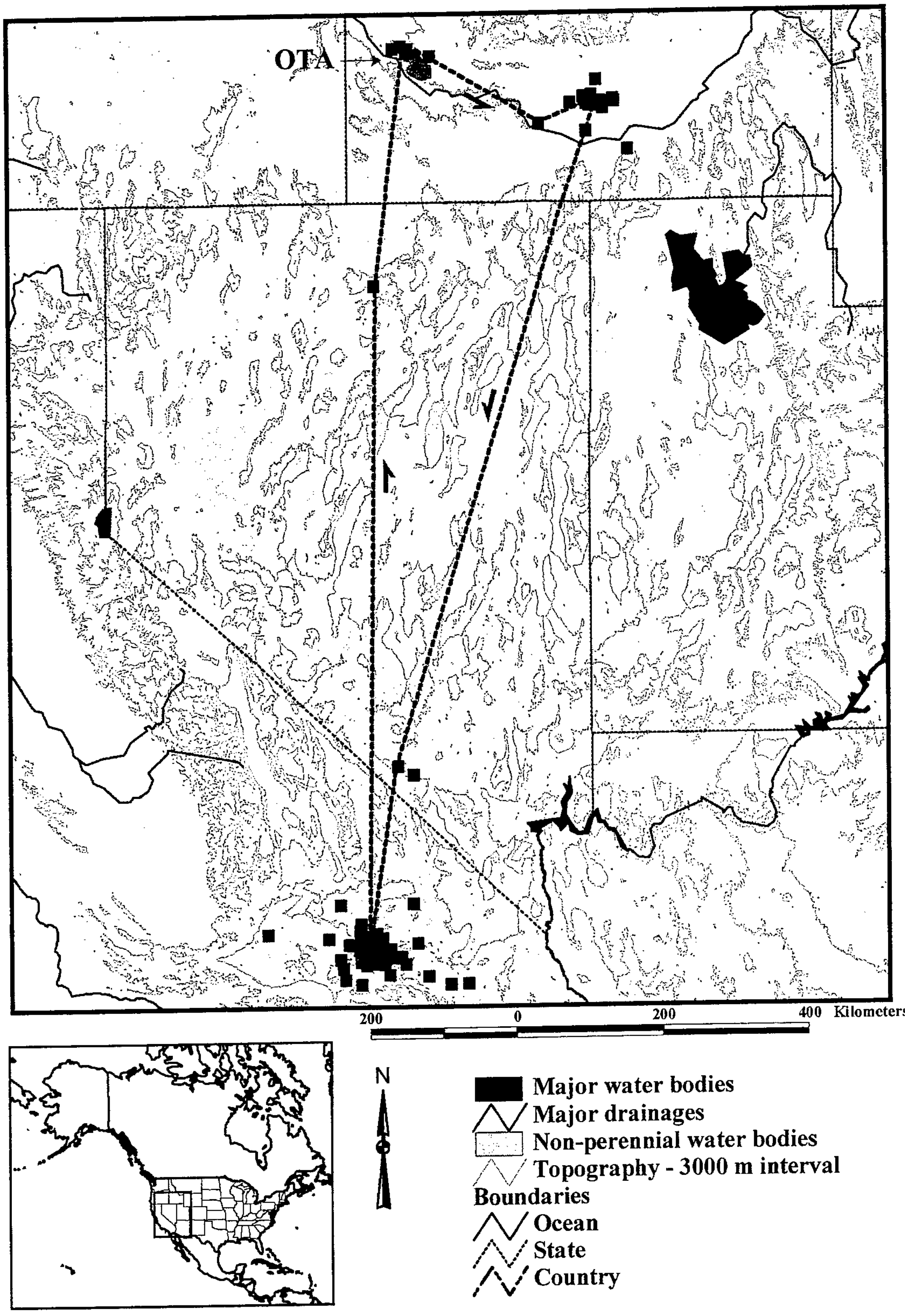

Figure OTA-17. Argos location estimates for PTT #11981, attached to a ferruginous hawk. Shown are location estimates of LC 0 - 3 from 8/25/96 - 3/11/97. Background Data Source: Digital Chart of the World.

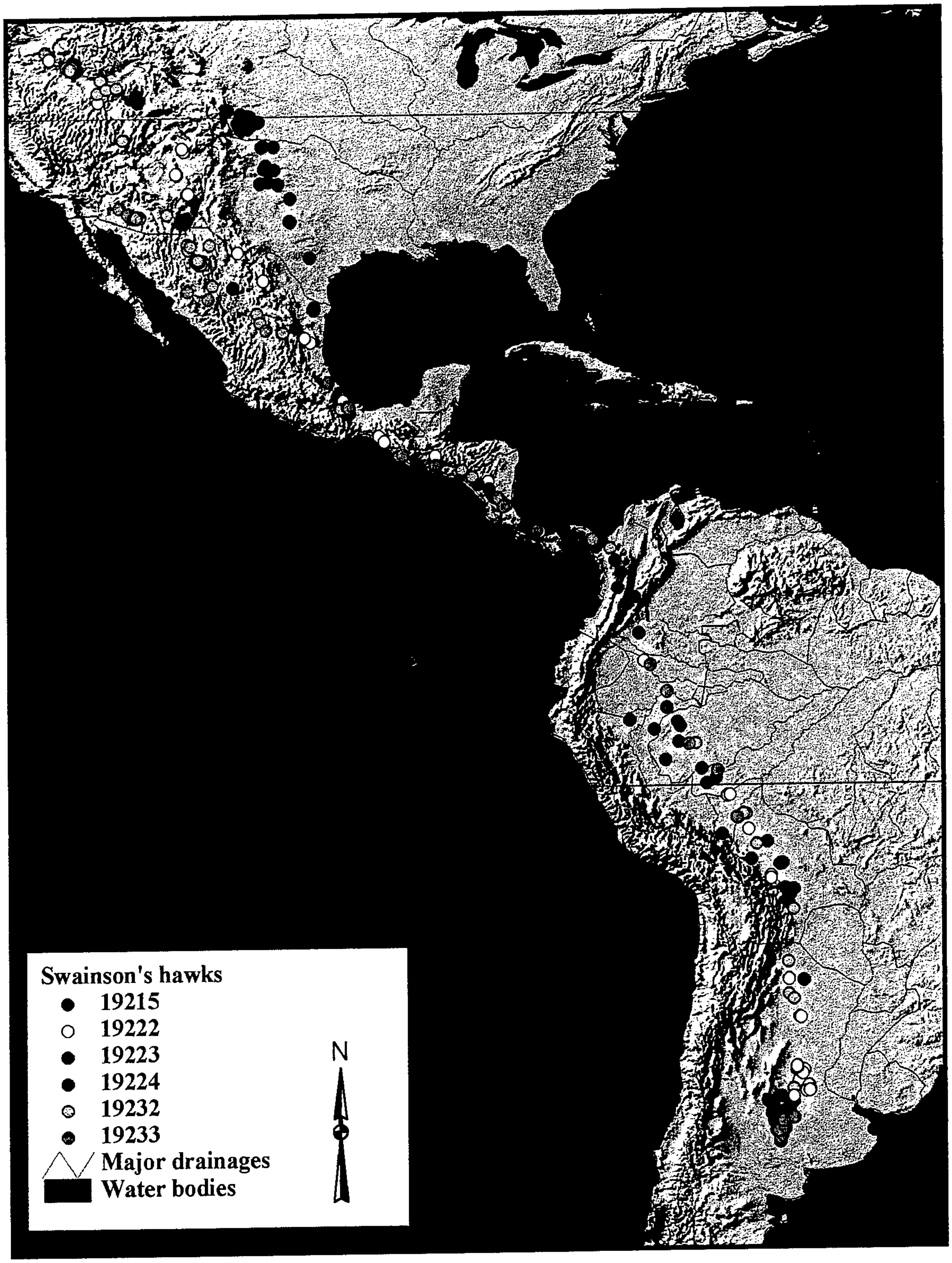

Figure OTA-18. Argos location estimates for 6 Swainson's hawks during southward migration. Shown are location estimates of LC 0 - 3 from 9/1/96 - 12/31/96. Background is a shaded relief map from a global digital elevation model (GTOPO30). Background Data Source: USGS.

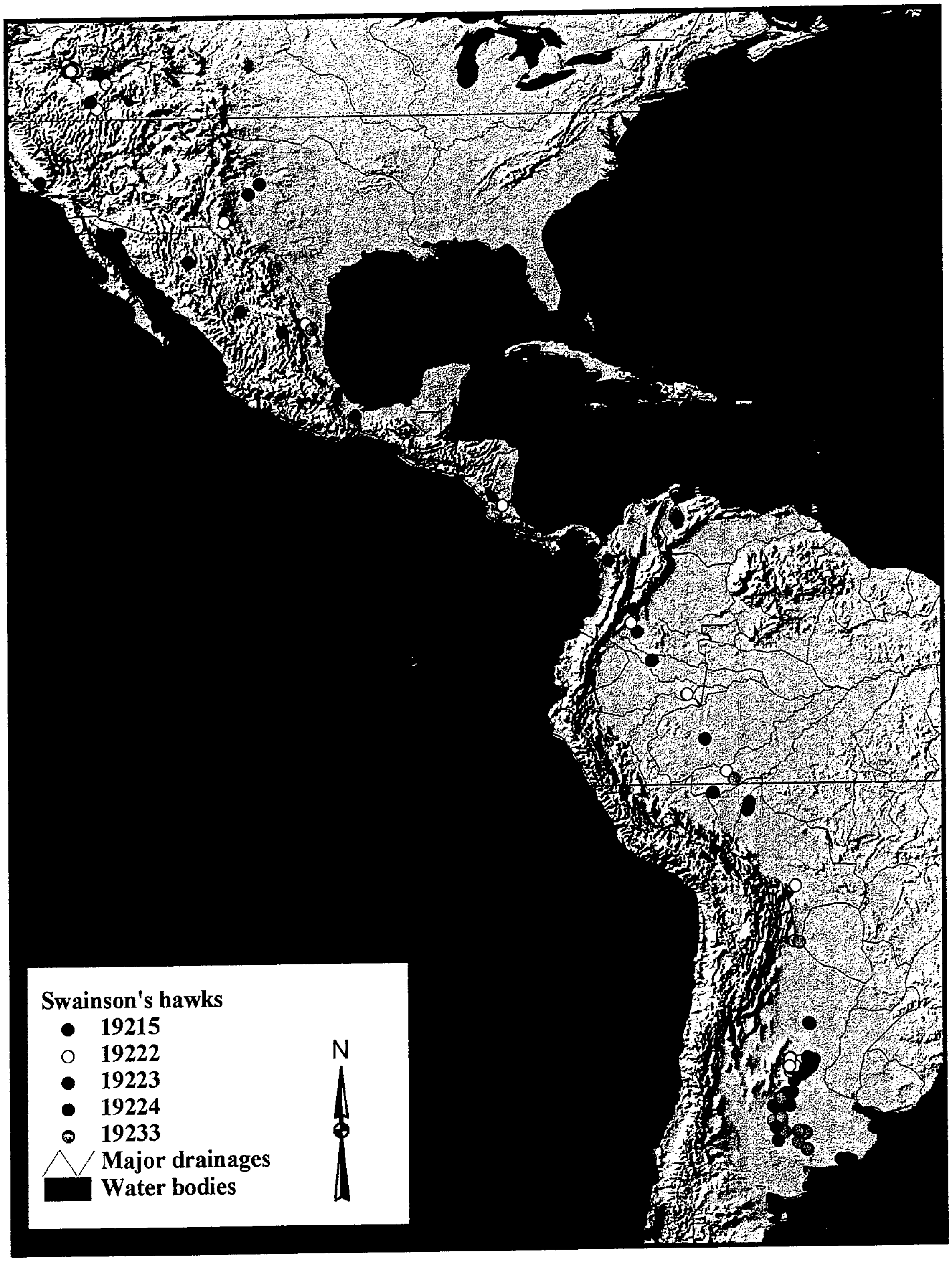

Figure OTA-19. Argos location estimates for 5 Swainson's hawks during northward migration. Shown are location estimates of LC 0 - 3 from 1/1/97 - 5/31/97. Background is a shaded relief map from a global digital elevation model (GTOPO30). Background Data Source: USGS.

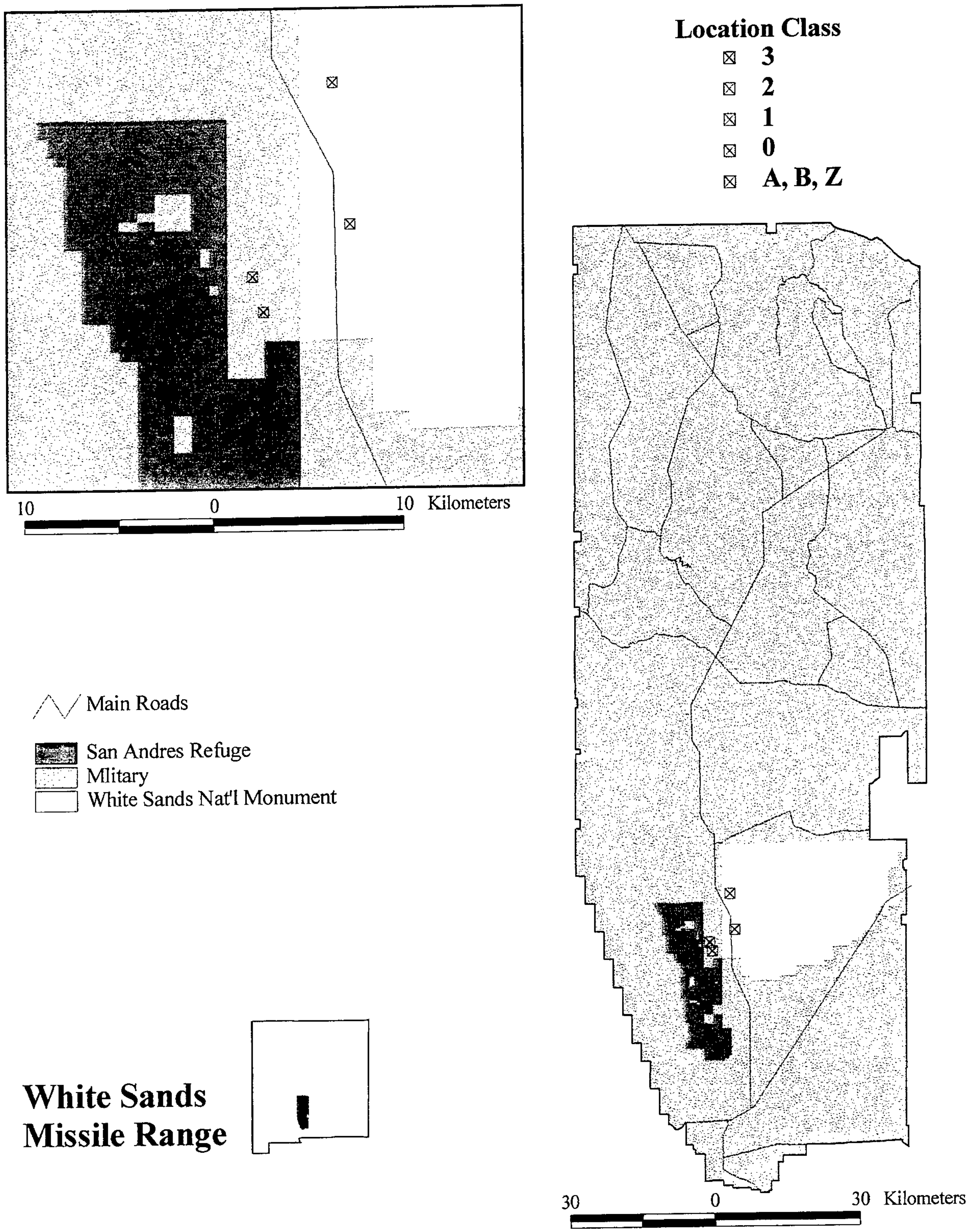

Figure WSMR-1. Argos location estimates for PTT #5732, attached to an African oryx. Shown are location estimates from 4/1/96 to 4/6/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: WSMR Environmental Services Division.

