A Review of Falconry as a Bird Control Technique with Recommendations for Use at the Shuttle Landing Facility, John F. Kennedy Space Center, Florida, U.S.A.

The Bionetics Corporation and Archbold Biological Station

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ABSTRACT

Falconry has been proposed as a method of reducing the bird/aircraft strike hazard, in addition to current bird control techniques, at the Shuttle Landing Facility (SLF), John F. Kennedy Space Center (KSC), Florida, U.S. Bird control programs using falconry have been employed at a number of military and commercial airfields in the U.S., Canada and Europe. Most falconry programs have been discontinued. In most situations, falconry did not prove cost effective when compared to alternative bird control techniques. Available literature and documents, as well as several raptor specialists and military personnel, suggest that falconry may be useful only against certain problem species and then only when other bird control methods have been proven inadequate. Because many of the most commonly used falcons are protected species, acquisition of falcons will complicate their use in bird control programs. Many avian species found at the SLF are federally and state protected or of conservation concern; therefore, environmental impacts may also result from the use of falcons.

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INTRODUCTION

The purpose of this review is to identify and evaluate bird control programs that have used falcons to reduce bird strike hazards at airfields. This review will provide recommendations on the potential of falconry as a means of reducing potential bird/aircraft strike hazards at the Shuttle Landing Facility (SLF), Kennedy Space Center (KSC), Florida, U.S.

Falconry

For hundreds of years, birds of prey have been trained to hunt wild game and until recently falconry was used solely for sport (Blaine 1970, Blokpoel 1976, Woodford 1987). Since the 1940's, airfields have been experimenting with falconry to control bird species that have been identified as hazardous to airfield operations

(Blokpoel 1976, Doughty 1976). Falconry programs use the instinctive predator ability of these raptors to hunt and disperse problem species either solely or in combination with traditional bird control methods.

Falconry evolved as the sport of using trained raptors for hunting wild game (i.e., grouse, quail, pheasant, etc.). Many species of raptors have been trained for falconry; however, falcons (family Falconidae, genus *Falco*), accipiters (family Accipitridae, genus *Accipiter*), and buteos (family Accipitridae, genus *Buteo*) are most often used (Blaine 1970, Blokpoel 1976, Woodford 1987).

Species of falcons commonly trained in falconry include the Peregrine Falcon (*Falco pereginus*), Gyrfalcon (*F. rusticolus*), Prairie Falcon (*F. mexicanus*), and Merlin (*F. columbarius*). The Northern Goshawk (*Accipiter gentilis*) is the only accipiter commonly used (Blaine 1970, Woodford 1987). Ferruginous Hawks (*Buteo regalis*) and Red-tailed Hawks (*B. jamaicensis*) are used less commonly, as are Golden Eagles (*Aquila chrysaetos*), which have been used by English, Chinese and Mongolian royalty for hunting large mammals. Females of both families are the most commonly trained because they are larger in size than males and have the ability to capture larger prey items. Raptors used in falconry are trained on specific prey or target species. Common training methods have the falcon return to the falconer's fist or to a lure (Woodford 1987). However, falcons often do not return to the handler and are retrieved by chase or the use of radio telemetry. For simplicity, the term falcon when used in general discussion throughout this report refers to any raptor species trained in falconry, and will not be restricted to members of the genus *Falco*.

Falcon Biology

Falcons (*Falco* spp.) generally utilize open country. Long, pointed wings adapt falcons for high speed aerial pursuit. Falcons typically hunt by climbing to high altitudes and diving upon prey either in the air or on the ground. Typical prey size of falcons ranges from 300-500 g, and their natural diet may include a mixture of avian and mammalian species (Sherrod 1978, Johnsgard 1990).

Accipiters (*Accipiter* spp.) are characterized by short, rounded wings and long, narrow tails, that allow a high degree of maneuverability and short bursts of high speed. Accipiters hunt in forests and woodlots, preying mainly on species of birds less than 100 g and small mammals, and often chasing their prey through dense vegetation (Johnsgard 1990). Goshawks, one of the larger accipiters, prey on small mammals and bird species from 100-600 g (e.g., jays, pigeons, grouse, ducks) (Sherrod 1978).

Buteos differ from falcons and accipiters by having broad, rounded wings designed for maximal lift. Buteos are well adapted for soaring, but are not suited for high speed flight. Morphological characteristics limit their capacity for pursuing prey items. Therefore, buteos rely upon surprising prey by stooping from the air or a perch. The larger buteos (e.g., Red-tailed and Ferruginous Hawks) are generally birds of open country, inhabiting grasslands, pastures, and open woodlands. These Buteos prey primarily on mammals and to a lesser extent on reptiles and birds (Sherrod 1978, Johnsgard 1990).

Target Species for Bird Control Using Falconry

Falconry has been suggested for use at the SLF on KSC as a method of enhancing current bird control techniques aimed at reducing bird/aircraft strike hazards. Bird control operations generally approach the regulation of problem birds by removing individuals (i.e., killing or trapping and relocating individuals) or by dispersal (i.e., use of scare tactics). Falconry has been used to kill and disperse birds at airfields. Factors related to the ecology of the target species, such as foraging and loafing habits, flight patterns, alarm communications, and size must be considered when determining the best approach for controlling birds within an airspace.

The success of the falconry bird control operation may be limited by the biology of the target species, the biology of the falcon, and the landscape near the airfield. Because of differences in the foraging patterns of raptors, a falconer must consider prey species characteristics, including type and size of the prey item (Sherrod 1978) and the landscape or preferred foraging habitat. Thus, the landscape and other environmental features surrounding the airfield and the appropriate bird species to target must be considered.

The landscape surrounding the SLF provides habitat for many species of birds which may impact the safety of aircraft operations. The runways, ruderal or grass areas and stormwater drainage systems associated with the airfield provide favorable conditions for many avian species to forage and loaf (pers. obs.). Several species are fedarally or state listed (Wood 1992). Avian families that use the airfield on a year-round or seasonal basis include Threskiornithidae (e.g., White Ibis, *Eudocimus albus*, Glossy Ibis, *Plegadis falcinellus*), Ardeidae (i.e., herons, egrets), Charadriidae (i.e., plovers), Columbidae (i.e., doves), Hirundinidae (i.e., swallows), and Emberizidae (i.e., blackbirds). Other species (e.g., Turkey Vultures, *Cathartes aura*, Black Vultures, *Coragyps atratus*, Ospreys, *Pandion haliaetus*, and Bald Eagles, *Haliaeetus leucocephalus*) using a large volume of the airspace surrounding the SLF also pose a threat for collision with aircraft.

Several potential target species for falcons have been identified by SLF personnel, bird activity investigations and by reviewing the NASA bird strike database (1992). These include Turkey Vulture, Black Vulture, Cattle Egret (*Bubulcus ibis*), White Ibis, Killdeer (*Charadrius vociferus*), Black-bellied Plover (*Pluvialis squatarola*), Ring-billed Gull (*Larus delawarensis*), Laughing Gull (*L. atricilla*), Caspian Terns (*Sterna caspia*), Tree Swallow (*Tachycineta bicolor*), Boat-tailed Grackle (*Quiscalus major*), Common Grackle (*Q. quiscula*), and Red-winged Blackbird (*Agelaius phoeniceus*).

