EFFECTS OF TRANSPLANTING SAGUAROS ON

NATIVE CAVITY NESTING BIRDS

by

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ABSTRACT

Expanding urbanization into undisturbed Sonoran Desert vegetation has led to public concern over the removal and destruction of large saguaro cacti (*Carnegia gigantea*). Development mitigation plans were established requiring transplantation, salvage and replacement of saguaros in certain development sites. However, no research has assessed whether native birds use transplanted saguaros at the same rate as non-transplanted cacti. The objective of this study was to determine the effects of saguaro transplantation on nest use.

In Tucson, Arizona, 87 transplanted and 28 non-transplanted saguaros on a developed site and 26 non-transplanted saguaros on an undisturbed site were selected for observation of bird nesting activity during the breeding seasons of 1997 and 1998. Birds showed a preference for saguaros, transplanted or non-transplanted, which were surrounded by native vegetation and in areas with low human activity. I suggest that guidelines be revised for development mitigation standards and saguaro transplanting.

INTRODUCTION

Saguaro cactus (*Carnegia gigantea*) is one of the signature species of the Sonoran Desert. This species occurs in southern Arizona, the southeastern edge of California, and northern Sonora, Mexico (Keasey 1981). The westward distribution of the saguaro is restricted by the limited and unpredictable summer precipitation received in the lower elevations of the Sonoran Desert along the Colorado River (McAuliffe 1996). Low temperature limits saguaros along the northern, northeastern and upper elevational margins of its range (Steenbergh and Lowe 1977, Turner et al. 1995). The limiting factors along its eastern Sonora border have not been clearly identified, but an increase in density and cover of associated species may discourage seedling development (Turner et al. 1995). To the south in southern Sonora, Mexico, the saguaro disappears as Sonoran desertscrub vegetation gives way to Sinaloan deciduous thorn forest (Brown 1994).

Populations of saguaros achieve their greatest densities in environments generally receiving more than 200 mm of precipitation per year split between summer and winter seasons (McAuliffe 1996). This zone in Arizona includes a belt on the eastern and northern limits of the Sonoran Desert referred to as the Arizona Uplands. The Arizona Upland subdivision includes the paloverde (Cercidium spp.)-cacti-mixed scrub series and paloverde-catclaw (Acacia greggii) xeroriparian associations (Brown 1994). Tucson, Arizona, is located near the eastern limit of the Sonoran Desert within this band of relatively lush vegetation (McAuliffe 1996). The most rapidly growing urban areas in southern Arizona have increasingly encroached on this zone of high saguaro density. Until recently, development within most of these areas was accomplished by the destruction of all vegetation and revegetation or "reintroduction" of native and exotic vegetation after construction was completed.

Due to public opposition to the practice of removal and destruction of native plants, particularly large saguaros, development practices have been re-evaluated. City and county ordinances in re-zoned areas now require mitigation plans for the conservation of native plants and the transplantation, salvage and replacement of saguaros (Pima County 1991). Transplanting requirements were established to maintain structural diversity of the natural Sonoran Desert landscape and provide habitat for native wildlife, including cavity nesting birds, while maintaining scenic values. Mitigation plans that require saguaros to be transplanted attempt to lessen the impact of development and urbanization on native wildlife and ecosystems. However, transplants tend to be placed in areas that have been graded and have little or no vegetation surrounding the plant. These alterations to the desert environment surrounding transplanted saguaros change the nature and quantity of resources available for native birds. Foraging situations, watering places, escape cover, and nesting and resting substrates are modified by development processes. The nature and magnitude of factors such as predators, pedestrian and vehicular traffic, intraspecific social spacing pressures and interspecific competition are also changed (Emlen 1974).

Residential development in the paloverde-cacti-mixed scrub habitat at a level of 2 houses per hectare does not reduce the density or diversity of native birds when native vegetation is maintained. However, removal of native vegetation and denser development eliminates or greatly reduces the numbers of most native bird species and allows the numbers of exotic species, such as house sparrows (*Passer domesticus*) and European starlings (*Sturnus vulgaris*), to increase (Tweit and Tweit 1986). The number and size of saguaros available for nesting and roosting largely determines the numbers of native cavity nesting birds.

The two most common primary cavity nesting birds (PCN) in the Arizona Uplands subdivision of the Sonoran Desert are gila woodpeckers (*Melanerpes uropygialis*) and guilded flickers (*Colaptes auratus chrysoides*). These woodpeckers excavate cavities within saguaros for nesting and roosting sites. Cavities abandoned by woodpeckers may be used by secondary cavity-nesters (SCN) such as elf owls (*Micrathene whitneyi*), western screech owls (*Otus kennicottii*), cactus ferruginous pygmy-owls (*Glaucidium brasilianum cactorum*), purple martins (*Progne subis*), ash-throated flycatchers (*Myiarchus cinerascens*), brown-crested flycatchers (*Myiarchus tyrannulus*), American kestrels (*Falco sparverius*), and exotic species such as European starlings (*Sturnus vulgaris*) and house sparrows (*Passer domesticus*). Saguaro limbs are used as support for nests of white-winged doves (*Zenaida asiatica*), cactus wrens (*Campylorhynchus brunneicapillus*), Harris's hawks (*Parabuteo unicinctus*), red-tailed hawks (*Buteo jamaicensis*) and great horned owls (*Bubo virginianus*).

Despite regulations that require transplantation of saguaros, little research has been done on the continued use of transplants for nesting by native cavity nesting birds or on the long term survival of the relocated cacti. Emlen (1974) and Tweit and Tweit (1986) found a reduction in the number of cavity nesting birds when native vegetation and saguaro cacti were removed due to grading and construction. However, the extent to which transplanted saguaro cacti are used by cavity nesting birds or the nest success of birds in transplanted saguaros are unknown.

During 1997 and 1998, I studied nest selection and nesting activity of PCNs and SCNs on the Sabino Springs Properties and Raven Golf Course in Tucson, Arizona. In 1998 the Fetzer Ranch, an undeveloped site 1 km east of the Sabino Springs Properties, was included as a reference site. I compared nest use within transplanted and non-transplanted saguaros at the Sabino Springs development site and nest use within non-transplanted saguaros at the Fetzer Ranch site. I also evaluated the effect of removing native vegetation and human disturbance on the nest use of PCNs and SCNs. The objectives of this study were to: 1) compare the use of transplanted and non-transplanted saguaros by cavity nesting birds within a developed area, 2) examine nest use of naturally growing saguaros within an undeveloped site and compare these with saguaros within the developed site, 3) evaluate the effects of human activities and removal of native vegetation near saguaro nest cavities on cavity nest use, 4) determine the presence and effect of exotic species on nest use by native species in study saguaros, and 5) determine the mortality rate of study saguaros.