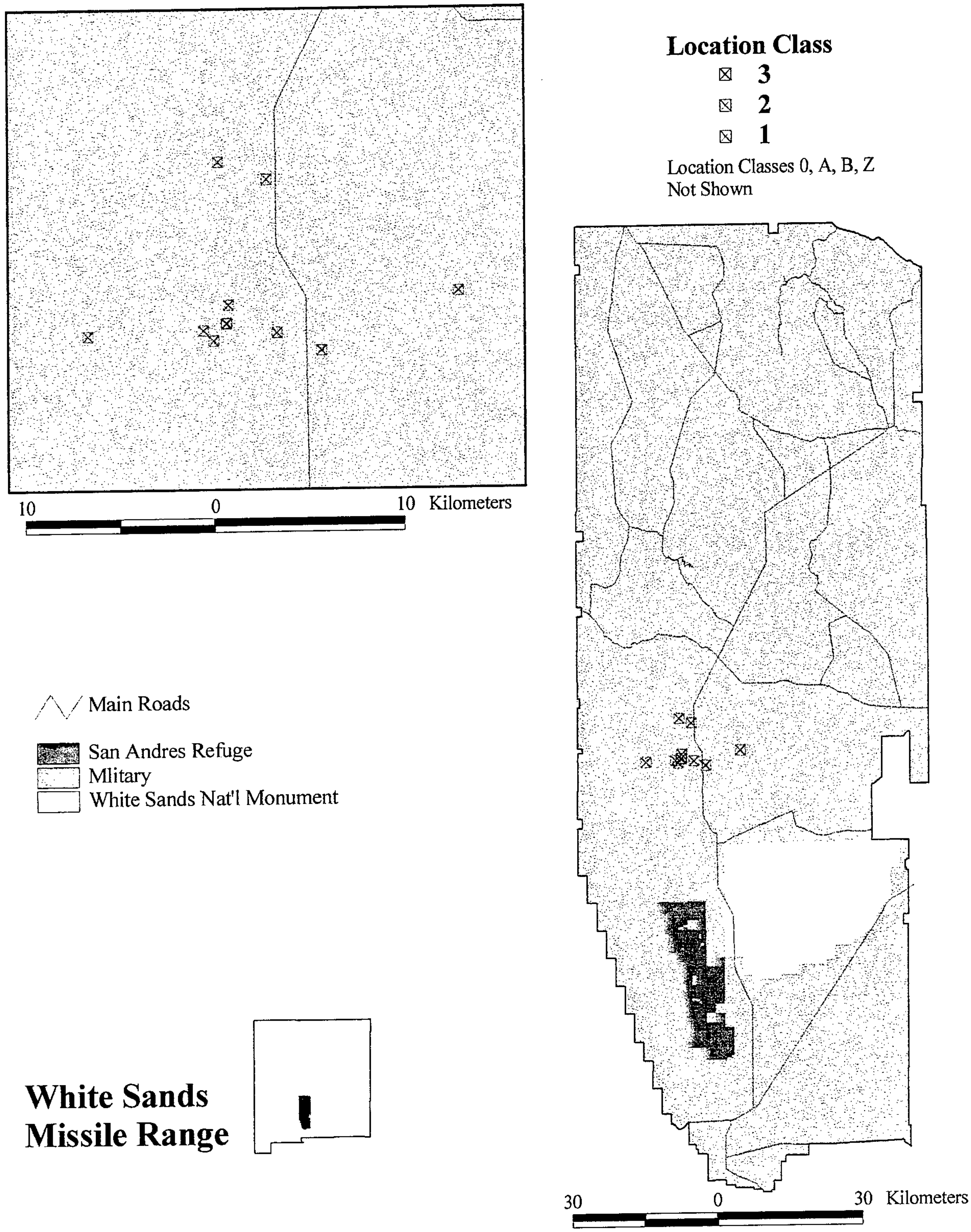

Figure WSMR-2. Argos location estimates for PTT #5733, attached to an African oryx. Shown are location estimates from 4/3/96 to 8/7/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: WSMR Environmental Services Division.

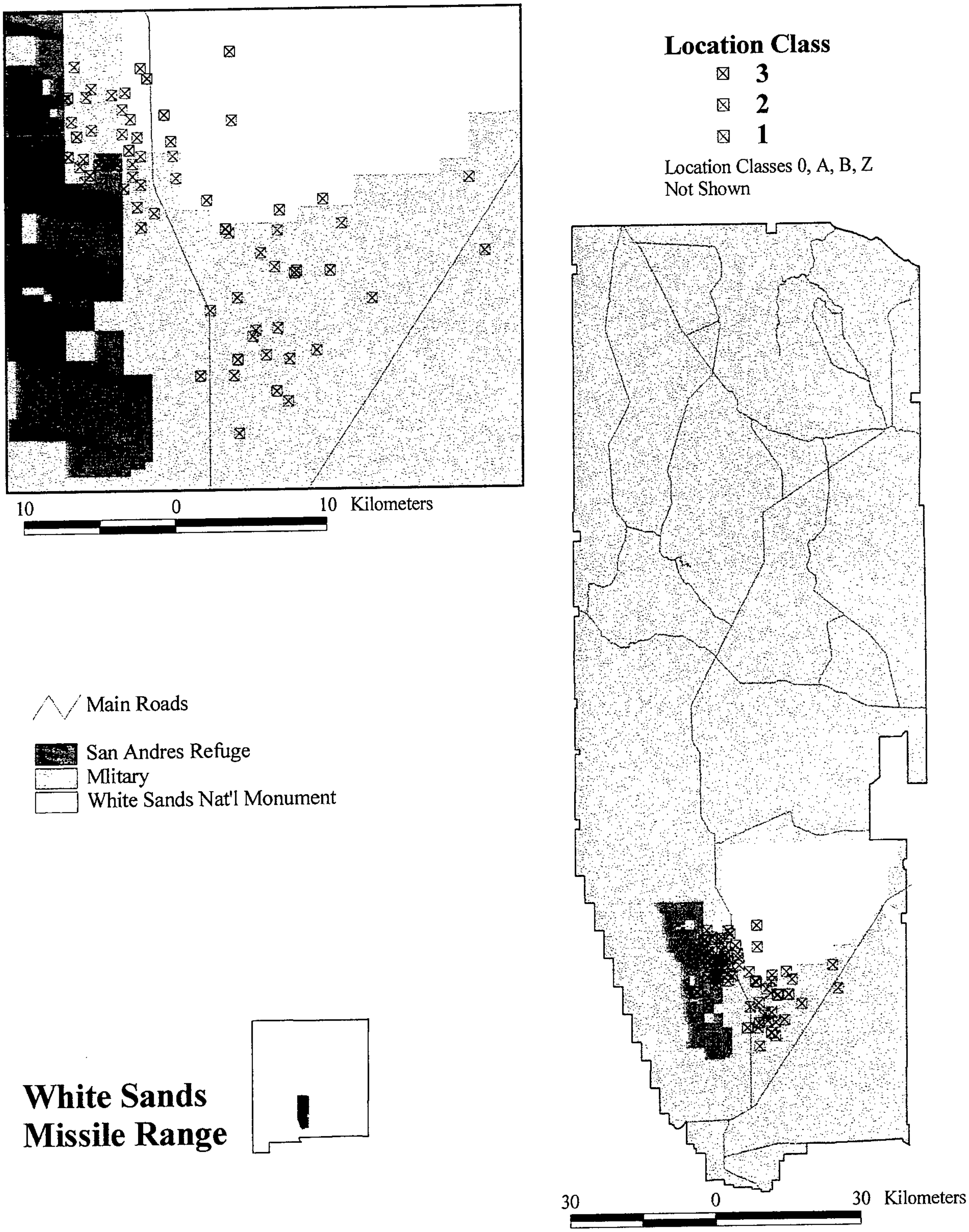

Figure WSMR-3. Argos location estimates for PTT #19190, attached to an African oryx. Shown are location estimates from 5/18/96 to 5/14/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: WSMR Environmental Services Division.

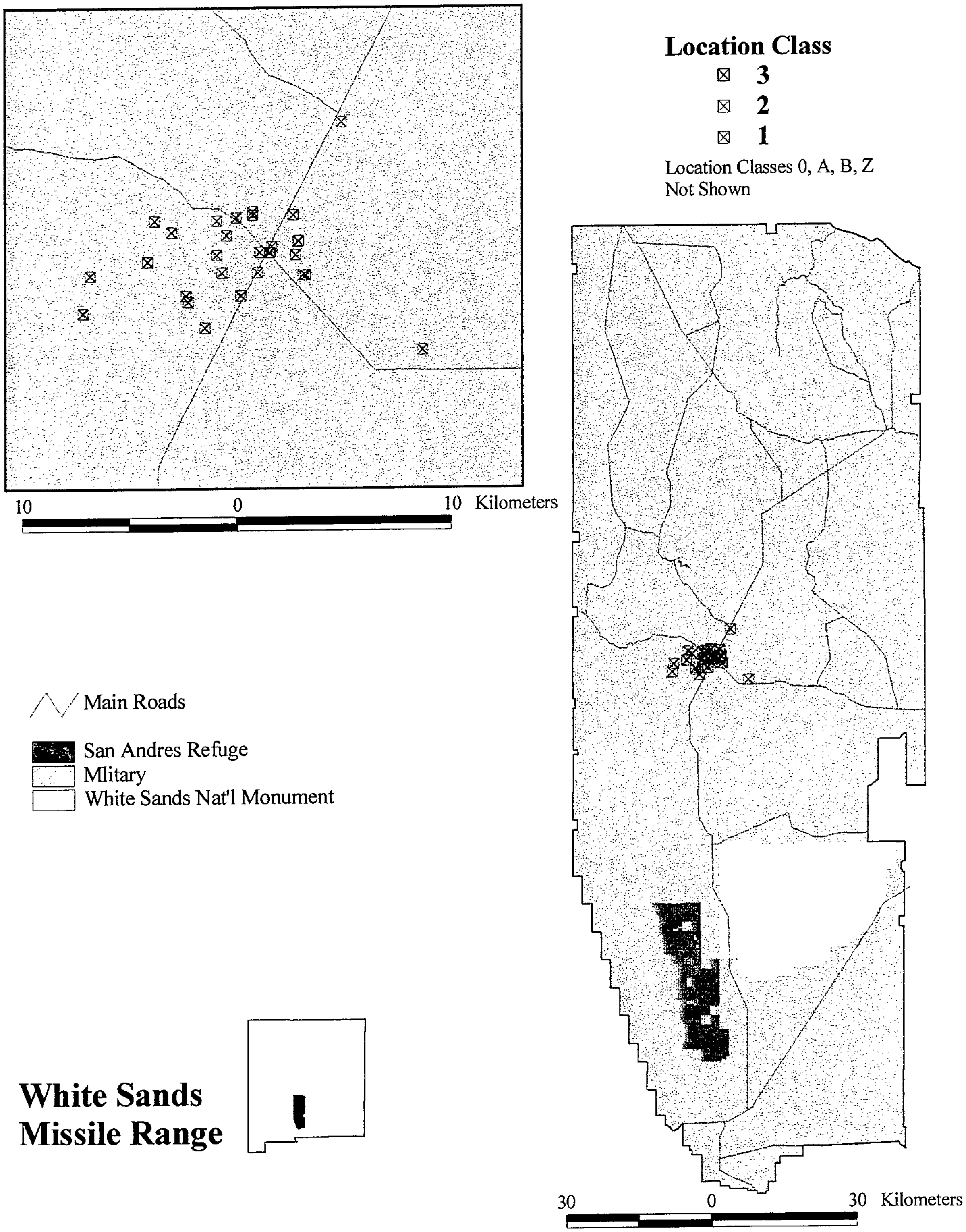

Figure WSMR-4. Argos location estimates for PTT #19191, attached to an African oryx. Shown are location estimates from 5/18/96 to 5/20/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: WSMR Environmental Services Division.

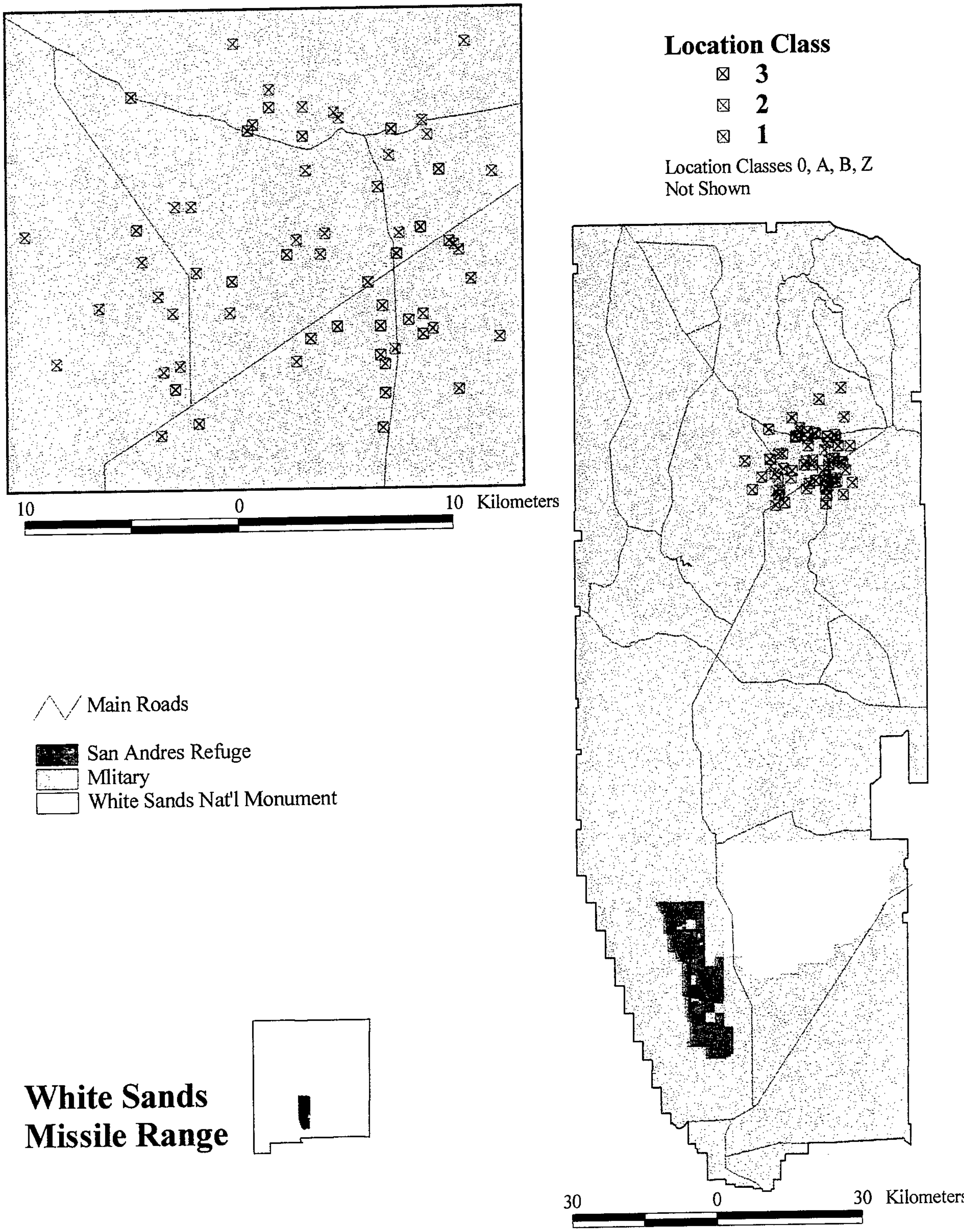

Figure WSMR-5. Argos location estimates for PTT #19192, attached to an African oryx. Shown are location estimates from 5/19/96 to 5/11/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: WSMR Environmental Services Division.