METHODS

Literature Search

Literature on falconry and the application of falconry in bird control programs at airfields was compiled from numerous sources; computer databases, information systems, bibliographies, literature reviews, and personal contacts. The RECON database maintained by NASA was used to search for published reports on the use of falconry for airport bird control. The following key phrases were used to locate references pertaining to airfield bird control: aircraft hazards, birds, and bird/aircraft hazards. The Raptor Management Information System (RMS) operated by the U.S. Bureau of Land Management, Raptor Research and Technical Assistance Center in Boise, Idaho was searched for references using the keywords falconry and aircraft. Additional information was collected from references and literature cited sections of reports and published results. Several raptor specialists and military personnel involved in bird control programs using falconry were contacted in order to obtain unpublished information and reports unavailable through other sources.

Potential Target Species for Falcons at the Shuttle Landing Facility

Because raptors have specific dietary constraints and falcons are trained on specific bird species, it is important to understand temporal and spatial patterns in activity and general biological characteristics of the avian community requiring control. Data collection on avian activity and abundance at the SLF began in February 1993 and will continue through 1994. Avian activity and abundance data were collected from seven stations. Five stations were located along the runway and one at each set of PAPI lights approximately 7500 ft north and south of the runway. Number of birds, species, and position of airspace occupied were recorded. Preliminary bird activity and abundance data collected at the SLF and information on general species biology were used to categorize potential target species for falcons. These categories are not exclusive and species can fall into one or more categories based on diurnal, seasonal, or general behavioral patterns. Categories include: size, airspace occupied (i.e., ground/near ground, traveling or soaring species) and seasonal occurrence (i.e., year-round resident, winter resident, summer resident, or migrant).

RESULTS

Bird Control Programs

An extensive literature search produced a number of scientific publications, government and miscellaneous reports or documents related to the use of falcons for controlling birds at airfields. The following section summarizes the falconry programs tested and used at airfields. Most of these programs took place in North America and Europe.

Great Britain

The use of falcons for bird control was first attempted in Britain in 1947-1949 (Blokpoel 1976, DeFusco and Nagy 1983). Blokpoel (1976) and DeFusco and Nagy (1983) reviewed work done by Wright (1963) and concluded that falcons could be successful at reducing bird strike hazards. Wright (1963) demonstrated that daily Peregrine Falcon flights could keep the airfield clear of birds. However, birds avoided the airfield for only one or two days following removal of the falcon. Disadvantages to the falconry program included high cost, limitations imposed by poor weather conditions, and loss of falcons, due to them flying off or being accidently shot (Wright 1963).

Scotland

In 1965, a bird control program using falcons began at the Royal Naval Air Station at Lossiemouth, Scotland. The four year program was aimed at reducing the number of birds, primarily gulls (species not reported), using the airfield for both roosting and nesting. An average of 650 birds could be counted on the airfield at any one time, prior to the implementation of the control program (Heighway 1969). Bird/aircraft collision rates were reduced from about 20 per year in 1965 to zero after the initiation of the bird control program (DeFusco and Nagy 1983).

The bird control program employed eight Peregrine Falcons, two falconers, and several other full time bird control personnel (Heighway 1969). The program experienced difficulty in procuring Peregrines and required a three to four month training period for the falcons and their handlers. The falcons reduced the number of gulls roosting on the airfield during the day. Because falcons could only be flown in daylight, shell crackers (i.e., pyrotechnics commonly used in bird control) were necessary to disperse large numbers of gulls that came to roost in the evenings.

During the breeding season, large numbers of gulls and other species nested on the airfield. The intense use of falcons and pyrotechnics successfully reduced the number of gull and oystercatcher (species not reported) nests on the airfield from several hundred in 1966 to four in 1967 (Heighway 1969). The success of this program was not due solely to the use of falcons. Other control methods, including shell crackers and gas cannons, used in conjunction with falcons is believed to have contributed to its success (Heighway 1969, DeFusco and Nagy 1983).

Netherlands

The Royal Netherlands Air Force began a bird control program in 1967 using Northern Goshawks at Leeuwarden Airbase, Netherlands. Goshawks were selected for the program because they were less expensive and easier to acquire than falcons. Goshawks' ground-to-ground hunting behavior reduced their interference with aircraft and made them easier to retrieve (Mikx 1969, Defusco and Nagy 1983). The program used one falconer, three assistants, and four to six goshawks (Slot and Mikx 1968). Because hawks cannot be worked during molting periods, several hawks were needed to ensure that at least one hawk would be ready to fly at all times (Slot and Mikx 1968, Mikx 1969, Defusco and Nagy 1983). The goshawks were successful at dispersing problem gulls (type of gull species not reported) from the airfield, and the gulls did not appear to become habituated to the presence of the goshawks (Mikx 1969). However, gulls learned to fly ahead of the approaching falconer before the hawk could be released, thereby staying beyond the range of the hawk (Slot and Mikx 1968). Traditional methods of bird control, such as shell crackers, were necessary to supplement the use of the goshawks (Slot and Mikx 1968, Mikx 1969).

Bird strikes at the airfield decreased from 12 per year 1965-1966 to seven in 1967 and three in 1968. This program was considered an effective falconry program (DeFusco and Nagy 1983) but has been discontinued due to high costs (Blokpoel 1976). It is difficult to determine whether the success of the bird control program was due to the presence of the hawks or the overall increased intensity of the bird control effort (Royal Netherlands Air Force 1969).

Spain

Blokpoel (1976) and DeFusco and Nagy (1983) reviewed results of a falconry program using six Peregrine Falcons at Torrejon Airbase, Spain, to control Little Bustards (species not reported). Falcons were reported as successfully dispersing all nuisance birds after three months (Collum undated) and strikes were reduced from nine per year to zero after the falconry program began (DeFusco and Nagy 1983). However, even after dispersal of the bustards, falcons had to be flown daily to prevent their return (Rodrigues de la Fuente 1971).

The removal of Little Bustards from Torrejon Airbase coincided with an increase in numbers of bustards at Barajas-Madrid civil airport five miles away (Solman 1969). Falcon programs were introduced to control the increased numbers of bustards, as well as Stone-curlews (*Burhinus oedicnemus*), and Mallards (*Anas platyrhynchos*). After six months, Peregrine Falcons had successfully cleared the airfield of all three problem species (Rodrigues de la Fuente 1971).

France

The French government experimented with the use of falconry for bird control at two military bases near Istres and Strasbourg during 1980-81 (Briot 1984). Accipiters, trained on gulls (species not reported), reduced bird aircraft collisions from 16 in 1979 to zero in 1983. Falcons were used at the base near Strasbourg on species of crows and gulls (Briot 1984).

Following the success of falconry at the French military bases, experiments were carried out at Toulouse-Blagnac Airport during 1983-84 (Briot 1984). Six to eight thousand wintering Crested Lapwings (species not reported) were targeted. Two falconers flew five falcons for an hour each day. Within three months, aircraft-lapwing encounters decreased 75% compared to the four previous years (Briot 1984). Work from 1984-86 concluded that falconry could alleviate the lapwing problem, but lower cost bird control methods, such as shotguns, alarm cries, and pyrotechnics, were more appropriate (Briot 1984).

The success of falconry experiments at Toulouse-Blagnac prompted Paris' Charles de Gaulle Airport to test a falconry program during 1985-86 (Briot 1987). The program used four Peregrine Falcons, seven hybrid Peregrine/Gyrfalcons, and four Northern Goshawks. After eight months, aircraft collisions with gulls, lapwings, and pigeons (species not reported) were reduced by an estimated 60%. Reported drawbacks to the use of falcons included: difficulty in locating falcons and falconers, high costs, limitation related to target species, and weather and lighting constraints (Briot 1987). Despite the success of this falconry program, three civil airfields decided against the use of falcons and instead adopted programs using randomly broadcasted artificial sounds, which had been shown to be as or more effective than the use of falcons and at a reduced cost (Briot 1987).