Differential resource selection is one of the principal relationships which permit species to coexist (Rosenzweig 1981). Adequate quantities of usable resources, such as nest cavities and vegetation cover, are necessary to sustain animal populations (Manly et al. 1995). It is often assumed that a species will select resources that are best able to satisfy its life requirements, and that high quality resources will be selected more than low quality ones. The availability of various resources is not generally uniform, and use may change as availability changes. Therefore, resources used should be compared to available (or unused) resources in order to reach valid conclusions concerning resource selection (Manly et al. 1995).

Species Studied

Gila woodpecker.--Gila woodpeckers are abundant in most parts of the southwestern United States and western Mexico. They are found in desert washes, saguaro forests, river groves, foothill canyons, and urban areas. They prefer cottonwood, willow and sycamore stands, and urban areas (Bent 1939, Peterson 1990). This species occurs from an elevation of 760 m to 1,300 m or even 1,400 m in the canyons and foothills. Gila woodpeckers are year-round residents and forage primarily on insects in and around arroyos (Bent 1939). Gila woodpeckers and guilded flickers are responsible for building the majority of nest cavities in saguaros (Bent 1939, Kerpez and Smith 1990, Moore 1995).

In the Sonoran Desert, gila woodpeckers nest predominantly in saguaros in either newly excavated or previously built cavities (Bent 1939, Gilman 1915). New nest cavities may be excavated in the spring and fall, typically after rainy seasons. Excavation may take up to 15 days (Bent 1939, Moore 1995, Walker 1974). Nesting typically begins in late March and early April and continues through mid-July with second broods. An average of 3 eggs are laid with an incubation period of 12-14 days (Bent 1939, Jackson 1976). Young birds leave the nest about 25 days after hatching but may continue to be fed by adults after leaving the nest (Bent 1939). During nesting, both the male and female feed the young. They spend more than half their foraging time on saguaros, feeding their nestlings pollen, fruit, and insects gleaned from these cacti (Martindale 1983).

Although gila woodpeckers are abundant throughout the Sonoran Desert, their numbers are reduced in urban areas due to fewer nest sites, the loss of native vegetation for foraging and roosting, and increased competition from exotic species such as house sparrows and European starlings (Emlen 1974, Tweit and Tweit 1986). Where saguaros are reduced or "thinned", competition between these exotic species and gila woodpeckers may increase (Emlen 1974, Kerpez and Smith 1990, Tweit and Tweit 1986). A decline in gila woodpeckers could affect SCNs due to a reduction in excavated cavites. Saguaros may also be affected by a decline in woodpeckers as they may be important pollinators (Kerpez and Smith 1990, Martindale 1983). However, exotic cavity-nesting birds typically do not compete with woodpeckers where cavities and nesting substrate are abundant.

<u>Guilded flicker</u>.--Guilded flickers are common in the Sonoran Desert of southern Arizona and northern Mexico west to the Colorado River Valley and the Gulf of California. Guilded flickers are strongly associated with saguaro forests at elevations below about 915-m but can also be found in cottonwood and willow riparian woodlands (Bent 1939, Gilman 1915, Moore 1995). This southern subspecies of the Northern flicker (*Colaptes auratus*) is believed to be non-migratory (Short 1965). Guilded flickers are ground foragers feeding primarily on ants and insects, plus the fruit of cactus and wild berries (Moore 1995, Terres 1987).

About 90% of guilded flicker nest cavities are excavated in saguaros (Gilman 1915). Nest-building usually begins in late March or April and lasts 12 to 15 days.

Flickers may build a new nest or use an existing cavity (Bent 1939). Nesting typically begins in early to mid April and lasts until about the middle of May. Generally only one brood per year is produced (Gilman 1915). An average of 4 eggs are laid with an incubation period of 11-14 days (Ehrlich et al. 1988). Fledglings depart the nest from 24 to 27 days after hatching (Moore 1995).

Guilded flicker populations are stable but the same factors that affect gila woodpeckers may also contribute to the reduction in the numbers of guilded flickers (Emlen 1974). A decline in the numbers of guilded flickers could impact woodland and desert ecosystems because it is the primary predator on ants and it excavates a large percentage of the nest cavities used by SCNs (Moore 1995).

Elf owl.--Elf owls are common to abundant in good habitat in the southwestern United States. They occur in a wide range of xeric to riparian plant communities in southern Arizona, southeastern California, southwestern New Mexico, northern Mexico, and southwestern Texas (Bent 1938, Millsap 1986). Elf owls can be found from the low deserts to mountain forests in Arizona up to 2,000 m (Millsap 1986, Phillips et al. 1964, Terres 1987). The elf owl is present in Arizona from March through September, but winters in southern Mexico (Millsap 1986).

Elf owls are obligate cavity nesters and nest almost exclusively in tree and saguaro cavities excavated by woodpeckers (Bent 1938, Ligon 1968, Millsap 1986, Terres 1987). This owl uses saguaros in areas where this cactus is the only species large enough to provide adequate nesting cavities (Johnson-Duncan et al. 1986). Nesting typically begins in late March or early April and clutches are completed by early May. An average of 3 eggs are laid in desert nests with an incubation period of 24 days (Ligon 1968, Millsap 1986). Young remain in the nest 28-33 days. Elf owl nestlings are generally fed arthropods, but scorpions and lizards are occasionally taken to the nest (Ligon 1968).

Elf owls are not in need of special protection, except in California. However, continuing loss of riparian and upland saguaro habitats from rural and urban development does present a threat to the species (Johnson-Duncan et al. 1986). Habitat loss due to housing developments in the desertscrub around Tucson and east and north of Phoenix may be affecting local populations (Millsap 1986).

Western screech-owls.--Western screech-owls are relatively abundant in northwestern Mexico, throughout Arizona and parts of New Mexico, Texas, Colorado and Utah (Miller and Miller 1951). They are found throughout most of the southwestern lowlands with trees or saguaros suitable for nesting cavities (Johnson-Duncan et al. 1986). Screech owls are year-round residents that feed almost entirely on insects and small rodents (Johnson et al. 1979).