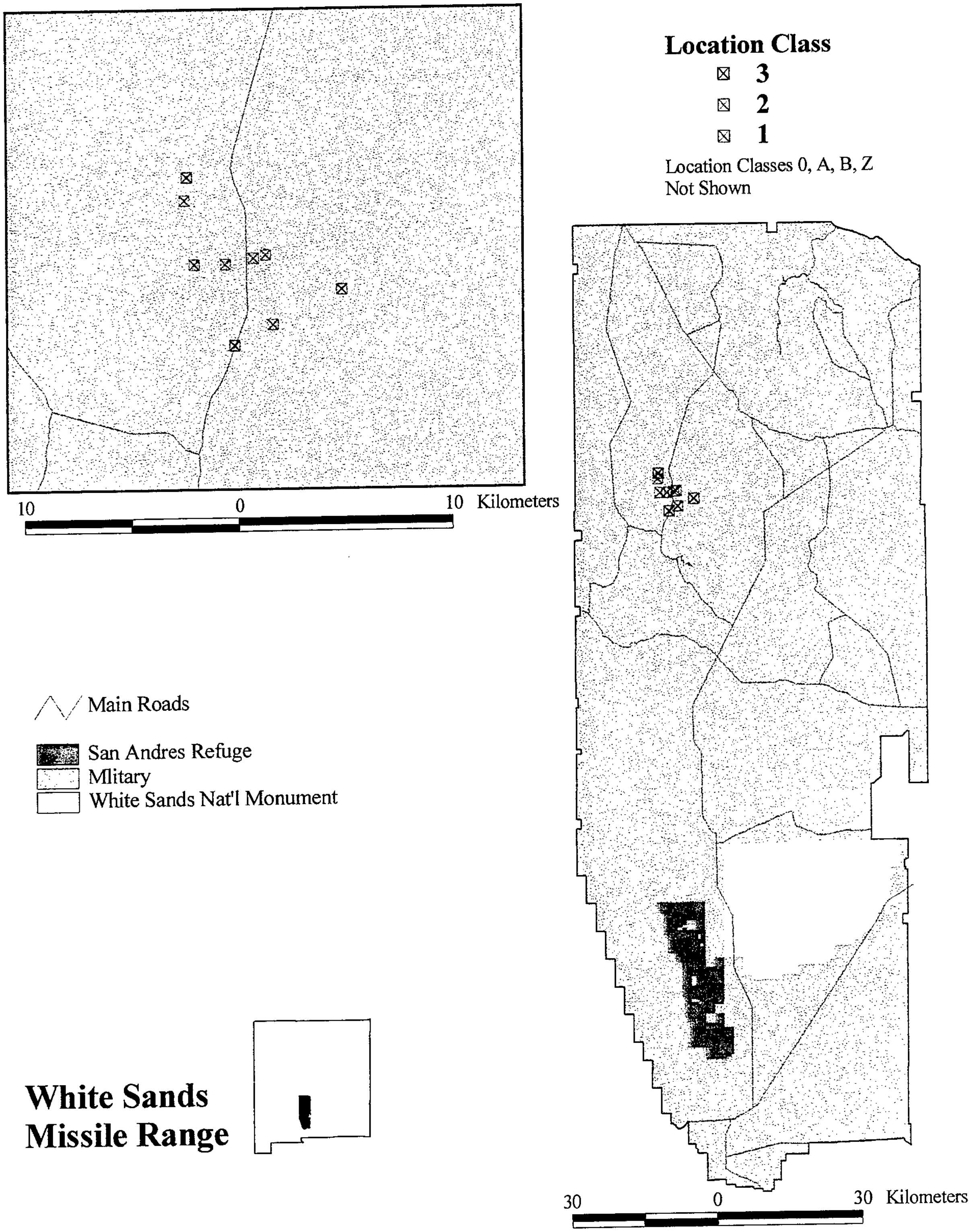

Figure WSMR-6. Argos location estimates for PTT #19193, attached to an African oryx. Shown are location estimates from 5/19/96 to 8/20/96. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: WSMR Environmental Services Division.

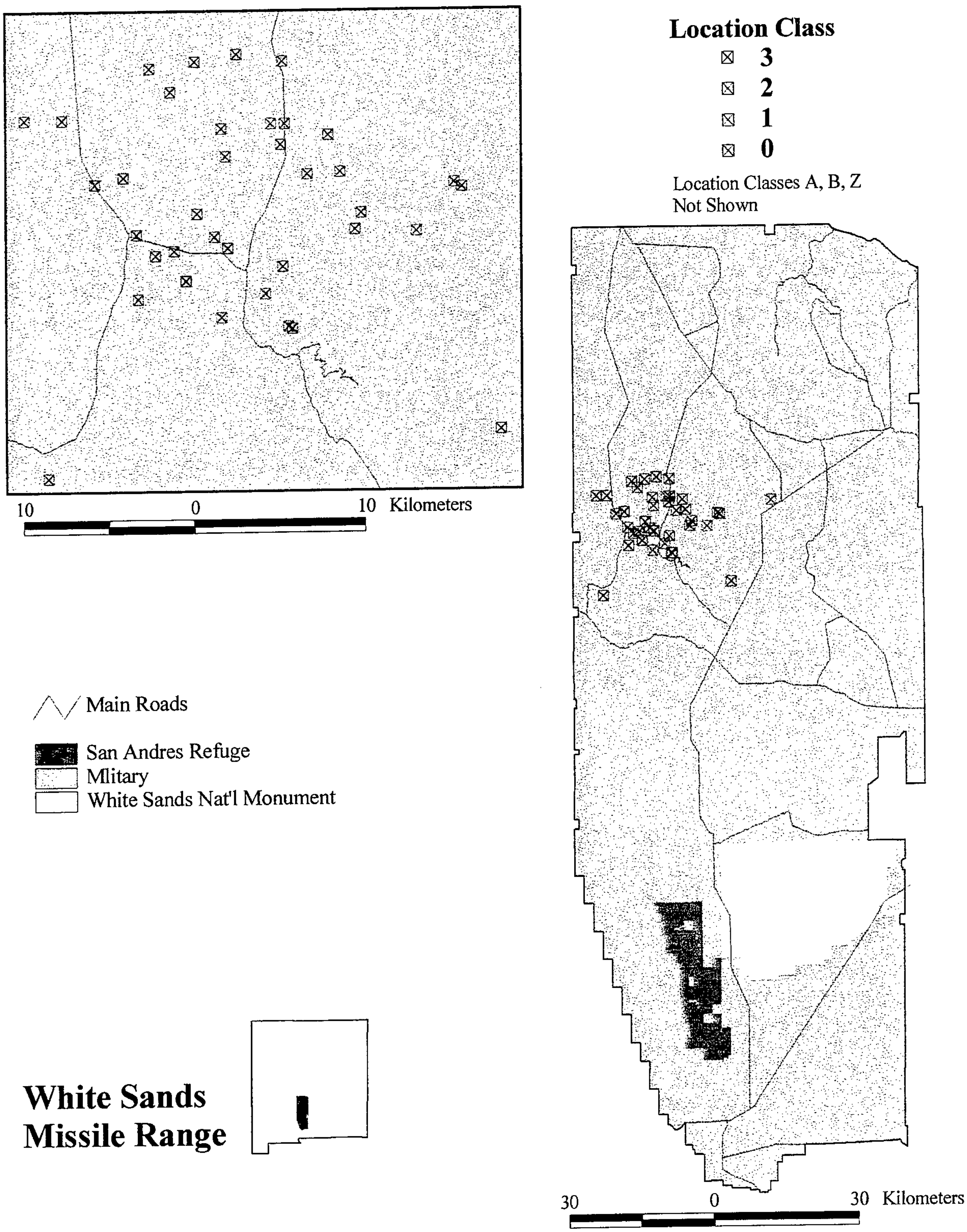

Figure WSMR-7. Argos location estimates for PTT #19194, attached to an African oryx. Shown are location estimates from 5/21/96 to 5/22/97. Land ownership is derived from 1:100,000 BLM surface management status maps. Background Data Source: WSMR Environmental Services Division.

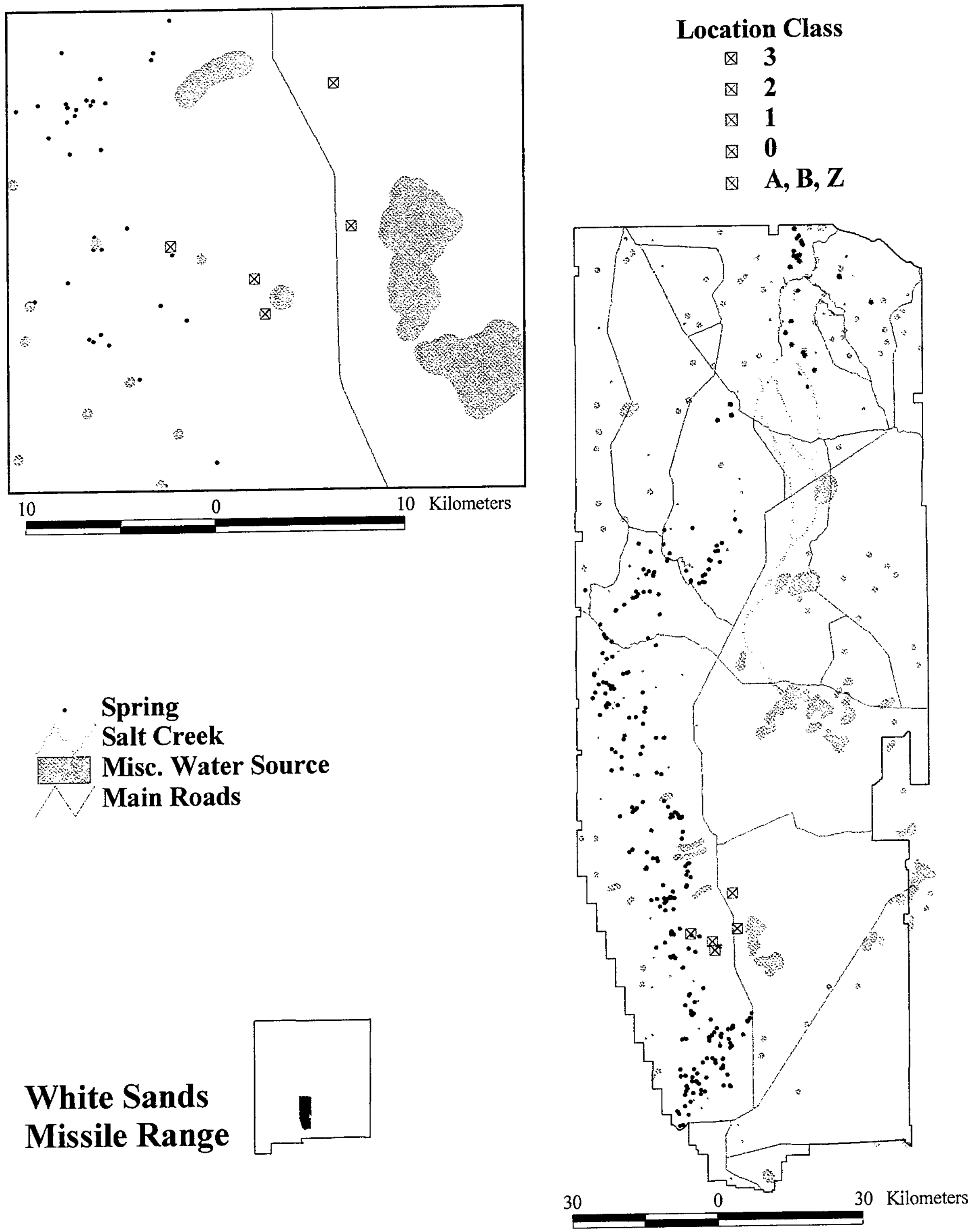

Figure WSMR-8. Argos location estimates for PTT #5732, attached to an African oryx. Shown are location estimates from 4/1/96 to 4/6/96. Background is WSMR springs and water bodies. Background Data Source: WSMR Environmental Services Division.