United States Air Force - Europe

The United State Air Force (USAF) Europe initiated falconry programs at six USAF bases in the United Kingdom (Blokpoel 1976, 1977). Three species of imported falcons, Saker (*F. cherrug*), Lagger (*F. jugger*), and Lanner (*F. biarmicus*), made up about 20% of the bird control effort. The remaining effort was a combination of dogs and traditional bird scaring devices (e.g., shell crackers, live ammunition). Few specifics are available on these programs; however, Blokpoel (1976) indicates that falconry represented an essential element of the bird control programs. No results of these programs have been published. Maj. Ron Merritt of the USAF Bird Aircraft Strike Hazard (BASH) team (pers. comm.) reports that a successful program at Mildenhall Air Base is currently operating to reduce the number of gulls using the airfield.

Canada

The Canadian Associate Committee of Bird Hazards to Aircraft (ACBHA) commissioned experiments with falcons as a method of bird control at two airfields during the early 1960's (Blokpoel 1976, 1977). At Victoria Airport on Vancouver Island, British Columbia, Peregrine Falcons were flown from 1962-1964 and Gyrfalcons from 1964-1965. The falconry program was aimed at reducing bird strike hazards associated with large numbers of Glaucous-winged Gulls (*L. glaucescens*), California Gulls (*L. californicus*), and Mew Gulls (*L. canus*). Falcons were able to disperse gulls (Ryan 1965, Blokpoel 1976, 1977, DeFusco and Nagy 1983); however, Blokpoel (1976) reported that gulls returned soon after the falcons quit flying. Review of this falconry control effort by Solman (1965) recommended the use of conventional bird control methods (e.g., shell crackers, flares, sirens) over falconry.

Tests were conducted during 1964 using Peregrine Falcons to scare Great Black-backed Gulls (*L. marinus*) and Herring Gulls (*L. argentatus*) at Shearwater Airport near Halifax, Novia Scotia (Blokpoel 1976, 1977). Falcons were trained to circle above the falconer, instead of attacking the flocks of gulls. This technique allowed for greater control of the falcons and reduced the likelihood of falcons becoming injured (Blokpoel 1976, 1977). Canadian officials discontinued the use of falcons in 1965, despite the reported successes of dispersing gulls using falconry (Blokpoel 1976). High cost of the falconry programs, difficulty in obtaining falcons, limitations related to the use of falcons, and the availability of less costly methods were reasons for the programs' discontinuance (Blokpoel 1976).

In 1976, several falconry programs were reinstated in Canada under the Ministry of Transport (MOT). A program at Vancouver International Airport used two Peregrine Falcons, two Prairie Falcons, two Merlins, and two Gyrfalcons (Blokpoel 1977). Target species included: large flocks of Dunlin (*Calidrus alpina*), European Starlings (*Sturnis vulgaris*), and gulls (species not reported) that occurred irregularly on the airfield and could not be dispersed by conventional methods. Difficulties in obtaining and training the falcons against certain target species were encountered (Davies 1977). The program reported 95% success in dispersing birds (Davies 1977); however, data showing a reduction in bird/aircraft strikes were not available. Attributing any decrease in bird strikes to the falconry program was difficult because of the initial low frequency of strikes. The program was discontinued due to high costs and limited usefulness (Blokpoel 1977).

Herring Gulls and Ring-billed Gulls were identified as problems at North Bay Airport, Ontario, Canada, due to the airport's proximity to a landfill where the birds commonly fed (Jerema 1977). The falconry program flew two Peregrine Falcons and a Prairie Falcon daily. At the beginning of the operation (April 1977) about 600 gulls were present at the dump and within three weeks few to no gulls were seen feeding. The falconry program alone may not have accounted for the reduction in the number of gulls at the dump; availability of other food sources and the onset of breeding season may have also contributed to a reduction in their number (Blokpoel 1977). By August more than 1000 gulls, both juveniles and adults, had returned to feed at the dump (Blokpoel 1977).

Toronto International Airport, Ontario, initiated a two-month experimental program using two Prairie Falcons and two Gyrfalcons in September 1977 (Blokpoel 1977). Target species included gulls, crows, pigeons, ducks, and starlings (species not reported). Other conventional bird control methods were used in conjunction with falcons. No published results of this program could be obtained. The program is still active and is reported to be successful at reducing the numbers of hazardous species using the airfield (Maj. Ron Merritt pers. comm.).

United States Air Force - U.S.

In 1972, a pilot experiment using falconry was implemented at Whiteman Air Force Base, Missouri. The program used a Red-tailed Hawk, a Ferruginous Hawk, a Goshawk, and a Prairie Falcon in attempt to control Greater Prairie-Chickens (*Tympanuchus cupido*) that were attracted to the base to breed. Only the Goshawk was successful at dispersing the prairie-chickens, and within about six weeks the number of prairie-chickens using the airfield dropped from 65 to 12 (Mattingly *et al.* 1973, Mattingly 1974, DeFusco and Nagy 1983).

As a result of the pilot study, another control program was initiated at Whiteman Air Force Base in 1973 with intentions of developing a long-term falconry program. Two Prairie Falcons, a Ferruginous Hawk and a German Short-haired Pointer were employed (Mattingly 1974). Since the Prairie Falcons were useful only in good light conditions, the Ferruginous Hawk was needed to disperse prairie-chickens around sunrise and sunset. Only one Prairie Falcon proved effective, even though it commonly chased other birds that flushed (e.g., meadowlarks, blackbirds). The second Prairie Falcon refused to hunt and would frequently wander over the airfield. The Ferruginous Hawk did not chase the prairie-chickens far, and the prairie chickens quickly learned that it posed little threat (Mattingly 1974).

Mattingly (1974) reported that by the beginning of May, the falconry program was becoming effective. Prairie-chickens were becoming "scarce," and the last prairie-chicken was seen on June 4, 1973. Mattingly (1974) indicates that prairie-chickens were attracted to the airfield only during March, April and May, with peak activity occurring in the last week of March. It was not clear whether the falcons or natural activity patterns associated with breeding were responsible for fewer prairie-chickens. Hence, the success of the falcons should be interpreted with caution since seasonal decline attributed to habitat use was not quantitatively distinguished from the effects of falcons. Despite the reported success of this program, the use of falcons was discontinued in 1974. High cost of the falcon program and the effectiveness of alternative, less costly harassment methods, including pyrotechnics and trapping and relocation, to effectively disperse the prairie-chickens were cited as the main reasons for discontinuation of the falcon program (D. Meuschke pers. comm.). The bird control program now consists mainly of habitat management and intensive harassment (Sgt. Keedy pers. comm.).

Summary of Falconry Programs

Bird control programs using falconry have targeted 12 different species of birds using eight different falcon species (Table 1). Sixty percent of the falconry programs reviewed used both falcons and conventional bird control techniques. Most programs reported were considered successful; however, few bird control programs are currently using falcons (Maj. Ron Merritt pers. comm.). Many falconry programs concluded that traditional, less expensive methods of bird control were more appropriate in reducing

Table 1. Summary of species targeted by falconry programs.