Screech owls are obligate cavity nesters. In the Sonoran Desert they use nest cavities in saguaros and mesquites abandoned by guilded flickers (Terres 1987). Nesting typically begins in late March or early April and incubation lasts about 30 days. On average 3 to 4 eggs are laid and the nestling period lasts about 28 days, owlets typically fledge by late May (Hardy 1997).

Although western screech owls are relatively abundant, there is evidence that this species has experienced large reductions in numbers in the southwestern United States (Johnson-Duncan et al. 1986). The highest densities of screech owls occurs within riparian habitats, and most of this habitat type has been destroyed by grazing, irrigation, flood control, agriculture and urbanization (Johnson et al 1979, Johnson-Duncan et al 1986, Miller and Miller 1951).

Flycatcher spp..--Brown-crested and ash-throated flycatchers are common to abundant within their southwestern range (Bent 1942). Brown-crested flycatchers are year-round residents in southern Nevada, central Arizona, southwest New Mexico and north central Mexico. Ash-throated flycatchers are migratory and their southwestern nesting range includes Colorado, New Mexico, north and central Texas to Baja California and Mexico. Both flycatchers feed predominantly on flying insects and wild berries (Bent 1942, Ehrlich et al. 1988, Terres 1987).

Both species frequently nest in abandoned woodpecker cavities in saguaros. Nesting begins in March lasting through July. There is an average of 5 eggs and the incubation period is about 15 days; young leave the nest between 14 and 20 days after hatching (Bent 1942, Ehrlich et al. 1988, Terres 1987).

Ash-throated flycatchers and brown-crested flycatchers are common summer residents in urban and rural portions of the Sonoran Desert (Phillips et al. 1964). Flycatchers have increased in urban areas, probably due to increased availability of forage (Emlen 1974). However, increased competition from exotic species and a reduction in numbers of nest cavities may have caused a decline in local populations (Tweit and Tweit 1986).

White-winged dove.-- White-winged doves are abundant summer residents in southern and central Arizona but mostly rare and irregular in the winter. The summer distribution is generally throughout the Sonoran Desert west and south of the Mogollon Rim (George et al. 1994, Phillips et al. 1964). White-winged doves are primarily seed eaters feeding on native, agricultural and ornamental seed crops (Cottam and Trefethen 1968, Terres 1987). In Arizona, white-winged doves depend on the seeds produced by saguaros and other cacti because these plants produce large quantities of fruit regardless of rainfall (George et al. 1994).

In the Sonoran Desert, white-winged doves nest in a variety of trees and shrubs. In southern Arizona this dove prefers to nest in mesquite, oak woods, salt cedar, native desert trees and shrubs, cholla cactus, and on arms of saguaros (Terres 1987). Nesting typically begins in late March and lasts until late July or early August (Arnold 1943). There are normally two eggs per nest and incubation lasts 13 to 14 days (Terres 1987). Young leave the nest at about 15 days. As soon as the first young of the year are safely fledged, or if the young or eggs are destroyed, the parents immediately begin their second nesting. The number of broods per season varies with habitat conditions. Where food is abundant white-winged doves typically have two broods (Cottam and Tefethen 1968). Over most of the southwestern range, saguaro fruit is the principal food for the birds during the peak of the mating season (Arnold 1943, George 1994).

White-winged doves are abundant throughout their southwestern range but woody habitat loss due to agricultural and urban development has resulted in total displacement of some breeding colonies (Cottam and Tefethen 1968, George et al 1994). Nesting habitat loss and overharvest continue to be problems for this species (George et al. 1994). Higher densities of white-winged doves are found within urban areas because seed supplies are enhanced in urban habitats, such as weedy lawns and home feeders, and abundant water (Emlen 1974).

Cactus wren.-- Cactus wrens are common residents throughout the Lower Sonoran Zone. They especially prefer cholla cactus, but also occur in open mesquite and shade trees in towns (Phillips et al. 1964). This species ranges from southern California south to southern Baja California, southern Nevada, southwestern Utah, western and south central Arizona, southern New Mexico and central Texas to Mexico but is limited to regions where thorny shrubs and trees offer nesting sites (Terres 1987). Cactus wrens forage primarily on the ground for insects but also feed on small vertebrates, fruits and seeds (Ehrlich et al. 1988, Phillips et al. 1964).

Cactus wren nests are generally built in cholla cactus but can also be found in a variety of trees, shrubs and abandoned woodpecker holes. Nesting typically begins in March and may last through August with two or three broods per year. Commonly 4 to 5 eggs are laid with an incubation period of 16 days (Anderson and Anderson 1973, Terres 1987). Young leave the nest 19 to 23 days after hatching, some parental care continues after fledging but ends with the onset of another brood (Anderson and Anderson 1973).

Cactus wrens are abundant throughout their range but are found in lower densities in urban areas than in native vegetation. Competition for nesting sites occurs within urban areas due to few cholla cactus and native thorny shrubs and trees. Other resources, such as insect availability and roosting sites, are also affected by the decrease in native vegetation (Emlen 1974).

House sparrow.-- The house sparrow is an abundant resident of cities and towns, a common resident of large ranch headquarters, irrigated fields and farmland buildings throughout Arizona (Phillips et al. 1964, Terres 1987). House sparrows are native to Europe and were first introduced into the United States in 1851 (Lowther and Cink 1992). The first house sparrow was seen in Arizona in the early 1900's and this species was widespread by 1915 (Phillips et al. 1964). Adult house sparrows forage primarily on the ground for seeds, insects and fruit but primarily feed nestlings insects (Ehrlich et al. 1988, Lowther and Cink 1992).

In Arizona, house sparrows nest in a variety of structures with cavities or hollows including woodpecker cavities in trees and saguaros (Phillips et al. 1964, Terres 1987, Tweit and Tweit 1986). Nesting typically begins in March for first broods and later broods continue through August (Lowther and Cink 1992). An average of 5 eggs are laid per brood with an incubation period of 10 to 13 days. Nestlings generally fledged in 14 to 17 days (Ehrlich et al. 1988).

A general continental decline in house sparrow numbers occurred in the late 1960's, however, this species is still abundant in human modified environments. House sparrows are aggressive in defending nest sites, defending nest cavities against returning migrant cavity nesters and also forcibly evicting established cavity nesters (Lowther and Cink 1992).