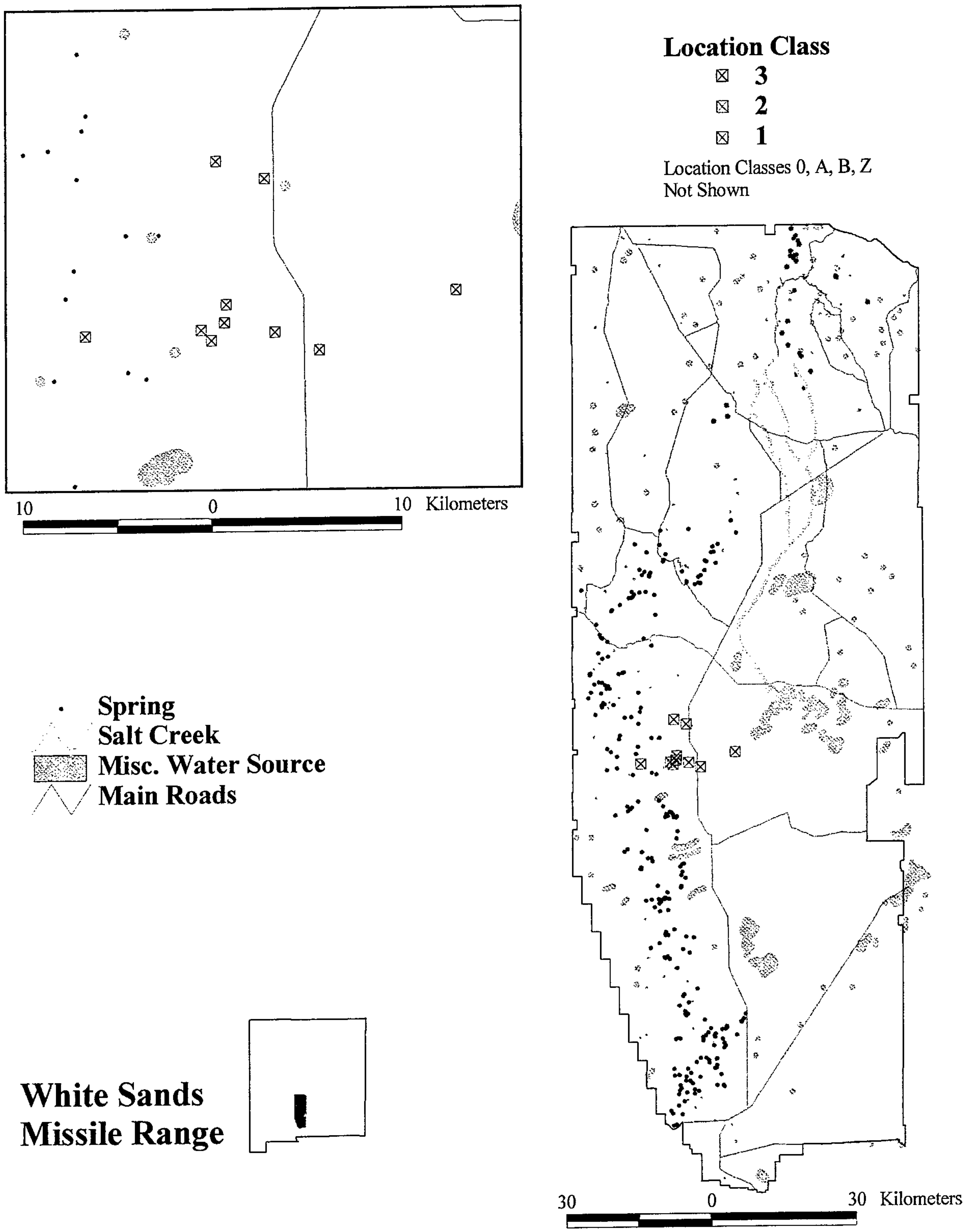

Figure WSMR-9. Argos location estimates for PTT #5733, attached to an African oryx. Shown are location estimates from 4/3/96 to 8/7/96. Background is WSMR springs and water bodies. Background Data Source: WSMR Environmental Services Division.

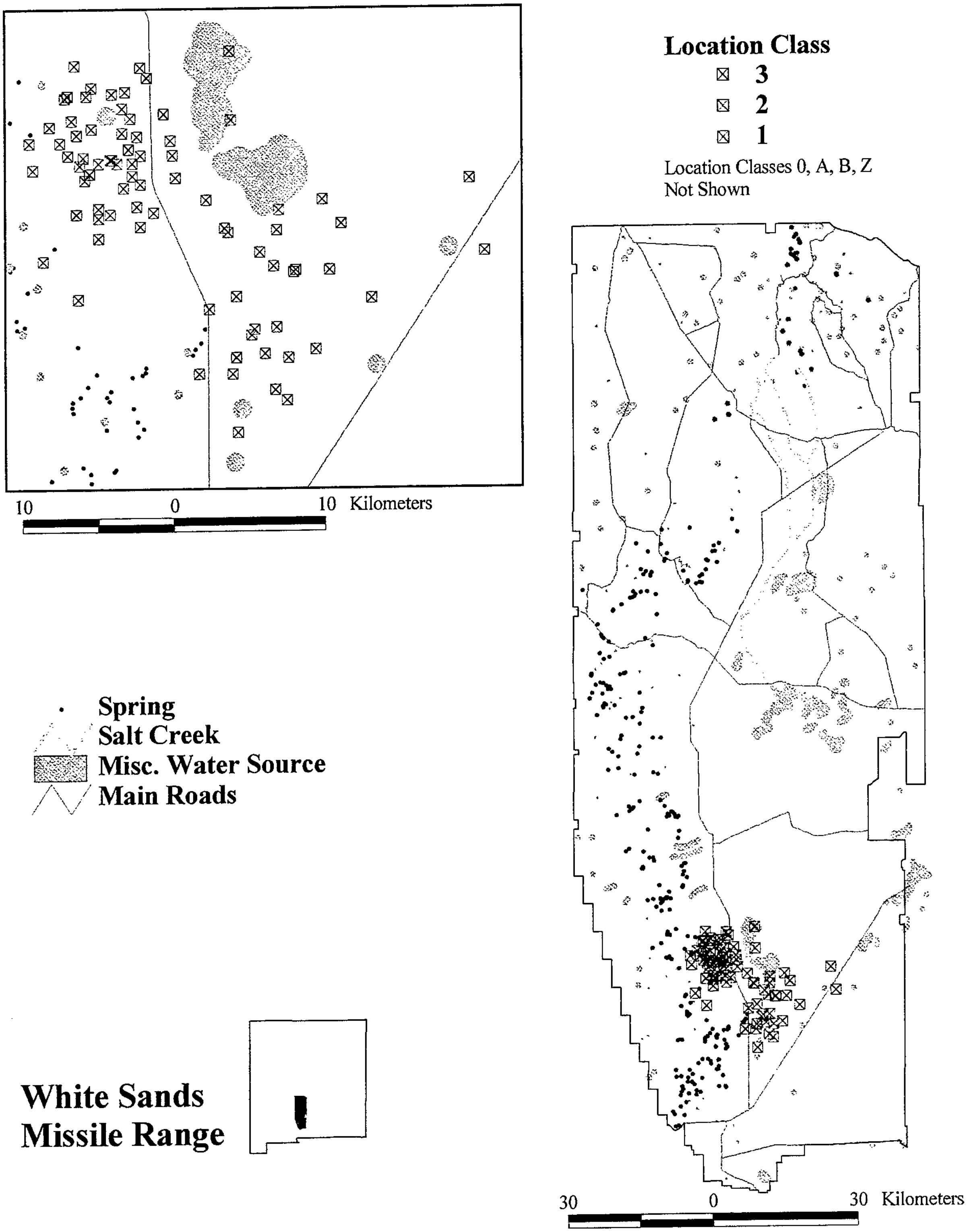

Figure WSMR-10. Argos location estimates for PTT #19190, attached to an African oryx. Shown are location estimates from 5/18/96 to 5/14/97. Background is WSMR springs and water bodies. Background Data Source: WSMR Environmental Services Division.

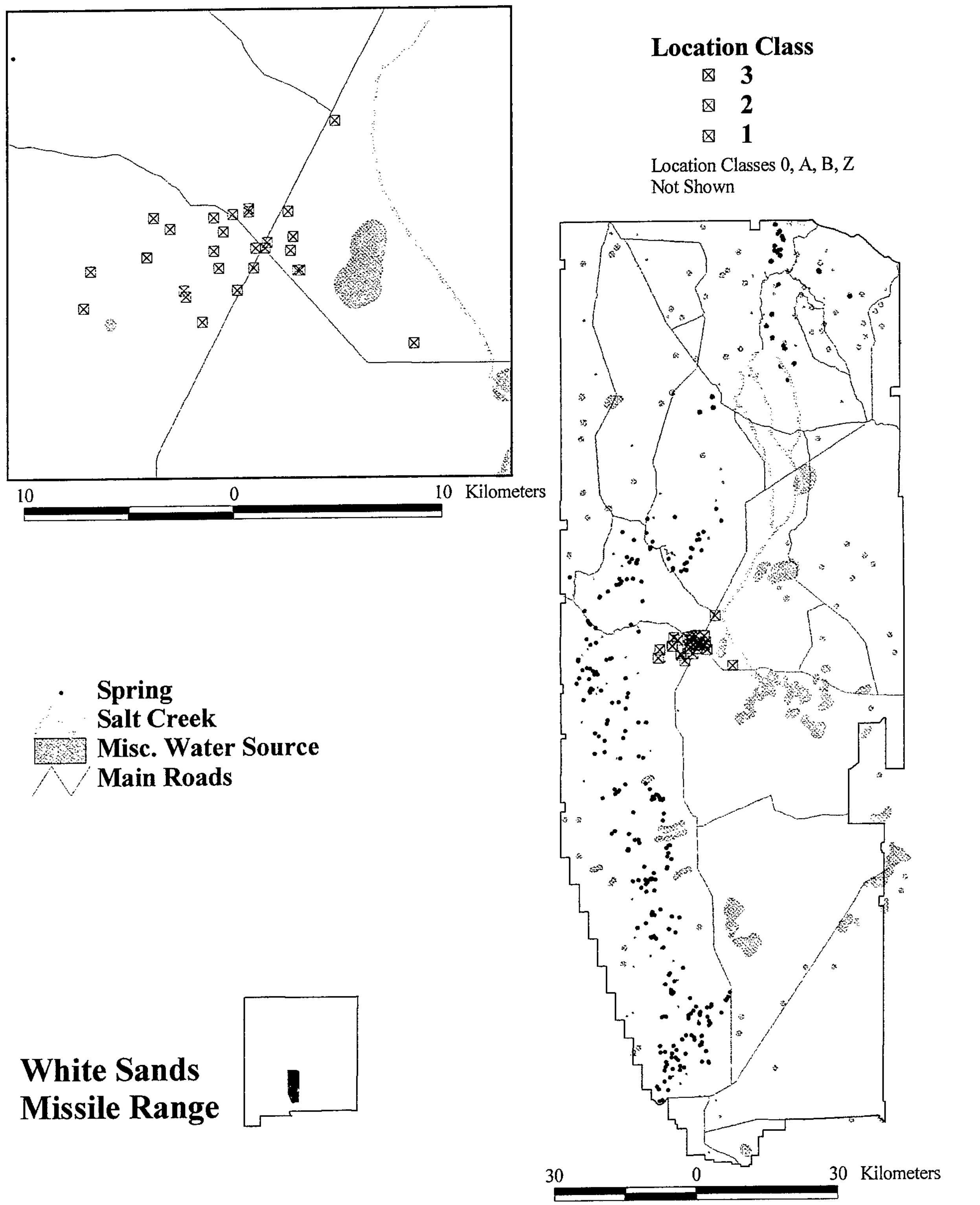

Figure WSMR-11. Argos location estimates for PTT #19191, attached to an African oryx. Shown are location estimates from 5/18/96 to 5/20/97. Background is WSMR springs and water bodies. Background Data Source: WSMR Environmental Services Division.

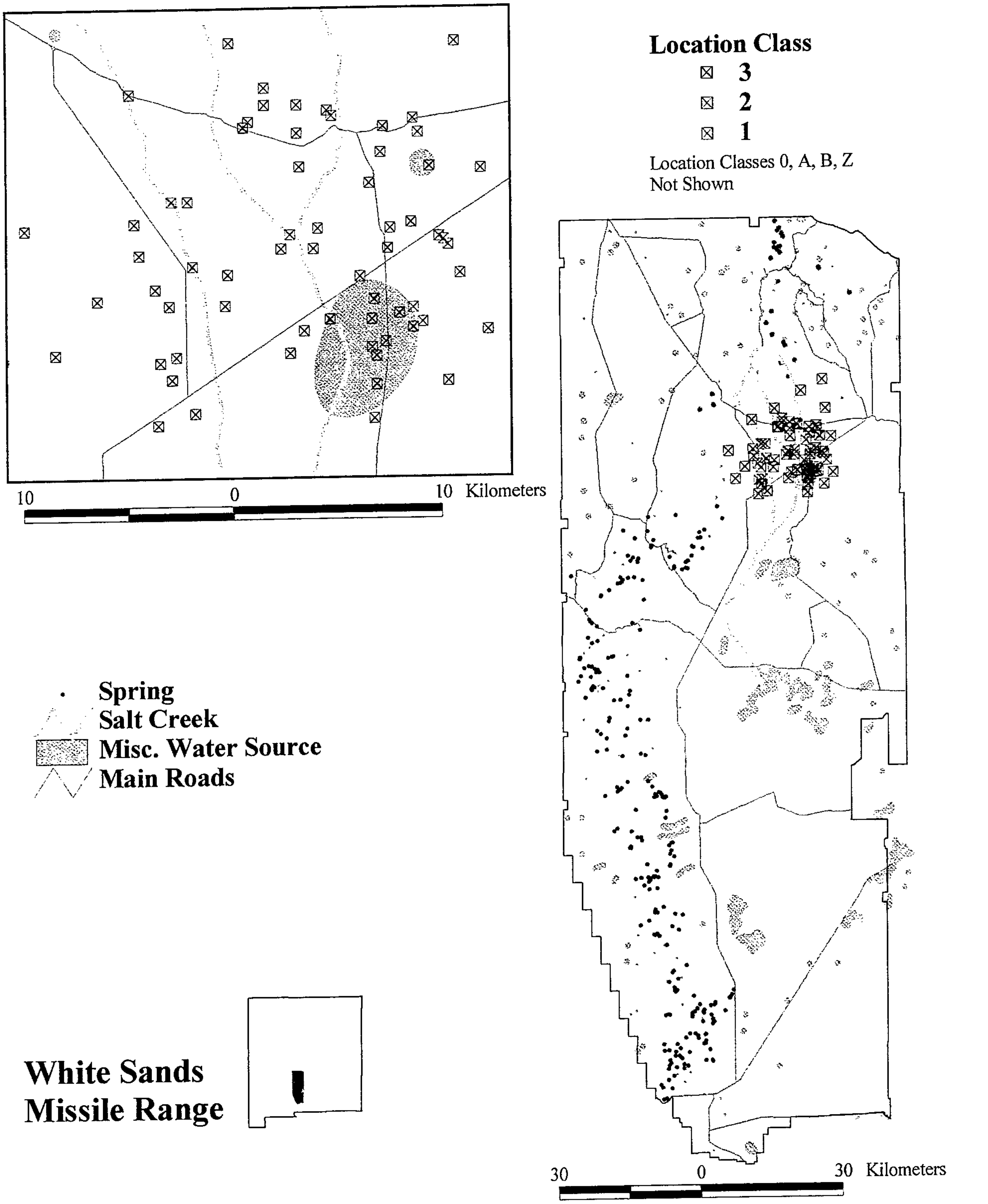

Figure WSMR-12. Argos location estimates for PTT #19192, attached to an African oryx. Shown are location estimates from 5/19/96 to 5/11/97. Background is WSMR springs and water bodies. Background Data Source: WSMR Environmental Services Division.