Raptor Species	A	B	Target Species	Literature Cited
Northern Goshawk *(Accipiter gentilis)*	3	--	Greater Prairie-Chicken, gull spp., Corvidae	Mikx 1969, Mattingly 1974, Briot 1987
Red-tailed Hawk *(Buteo jamaicensis)*	1	--	Greater Prairie-Chicken	Mattingly 1974
Ferruginous Hawk *(B. regalis)*	1	--	Greater Prairie-Chicken	Mattingly 1974
Merlin *(Falcon columbarius)*	1	--	Dunlin, gull spp., European Starling	Blokpoel 1977
Peregrine Falcon *(F. peregrinus)*	2	4	oystercatcher sp., Herring Gull, Ring-billed Gull, Mew Gull, Crested Lapwing, California Gull, Glaucous-winged Gull, Great Black-backed Gull, Mallard, Little Bustard, Dunlin, Stone Curlew, European Starling, pigeon sp., crow sp.	Wright 1963, Heighway 1969, Rodriguez de la Fuente 1971, Blokpoel 1976, Jerema 1977, DeFusco and Nagy 1983, Briot 1987, Collum (undated)
Gyrfalcon *(F. rusticolus)*	1	2	Glaucous-winged Gull, California Gull, Mew Gull, gull spp., duck sp., Dunlin, pigeon sp., crow sp., European Starling	Blokpoel 1976
Prairie Falcon *(F. mexicanus)*	2	--	Herring Gull, Ring-billed Gull, gull spp., duck spp., Greater Prairie-Chicken, Dunlin, pigeon sp., crow sp., European Starling	Mattingly 1974, Blokpoel 1976, Jerema 1977
Peregrine/Gyrfalcon (hybrid)	1	--	gull spp., "buzzards"	Briot 1987
Other*	--	2	Crested Lapwing, gull spp., crow sp.	Blokpoel 1976, Briot 1984
TOTAL	12	8		

* Laggar (Falco jugger), Lanner (F. biarmeieus), Pilgrim (species not reported) and Saker Falcons (F. cherrug)
A = number of control programs using falcons and conventional methods
B = number of control programs using falcons only

bird/aircraft strikes. Trouble obtaining falcons and/or falconers and limitations related to weather and target species were also common reasons for discontinuing many of the falcon programs.

Bird/Aircraft Hazards at the Shuttle Landing Facility

Bird/aircraft collisions at the SLF average 6.4 strikes/year from 1983-92 (NASA 1992, unpub. data). Aircraft activity at the SLF is related to Shuttle operations and varies considerably in intensity. Air traffic by helicopters, T-38s, and Shuttle Training Aircraft (STA) are most common since these aircraft support Shuttle Transport System operations.

Ten different types of birds have been identified in bird/aircraft collisions at the SLF (Table 2) (NASA 1992). Identification of species involved in aircraft strikes is difficult. The species involved cannot be determined in about 42% of the strikes (NASA 1992). Tree Swallows had the highest frequency of bird/aircraft strikes at the SLF from 1983-1992. Tree Swallows and sparrows (species not reported) represented 32.3% of all strikes (55.5% of strikes in which the type of bird was identified) (Table 2). Plovers (species not reported) represented 6.5% of the total strikes and are the second most frequently hit bird that can be identified. Others species involved in bird/aircraft strikes at the SLF represent less than 5% of the total strikes (Table 2).

A total of 23 avian species, six of which have been involved in bird/aircraft collisions (Table 2), have been identified as potential target species for falconry at the SLF (Table 3). Gulls are the only potential target species identified at the SLF that have been successfully controlled in other falconry bird control programs (Table 1) (Mikx 1969, Blokpoel 1976, 1977, Briot 1987).

Table 2. Bird/aircraft strikes at the Shuttle Landing Facility (SLF), John F. Kennedy Space Center, Florida (1983-1992). (NASA 1992)

Species/Description	No. Strikes	% Total
Tree Swallow	20	32.3
plover (species unidentified)	4	6.5
sparrow (species unidentified)	3	4.8
hawk (species unidentified)	2	3.2
grackle (species unidentified)	2	3.2
Double-crested Cormorant	1	1.6
Killdeer	1	1.6
Eastern Screech-Owl	1	1.6
gull (species unidentified)	1	1.6
egret/ibis (species unidentified)	1	1.6
SUBTOTAL	36	--
small unidentified	7	11.3
medium unidentified	2	3.2
unidentified	17	27.4
TOTAL	62	

Table 3. Potential target species for falconry at the Shuttle Landing Facility (SLF), John F. Kennedy Space Center, Florida.

Airspace Occupied	Species(1)	Seasonal Occurrence(2)
Ground/Near Ground	Red-winged Blackbird	Y
(<20 ft)	American Robin	W,M
	Killdeer	Y,W(3)
	Common Grackle	Y
	Boat-tailed Grackle	Y
	Black-bellied Plover	W,M
	Royal Tern	Y,W(3)
	Ring-billed Gull	Y,W(3)
	Caspian Tern	W
	Cattle Egret	S
	White Ibis	Y
SUBTOTAL	11	
Traveling	Tree Swallow	W,M
(>20 and <300 ft)	Little Blue Heron	Y
	Snowy Egret	Y
	Tricolor Heron	Y
	Glossy Ibis	Y
	White Ibis	Y
	Great Egret	Y
	Double-crested Cormorant	Y,W(3)
	Great Blue Heron	Y
SUBTOTAL	9	
Soaring	Anhinga	Y
(>300 ft)	Turkey Vulture	Y
	Black Vulture	Y
	Wood Stork	Y
SUBTOTAL	4	
TOTAL SPECIES	23	

S = Summer Resident, W = Winter Resident, M = Migrant,
Y = Year-round Resident
(1) listed in order of increasing mass
(2) Robertson and Woolfenden (1993)
(3) Year-round residents with numbers increasing greatly in winter

Potential Target Species for Falcons at the Shuttle Landing Facility

Mass of prey item, prey behavior, and region of airspace occupied by target species were used to identify potential types of falcons that may be useful. Generally, the size of a raptor is proportional to the size of a potential prey item (Figure 1). Larger falcons feed on a broader range of prey sizes (Blaine 1970, Sherrod 1978, Woodford 1987, Johnsgard 1990, R. Yosef pers. comm.). Potential target species were characterized based on general morphology (i.e., mean body mass), activity patterns (i.e., region of airspace commonly occupied) and relative seasonal occurrence (i.e., summer resident, winter resident, or spring/fall migrant) (Table 3).