European starling.-- The European starling is a widely distributed resident across nearly all of North America (Cabe 1993). It was successfully introduced to North America in 1890. It has become a common breeding resident throughout Arizona since it's first occurrence in the state in 1946 (Monson 1948, Phillips et al.1964). Starlings in

Arizona are found primarily in cities and towns, irrigated farmlands and adjacent desert areas that include saguaros (Phillips et al. 1964). They forage in open country on short, mown, or grazed fields. Starlings forage primarily on the ground for insects, berries and seeds (Cabe 1993, Ehrlich et al. 1988).

In the Sonoran Desert, European starlings are closely associated with human-modified landscapes. They have been observed nesting in woodpecker cavities in mature hardwood trees, palm trees, native trees and saguaros in or near urban areas (Royall 1966, Terres 1987). Incubation begins by early March and lasts until late July. An average of 4 eggs are laid with an incubation period of 12 days (Cabe 1993, Terres 1987, Royall 1966). Young fledge from the nest 21 days after hatching and are independent from parents 4 to 5 days later (Terres 1987).

The nesting season of the European starling overlaps that of many of the native Sonoran Desert's cavity nesting birds (Bent 1939, Cabe 1993, Royall 1966). Starlings have been observed usurping cavities from gila woodpeckers, northern flickers and purple martins (Kerpez and Smith 1990). Elf owls are also susceptible to nest eviction by starlings. Urban environments and human activities have increased the amount of starling habitat and resulted in a significant increase in numbers since their introduction to the United States (Cabe 1993). Although European starlings have increased in numbers in the Sonoran Desert and have been observed competing for nest sites with native species, it is difficult to determine whether exotic cavity-nesting birds have negatively influenced native cavity-nesting birds (Bibles 1992). Influences may be site-specific and will depend on factors such as the number of large saguaro cacti, distance to sites where starlings can forage, amount of forage available, and environmental features that affect the number of woodpeckers (Bibles 1992).

Study Sites

This study was conducted on 2 sites. Site 1 was the Sabino Springs housing development and Raven Golf Course located in the foothills of the Santa Catalina Mountains in Tucson, Arizona (Figure 1). The site is about 1.7 km^2 and is bordered on the northeast by the federally protected Pusch Ridge Wilderness (within Coronado National Forest). Prior to development, the site contained relatively undisturbed vegetation in the paloverde-cacti-mixed scrub series of the Arizona Uplands subdivision of Sonoran Desertscrub (Brown 1994). Several riparian areas and 9 natural springs also existed on the site. The property consists of an 18-hole golf course and construction has begun on approximately 450 single-family homes. The development was planned around the riparian areas and springs with these areas designated as natural rough areas within the golf course layout.

The transplanted saguaros studied had been moved to open spaces, along the roadway and median, in the landscape near the golf course club house, adjacent to the golf course fairways, and along cart paths. A few saguaros were transplanted to riparian edges near undisturbed non-transplants but many were planted in large clusters on fairway edges with no non-transplants nearby. The majority, about 53% of transplants, were located in parking lots and roadway medians.

Site 2 is the Fetzer Ranch, located about 0.4 km east of the Sabino Springs Development and Raven Golf Course (Figure 1). This site is approximately 1.2 km^2 and contains relatively undisturbed vegetation in the paloverde-cacti-mixed scrub series of the Arizona Uplands subdivision of Sonoran Desertscrub (Brown 1994). This property contains 2 homes with one main road connecting them and 2 riparian areas. No other construction exits on the site and no saguaros have been removed or transplanted.

METHODS

Study saguaros

Between May 1994 and December 1996, >1700 saguaros were transplanted within the Sabino Springs Development. From December 1996 through February 1997, I located the majority (>90%) of these saguaros and found 87 transplants with cavities that were potentially suitable for nesting. All cavities where "inspected" with a plummet attached to a telescoping pole to determine if they were deep enough for use by cavity nesting birds (Brush 1983). Transplants with suitable nest cavities were located along roadways (n = 27), graded or developed housing lots (n = 20) and along golf course fairways and paths (n = 40). These plants were sampled as transplanted saguaros within a disturbed site. A disturbed site was defined as a location on the Sabino Springs Development and Raven Golf Course containing graded pods with ongoing housing construction, completed residential housing clusters, 18-hole golf course, golf course club house, parking lots, paved streets and/or sidewalks.

Non-transplanted saguaros located within approximately 50 meters of transplanted saguaros along the roadways, fairways and golf paths were inspected for potential nest cavities. Potential nest cavities were found in 28 non-transplanted saguaros. These non-transplanted saguaros with nest cavities were located along roadways (n = 4), graded or developed housing lots (n = 7) and along golf fairways and paths (n = 17). These plants were sampled as non-transplanted saguaros within a disturbed site.

Within the Fetzer Ranch site I examined about 500 saguaros and found 26 non-transplanted saguaros with suitable nest cavities. The site was searched in November 1997 for saguaros containing cavities potentially suitable for nesting. These plants were sampled as non-transplanted saguaros within an undisturbed site. An undisturbed site was defined for this study as the Fetzer Ranch which contains 2 homes and one graded road on 300 acres, no additional development is planned until 1999 and the site has not been grazed since the late 1970's. No other grading or construction exists on the ranch and no saguaros have been transplanted on the property.

Shrubs, trees and cacti within a 30 meter radius of each study saguaro, as well as buildings, graded areas, paved areas or any other construction were mapped. I used the line intercept method to estimate vegetative cover (Bonham 1989). Lines were established 30 m for each study saguaro, 1 at each cardinal direction.

Human activity within 30 meters of saguaros was recorded during observation periods (Altmann 1974, Harris 1995). Observation periods consisted of viewing study saguaros for 15 minutes each session from a distance that allowed a clear view without disturbance to nesting activity, if any. Human activities considered during observation periods were pedestrian traffic, motor vehicle traffic, golfing, maintenance work and construction work. Little or no golfing activity, maintenance work or construction was typically conducted after sunset but any human activity observed during night-time cavity monitoring periods was noted.

I measured the height (meters) and circumference at breast height (centimeters) of each saguaro, and counted the number of arms. A 2-m measuring tape was used to measure circumference and a 7.5-m fiberglass telescoping pole was used to measure height and "inspect" cavities. Each cavity was "inspected" with a telescoping pole and plummet attachment to determine depth. Number of cavities determined suitable for nesting was noted along with compass orientation and location of cavities in the saguaro (arm, main stem).