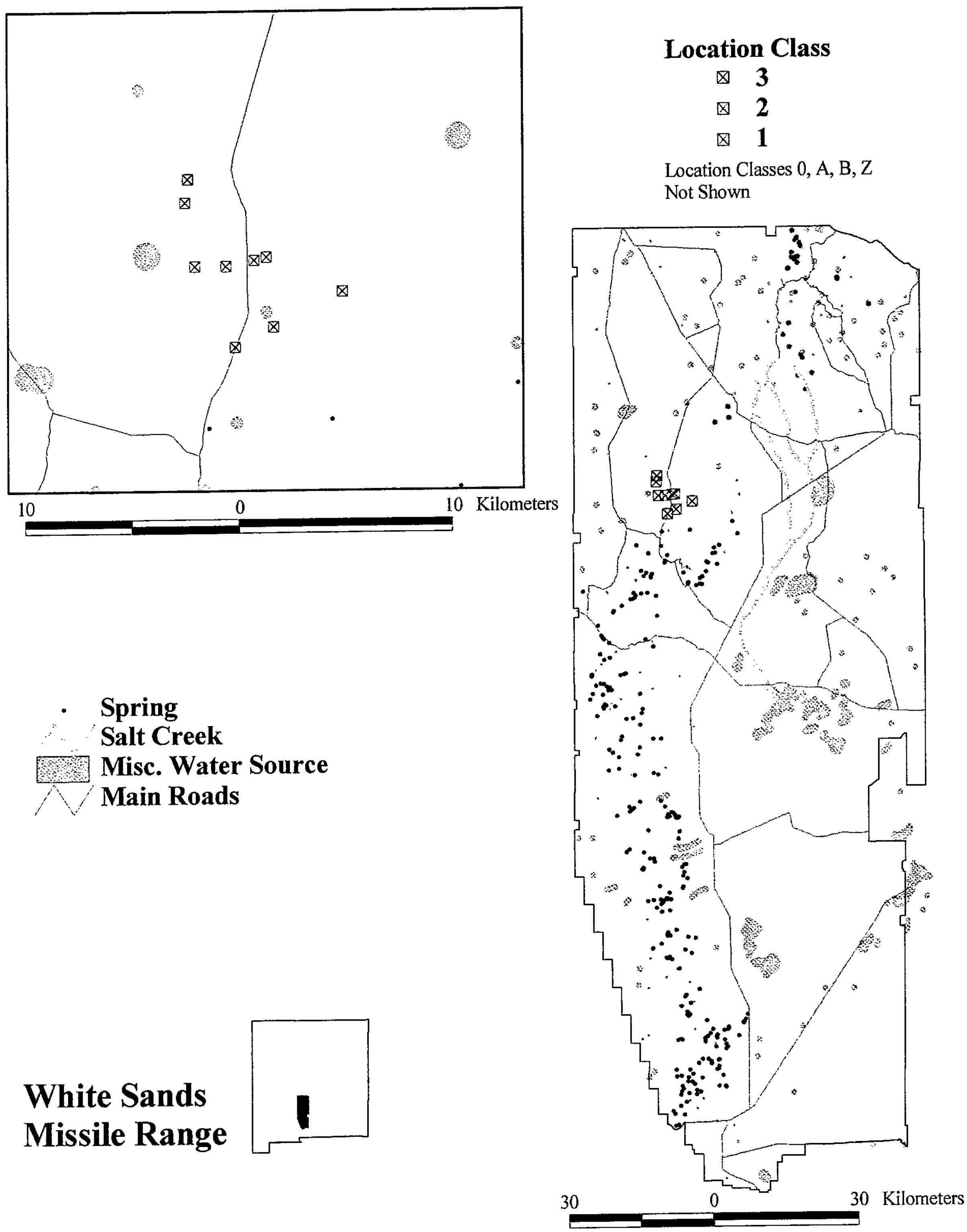

Figure WSMR-13. Argos location estimates for PTT #19193, attached to an African oryx. Shown are location estimates from 5/19/96 to 8/20/96. Background is WSMR springs and water bodies. Background Data Source: WSMR Environmental Services Division.

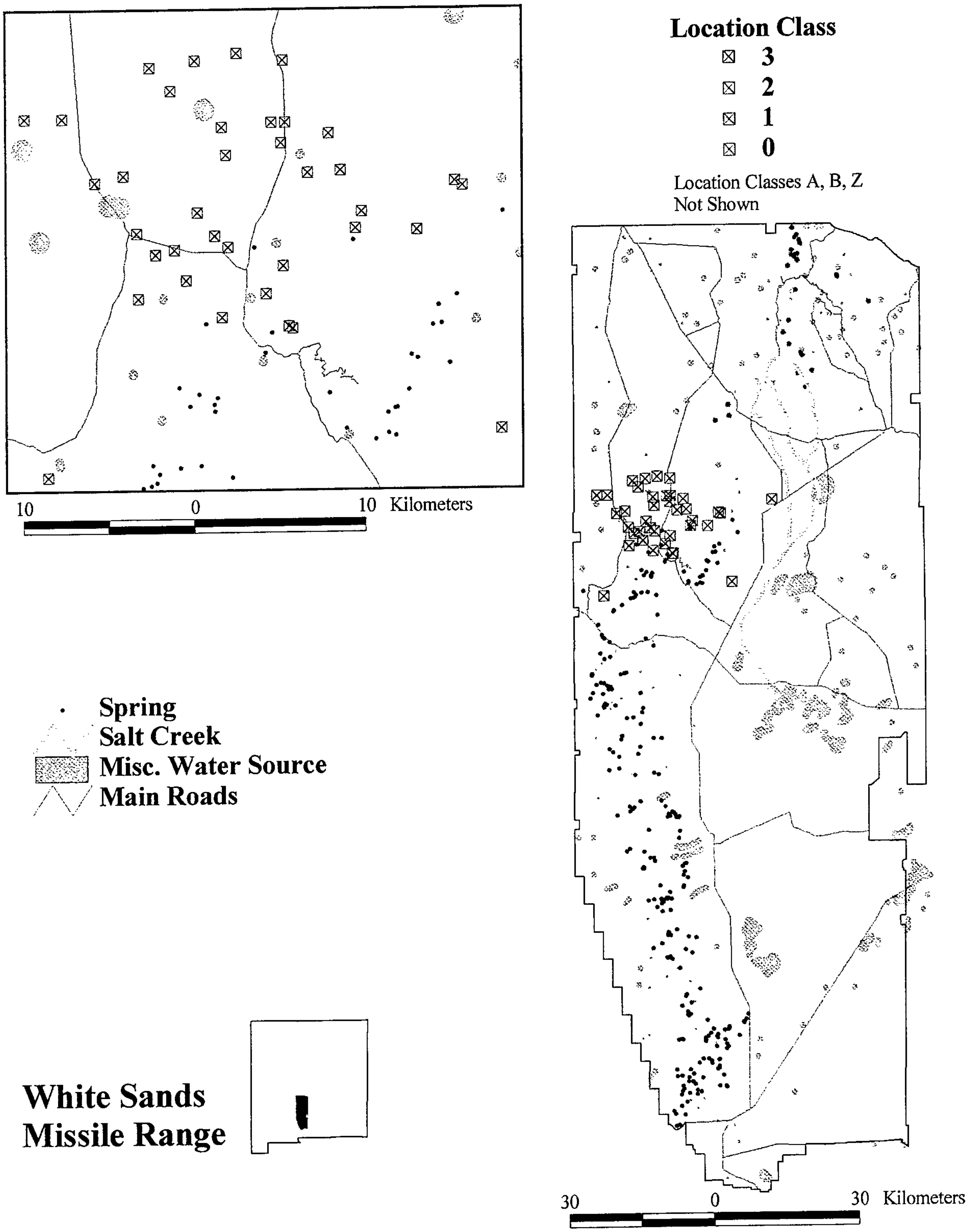

Figure WSMR-14. Argos location estimates for PTT #19194, attached to an African oryx. Shown are location estimates from 5/21/96 to 5/22/9. Background is WSMR springs and water bodies. Background Data Source: WSMR Environmental Services Division.

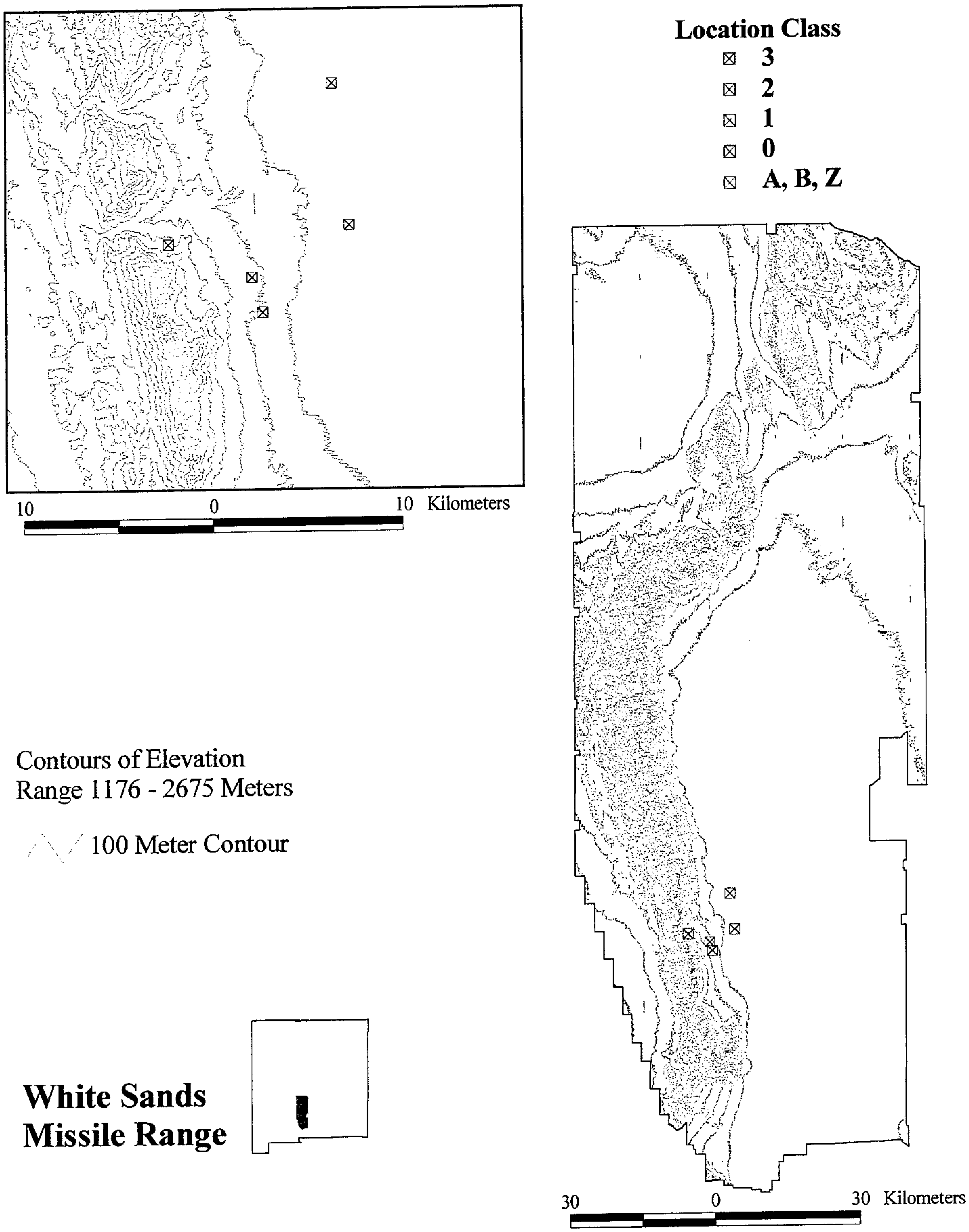

Figure WSMR-15. Argos location estimates for PTT #5732, attached to an African oryx. Shown are location estimates from 4/1/96 to 4/6/96. Background is WSMR elevation. Background Data Source: WSMR Environmental Services Division.

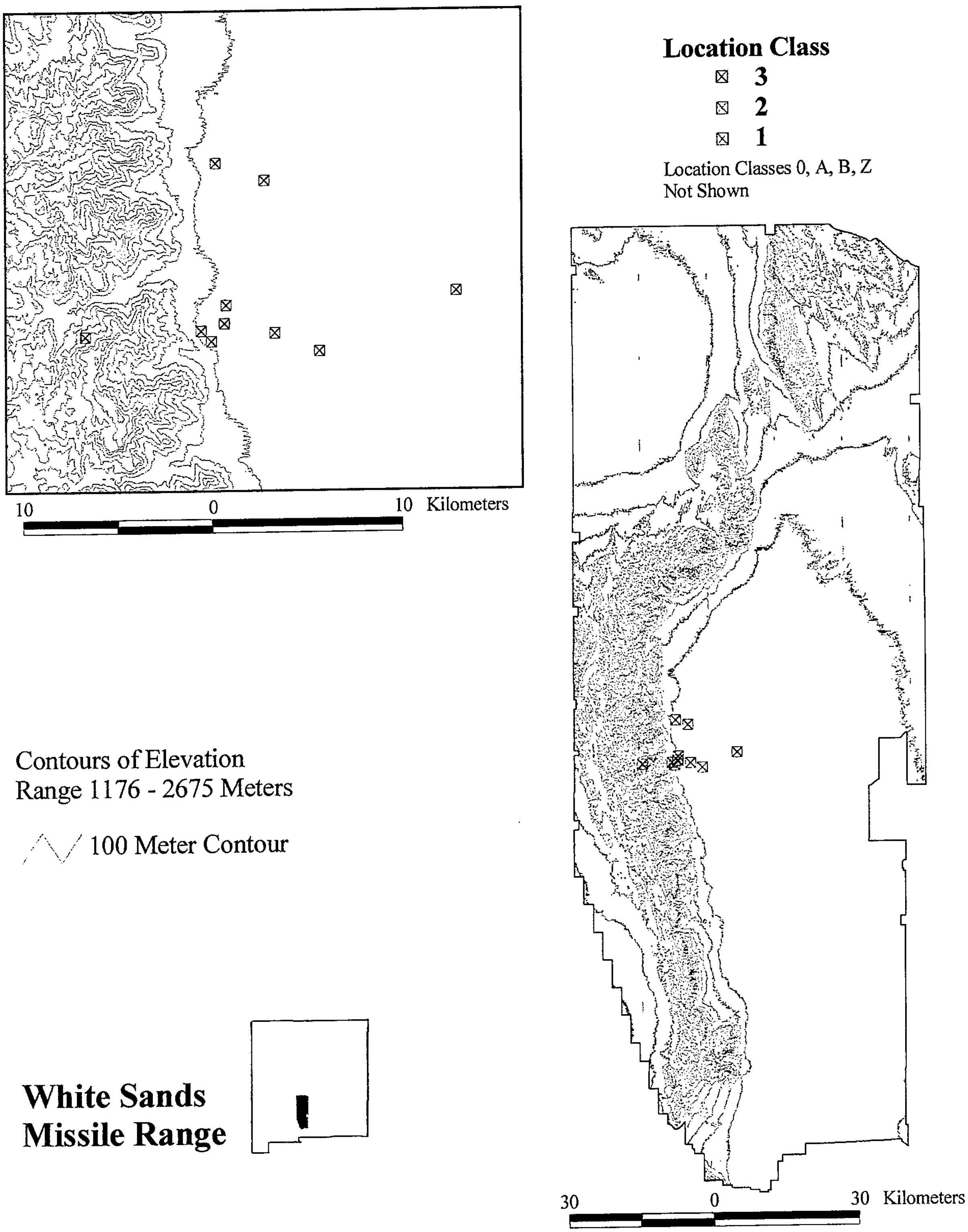

Figure WSMR-16. Argos location estimates for PTT #5733, attached to an African oryx. Shown are location estimates from 4/3/96 to 8/7/96. Background is WSMR elevation. Background Data Source: WSMR Environmental Services Division.