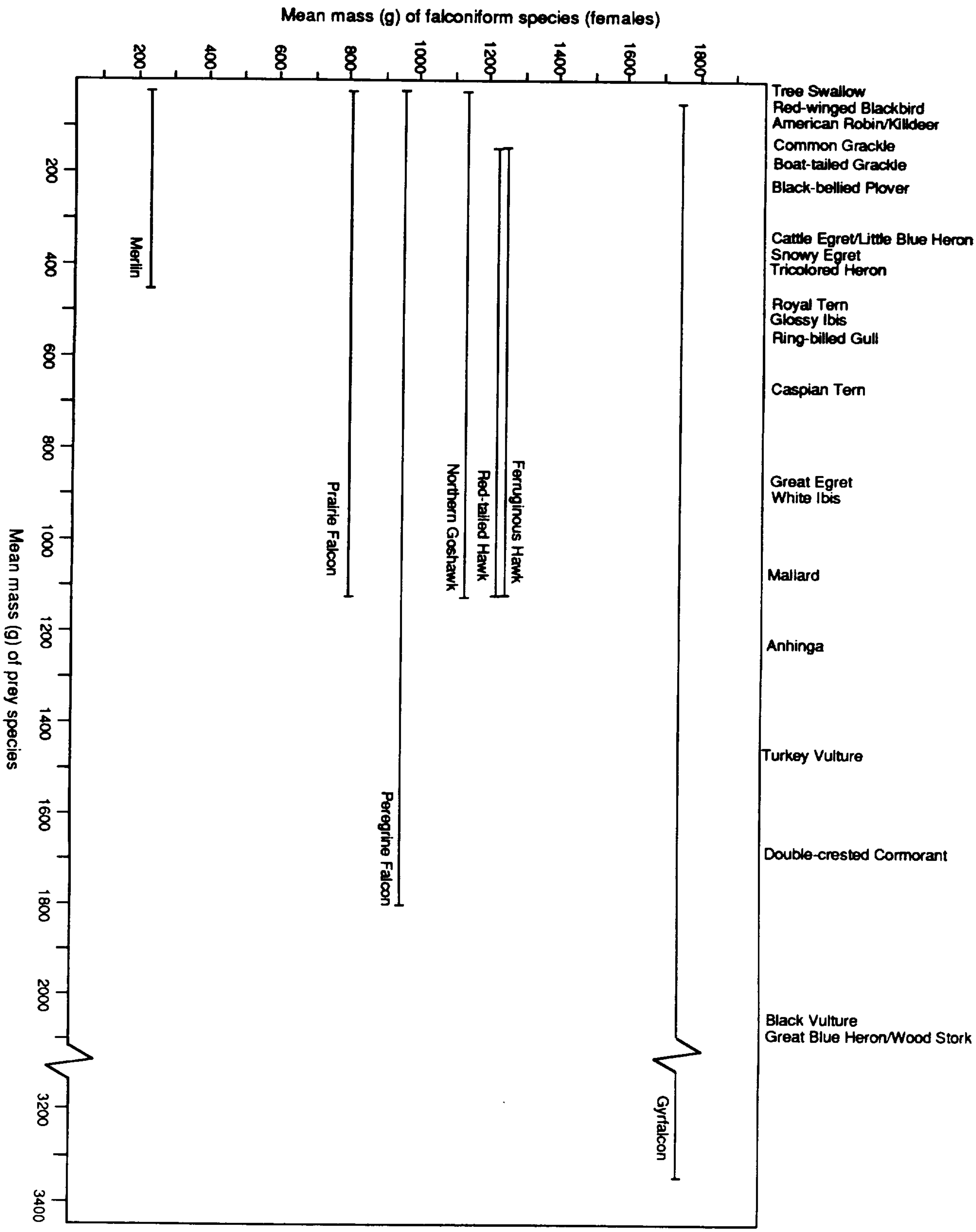
General Morphology

General morphology (i.e., body mass) was used to characterize species to determine the best relationship between size of target species (i.e., potential prey item) and dietary specifications of falcons commonly used in falconry (Figure 1). Seventy four percent of the potential target species for falconry at the SLF are >1100 g, making them reasonable prey items for most types of falcons (Figure 1, Table 3). The remaining 6 species are large and may only be hunted by the very large Gyrfalcon or Peregrine falcon.

Activity Patterns

Describing activity patterns of potential target species assists in identifying types of falcons that may be effective in controlling the species. Species that occupy low regions of airspace (i.e., ground or near ground, <20 ft or 6.1 m) have the highest probability of being controlled through the use of falconry. Falcons are natural predators of many of these ground species, making them vulnerable for control by the use of falcons (Sherrod 1978, Johnsgard 1990). Ground or near ground species make up 92% of the species targeted by bird control programs using falconry (Table 1).

Figure 1. Mean mass of avian prey species that are depredated by female falconiform species used in falcon bird control programs. Lines represent the range in mean mass of avian prey species. (Laing 1985; graph modified from Johnsgard 1990)


Mean mass (g) of falconiform species (females)
200
400
600
800
1000
1200
1400
1600
1800
Mean mass (g) of prey species
200
400
600
800
1000
1200
1400
1600
1800
2000
3200
3400
Merlin
Prairie Falcon
Peregrine Falcon
Northern Goshawk
Red-tailed Hawk
Ferruginous Hawk
Gyrfalcon
Tree Swallow
Red-winged Blackbird
American Robin/Killdeer
Common Grackle
Boat-tailed Grackle
Black-bellied Plover
Cattle Egret/Little Blue Heron
Snowy Egret
Tricolored Heron
Royal Tern
Glossy Ibis
Ring-billed Gull
Caspian Tern
Great Egret
White Ibis
Mallard
Anhinga
Turkey Vulture
Double-crested Cormorant
Black Vulture
Great Blue Heron/Wood Stork

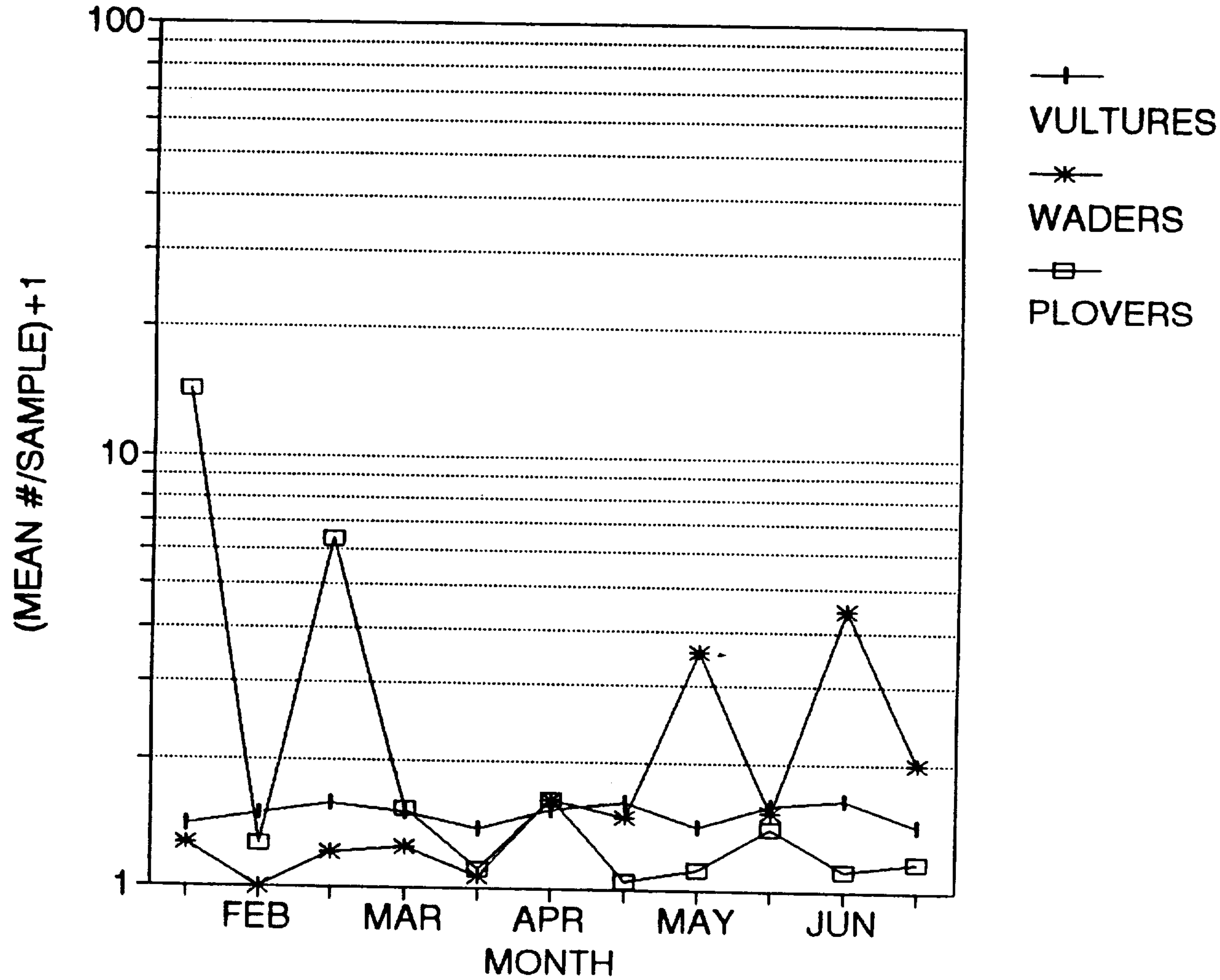
Ground or near ground species make up 47.8% of the potential target species for falconry at the SLF (Table 3). The thirteen species of traveling or soaring species are may be more difficult to control using falconry.