Nest monitoring

I monitored study saguaros for activity of breeding birds from February through mid-September 1997 and 1998. To monitor for diurnal bird species, saguaros were visited in the early morning (after sunrise) or late afternoon (before sunset) approximately every two weeks. Monitoring occurred from a distance of 5 to 10 m from the saguaros from a location where there was an unobstructed view of the saguaro. Each monitoring period lasted 15 minutes. Activity around the saguaros was observed through binoculars. All activities in or around cavities were noted as well as species, sex of bird, nestling sounds and feeding intervals.

Saguaros were monitored for use by nocturnal species after sunset approximately every two weeks from February through July. During each visit, screech owl and elf owl calls were broadcast by megaphone 5 to 10 m from study saguaros. All responses to broadcast calls were followed to determine the location of birds. Study saguaros located within 50 m of call responses were monitored for 15 minutes. During that period, I played intermittent broadcasts to determine if owls were defending a nest cavity within the study saguaros.

I used a camera and pole to apparatus to examine the interior of all cavities within study saguaros (TreeTop II, provided by Christensen Designs) in June and July of 1998. The apparatus consisted of a 50 ft fiberglass extension pole with a near-infrared camera attachment at the top and video image screen at eye level. The camera attachment was inserted into the nest cavities and any contents viewed were recorded. In cavities containing nestlings or fledglings, the species was identified and the camera was removed quickly to minimize disturbance of the nest.

Nest use and nest status

Behavioral cues of birds observed in and around nest cavities were used to determine the nesting status of all species (Ehrlich et al. 1988, Jackson 1976, Ralph et al. 1993, Vickery et al. 1992). The nest status of each cavity determined whether a cavity was used or unused. Used cavities were defined as those cavities with confirmed egg incubation (by use of the peeper apparatus) and those with nestlings or fledged young. All other cavities were determined to be available but unused for nesting. The habitat variables of "transplant" or "non-transplant", percent vegetation cover (total line-intercepts for four cardinal directions/total length of transects) and human disturbance (total number of events/number of observation periods) were used for analysis of differences in nest use of transplanted versus non-transplanted saguaros.

The number of exotic species nesting in study saguaros at the Sabino Springs site was compared to exotic species found at the Fetzer site. Mortality of saguaros within the disturbed site and between sites was examined to determine any significant differences.

Data analysis

Logistic regression analysis was used to model relationships between saguaro use and three explanatory variables. My response variable was used or unused saguaros for nesting (binary response variable, 1 = used, 0 = unused). My explanatory variables were transplanted or non-transplanted saguaro, percent vegetation cover and percent human disturbance. For purposes of interpretation, differences in the range of $\alpha = .06$ to .10 (i.e., $P = .06$ to .10) were considered suggestive and those in the range of $\alpha \leq .05$ were considered convincing evidence of a difference (Ramsey and Schafer 1997).

Odds ratios were used to determine how much more likely a saguaro would be used for each 1 unit increase in the specific explanatory variables (Menard 1995). An odds ratio equal to 1 indicates a zero variable effect on nest use, an odds ratio >1 indicates an increase in odds of nest use with an increase in the explanatory variable and an odds ratio <1 indicates a decrease in odds of nest use with an increase in the explanatory variable (Menard 1995).

Analysis of variance was used to determine differences in number of arms and nest cavities as height of saguaros increased. Contingency tables were used to determine differences in nest cavity orientation and mortality.

RESULTS

In 1997, nest use was not affected by whether a saguaro was a transplant or non-transplant ($\chi^2 = 1.35$, 1 df, $P = 0.24$), by percent vegetation cover ($\chi^2 = 0.89$, 1 df, $P = 0.34$) or by human activity ($\chi^2 = 1.11$, 1 df, $P = 0.29$) (Table 1). There was no difference in nest use after accounting for all explanatory variables.

In 1998, however, nest use was affected by percent vegetation cover ($\chi^2 = 2.98$, 1 df, $P = 0.08$) and human activity ($\chi^2 = 5.10$, 1 df, $P = 0.02$) but not by whether a saguaro was transplanted or not ($\chi^2 = 0.03$, 1 df, $P = 0.87$) (Table 1). For each 1% increase in percent vegetation cover the odds of nest use decreased by .96 times (95% CI: -0.06 to 1.98); for each 1% increase in human activity the odds of nest use decreased by 0.92 times (95% CI: -0.11 to 1.95) (Table 2).

Within the 87 transplanted study saguaros, 103 cavities suitable for nesting were found. Within the 28 non-transplanted saguaros on the Sabino Springs site, 79 cavities suitable for nesting were found and within the 26 Fetzer Ranch non-transplanted saguaros, 52 cavities suitable for nesting were found. A total of 234 nest cavites were located on the two study sites (Table 3). In 1997, 35 saguaros were used for nesting with 41 used nests found. In 1998, 43 saguaros were used for nesting, including the Fetzer Ranch site, with 69 used nests found (Table 3). Nests were used by 8 bird species (Table 4).

European starlings were found nesting in 5 saguaros in the Sabino Springs site in 1997, of these nests, 4 (80%) were in transplanted saguaros (Table 5). European starlings and house sparrows attempted nesting in 11 saguaros at the Sabino Springs site in 1998, of these nests, 10 (91%) were in transplanted saguaros (Table 5). No exotic species were found nesting at the Fetzer site.

In 1997, 9 (10%) of the 87 transplanted saguaros containing suitable nest cavities were found dead on the Sabino Springs site. None of the 28 non-transplanted saguaros containing suitable nest cavities had died. An additional 15 transplanted saguaros (27% of total) and 1 non-transplanted saguaro (3%) died prior to the 1998 observation period. No saguaros died at the Fetzer site.

The minimum height of study saguaros with nest cavities was 3.64 meters and the maximum was about 13.0 meters. There was significant evidence indicating an increase in the number of nest cavities as size of saguaro increased (ANOVA $F = 31.52$, 1 df, $P = <0.0001$). There was also significant evidence indicating an increase in the number of arms as size of saguaros increased (ANOVA $F = 57.37$, 1 df, $P = <0.0001$) (Table 6).

Of the 234 potential nest cavities found, a total of 85 were used. The majority, 74%, of unused nests were oriented North, Northeast, Northwest or Southeast ($\chi^2 = 30.99$, 7 df, $P = <0.0001$) (Table 7). The majority, 66%, of used nest were oriented South, East, West or Southwest ($\chi^2 = 30.99$, 7 df, $P = <0.0001$) (Table 7).

DISCUSSION

Native cavity nesting birds showed no preference between transplanted and non-transplanted saguaros in 1997 or 1998. However, the two exotic species showed a strong found nesting at the Fetzer site.