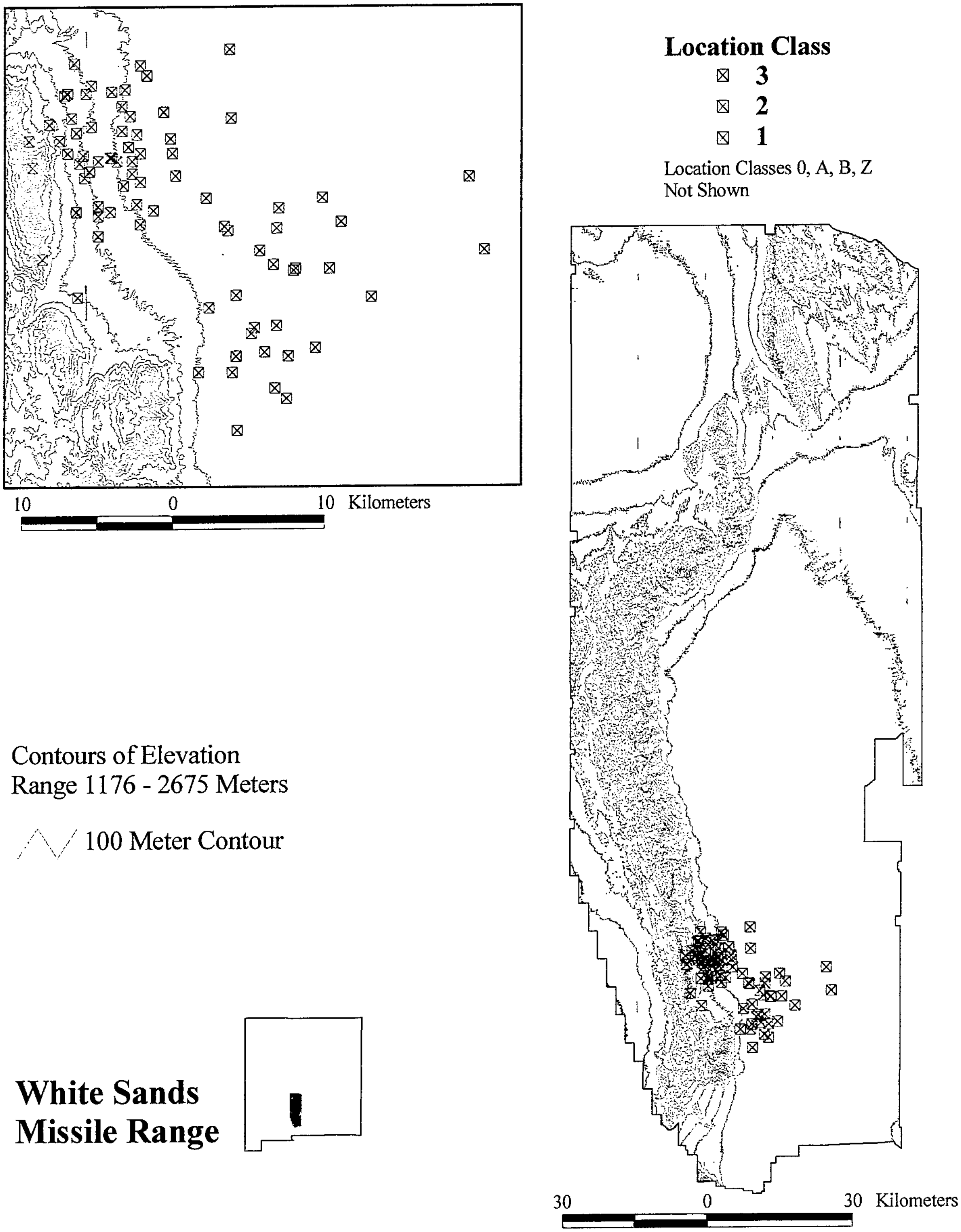

Figure WSMR-17. Argos location estimates for PTT #19190, attached to an African oryx. Shown are location estimates from 5/18/96 to 5/14/97. Background is WSMR elevation. Background Data Source: WSMR Environmental Services Division.

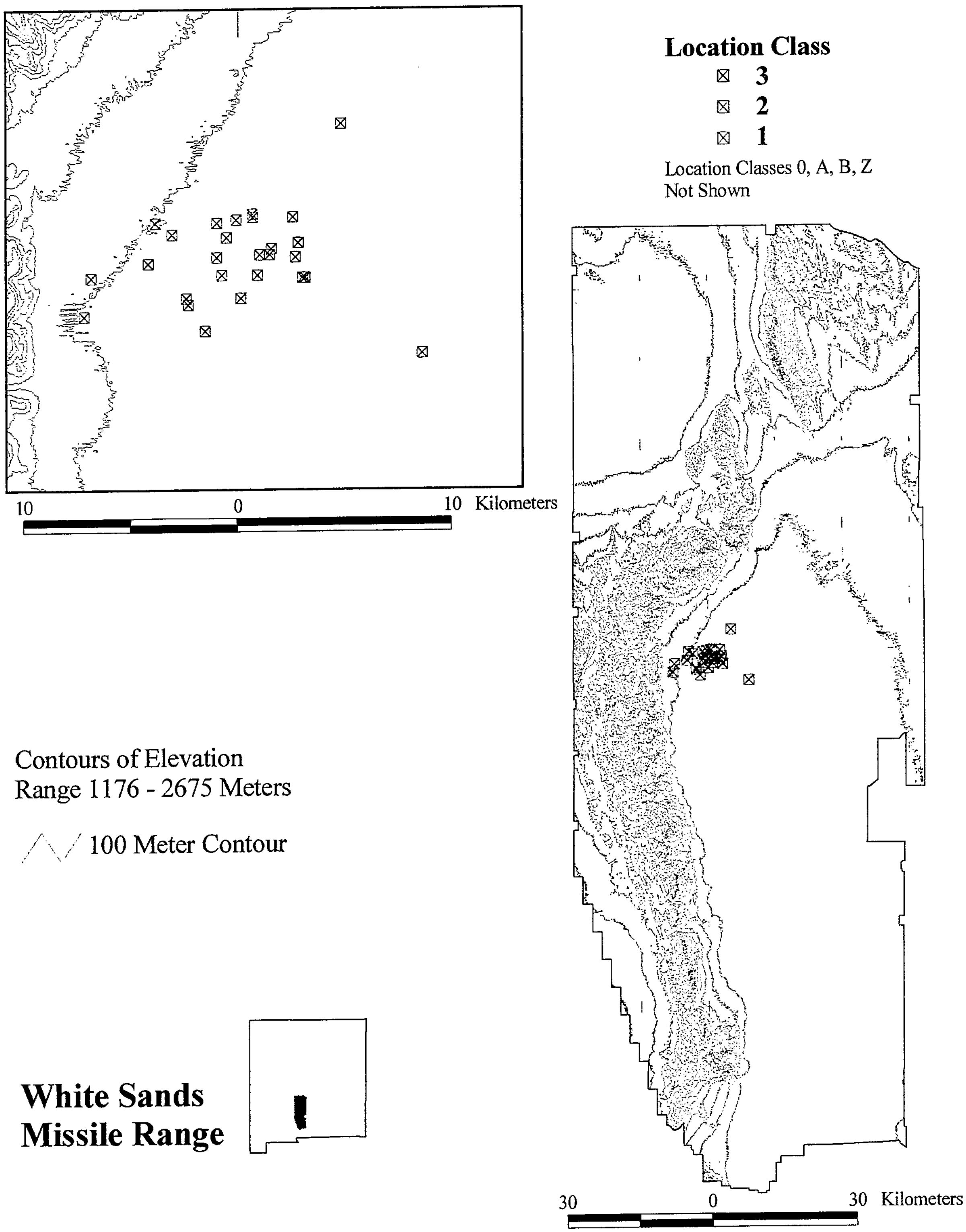

Figure WSMR-18. Argos location estimates for PTT #19191, attached to an African oryx. Shown are location estimates from 5/18/96 to 5/20/97. Background is WSMR elevation. Background Data Source: WSMR Environmental Services Division.

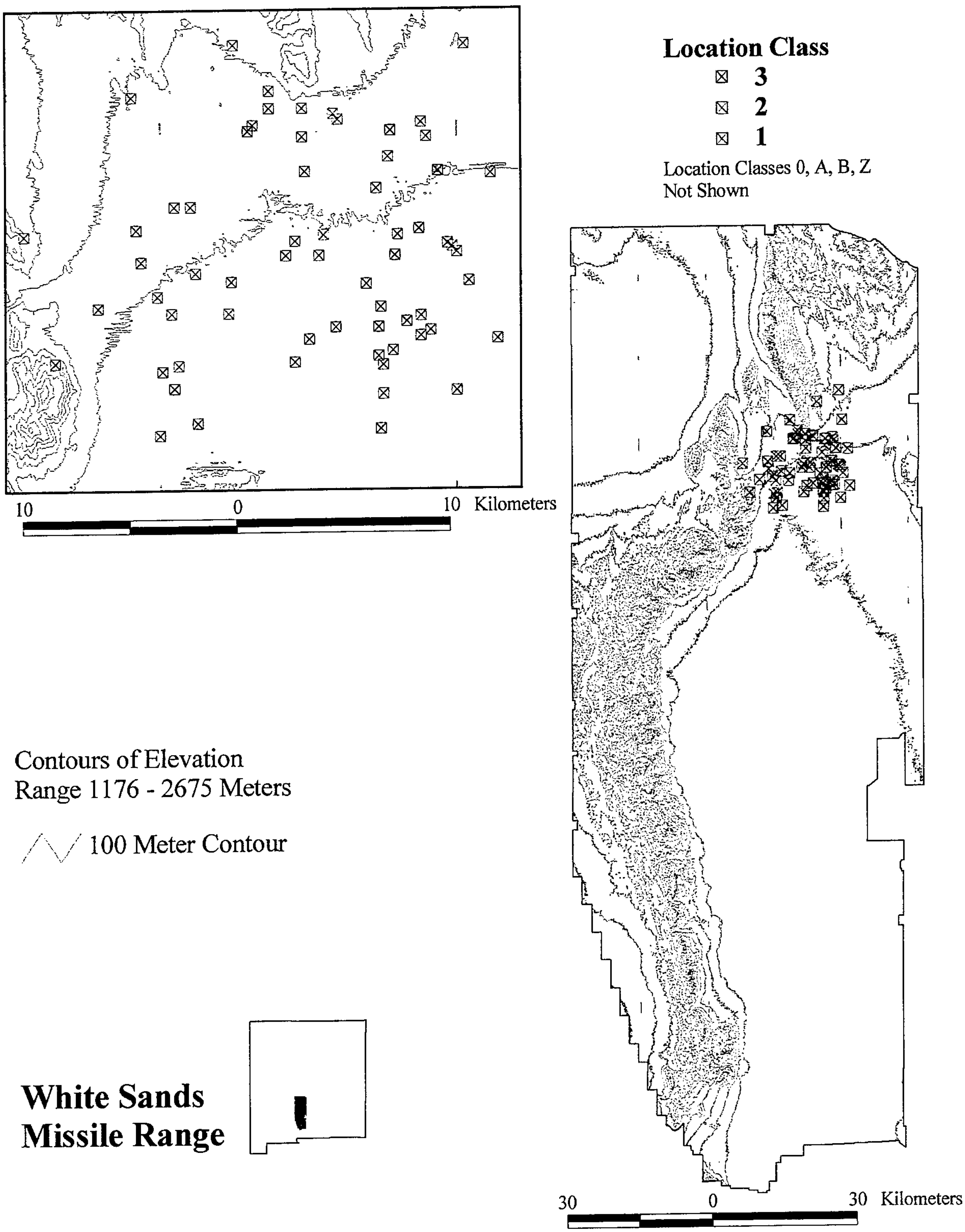

Figure WSMR-19. Argos location estimates for PTT #19192, attached to an African oryx. Shown are location estimates from 5/19/96 to 5/11/97. Background is WSMR elevation. Background Data Source: WSMR Environmental Services Division.

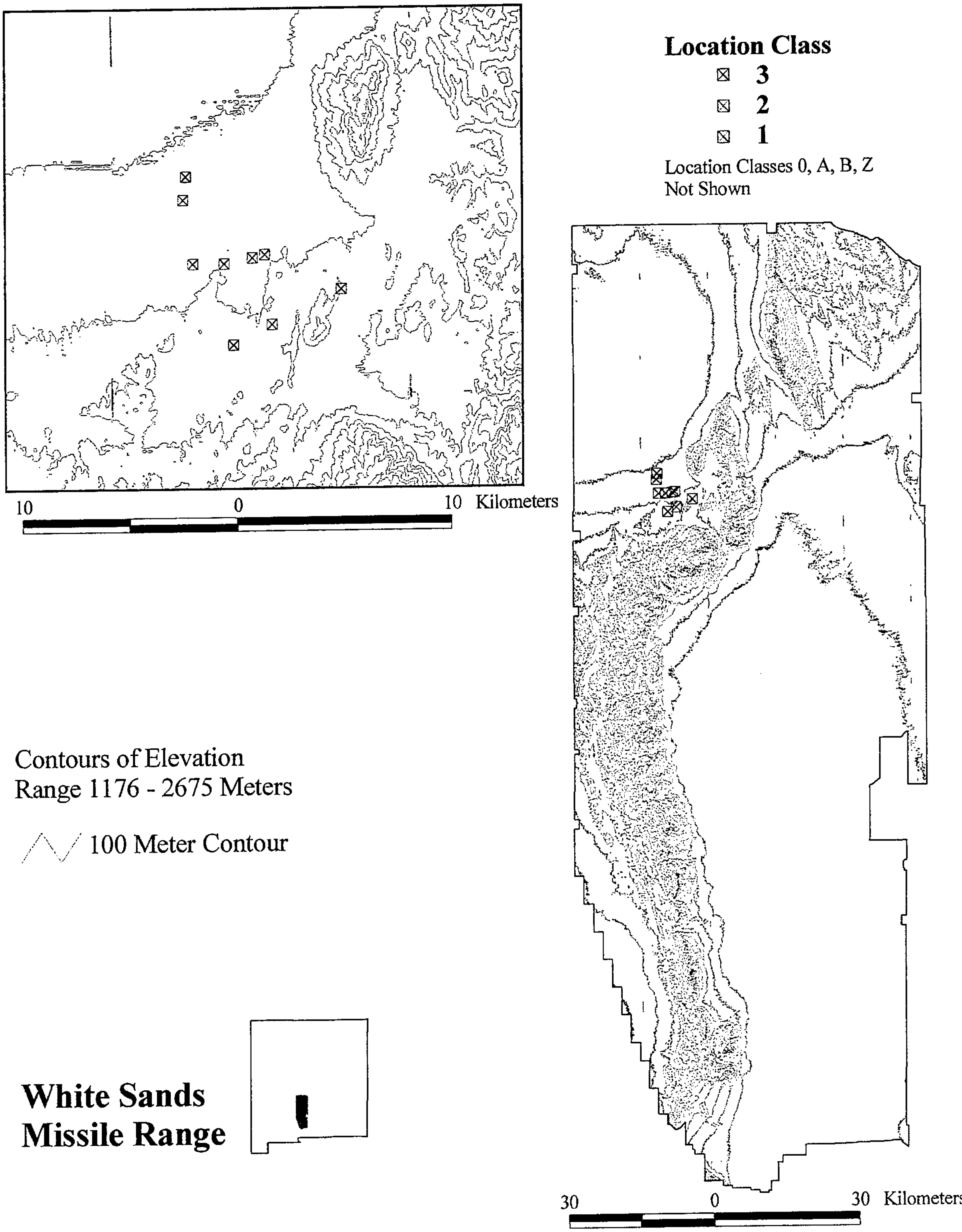

Figure WSMR-20. Argos location estimates for PTT #19193, attached to an African oryx. Shown are location estimates from 5/19/96 to 8/20/97. Background is WSMR elevation. Background Data Source: WSMR Environmental Services Division.