Seasonal Occurrence

Seasonal occurrence was considered because large aggregations of birds (e.g., Tree Swallows, plovers) are difficult to control and pose potentially serious risk to aircraft (Mattingly 1974, Blokpoel 1976, NASA 1992). Spring and fall migrants represent 69% of the bird/aircraft strikes at the SLF in which the birds have been identified (NASA 1992, unpub. data). Migratory species make up 30% of the potential target species for falconry at the SLF.

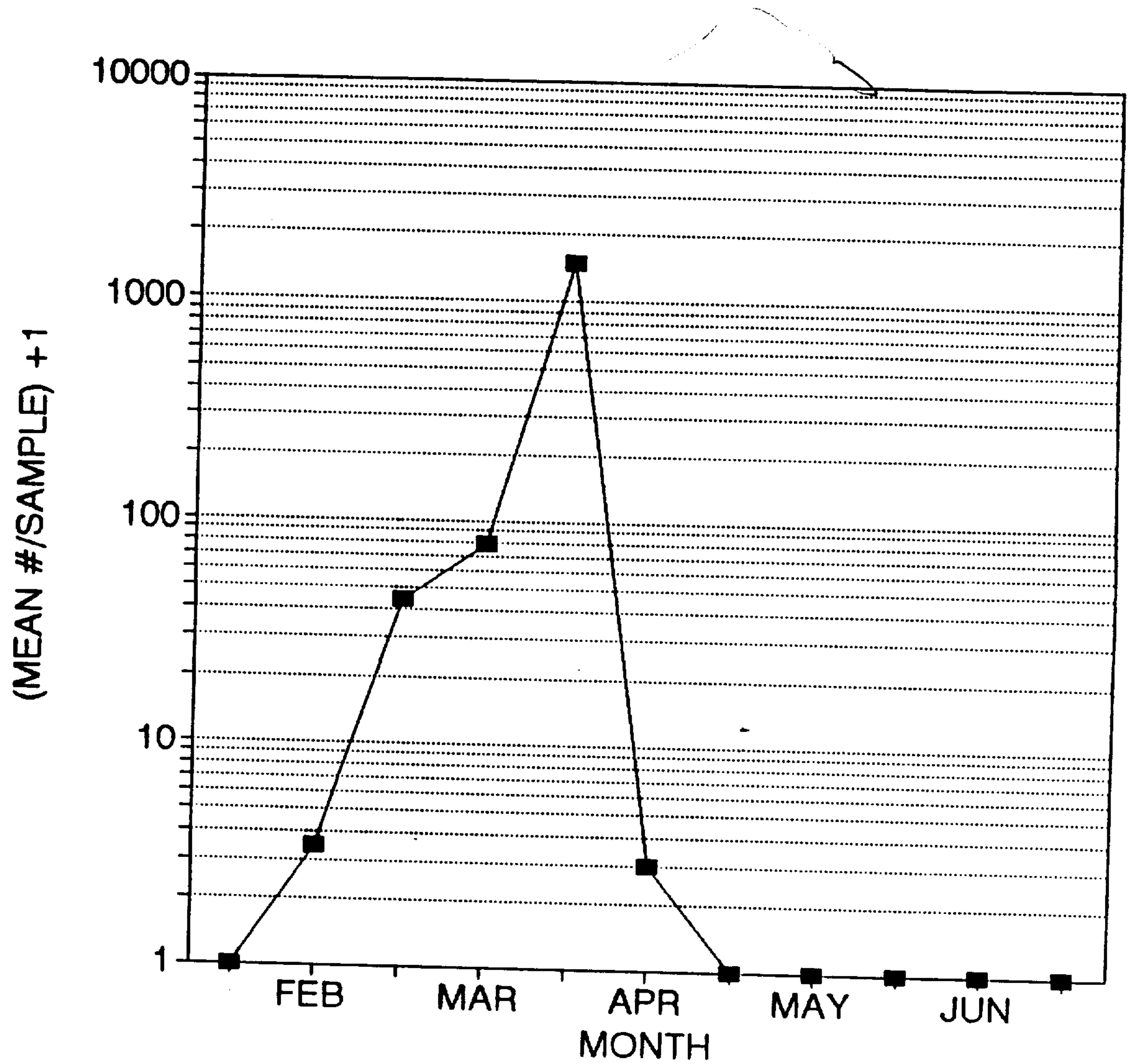
Examples of bird activity data collected at the SLF are given in Figure 2a and Figure 2b. Potential target species are presented as mean bird number per sample from February through June for vultures, waders, (e.g., Great Blue Heron, *Ardea herodias*, Great Egret, *Casmerodius albus*, Cattle Egret, White Ibis, Glossy Ibis, Little Blue Heron, *Egretta caerula*, Snowy Egret, *Egretta thula*, Tricolored Heron, *Egretta tricolor*, Wood Stork, *Mycteria americana*), and plovers (e.g., Black-bellied Plover, Killdeer). Many of the potential target species at the SLF are permanent and winter residents (Table 3). Large numbers of migrants also use the SLF during certain seasons (Figure 2a and 2b). Increased bird control efforts may be needed during winter or migration because the number of birds using habitats found on KSC often doubles (Breininger 1990, Breininger and Schmalzer 1990).

Figure 2a. Mean number of birds per sample of vultures, waders, and plovers from February to June 1993 at the Shuttle Landing Facility (SLF), John F. Kennedy Space Center, Florida.



100
10
1
(MEAN #/SAMPLE)+1
FEB
MAR
APR
MAY
JUN
MONTH
VULTURES
WADERS
PLOVERS

Figure 2b. Mean number of birds per sample of Tree Swallows (*Tachycineta bicolor*) from February to June 1993 at the Shuttle Landing Facility (SLF), John F. Kennedy Space Center, Florida.


10000
1000
100
10
1
(MEAN #/SAMPLE) +1
FEB
MAR
APR
MAY
JUN
MONTH

DISCUSSION

Bird Control Using Falcons

Bird control programs using falcons were most common during the 1950's to early 1970's. This corresponds to a time period in which falconry was popular throughout the U.S. An extensive literature search yielded no convincing evidence that falcons alone can provide a permanent, cost effective, successful means of bird control. Twelve of the 20 programs reviewed (Table 1) relied on a combination of bird control techniques that included traditional control methods, as well as falconry. The use of falcons is considered a viable option for airfield bird control only under circumstances when other, more conventional, control methods have proven inadequate (Blokpoel 1976, Maj. R. Merritt pers. comm.). All of the current falconry programs use conventional methods in addition to falcons (Maj. R. Merritt pers. comm.).