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DISCUSSION

Native cavity nesting birds showed no preference between transplanted and non-transplanted saguaros in 1997 or 1998. However, the two exotic species showed a strong preference for transplanted saguaros in areas with high human disturbance (parking lots, roadways and golf course greens). I did not observe exotic species compete for nest cavities with native cavity-nesting birds in these high use areas.

I observed a reduction in the number of saguaros due to transplant mortality within the Sabino Springs site. A long term study on the mortality of transplanted saguaros in progress at the Sabino Springs site has shown that larger age class saguaros (>5m) are experiencing a mortality rate of 33% over the first 3 years after transplanting (Pers. comm., Lisa Harris).

The percent vegetative cover surrounding saguaros had a moderate effect on nest use in 1998. The majority of used nests were in saguaros with 10 to 30% cover (Figure 2). There was a moderate decline in nest use as percent vegetative cover increased. There was no effect on nest use due to vegetative cover in 1997. Although vegetative cover requirements for foraging and roosting differs for the various cavity nesting species observed, analysis of percent vegetative cover helped determine if the loss of vegetation due to grading and construction had an effect on cavity nesters as a whole. The difference in effects of vegetative cover between years may be due to an increase in occupied homes, increased construction activities and golfing activity. Although irrigation practices throughout the golf course area increased vegetative cover, increased human activity may have caused a decline in nest use surrounding these high disturbance/high vegetation cover areas.

High levels of human activity (number of events/observation period) had an adverse effect on nest use by native cavity nesting birds in 1998. The majority of used nests were in areas with ≤ 10 events (pedestrians, golfers, vehicle traffic, construction, etc.) per observation period (Figure 3). Human activity can affect nest use through habitat alteration, disturbance during nesting or direct mortality. During observation periods I noted that nesting birds were disturbed by golf ball impacts near nest cavities, human activity directly below nest saguaros (primarily passing golfers and maintenance workers) and passing vehicle traffic. On several occasions birds returning or departing nest cavities had near collisions with vehicle traffic. Mechanized forms of activity presented the most serious potential impacts, but even the most casual intrusion by a person on foot may have significantly affected sensitive species (Boyle and Samson 1985).

Larger saguaros had a significantly greater number of cavities than smaller saguaros found on the study sites. Gila woodpecker and guilded flicker nest cavities are found more frequently in larger saguaros (>5-m) and among saguaros containing at least one woodpecker nest cavity. The number of nest cavities per saguaro positively correlated with saguaro height. There was also a significant increase in the number of arms as saguaro height increased. Large, older saguaros with multiple arms have been available for nest excavation for a longer period of time, may have lower predation rates and have lower thermal stresses than smaller saguaros (Korol and Hutto 1984, Steenbergh and Lowe 1977). Currently, larger size transplanted saguaros also have the highest mortality rates (Pers. comm., Lisa Harris).

The orientation of nest cavities was significantly different between used and unused saguaros. The majority of used nests were oriented towards the south and unused nests were oriented towards the north. Foraging, predatory, thermoregulatory, and architectural constraints probably affect the orientation of nest cavities (Korol and Hutto 1984). An additional factor affecting cavity orientation in transplanted saguaros is placement of saguaros after removal from their original location. Saguaros were to be transplanted in the same orientation as they were found but difficulties in transplanting, transplant locations and loss of orientation markings may have caused changes in orientation, possibly affecting nest use.

MANAGEMENT IMPLICATIONS

During my study I did not observe exotic cavity-nesting birds compete with native species where cavities and nesting substrate were abundant. Competition with exotic species is unlikely as long as large saguaros are abundant providing ample substrate for cavity excavation by woodpeckers (Bibles 1992, Waters et al. 1990). However, as development expands the number of disturbed sites, populations of exotic species will increase (Aldrich and Coffin 1980, Emlen 1974, Tweit and Twiet 1986, VanDruff et al. 1994). Exotic species prefer habitats adjacent to agricultural sites, golf courses and parks. As these areas are filled and development increases, exotic species will start invading undisturbed desert areas, causing a threat to the survival of native cavity-nesting species (Kerpez 1986).

Competition may not play a leading role in the reduction of native cavity-nesting birds along urban gradients. However, competion from exotic species in conjunction with the loss of native vegetation, increased human disturbance, and continued high transplant mortality rates have a significant impact on native cavity-nesting birds.

The majority of saguaros found on the golf course were located in areas where natural undisturbed vegetation joined with heavily maintained golf course greens. These types of areas are characteristic of developments where planning has allowed for natural plots interspersed with developed areas (commonly referred to as cluster development).

Such clusters are likely to have the largest numbers of avian species as well as largest populations due to edge effects, the tendency for increased variety and density at community junctions (Duncan et al. 1986). In addition, during early stages of disturbance, land development will result in a greater diversity of species as natural succession is selectively altered and new elements and habitat types are introduced (VanDruff et al. 1994). However, these areas typically do not maintain the original species composition or abundance of native species found in the predevelopment community for extended periods (Blair 1996).

Native plant protection ordinances have been designed with the intent to maintain habitat for native species as well as the structural diversity of the Sonoran desert. Guidelines for transplanting saguaros should address this intent. Results from my study indicate that nest use in saguaros is not affected by transplanting. However, placement of transplanted saguaros in areas with native vegetation and low human activity increase nest use by native cavity nesting species and minimize nest use by exotic species. Native plant protection ordinances should address placement of large age class transplanted saguaros in locations near areas of native vegetation.

Additional research on placement of transplanted saguaros, transplant mortality, and long term species diversity within cluster developments using native plant protection guidelines should be conducted in order to increase protection of native wildlife within the Sonoran desert.

Table 1. Three-variable logistic regression model of nest use for 1997 and 1998, Tucson, Arizona.

1997

Variable	Parameter Estimates	SE	χ^2	*P*-value
Intercept	1.55	0.92	2.86	0.09
Transplant	-0.34	0.29	1.35	0.50
% Vegetation Cover	-0.03	0.03	0.89	0.34
% Human Activity	-0.04	0.04	1.11	0.29

1998

Variable	Parameter Estimates	SE	χ^2	*P*-value
Intercept	2.34	0.87	7.14	0.007
Transplant	0.05	0.30	0.03	0.87
% Vegetation Cover	-0.04	0.02	2.98	0.08
% Human Activity	-0.09	0.04	5.10	0.02

Table 2. Odds ratios for the 3-variable logistic regression model of nest use for 1997 and 1998, Tucson, Arizona. For continuous variables, the odds ratio reflects the change in odds for a 1 unit increase in the variable. For categorical variables, the odds ration reflects that the condition is true.