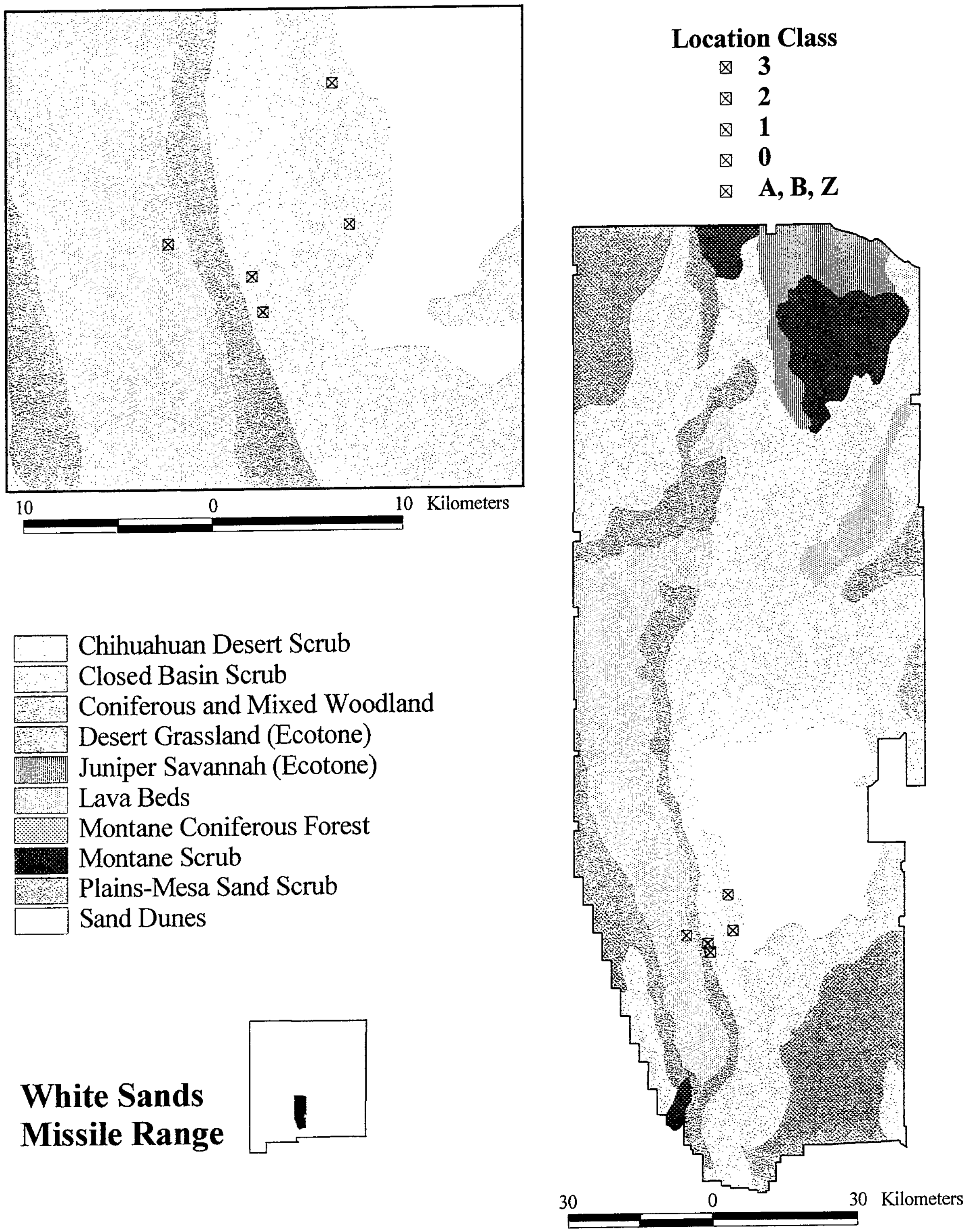

Figure WSMR-22. Argos location estimates for PTT #5732, attached to an African oryx. Shown are location estimates from 4/1/96 to 4/6/96. Background is "Dick Peddie" vegetation. Vegetation Data Source: Technology Applications Center, University of New Mexico, 1993.

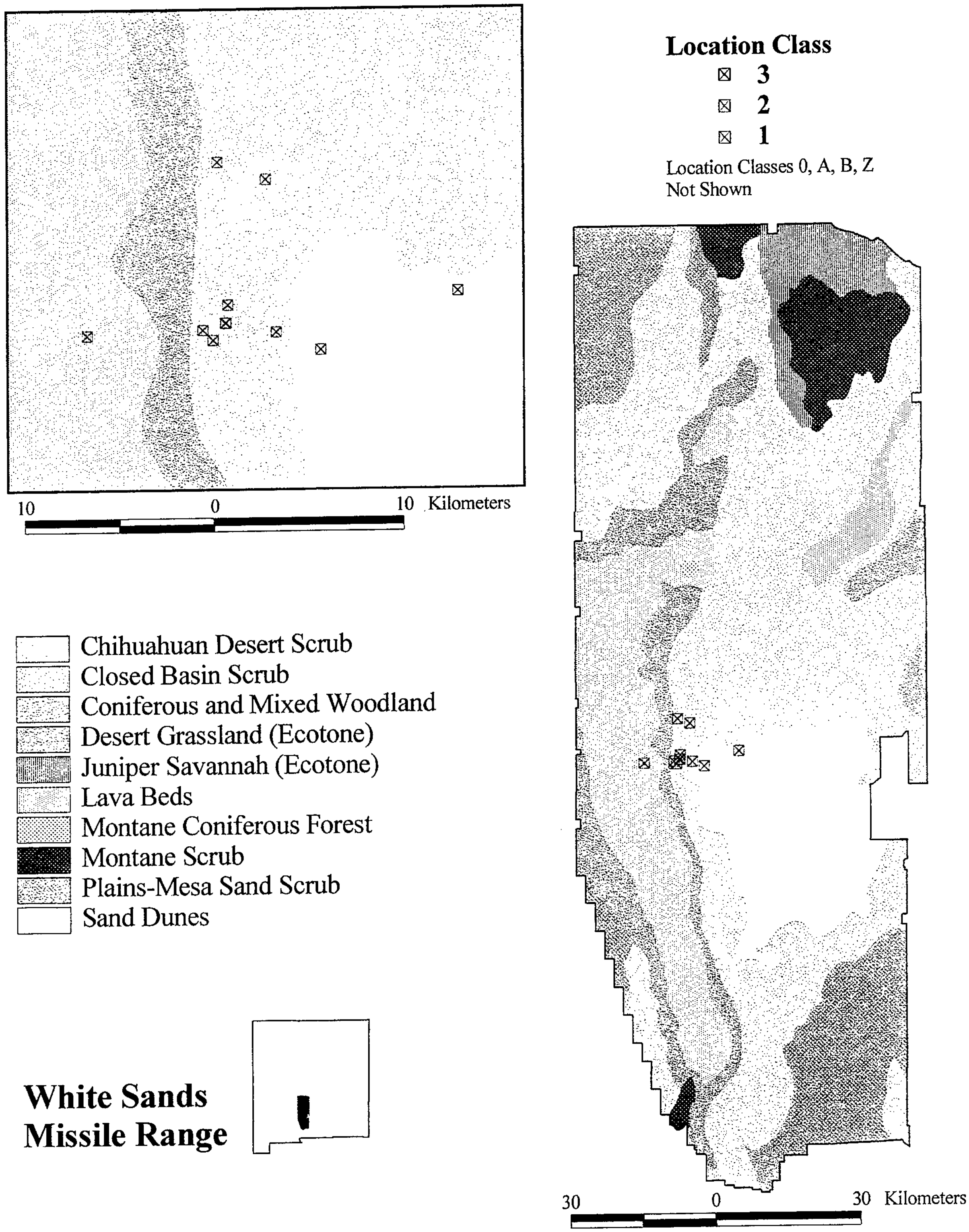

Figure WSMR-23. Argos location estimates for PTT #5733, attached to an African oryx. Shown are location estimates from 4/3/96 to 8/7/96. Background is "Dick Peddie" vegetation. Vegetation Data Source: Technology Applications Center, University of New Mexico, 1993.

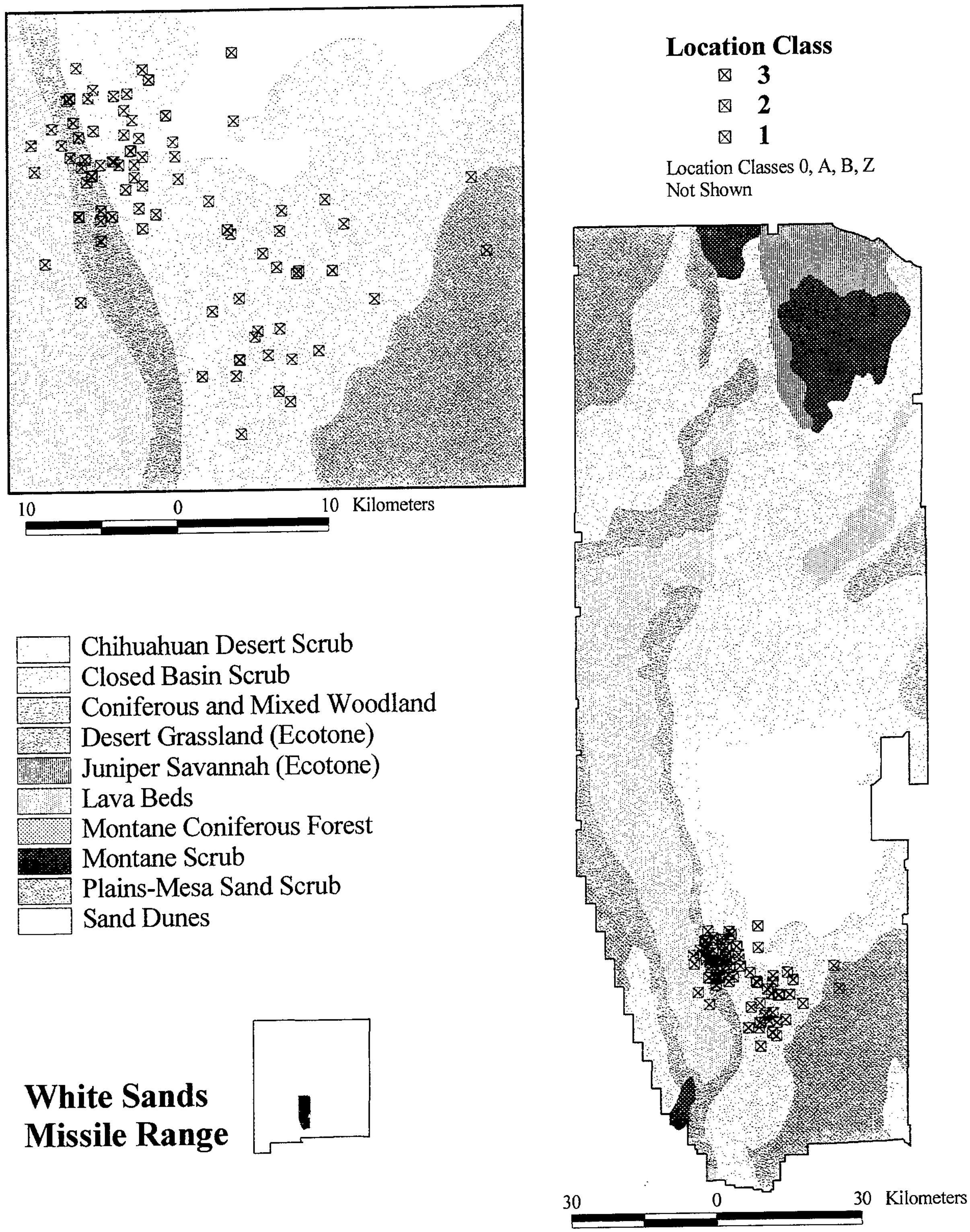

Figure WSMR-24. Argos location estimates for PTT #19190, attached to an African oryx. Shown are location estimates from 5/18/96 to 5/14/97. Background is "Dick Peddie" vegetation. Vegetation Data Source: Technology Applications Center, University of New Mexico, 1993.