Several references in popular literature and government documents indicate that a falcon program can be successful; however, they rarely provide specific information. Published reports documenting a successful falconry program are scarce in the literature. The details of data collected for programs were not described sufficiently. Most programs appeared to be pragmatic and were not designed to quantify success. Published reports do not provide convincing quantitative evidence that falcons are responsible for a reduction in the bird strike hazard. Many report success without quantifying a reduction in bird activity or bird/aircraft collisions. When data are presented, it is unclear whether researchers controlled for confounding factors such as the effects of seasonal occurrence or an overall increase in the intensity of the bird control. Most of the falcon programs have been discontinued. No reports of falconry programs were presented at the 1992 annual meeting of the Bird

Strike Committee Europe (BSCE 1992). Major reported constraints of falconry control programs are: 1) falcons must be flown regularly (i.e., daily) and often on a year-round basis to be effective, 2) falcons can be used only in daylight and in good weather, 3) falcons are frequently temperamental and uncooperative, 4) falcons must be properly trained to specific groups of birds requiring control, 5) falcons are difficult to acquire, maintain, and train, and 6) falconry programs are expensive (Blokpoel 1976, Doughty 1976, Briot 1987).

Falconry programs have most often been used to control species found foraging or loafing on the ground or at low altitudes within the airspace (Table 1). Based on the available literature, no falconry programs have attempted to control large soaring/traveling species such as vultures and wading birds. In order for falconry to be useful, falcons must hunt (i.e., remove individuals) or disperse problem species (i.e., scare them away). Target species must have a sufficient amount of fear for the raptor to be dispersed by a falcon. The potential success of the falconry effort is increased by using falcons to target species that are most closely related to their natural prey items. Even though falcons are trained on specific species, these species may not be the only ones with which the falcon interacts (Mattingly 1974, R. Yosef pers. comm.) For this reason, falconry at the SLF has a potential environmental impact on species that are state or federally listed or are of conservation concern.

Species found mostly on or near the ground can often be frightened successfully from airfields using conventional bird control methods such as shotguns, gas cannons, and noise makers (Blokpoel 1976, SLF personnel pers. comm.) Soaring species and other large species that consistently use high altitude flight paths from roost locations to remote foraging areas are more difficult to control (SLF personnel pers. comm., pers. obs.). Target species with large mass will require very large raptors (i.e., Gyrfalcon, Peregrine Falcon). Many falcons would be needed to clear the airspace since these species cover a large distance rapidly.

Application of Falcons in Bird Control at the Shuttle Landing Facility

SLF personnel have indicated that four main groups of birds present the greatest hazard to aircraft operations based on near misses and potential strikes. These are Ciconiiformes (i.e., bitterns, herons, ibises, storks), American vultures (family Cathartidae), Charadriformes (e.g., plovers, gulls and terns), and migratory passerines (e.g., mainly American Robins, *Turdus migratorius*, and Tree Swallows).

Ciconiiformes

Wading birds that use the lawn and ditches for foraging pose a potential threat to SLF operations. Wading birds also pass through the SLF airspace traveling between feeding, roosting, and nesting sites which are abundant in the vicinity of the SLF (Smith and Breininger unpub. data). Cattle Egrets and White Ibis are the most common waders using the perimeter lawn at the SLF. Tricolored Herons, Little Blue Herons, White Ibis and Snowy Egrets commonly use the airspace above the SLF (unpub. data). Wading bird populations are least abundant on KSC during winter (Cruickshank 1980, Smith and Breininger unpub. data). Several thousand Tricolored Herons, White Ibis, and Snowy Egrets nest in colonies on KSC (Smith and Breininger unpub. data). Cattle Egrets are common residents throughout Florida (Robertson and Woolfenden 1992); however, during colder winters they move south and may become rare in the central Florida region (Cruickshank 1980).

To our knowledge, no falconry programs have specifically targeted wading birds. For this reason, it is difficult to estimate the potential success of a falconry program in controlling wading birds; however, several facts suggest that a successful program may be limited. Herons, egrets, and ibis are relatively large birds and are not commonly preyed upon by falcons (Sherrod 1978, Johnsgard 1990) (Figure 1). Large falcons would be required to target wading birds and difficulties may be encountered training falcons to attack these species. Waders usually travel through the airspace of the SLF in small isolated groups (unpub. data). Although the waders pose a potential threat to aircraft, a falcon pursuing these species may represent a greater hazard (Mikx 1969). Because of the flight characteristics of the waders, a falcon would have to work a large area surrounding the SLF. This would require using several falcons simultaneously. Furthermore, most wading birds on KSC are listed by either the United States Fish and Wildlife Service (USFWS) or Florida Game and Fresh Water Fish Commission (FGFWFC) (e.g., Wood Storks are endangered). The use of falcons to control waders could have environmental impacts given the need for falcons to pursue and attack prey.

Vultures

Turkey Vultures and Black Vultures are both year-round resident species in Florida. The resident breeding population of both species is supplemented in fall and winter (November through March) by migratory individuals (Cruickshank 1980). Further studies would be required to understand the proportions of resident and migrant vultures in the population on KSC. Vultures are carrion eaters and road-killed animals appear to represent a significant source of food. Both species of vultures are regularly seen in groups up to ca. 30 individuals feeding at carcasses of dead animals along major roadways on KSC (pers. obs.). Both species are highly gregarious, forming large mixed groups foraging and roosting aggregations. One particularly large roost of ca. 300 individuals is located directly in the south approach path of the SLF. The major strike hazard resulting from this roost occurs during a mid-morning period when a majority of the individuals leave the roost.

Typically, vultures leave this roost en masse at ca. three hours after sunrise, forming large mixed-species kettles soaring upwards on thermal currents. Many disperse searching for food and other are attracted to air patterns surrounding the Vehicle Assembly Building (VAB) (pers. obs.). During mid-day hours (ca. 1030-1600 hours), vultures are often seen on the ground foraging or loafing at carcasses along roads and ditches. When flying or soaring during mid-day, vultures generally remain highly dispersed over large areas and soar at altitudes above ca. 150 feet, traveling long distances (pers. obs.). The greatest hazard presented by vultures occurs during late morning hours when large numbers of vultures are soaring at various altitudes. This hazard decreases after vultures have dispersed from their roosts and begin foraging or soaring at high altitudes. Further studies of marked individuals would help to understand vulture dispersal patterns and identify effective potential vulture control techniques.

A falconry program targeted at vultures is unlikely to be successful. Falcons are not natural predators of vultures; hence, vultures have little or no innate fear of falcons or other birds of prey. A falconry program targeted at vultures will require falcons that are specially trained to harass vultures. This will be much more difficult than training falcons to hunt species that falcons naturally prey on or are similar in size and habits to the falcons' natural prey (T. Cade pers. com., B. Millsap pers. com., B. Toland pers. com., R. Yosef pers. comm.). It would be very difficult for a falconry team to be able to effectively patrol the entire airspace (i.e., 1050 ha from 20-1800 ft or 6.1-548.6 m) that could be used by vultures at any given time. Black Vultures have been documented traveling a distance of 14 km in 30 min. (Rabenold 1987). The presence of falcons will not deter vultures from the airspace (T. Cade pers. comm., B. Millsap pers. com., R. Yosef pers. com.). Falcons will need to target individual vultures and other vultures in the vicinity will probably not be deterred unless directly attacked. The large resident vulture population is supplemented in winter months by migrant individuals; turnover at vulture roost sites can approach 100% in as little as five days (E. Stolen pers. comm.). It is unlikely that the vulture population will learn to avoid the SLF airspace to keep from getting harassed by falcons given the large distances traveled by vultures while searching for food.

Charadriiformes

Killdeer are year-round residents at KSC. From September through May, the resident breeding population is enhanced by large numbers of wintering individuals (Cruickshank 1980). Killdeer numbers peak during May when spring migrants pass through the area (Breininger and Smith 1990). The large numbers of Killdeer that use the lawn for foraging and the runway for loafing during the winter months present a potential aircraft hazard; however, few individuals remain during the summer. Small numbers of Killdeer nest within the SLF (S. Rowe, pers. obs.). Unlike the wintering flocks of Killdeer, breeding individuals rarely use the runway and are most frequently seen foraging in the lawn (unpub. data). Thus, bird/aircraft strike hazard associated with resident Killdeer during the breeding season is minimal.