1997

Condition	Odds Ratio
Transplant	0.50
% Vegetation cover	0.23
% Human Activity	0.37

1998

Condition	Odds Ratio
Transplant	1.10
% Vegetation cover	0.08
% Human Activity	0.09

Table 3. Number of saguaros, number of potential nest cavities and nest use in 1997 and 1998 for transplanted and non-transplanted study saguaros, Tucson, Arizona.

Category	# of Cavities	# of Saguaros	1997 Used Nests	1998 Used Nests
Transplanted	103	87	23	34
Non-Transplanted	79	28	18	21
Fetzer Non-Transplanted	52	26	N/A	14
Total	234	141	41	69

Table 4. Bird species and number of nests found in study saguaros for 1997 and 1998, Tucson, Arizona.

Species	# of Nests in 1997	# of Nests in 1998
Cactus Wren	2	1
Elf Owl	1	3
Flycatcher spp.	1	2
Gila Woodpecker	29	47
Guilded Flicker	2	4
White-winged dove	1	1
European starling	5	10
House sparrow	0	1
Total	41	69

Table 5. Number of birds, segregated into native and exotic species, nesting in transplanted and non-transplanted saguaros in 1997 and 1998 at the Sabino Springs site, Tucson, Arizona.

1997

Saguaro Type	Native	Exotic	Total
Transplanted	20	4	24
Non-transplanted	16	1	17
Total	36	5	41

1998

Saguaro Type	Native	Exotic	Total
Transplanted	24	10	34
Non-transplanted	34	1	35
Total	58	11	69

Table 6. Mean, maximum and minimum height of saguaros, number of nests and number of arms of study saguaros for Sabino Springs and Fetzer study sites, Tucson, Arizona.

	Maximum	Minimum	$\bar{X}$	SE	*P*[a]
Saguaro height (m)	13.0	3.64	6.69	0.119	
Number of nest cavities	10	1	2.06	0.148	<0.0001
Number of arms	0	17	3.82	0.243	<0.0001

[a]Significance of Analysis of Variance test on height of saguaro for number of nests and number of cavities.

Table 7. Orientation of cavities in study saguaros and nest use of study saguaros at the Sabino Springs and Fetzer study sites, Tucson, Arizona.

	Orientation								
Cavities	N	NE	E	S	SE	W	NW	SW	Total
Used	16	3	17	11	2	17	8	11	149
Unused	26	31	12	5	10	24	23	18	85

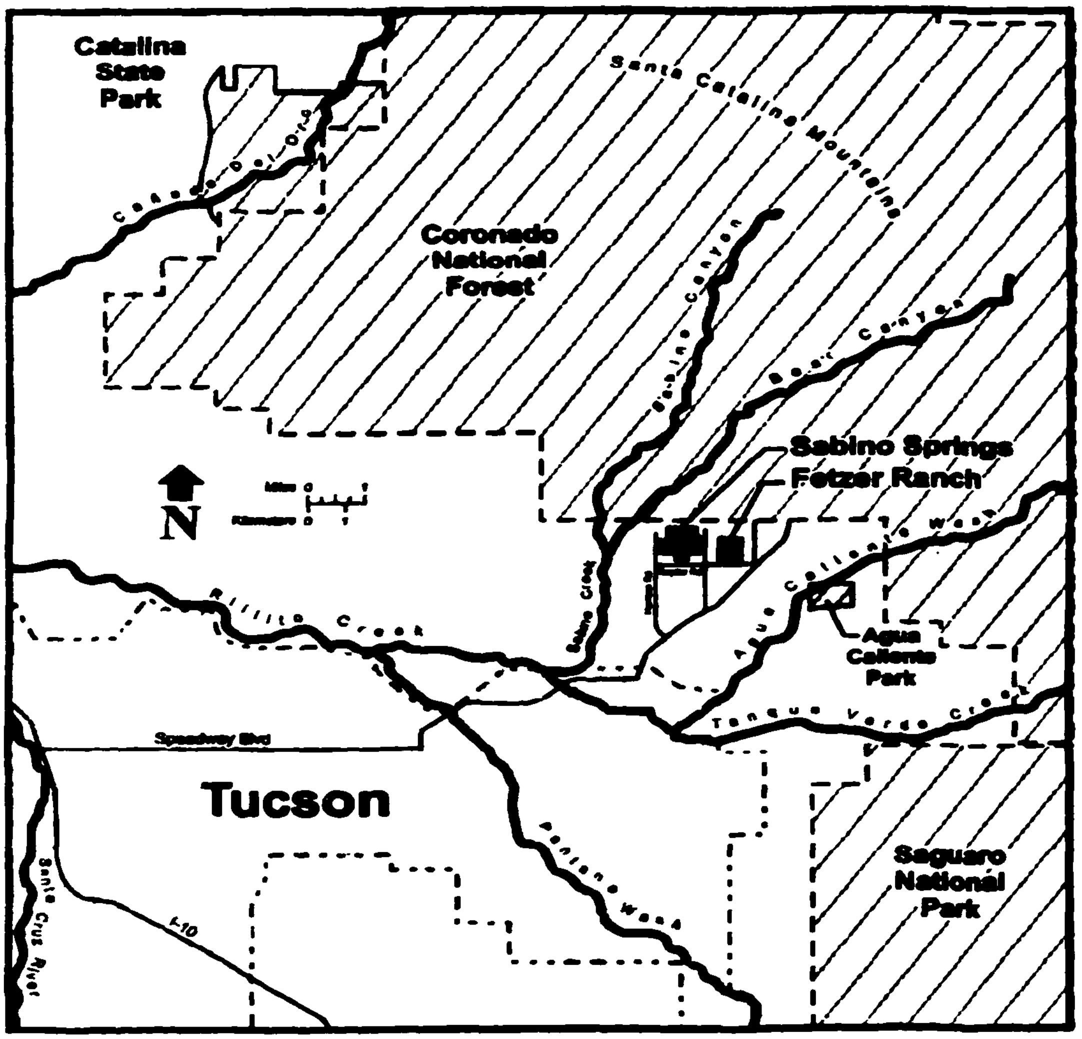

Figure 1. Location of the Sabino Springs Development containing the Raven Golf Course and Fetzer Ranch in Tucson, Arizona.