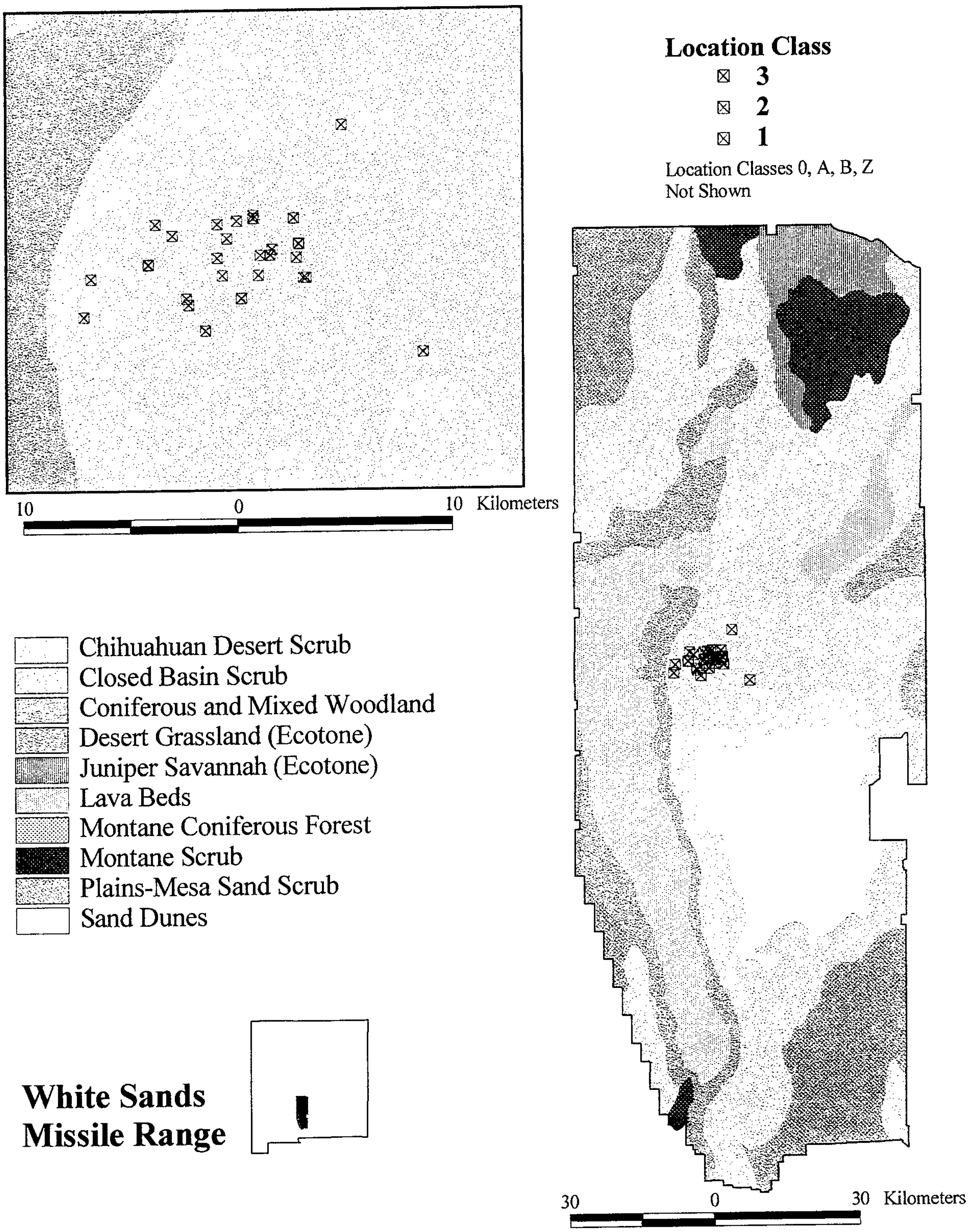

Figure WSMR-25. Argos location estimates for PTT #19191, attached to an African oryx. Shown are location estimates from 5/18/96 to 5/20/97. Background is "Dick Peddie" vegetation. Vegetation Data Source: Technology Applications Center, University of New Mexico, 1993.

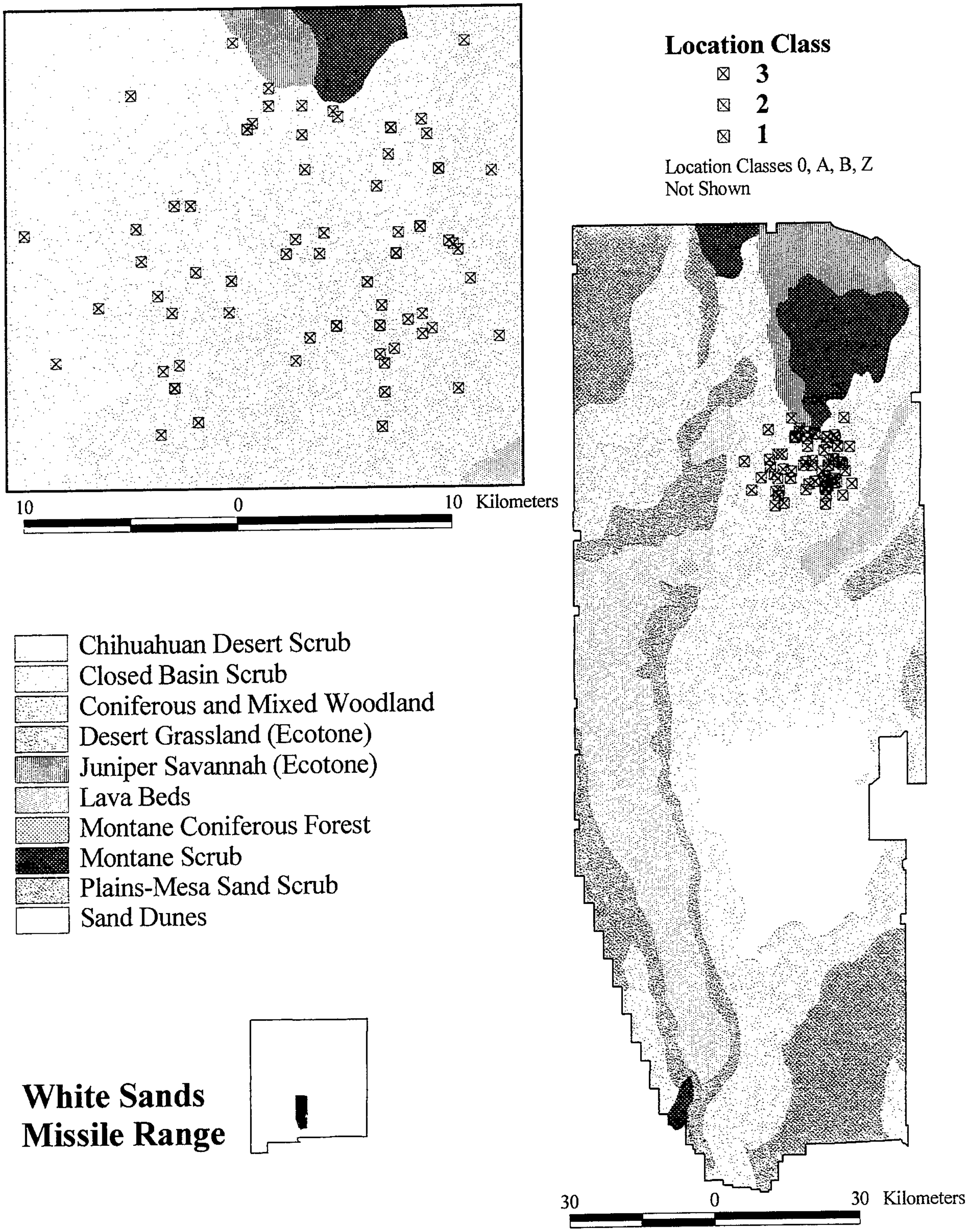

Figure WSMR-26. Argos location estimates for PTT #19192, attached to an African oryx. Shown are location estimates from 5/19/96 to 5/11/97. Background is "Dick Peddie" vegetation. Vegetation Data Source: Technology Applications Center, University of New Mexico, 1993.

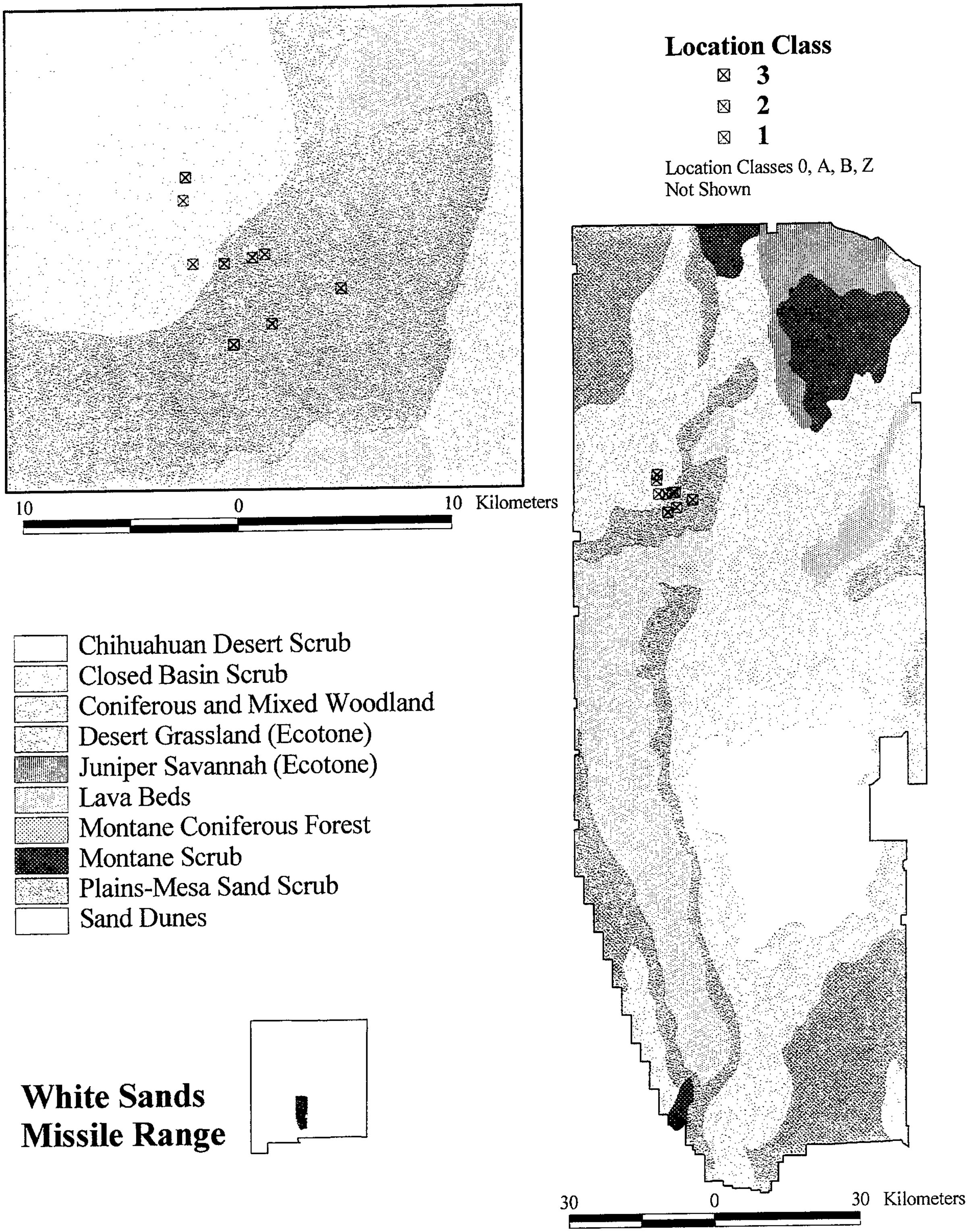

Figure WSMR-27. Argos location estimates for PTT #19193, attached to an African oryx. Shown are location estimates from 5/19/96 to 8/20/96. Background is "Dick Peddie" vegetation. Vegetation Data Source: Technology Applications Center, University of New Mexico, 1993.

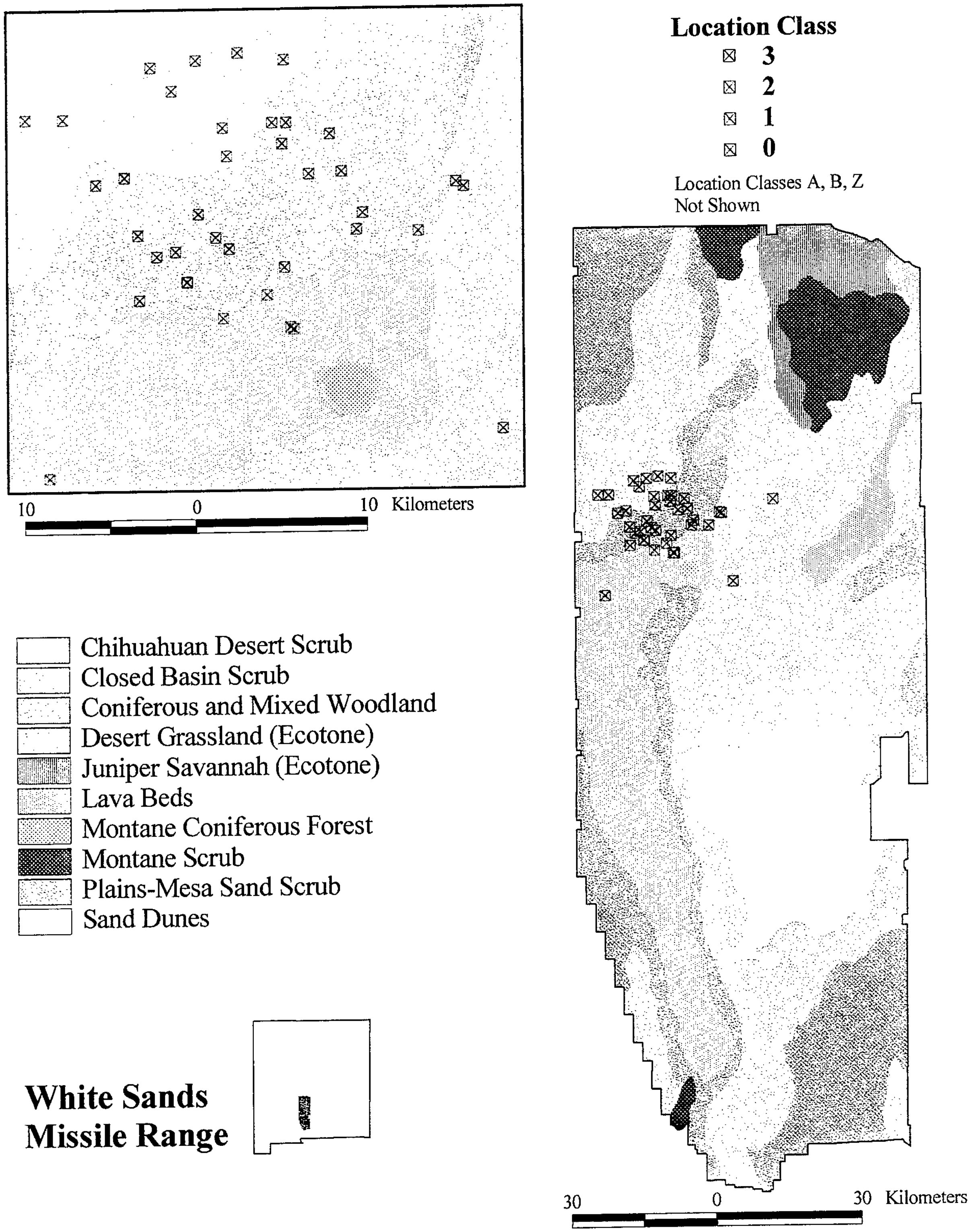

Figure WSMR-28. Argos location estimates for PTT #19194, attached to an African oryx. Shown are location estimates from 5/21/96 to 5/22/97. Background is "Dick Peddie" vegetation. Vegetation Data Source: Technology Applications Center, University of New Mexico, 1993.