Black-bellied Plovers also present a significant aircraft hazard because of their seasonal abundance. Unlike Killdeer, Black-bellied Plovers are mainly winter residents, common September through April with small numbers remaining in the summer (Cruickshank 1980). During winter months, large numbers of Black-bellied Plovers use the runway and lawn for loafing and foraging (unpub. data). Black-bellied Plovers remain on KSC in small numbers during the summer, however, from late spring through early fall they rarely use the SLF (unpub. data).

A falconry program aimed at plovers may prove successful; however, targeting plovers using falcons is not recommended. The large expanse of open area at the SLF attracts plovers to forage and loaf. It is likely that resident plovers will grow accustom to the presence of a falcon, unless falcons kill plovers on a regular basis. Black-bellied Plovers are considered species of conservation concern (Millsap *et al.* 1990) and are present on KSC during most of the year. A significant ($P<0.10$) decrease in Black-bellied Plovers has occurred between 1972-1983, along the U.S. Atlantic coast migration stopovers (Howe *et al.* 1989). Counts of Black-bellied Plovers in South Carolina have also indicated a decline from 1961-1988 (Marsh and Wilkinson 1991). Black-bellied Plovers are one of 13 shorebird species that have been identified as a species of management and research concern at KSC (Breininger *et al.* in prep.). Additionally, Piping Plovers (*Charadrius melodus*) and Snowy Plovers (*C. alexandrius*) are listed as threatened species by both the FGFWFC and USFWS (Wood 1992) and could occur at the SLF although such occurrence would be rare.

Migratory Passerines

A falconry program aimed at the control of large flocks of migratory passerines, most notably American Robins has the greatest chance of success. Passerines are natural prey items for many species of raptors used in falconry (Figure 1) (Johnsgard 1990). Falcon control requires raptors trained to harass and kill specific target species or related species (Blokpoel 1976). A greater chance of success can be expected when the raptor is a natural predator of the targeted species. In natural situations, large flocks of passerines often react to the presence of a wild falcon by flushing and leaving the area (pers. obs.).

American Robins are abundant migrants and winter residents on KSC, present from mid-November through mid-April. Robins generally form transient flocks that can be as large as 50,000 individuals (Cruickshank 1980). It is likely that different individuals are visiting the SLF on a daily basis. In addition, birds such as robins frequently encounter falcons during migration. This reduces the chance of transient birds becoming habituated to the presence of a falcon at the SLF.

Tree Swallows are migrants and winter residents on KSC, present from late August through late April (Cruickshank 1980). These highly gregarious aerial foragers are often seen foraging for insects over the lawn and perimeter ditches at the SLF and are attracted to the fruiting wax myrtle (*Myrica cerifera*) that are abundant in the vicinity of the SLF (pers. obs.). Flocks of ca. 20,000 individuals are common on KSC, and one exceptionally large flock of ca. 250,000 individuals frequented the SLF area during the last two weeks of April 1993 (unpub. data, SLF personnel pers. comm.).

Tree Swallows present a unique problem because of the size and density of the flocks. Flocks are highly dynamic and often pass back and forth over the runway. Conventional bird control methods have little effect on dispersing Tree Swallows (SLF personnel pers. comm.). It is unlikely that a falcon would prove effective on such large aggregations since flocks show only a localized dispersal response to shell crackers as well as aircraft. Personal observations suggest that falcons can disperse roosting flocks of Tree Swallows, however, the swallows respond by becoming airborne and do not leave the vicinity of the SLF. Alternative methods such as habitat manipulation (e.g. removing wax myrtles) may prove effective in controlling the movements of Tree Swallow flocks.

The presence of falcons is likely to have only minimal effect on resident bird populations, such as Red-winged Blackbirds, Boat-tailed Grackles, and Eastern Meadowlarks (*Sturnella magna*), that use the perimeter ditches and lawn for nesting and foraging. Because these birds are residents they are likely to habituate quickly to the presence of a falcon in the vicinity. Grackles and blackbirds commonly forage and loaf on the runway and lawn (unpub. data). A falconry program may be successful at reducing the number of birds loafing and foraging on the runway; however, it is unlikely that the presence of a falcon will cause resident species to abandon breeding territories within the SLF.

CONCLUSIONS AND RECOMMENDATIONS

Although published documents commonly report that falcons can be used with success in controlling problematic bird species at airfields, falconry is not necessarily an efficient control method (Mikx 1969, Mattingly 1974, Blokpoel 1976, Doughty 1976, DeFusco and Nagy 1983, Briot 1987, R. Merritt, pers. comm.). When employed intensively, conventional bird control techniques, such as pyrotechnics and acoustics, have proven less costly and as effective or more effective than falconry (Briot 1987, Maj. R. Merritt pers. comm., D. Meuschke pers. comm.). Falconry might be considered a last resort to supplement conventional bird control methods where all other methods have been proven ineffective (Maj. R. Merritt pers. comm.). The high cost associated with the use of falcons is most often cited as the reason for the discontinuation of falconry programs.

Conservation issues must be considered when assessing the potential for using falconry in bird control operations. All falconiformes are protected by federal law and many species used in falconry are federally listed as threatened or endangered. This can make acquisition difficult and costly (Mikx 1969, Doughty 1976, Blokpoel 1976). Stringent environmental laws are considered a major impediment to falconry programs in the United States (Maj. Ron Merritt, Sgt. Keedy pers. comm.).

Additionally, many potential target species at the SLF are species of conservation concern (e.g., Black-bellied plovers). Several non-target species (e.g., Florida Scrub Jay, *Aphelocoma c. coerulescens*; Bald Eagle) that occur in the vicinity of the SLF are state and federally protected (Breininger *et al.* 1991, Hardesty and Collopy 1991).

A bird control program that intensively employs non-lethal control methods such as habitat manipulation, pyrotechnics, and acoustics may have as high a probability of being as successful as falconry while being more cost effective. Manipulation of the habitat at airfields, such as increasing the height of grasses surrounding the runway, has been tested with some success (Sgt. Keedy pers. comm.). Remote control aircraft have also been shown to effectively reduce hazards resulting from vultures and other problem bird species (Briot 1984, R. Yosef pers. comm.). Bird control using remote control aircraft may have less of an environmental impact than falconry, while being more flexible and dependable. Furthermore, baiting vultures with carrion to foraging locations outside of critical airspace during operations has also been successful in reducing bird/strike hazards in Israel (R. Yosef pers. comm.).

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A Review of Falconry as a Bird Control Technique with Recommendations for Use at the Shuttle Landing Facility, John F. Kennedy Space Center, Florida, USA

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13. ABSTRACT *(Maximum 200 words)*

Falconry has been proposed as a method of reducing the bird/aircraftstrike hazard, in addition to current bird control techniques, at the ShuttleLanding Facility (SLF), John F. Kennedy Space Center (KSC), Florida, U.S. Bird control programs using falconry have been employed at a number ofmilitary and commercial airfields in the U.S., Canada and Europe. Mostfalconry programs have been discontinued. In most situations, falconrydid not prove cost effective when compared to alternative bird controltechniques. Available literature and documents, as well as several raptorspecialists and military personnel, suggest that falconry may be usefulonly against certain problem species and when other bird control methodshave been proven inadequate. Because many of the most commonly usedfalcons are protected species, acquisition of falcons will complicate theiruse in bird control programs. Many avian species found at the SLF arefederally and state protected or of conservation concern, therefore,environmental impacts may also result from the use of falcons.

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