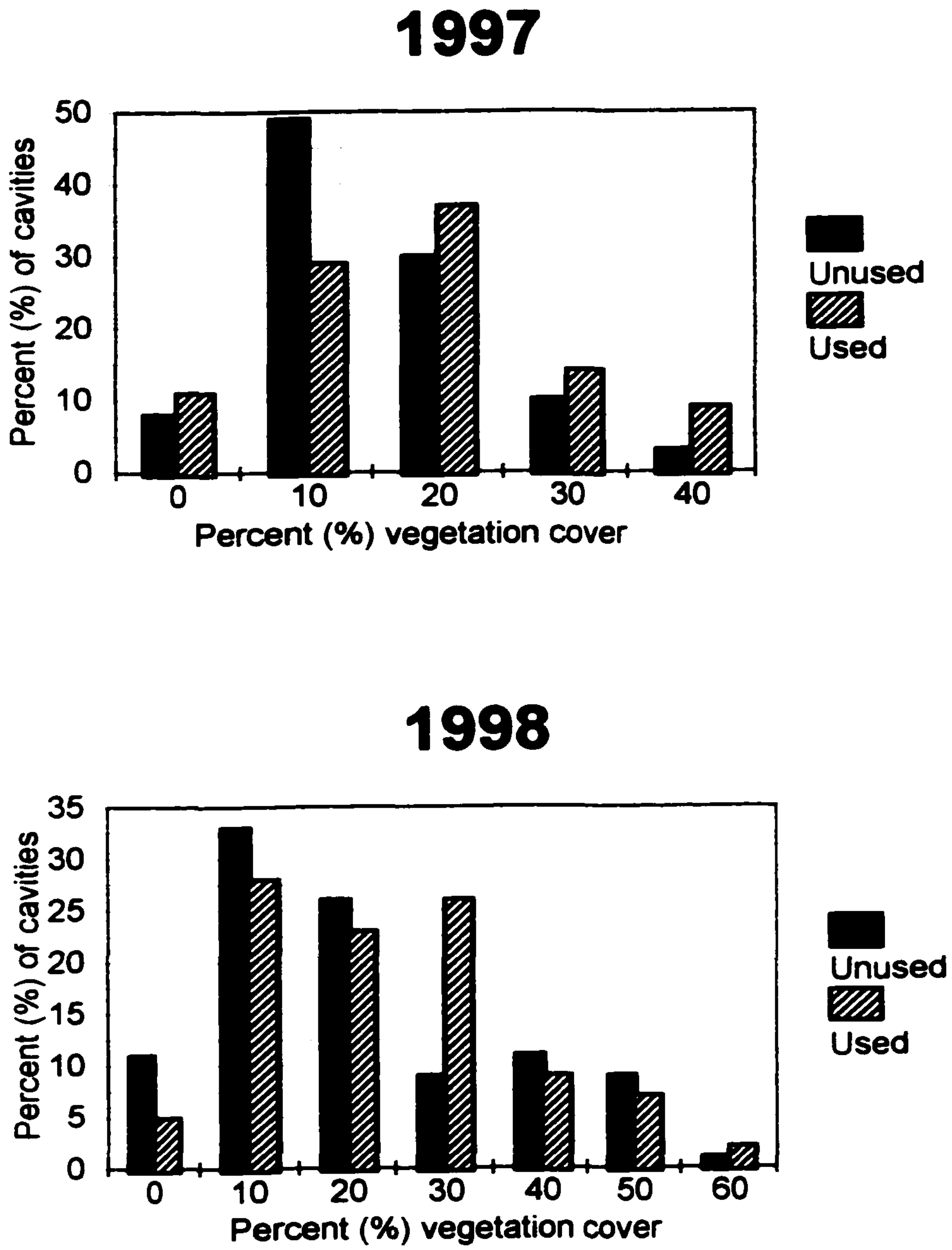

Figure 2. Percent vegetation cover for used and unused saguaros in 1997 and 1998. The 1998 data include the Fetzer Ranch site.

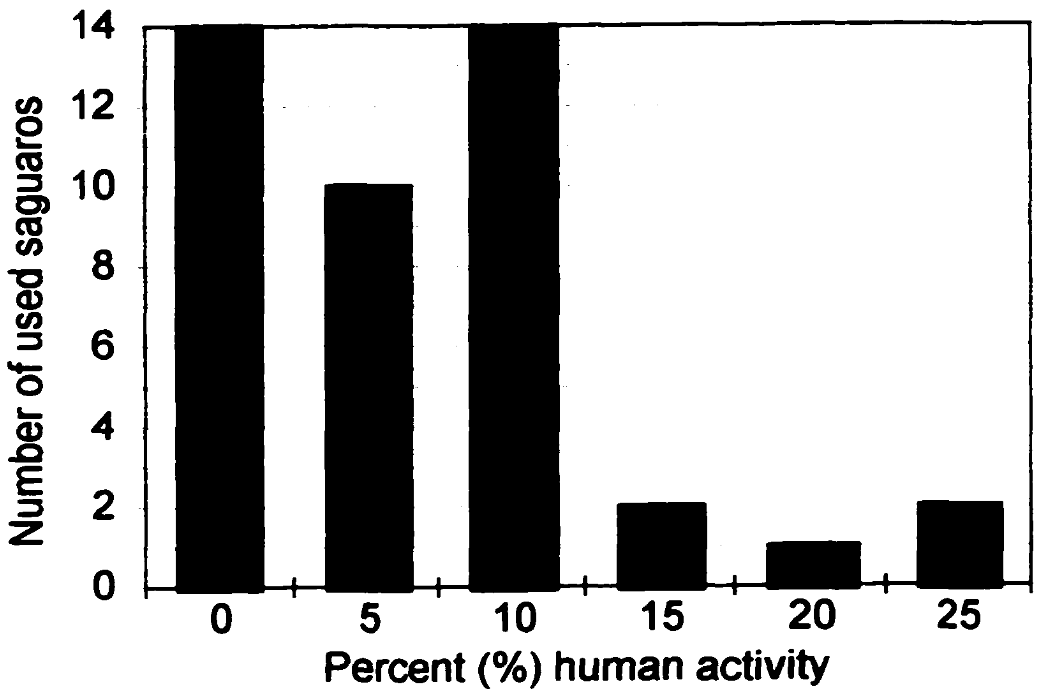

Figure 3. Percent human activity (number of events/observation period) at saguaros used for nesting in 1998.

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